SANBI
Biodiversity for Life
South African National Biodiversity Institute

National Biodiversity Assessment 2018

TECHNICAL REPORT

Volume 4:

Marine



CITATION FOR THIS REPORT:

Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Many people have contributed their expert knowledge to particular chapters or boxes in this report. We encourage you to **cite the specific chapters** rather than the full report, where relevant.

CHAPTER CITATIONS:

Chapter 1: Sink KJ, Skowno AL, Green A, Landschoff J, Lamont T, and Franken M. 2019. Chapter 1: Introduction and Approach. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Chapter 2: van der Bank MG, Poole CJ, Sink KJ, Perschke M, Franken M, Rylands S, Miza SA, Majiedt PA, Sibanda SM, Harris LR, Whitehead TO, Dunga LV, Adams R. 2019. Chapter 2: Benefits of Biodiversity in the Marine Realm. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Chapter 3: Sink KJ, Harris LR, Skowno AL, Livingstone T, Franken M, Porter S, Atkinson LJ, Bernard A, Cawthra H, Currie J, Dayaram A, de Wet W, Dunga LV, Filander Z, Green A, Herbert D, Karenyi N, Palmer R, Pfaff M, Makwela M, Mackay F, van Niekerk L, van Zyl W, Bessinger M, Holness S, Kirkman SP, Lamberth S, Lück-Vogel M. 2019. Chapter 3: Marine Ecosystem Classification and Mapping. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Chapter 4: Majiedt PA, Holness S, Sink KJ, Reed J, Franken M, van der Bank MG, Harris LR, Adams L, Perschke M, Miza SA, Currie J, Dunga LV. 2019. Chapter 4: Pressures on Marine Biodiversity. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Chapter 5: Miza SA, Robinson TB, Peters K, Majiedt PA, Jackson L, Hampton SL, Sink KJ. 2019. Chapter 5: Alien and Invasive Species. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Chapter 6: Kelly C, Foden W, Midgley G, Porter S, Lamberth S, van der Lingen C, Atkinson LJ, Robinson J. 2019. Chapter 6: Climate Change. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Chapter 7: Sink KJ, Holness S, Skowno AL, Franken M, Majiedt PA, Atkinson LJ, Bernard A, Dunga LV, Harris LR, Kirkman SP, Oosthuizen A, Porter S, Smit K, Shannon L. 2019. Chapter 7: Ecosystem Threat Status. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Chapter 8: Sink KJ, Sibanda SM, Fielding P, Skowno AL, Franken M, Harris LR, Adams R, Baleta T. 2019. Chapter 8: Ecosystem Protection Level. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Chapter 9: van der Bank MG, Adams R, Raimondo DC, Sink KJ, van der Colff D, Makhado A, Kock A, Porter S, Seakamela SM, Louw S, Mann BQ, Bürgener M. 2019. Chapter 9: The State of Indigenous Species. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Chapter 10: da Silva J, van Vuuren B. 2019. Chapter 10: The genetic perspective on marine biodiversity. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

Chapter 11: Sink KJ, Harris LR, van der Bank MG, Franken M, Skowno A, Driver A, Atkinson LJ, Fairweather TP, Kerwath S, Majiedt PA, Robinson T, Pfaff M, Rikhotso W, Smith C. and van Niekerk L. 2019. Chapter 11: Key findings, priority actions and knowledge gaps. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

This report uses the names of the government departments confirmed in June 2019. Please refer to www.gov.za to see all the changes in government departments and ministries.

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06 12 2019

This report forms part of a set of reports that make up the South African National Biodiversity Assessment 2018:

NBA SYNTHESIS REPORT NBA 2018

For reference in non-scientific publications

South African National Biodiversity Institute (SANBI). 2019. National Biodiversity Assessment 2018: The status of South Africa's ecosystems and biodiversity. Synthesis Report. South African National Biodiversity Institute, an entity of the Department of Environment, Forestry and Fisheries, Pretoria.

For reference in scientific publications

Skowno AL, Poole CJ, Raimondo DC, Sink KJ, Van Deventer H, Van Niekerk L, Harris LR, Smith-Adao LB, Tolley KA, Zengeya TA, Foden WB, Midgley GF, Driver A. 2019. *National Biodiversity Assessment 2018: The status of South Africa's ecosystems and biodiversity. Synthesis Report*. South African National Biodiversity Institute, an entity of the Department of Environment, Forestry and Fisheries, Pretoria. http://hdl.handle.net/20.500.12143/6362

TECHNICAL REPORTS NBA 2018:

1. Terrestrial

Skowno AL, Raimondo DC, Poole CJ, Fizzotti B, Slingsby JA (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 1: Terrestrial Realm*. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6370

2. Inland Aquatic (Freshwater)

Van Deventer H, Smith-Adao L, Collins NB, Grenfell M, Grundling A, Grundling PL, Impson D, Job N, Lötter M, Ollis D, Petersen C, Scherman P, Sieben E, Snaddon K, Tererai F, Van der Colff D. 2019. *South African National Biodiversity Assessment 2018: Technical Report. Volume 2: Inland Aquatic (Freshwater) Realm*. CSIR report number CSIR/NRE/ECOS/IR/2019/0004/A. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6230

3. Estuarine

Van Niekerk L, Adams JB, Lamberth SJ, Mackay F, Taljaard S, Turpie JK, Weerts S, Raimondo DC. 2019 (eds). *South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm.* CSIR report number CSIR/SPLA/EM/EXP/2019/0062/A. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A. http://hdl.handle.net/20.500.12143/6373

4. Marine

Sink KJ, Van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372

5. Coast

Harris LR, Sink KJ, Skowno AL, Van Niekerk L (eds). 2019. *South African National Biodiversity Assessment 2018: Technical Report. Volume 5: Coast*. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6374

6. Sub-Antarctic territory

Whitehead TO, Von der Meden C, Skowno AL, Sink KJ, Van der Merwe S, Adams R, Holness S (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 6: Sub-Antarctic Territory*. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6375

7. Genetics

Tolley KA, Da Silva JM, Jansen van Vuuren B. 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 7: Genetic Diversity*. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6376

OTHER ANNEXURES

Each technical report listed has a number of annexures such as inventory reports, method explanations, and both spatial and non-spatial datasets, available at http://nba.sanbi.org.za/

Three other independent annexures exist as supplementary material for NBA 2018:

SANBI. 2019. *National Biodiversity Assessment 2018 Supplementary Material: Compendium of Benefits of Biodiversity*. South African National Biodiversity Institute, Pretoria.

SANBI. 2019. *South Africa's National Biodiversity Assessment: Contextual and Operational Framework. Released as supplementary material to the National Biodiversity Assessment 2018*. South African National Biodiversity Institute, Pretoria.

SANBI. 2019. *National Ecosystem Classification System. Released as supplementary material to the National Biodiversity Assessment 2018*. South African National Biodiversity Institute, Pretoria.

ACKNOWLEDGEMENTS

This report draws extensively from work conducted by many marine scientists and managers in South Africa and from the broader National Biodiversity Assessment (NBA) team. We thank all of you for your contributions to this body of knowledge and for helping to shape, contribute and improve this product. Your engagement, hard work, data, time and discussions are appreciated. We ask for forgiveness if you are not specifically mentioned by name. The Terrestrial, Estuarine, Inland Aquatic, Species and Genetic teams of the NBA are all acknowledged for their contributions and influence in the marine assessment and beyond. Andrew Skowno, is acknowledged for leadership of the broader NBA team, for technical and analytical support and for understanding the competing work priorities in the last phase of this assessment. Carol Poole is thanked for her coordination efforts, patience, unplanned contributions and brownies. We thank Mandy Driver for her long-term vision, exceptional clarity of thought, messaging advice and support. Stephen Holness processed the many pressure data sets for this assessment and led the analyses for ecosystem threat status. Sizakele 'Sizo' Sibanda undertook the analyses for protection level with support from Andrew Skowno. We are deeply indebted to our competent and ever reliable colleagues Anisha Dayaram and Sediqa Khatieb for GIS support and other contributions that are not always sufficiently reflected in this report. Tamsyn Livingstone is thanked for a considerable amount of GIS support between 2014 and 2018 and Linda Harris and other GIS team member helped when Tamsyn was not able to. Thank you all. There is a considerable amount of GIS work, data management, data processing and data collation work that supports this process.

Within the SANBI marine unit we thank our support staff interns and research assistants over the last five years and Mari-Lise Franken who contributed beyond that reflected in authorship of this report. The Pew Charitable Trusts is thanked for facilitating this additional support over three years and for enabling broader participation and contributions to this report including additional inputs from post-doctoral and masters students and research assistants. Robyn Adams provided exceptional support in terms of graphics and we appreciate her many versions of products supporting this assessment and contributions in most chapters. We look forward to her future data visualisation products and inspirational infographics.

We specially highlight and thank the students and young people who helped with the millions of small steps required to compile this assessment. We appreciate your willingness to help enter hundreds of references, locate and download many papers, help summarise information, write sections of his report and craft graphics to improve the communication of key points. We hope you will become the leaders of future assessments and apply knowledge gained in future endeavours to help manage marine biodiversity in South Africa.

We thank SANBI for the core funding to undertake this assessment. Shore mapping and analytical support (funding for Linda Harris and Stephen Holness, Nelson Mandela University) were supported by the Benguela Current Marine Spatial Management and Governance Project (MARISMA). The project is a partnership between the Benguela Current Convention (BCC), its Contracting Parties Angola, Namibia and South Africa, and the Government of the Federal Republic of Germany in pursuit of the sustainable development of the Benguela Current Large Marine Ecosystem (BCLME). MARISMA is implemented by the BCC, the Governments of Angola, Namibia and South Africa, and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The project is funded through the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The BMU supports this initiative on the basis of a decision adopted by the German Bundestag.

We thank the National Research Foundation for funding research that provided key inputs into the NBA especially projects funded through the Foundational Biodiversity Information Program (FBIP) and the African Coelacanth Ecosystem Program (ACEP). The FBIP funded SeaKeys project and the ACEP Deep Secrets and

ACEP Deep Forests grants held by Kerry Sink are acknowledged. We also acknowledge the ACEP Imida Frontiers Project, ACEP Spatial Solutions, ACEP Algoa Bay Project and ACEP Surrogacy projects for providing opportunities, data and capacity to iteratively improve the classification and mapping of marine ecosystems in South Africa. We thank Ryan Palmer, Grant Van der Heever, Charlie von der Meden, Laurenne Snyders and Fred Fourie for helping shine a light on the deep seabed. The benthic ecology teams and all associated technicians at both the Department of Environment, Forestry and Fisheries and the South African Environmental Observation Network are thanked in this regard. We also thank the Masters and crew of the offshore vessels that enable marine research at sea. Siyabonga Dlulisa and Robin Adams are thanked for sharing insights on Marine Protected Area (MPA) priorities included in Chapter 8.

We thank the photographers who contributed images for this report, especially Peter Chadwick, Geoff Spiby, Steve Benjamin, Charlie Griffiths and Eve Marshall (cover). Many people have contributed to the conceptualisation of ideas and approaches for this report and helped to identify key limitations and suggest new approaches going forward. We also thank the National Marine Biodiversity Scientific Working group who were the reference group for the NBA 2018 marine assessment and the Marine Ecosystem Committee and six task teams who helped identify key data sets and advice on the classification and mapping of marine ecosystems. We also acknowledge members of the Provincial and Metro Biodiversity Planning Technical Working Group, the National Ecosystem Classification Committees, and the NBA Core Reference Group for their input.

We acknowledge the individuals and institutes represented within the editorial team who facilitated support and time often at short notice to complete this task. You all helped strengthen this product and we are grateful for your investment of time and expertise. We thank Shahieda Davids for further editorial assistance on the executive summary. We also thank Linda Harris who is an editor and co-author of this report, but who also ably led an additional coastal component, from which we also drew substantially from in this work. The collaborations and learning facilitated by the NBA are exceptional and we thank all of those who have facilitated learning within and across realms and themes.

Finally, we are deeply grateful to our three reviewers who devoted significant time to this task. Sean Fennessy is thanked for thoroughly reviewing this report and making many constructive recommendations. We highly appreciated your attention to detail. Amanda Lombard is acknowledged and appreciated for ongoing guidance and iterative reviews at key stages over the last 18 months. Piers Dunstan is thanked sincerely for his international review and guidance on improving future iterations of this assessment. We look forward to future collaborations in this regard.

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B: Pressure source data and processing

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Annexure 2. SANBI. 2018. Marine Protected Areas Factsheet: How South African marine protected areas benefit people. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6637

Annexure 3. Sink KJ, Majiedt PA, Franken M, Adams L, Dunga LV, Perschke M, Rylands S, Gqaleni MC. 2019. Annexure 3: Ecosystem Classification and Pressure References. National Biodiversity Assessment 2018 Supplementary Material. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6651

Annexure 4. Franken M, Sink KJ, Majiedt PA, Sibanda S, Chadwick P. 2018. Increasing Benefits from Marine Protected Areas. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6652

Annexure 5. van der Bank MG, Adams R, Attwood C, Sink KJ. 2019. Annexure 5: Harvested species in the marine realm. National Biodiversity Assessment 2018 Supplementary Material. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6654

Annexure 6. van der Bank MG, Sink KJ, Franken M, Rylands R. 2019. Annexure 6: Progress against the NBA 2011 Priority Actions. National Biodiversity Assessment 2018 Supplementary Material. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6655

LIST OF ACRONYMS, ABBREVIATIONS, INITIALISMS AND SYMBOLS

AABW	Antarctic Bottom water
ACEP	African Coelacanth Ecosystem Program
AIS	Alien Invasive Species
AOO	Area of Occupancy
ASCA	Agulhas System Climate Array
BCC	Benguela Current Commission
BRUV	Baited Remote Underwater Video
CBA	Critical Biodiversity Area
CBD	Convention on Biological Diversity
CCAMP	Climate Change Adaptation and Mitigation Plan
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CITES	Convention on the International Trade in Endangered Species
ConGRESS	Conservation Genetic Resources for Effective Species Survival
CoP	Conference of the Parties
CPUE	Catch Per Unit Effort
CR	Critically Endangered
CSIR	Council for Scientific and Industrial Research
CTD	Conductivity, Temperature, Depth
DAFF	Department of Agriculture, Forestry and Fisheries
DD	Data Deficient
DEA	Department of Environmental Affairs
DEFF	Department of Environment, Forestry and Fisheries
DNA	Deoxyribonucleic acid
DoT	Department of Transport
DST	Department of Science and Technology
DWS	Department of Water and Sanitation
EAF	Ecosystem Approach to Fisheries
EBSA	Ecologically or Biologically Significant Marine Areas
ED	Evolutionary distinctiveness
EDGE	Evolutionarily distinct and globally endangered
eDNA	environmental-Deoxyribonucleic acid
EEO	Extent of Occurrence
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMP	Estuary Management Plan
EN	Endangered
ENSO	El Niño Southern Oscillation
ESA	Ecological Support Area
FAO	Food and Agriculture Organization
FBIP	Foundational Biodiversity Information Programme
FEPA	Freshwater Ecosystem Priority Areas
GDP	Gross Domestic Product
GEBCO	General Bathymetric Chart of the Ocean
GIS	Geographic Information Systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HAB	Harmful Algal Bloom
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICMA	Integrated Coastal Management Act
IMO	International Maritime Organization
IOSEA	Indian Ocean and South-East Asia
IOTC	Indian Ocean Tuna Commission
IPBES	The Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
IUU	Illegal, unregulated and unreported catches
JABBA	Just Another Bayesian Biomass Assessment
KBA	Key Biodiversity Area
KEEN	Kelp Ecosystem Ecology Network
KZN	KwaZulu-Natal
LC	Least Concern
LMP	Linefish Management Protocol
LTAS	Long-Term Adaptation Scenarios Flagship Research Program
MARISMA	Marine Spatial Management and Governance Programme

MEC	Marine Ecosystem Committee
MLRA	Marine Living Resources Act
MOU	Memorandum of Understanding
MPA	Marine Protected Area
MSP	Marine Spatial Planning
MSY	Maximum Sustainable Yield
mtDNA	Mitochondrial DNA
NADW	North Atlantic Deep Water
NBA	National Biodiversity Assessment
NBF	National Biodiversity Framework
NBSAP	National Biodiversity Strategy and Action Plan
NDP	National Development Plan
NE	Not Evaluated
NEM:PAA	National Environmental Management: Protected Areas Act, NEM: PAA, Act No 57 of 2003
NEMBA / NEM:BA	National Environmental Management: Biodiversity Act (10 of 2004) / Biodiversity Act
NGO	Non-government Organization
NGS	Next Generation Sequencing
NPAES	National Protected Area Expansion Strategy
NRF	National Research Foundation
NSBA	National Spatial Biodiversity Assessment
NT	Near Threatened
OMP	Operational Management Procedure
ORI-CFTP	Oceanographic Research Institute's conventional fish tagging program
PA	Protected area
PD	Phylogenetic diversity
PE	Phylogenetic endemism
PEIs	Prince Edward Islands – consisting of Marion and the smaller Prince Edward Island and their EEZ
POC	Particulate Organic Matter
PUCL	Precautionary Upper Catch Limit
RFMO	Regional Fisheries Management Organization
RLA	Red List Authority
RLE	Red List of Ecosystems
RLI	Red List Index
RLU	Red List Unit
ROV	Remote Operated Vehicle
SABAP	Southern African Bird Atlas Project
SAEON	South African Environmental Observation Network
SAM	Southern Annular Mode
SAMSA	South African Maritime Safety Authority
SANBI	South African National Biodiversity Institute
SANHO	South African Navy Hydrographers Office
SAPAD	South African Protected Areas Database
SARVA	South African Risk and Vulnerability Atlas
SASSI	South African Sustainable Seafood Initiative
SBR	Spawner Biomass Per Recruit
SDF	Spatial Development Framework
SDG	National Protected Area Expansion Strategy
SDG	Sustainable Development Goals
SPLUMA	Spatial Planning and Land Use Management Act (16 of 2013)
SPM	Surplus Production Model
SSC	Species Survival Commission
SST	Sea Surface Temperature
SWG	Scientific Working Group
SWSA	Strategic Water Source Areas
TAB	Total Allowable Bycatch
TAC	Total Allowable Catch
TAE	Total Allowable Effort
TNPA	Transnet National Port Authority
ToCC	Taxa of Conservation Concern
TOPS regulations	Threatened or protected species regulations under NEM:BA
TURF	Territorial Use Rights in Fisheries
UCT	University of Cape Town
UNESCO	United Nations Educational, Scientific and Cultural Organisation
VME	Vulnerable Marine Ecosystem
VU	Vulnerable
WCRL	West Coast Rock Lobster
WfFP	Working for Fisheries Programme

WftC	Working for the Coast
WHS	World Heritage Site
WRC	Water Research Commission
WWF-SA	World Wide Fund for Nature- South Africa
YPR	Yield Per Recruit

GLOSSARY OF TERMS

See the Lexicon of Biodiversity Planning in South Africa, which provides standard definitions of key concepts and often used terms.

Allelic diversity (N_A): The presence and number of different alleles at a gene locus.

Area of occupancy (AOO): A standardised measure of the area that is occupied by an ecosystem type or species.

Backshore: defined in NBA 2018 as the coastal zone that is equivalent to the primary dunes, delimited between the dune base and the scrub-thicket break (as defined by Tinley, 1985). The combined backshore and shore are defined in NBA 2018 as the seashore.

Ballast water: Water that is stored in the ballast tank or cargo hold of a ship in order to stabilise the ship's movement during voyage when it is not carrying cargo. This water is usually taken onboard a ship from one geographical area and discharged in another.

Benefits of biodiversity: a general term meant to encompass terminology in popular use for various purposes, such as 'ecosystem services', 'ecosystem goods', 'ecological infrastructure', and 'nature's contributions to people'. The NBA 2018 authors felt that 'benefits' is a term that is currently understood well in South Africa by multiple audiences. The work on the term 'nature's contributions to people' (defined as: All the benefits (and occasionally losses or detriments that humanity obtains from nature), underway through the Intergovernmental Platform on Biodiversity and Ecosystem Services, is fully acknowledged and efforts to find inclusionary terminology that encompasses the diverse world views on the human-nature relationship and further opportunities to incorporate non-monetary values into our discourse are welcomed.

Benthic: Relating to the bottom of the ocean or the seabed.

Biodiversity: The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Biodiversity assets: Species, ecosystems and other biodiversity-related resources that generate ecosystem services, support livelihoods, and provide a foundation for economic growth, social development and human wellbeing.

Biodiversity Management Plan: A plan aimed at ensuring the long-term survival in nature of an indigenous species, a migratory species or an ecosystem, published in terms of the Biodiversity Act. Norms and standards to guide the development of Biodiversity Management Plans for Species have been developed. At the time of writing, norms and standards for Biodiversity Management Plans for Ecosystems were in the process of being developed.

Biodiversity planning: Spatial planning to identify geographic areas of importance for biodiversity. Also see Systematic biodiversity planning.

Biodiversity priority areas: Features in the landscape or seascape that are important for conserving a representative sample of ecosystems and species, for maintaining ecological processes, or for the provision of ecosystem services. They include the following categories, most of which are identified based on systematic biodiversity planning principles and methods: protected areas, Critically Endangered and Endangered ecosystems, Critical Biodiversity Areas and Ecological Support Areas, Freshwater Ecosystem Priority Areas, high water yield areas, flagship free-flowing rivers, priority estuaries, focus areas for land-based protected area expansion, and focus areas for offshore protection. Marine ecosystem priority areas and coastal ecosystem priority areas have yet to be identified but will be included in future. The different categories are not mutually exclusive and, in some cases, overlap, often because a particular area or site is important for more than one reason. They should be seen as complementary, with overlaps reinforcing the importance of an area.

Biodiversity target: The minimum proportion of each ecosystem type that needs to be kept in a natural or near natural state in the long term in order to maintain viable representative samples of all ecosystem types and the majority of species associated with those ecosystem types.

Biodiversity thresholds: A series of thresholds used to assess ecosystem threat status, expressed as a percentage of the original extent of an ecosystem type. The first threshold, for Critically Endangered ecosystems, is equal to the biodiversity target; the second threshold, for Endangered ecosystems, is equal to the biodiversity target plus 15%; and the third threshold, for Vulnerable ecosystems, is usually set at 60%. Also see Ecosystem threat status.

Biodiversity: The diversity of genes, species and ecosystems on Earth, and the ecological and evolutionary processes that maintain this diversity.

Biofouling: The accumulation of organisms on surfaces and structures immersed in or exposed to the aquatic environment.

Biogeography: A study of the geographical distribution of biodiversity over space and time.

Biome: An ecological unit of wide extent, characterised by complexes of plant communities and associated animal communities and ecosystems, and determined mainly by climatic factors and soil types. A biome may extend over large, more or less continuous expanses or land surface, or may exist in small discontinuous patches.

Biomimicry: The science of applying nature-inspired designs in human engineering and invention to solve human problems. It is the practice of learning from (not just about) nature and then emulating its forms, processes, and ecosystems to create more sustainable products, processes and systems.

Biomonitoring: The act of observing and assessing the state and ongoing changes in ecosystems, components of biodiversity and landscape, including the types of natural habitats, populations and species.

Bioregional plan (published in terms of the Biodiversity Act): A map of Critical Biodiversity Areas and Ecological Support Areas, for a municipality or group of municipalities, accompanied by contextual information, land- and resource-use guidelines and supporting GIS data. The map should be produced using the principles and methods of systematic biodiversity planning, in accordance with the Guideline for Bioregional Plans. A bioregional plan represents the biodiversity sector's input into planning and decision making in a range of other sectors. The development of the plan is usually led by the relevant provincial conservation authority or provincial environmental affairs department. A bioregional plan that has not yet been published in the Government Gazette in terms of the Biodiversity Act is referred to as a biodiversity sector plan.

Bio-discovery: Also referred to as bioprospecting. The systematic search for genes, compounds, designs, and organisms that might have a potential economic use and might lead to a product development.

Bycatch: Animals caught by accident in fishing gear; species that the fishers do not intend to catch. These can include, for example, marine mammals, sea turtles, sea birds and sharks.

Coast: The coast or coastal zone was determined ecologically by identifying terrestrial and marine ecosystem types with strong coastal affinities. In addition, all estuarine ecosystem types were considered coastal. It is recognised that this is different to the definition of coastal zone in the Integrated Coastal Management Act which uses fixed buffer distances from the high-water mark.

Coastline: non-specific coastal boundary referring to the general land-sea interface, used synonymously with shoreline.

Collapsed (CO) (Red List category): An ecosystem type is Collapsed when it is virtually certain that its defining biotic or abiotic features are lost, and the characteristic native biota are no longer sustained.

Conservation area: Areas of land not formally protected by law but informally protected by the current owners and users and managed at least partly for biodiversity conservation. Because there is no long-term security associated with conservation areas, they are not considered a strong form of protection. Also see Protected Area.

Conservation planning—see Biodiversity planning

Coral bleaching: Loss of symbiotic dinoflagellates, triggered by elevated sea temperatures and other environmental stressors, leaving corals physiologically and nutritionally compromised.

Critical Biodiversity Area: Areas required to meet biodiversity targets for ecosystems, species or ecological processes, as identified in a systematic biodiversity plan. May be terrestrial or aquatic.

Critically Endangered (CR) (IUCN Red List category): Applied to both species/taxa and ecosystems: A species is Critically Endangered when the best available evidence indicates that it meets at least one of the five IUCN criteria for Critically Endangered, indicating that the species is facing an extremely high risk of extinction. Critically Endangered ecosystem types are considered to be at an extremely high risk of collapse. Most of the ecosystem type has been severely or moderately modified from its natural state. The ecosystem type is likely to have lost much of its natural structure and functioning, and species associated with the ecosystem may have been lost. Critically endangered species are those considered to be at extremely high risk of extinction.

Cryptogenic: Referring to species that cannot be reliably demonstrated as being introduced or native.

Data Deficient (DD) (Red List category): An ecosystem type or species is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction (species) or risk of collapse (ecosystems). Listing ecosystems or species in this category indicates that their situation has been reviewed, but that more information is required to determine their risk status.

Degradation: the many human-caused processes that drive the decline or loss in biodiversity, ecosystem functions or ecosystem services in any terrestrial and associated aquatic ecosystems.

DNA: Deoxyribonucleic acid; hereditary material in almost all living organisms.

Dune base: the foot of the dune, often the seaward point to which dune pioneer plants extend. In NBA 2018, this is a coastal boundary line separating the shore and backshore zones, and is considered equivalent to a decadal-scale high-water mark.

Ecological infrastructure: The stock of ecosystems and species, or natural capital, that provides a flow of essential ecosystem services to human communities. Networks of ecological infrastructure may takes the form of large tracts of natural land or ocean, or small remaining patches or corridors embedded in production landscapes. If ecological infrastructure is degraded or lost, the flow of ecosystem services will diminish. Ecological infrastructure is just as important as built infrastructure for providing vital services that underpin social and economic activity.

Ecological or Biologically Significant Marine Area (EBSA): Geographically or oceanographically discrete areas that provide important services to one or more species/populations of an ecosystem or to the ecosystem as a whole, compared to other surrounding areas or areas of similar ecological characteristics, or otherwise meet the [EBSA] criteria. These criteria include a) uniqueness or rarity, b) special importance for life history stages of species, c) importance for threatened or declining species and/or habitats, d) vulnerability or slow recovery, e) biological productivity, f) biological diversity and g) naturalness.

Ecological Support Area: An area that is not essential for meeting biodiversity targets but plays an important role in supporting the ecological functioning of one or more Critical Biodiversity Areas or in delivering ecosystem services. May be terrestrial or aquatic.

Ecoregion: A relatively large area of land or water, containing characteristic, geographically distinct assemblages of natural communities and species. Used in South African river and marine ecosystem classification systems, the ecoregion is larger than an ecosystem type. The flora, fauna and ecosystems that characterise an ecoregion tends to be distinct from that of other ecoregions.

Ecosystem Protection Level: Indicator of the extent to which ecosystems are adequately protected or under-protected. Ecosystem types are categorised as Well Protected, Moderately Protected, Poorly Protected, or Not Protected, based on the proportion of the biodiversity target for each ecosystem type that is included within one or more protected areas. Not Protected, Poorly Protected or Moderately Protected ecosystem types are collectively referred to as under-protected ecosystems.

Ecosystem services: the benefits that people obtain from ecosystems, including provisioning services (such as food and water), regulating services (such as flood control), cultural services (such as recreational benefits), and supporting services (such as nutrient cycling, carbon storage) that maintain the conditions for life on Earth. Ecosystem services are the flows of value to human society that result from a healthy stock of ecological infrastructure. If ecological infrastructure is degraded or lost, the flow of ecosystem services will diminish. See also benefits of biodiversity.

Ecosystem threat status: Indicator of how threatened ecosystems are, in other words the degree to which ecosystems are still intact or alternatively losing vital aspects of their structure, function or composition. Ecosystem types are categorised as Critically Endangered, Endangered, Vulnerable, Near Threatened or Least Concern, based on the proportion of the original extent of each ecosystem type that remains in good ecological condition relative to a series of biodiversity thresholds. Critically Endangered, Endangered and Vulnerable ecosystems are collectively referred to threatened ecosystems, and may be listed as such in terms of the Biodiversity Act.

Ecosystem type: An ecosystem unit that has been identified and delineated as part of a hierarchical classification system, based on biotic and/or abiotic factors. Factors used to map and classify ecosystems differ in different environments. Ecosystem types can be defined as, for example, vegetation types, river ecosystem types, wetland ecosystem types, estuary ecosystem types, or marine or coastal habitat types. Ecosystems of the same type are likely to share broadly similar ecological characteristics and functioning. Also see National ecosystem classification system.

Ecosystem-based Adaptation (to climate change): The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change. Includes managing, conserving and restoring ecosystems to buffer humans from the impacts of climate change, rather than relying only on engineered solutions. Combines socio-economic benefits, climate change adaptation, and biodiversity and ecosystem conservation, contributing to all three of these outcomes simultaneously.

Endangered (EN) (Red List category): Applied to both species/taxa and ecosystems: A species is Endangered when the best available evidence indicates that it meets at least one of the five IUCN criteria for Endangered, indicating that the species is facing a very high risk of extinction. Endangered ecosystem types are considered to be at a very high risk of collapse. Endangered species are those considered to be at very high risk of extinction.

Endemic: A species that is native to, and restricted to, a particular geographical region. Highly endemic species and those with very restricted natural ranges, are especially vulnerable to extinction if their natural habitat is eliminated or significantly disturbed.

Estuarine functional zone: The open water area of an estuary together with the associated floodplain, incorporating estuarine habitat (such as sand and mudflats, salt marshes, rock and plant communities) and key physical and biological processes that are essential for estuarine ecological functioning.

Extent of occurrence (EOO): A standardised measure of the area within which all occurrences of an ecosystem type or species exist.

Freshwater Ecosystem Priority Area: A river or wetland that is required to meet biodiversity targets for freshwater ecosystems.

Functional impact: A broad evaluation of the degree to which the natural state of any given ecosystem (including component species, community structure, physical habitat structure and ecosystem function) is impacted by a specific activity.

Genetic diversity: The number of different alleles or haplotypes for a population or species. High genetic diversity means the sample of individuals from a population or species have many different versions (alleles or haplotypes) of the gene that was quantified.

Heterozygosity: The condition when an individual has two different alleles for one gene.

Hydrological regime / flow regime: The hydrological regime (also referred to as flow regime) includes all aspects relating to the flow of water, including: magnitude, frequency, duration, predictability and flashiness.

Least Concern (LC) (Red List category): An ecosystem type that has experienced little or no loss of natural habitat or deterioration in condition or a species considered at low risk of extinction. Widespread and abundant species are typically classified in this category.

Littoral Active Zone: The coupled dune-beach-surf zones that function together as a single geomorphic unit and within which sand is actively transferred offshore and onshore during natural erosion and accretion cycles.

Marine Spatial Planning (MSP): Marine Spatial Planning is the governance process of collaboratively assessing and managing the spatial and temporal distribution of human activities to achieve economic, social and ecological objectives.

Maximum Sustainable Yield (MSY): The largest average catch or yield that can continuously be taken from a fish stock under existing environmental conditions.

Moderately Protected (MP): An ecosystem type or species that has between 50 and 100% of its biodiversity target included in one or more protected areas.

National ecosystem classification system: A hierarchical system for mapping and classifying ecosystem types in the terrestrial, river, wetland, estuarine, coastal and marine realm. South Africa has a well-established classification system for terrestrial ecosystems in the form of vegetation mapping, and much progress has been made in mapping and classifying aquatic ecosystems as part of the NBA 2011. Factors used to map and classify ecosystems differ in different environments, but in all cases ecosystems of the same type are expected to share broadly similar ecological characteristics and functioning. The national ecosystem classification system provides an essential scientific foundation for ecosystem-level assessment, planning, monitoring and management. Also see Ecosystem type.

Near Threatened (NT) (Red List category): An ecosystem type or species is Near Threatened when it has been evaluated against the IUCN criteria but does not qualify for CR, EN or VU, but it is close to qualifying for or is likely to qualify for a threatened category in the near future.

Not Evaluated (NE) (Red List category): An ecosystem type or species is Not Evaluated when it is has not been assessed against any of the IUCN criteria for assessing the threat status of species or ecosystems.

Not Protected (NP): An ecosystem type or species that has less than 5% of its biodiversity target included in one or more protected areas

Operation Phakisa: Operation Phakisa is an initiative of the South African government designed to fast track the implementation of solutions on critical development issues highlighted in the National Development Plan (NDP) 2030 such as poverty, unemployment and inequality. Operation Phakisa is an innovative and pioneering approach to translate detailed plans into concrete results through dedicated delivery and collaboration. 'Phakisa' means 'hurry up' in Sesotho and the application of this methodology highlights government's urgency to deliver. Through Operation Phakisa, government aims to implement priority programmes better, faster and more effectively. www.operationphakisa.gov.za

Pelagic: Relating to the water column in the ocean.

Poorly Protected (PP): An ecosystem type or species which has between five percent and 50% of its biodiversity target included in one or more protected areas.

Protected Area Target: A quantitative goal for how much of an ecosystem type should be included in the protected area network by a certain date. The National Protected Area Expansion Strategy 2008 sets five-year and twenty-year protected area targets for each terrestrial ecosystem type, based on a portion of its biodiversity target. Protected area targets are revised every five years.

Protected Area: An area of land or sea that is formally protected by law and managed mainly for biodiversity conservation. This is a narrower definition than the IUCN definition, which includes areas that are not legally protected and that would be defined in South Africa as conservation areas rather than protected areas. Also see Conservation area.

Recovery: A measure of the time required for the ecosystem (including affected species, physical habitat structure, and community trophic structure) to return to a natural state following cessation of disturbance by a given activity.

Regional Fisheries Management Organisations (RFMOs): Affiliations of nations which co-ordinate efforts to manage fisheries in a particular region. RFMOs may focus on certain species of fish (e.g. the Commission for the Conservation of Southern Bluefin Tuna) or have a wider responsibility related to living marine resources in general within a region (e.g. the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

SeaKeys: The SeaKeys project (funded by the NRF-FBIP) was initiated to help collate knowledge and address key gaps in South African foundational marine biodiversity knowledge. The project aimed to unlock marine biodiversity knowledge through the co-ordinated capture and dissemination of data, limited and focused new research and innovative knowledge generation, capacity building and information flow approaches.

Seashore: defined in NBA 2018 as the land-sea interface comprising the backshore and shore zones, extending from the scrub-thicket break to the back of the surf zone.

Shore: defined in NBA 2018 as the coastal zone that spans the intertidal systems from the dune base to the back of the surf zone. The combined backshore and shore are defined in NBA 2018 as the seashore.

Shoreline: non-specific coastal boundary referring to the general land-sea interface, used synonymously with coastline.

Spatial biodiversity plan: A plan that identifies one or more categories of biodiversity priority area, using the principles and methods of systematic biodiversity planning. South Africa has a suite of spatial biodiversity plans at national and sub-national level, which together should inform land-use planning, environmental impact assessment, water resource management, and protected area expansion.

Systematic biodiversity planning: A scientific method for identifying geographic areas of biodiversity importance. It involves: mapping biodiversity features (such as ecosystems, species, spatial components of ecological processes); mapping a range of information related to these biodiversity features and their ecological condition; setting quantitative targets for biodiversity features; analysing the information using software linked to GIS; and developing maps that show spatial biodiversity priorities. The configuration of priority areas is designed to be spatially efficient (i.e. to meet biodiversity targets in the smallest area possible) and to avoid conflict with other land and water resource uses where possible.

Target catch: The catch which is the subject of directed fishing effort within a fishery; the catch consisting of the species primarily sought by fishers.

Taxa of Conservation Concern (ToCC) are species and subspecies that are important for South Africa's conservation decision making processes. They include all taxa that are assessed according the IUCN Red List criteria as Critically Endangered (CR) Endangered (EN), Vulnerable (VU), Data Deficient (DD) or Near Threatened (NT). They also include range restricted taxa (Extent of Occurrence < 500 km^2) that are classified according to South Africa's national criteria as Rare. Detailed information on the pressures impacting these taxa has been captured during the Red List assessment processes. Throughout the NBA reference to the impact of a particular pressure on a taxonomic groups is determined from the proportion of taxa of conservation concern impacted by that pressure.

Taxon (plural taxa) is any unit used in the science of biological classification, or taxonomy. Some species have been split into sub-species and/or varieties and assessed at these levels. Consequently, if a taxonomic group includes sub-species or varieties, the summary statistics use the term 'taxa'. If a group contains only species then the term 'species' is used in the summary statistics.

Taxonomy: Refers to the system that classifies all worldwide species including plants, animals and microorganisms.

Threatened ecosystem: An ecosystem that has been classified as Critically Endangered, Endangered or Vulnerable, based on an analysis of ecosystem threat status. A threatened ecosystem has lost or is losing vital aspects of its structure, function or composition. The Biodiversity Act allows the Minister of Environmental Affairs or a provincial MEC for Environmental Affairs to publish a list of threatened ecosystems. To date, threatened ecosystems have been listed only in the terrestrial environment. In cases where no list has yet been published by the Minister, such as for all aquatic ecosystems, the ecosystem threat status assessment in the NBA can be used as an interim list in planning and decision making. Also see Ecosystem threat status.

Threatened species: A species that has been classified as Critically Endangered, Endangered or Vulnerable, based on a conservation assessment (Red List), using a standard set of criteria developed by the IUCN for determining the likelihood of a species becoming extinct. A threatened species faces a high risk of extinction in the near future.

Total Economic Value: The sum of all marketed and non-marketed benefits associated with an ecosystem or environmental resource, including direct, indirect, option and existence values.

UNESCO World Heritage Site: A World Heritage Site is a landmark or area which is chosen by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) as having cultural, historical, scientific or other form of significance, and is legally protected by international treaties. The sites are judged important to the collective interests of humanity.

Vulnerable (VU) (Red List category): Applied to both species/taxa and ecosystems: A species is Vulnerable when the best available evidence indicates that it meets at least one of the five IUCN criteria for Vulnerable, indicating that the species is facing a high risk of extinction. An ecosystem type is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for VU, and is then considered to be at a high risk of collapse.

Vulnerable Marine Ecosystem: Fragile marine ecosystems in the deep sea that comprise benthic species that are vulnerable to impacts by fishing gear, and that have a low capacity to recover from disturbance as a result of conservative life histories (i.e. very slow growing, slow to mature, high longevity, low levels of recruitment), and sensitivity to changes in environmental conditions.

Well Protected (WP): An ecosystem type or species that has its full biodiversity target included in one or more protected areas.

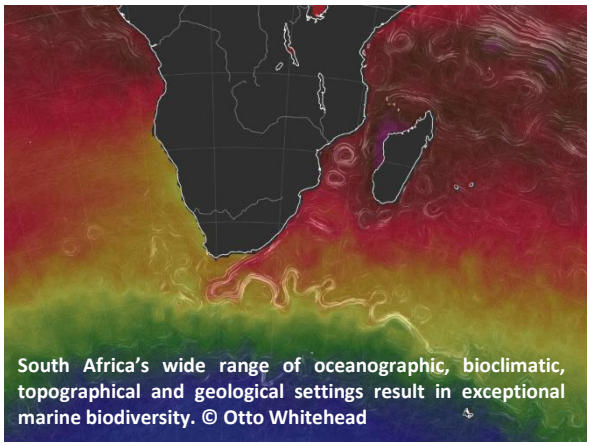
EXECUTIVE SUMMARY

The National Biodiversity Assessment (NBA) 2018 is a collaborative effort to synthesise the best available science on South Africa's biodiversity. The overarching aim of the NBA is to **inform policy and decision-making** in a range of sectors, and contribute to national development priorities. The NBA is used to inform policy in the biodiversity sector and other sectors that rely on and / or impact the environment and associated natural resources, such as agriculture and fisheries, water, mining, transport and human settlements. The NBA provides information to help prioritise effort and resources for managing and conserving biodiversity, and provides context and information that underpins biodiversity inputs to marine and coastal planning processes. A range of national and international level monitoring, reporting and assessment processes rely on information gathered during the NBA. The NBA is also a key reference and educational product relevant to scientists, students, consultants and decision makers, and acts as a national level platform for collaboration, information sharing and capacity building in the biodiversity sector in South Africa. This report focusses on the Marine Realm with similar reports covering the Terrestrial, Inland Aquatic (Rivers and Wetlands) and Estuarine Realms respectively. There is a dedicated Coastal report that is cross- realm and presents the integrated results for South Africa's first ecologically-determined map of all coastal ecosystem types. The state of coastal ecosystems is thus determined in this assessment, the estuarine assessment and in the case of coastal vegetation types, in the terrestrial. There are also technical reports on Genetic Diversity and on the Prince Edward Islands and surrounding seas in South Africa's sub-Antarctic territory.

The **marine realm** covered by this report is defined from the dune base, effectively a decadal scale high water mark, to the outer boundary of South Africa's Exclusive Economic Zone (EEZ), an ocean area of 1.1 million km^2. This report covers the ecosystem, species and genetic levels of marine biodiversity, the pressures and threats to this marine biodiversity and the key actions to maintain the benefits from South Africa's marine biodiversity. The threat status of both ecosystems and species is reported and progress in ecosystem protection levels is examined. Trends in ecosystem threat status between previous biodiversity assessments and 2018 are not examined due to differences in ecosystem classification and mapping, pressure mapping and the assessment methodology. There is insufficient species data to produce species relist trends but key changes in stocks are noted. The effect of recent expansion in protected areas is examined by comparing 2018 and 2019 Protection Level Results. Generally, this assessment provides a new baseline to track the state of marine biodiversity into the future although further refinements in ecosystem classification and assessment are anticipated.

A total of **21 key findings** were distilled from this assessment and these are presented below. To address these findings and recognised limitations in this assessment, a number priority actions were identified including a top ten priority actions which are presented below the key findings.

South Africa's exceptional marine biodiversity is globally recognised



South Africa's wide range of oceanographic, bioclimatic, topographical and geological settings result in exceptional marine biodiversity. © Otto Whitehead

South Africa is globally recognised for its marine biodiversity and high levels of endemism.

South Africa's wide range of oceanographic, bioclimatic, topographical and geological settings have not only resulted in high species diversity and endemism, but also high ecosystem diversity. South Africa's marine ecosystems support more than 13 000 species (identified to date) with estimates of marine endemism for different groups of taxa ranging between 26 and 33%. South Africa is reported as having the third highest marine endemism after New Zealand (51%) and Antarctica (45%). Highest marine endemicity has consistently been reported for the warm temperate Agulhas ecoregion on the south coast which lies entirely within South Africa's territory and is geographically very isolated from other warm temperate regions. Endemic species and ecosystems should be a focus in management efforts to ensure safeguarding of unique biodiversity. It is South Africa's sole responsibility to manage, protect and avoid significant loss of habitats for those species and ecosystems found nowhere else on earth. The current lack in taxonomic expertise and foundational biodiversity information limits the evidence base for science to support management of this unique marine biodiversity heritage. Given the unique South African marine environment, biodiversity and endemism patterns, it is important that local taxonomic expertise is strengthened to capitalise on strategic research opportunities that can strengthen biodiversity science, research outputs and marine biodiversity management.

Marine biodiversity provides a wide array of benefits to South Africans



Benefits from biodiversity include the food and job security provided through fisheries. © Jaco Barendse

South Africa's exceptional marine biodiversity provides a wide array of benefits to the economy, society and human wellbeing.

Healthy marine biodiversity is central to South Africa's national objectives of increased economic growth and job creation. Tangible benefits include the direct harvesting of food and medicinal resources, and the recreational, tourism and educational benefits of the marine realm. Less tangible benefits include the spiritual and cultural values of South Africa's oceans and coasts and their likely role in modern human evolution. Naturally functioning ecosystems that generate or deliver valuable services to people and thereby enhance human wellbeing are referred to as ecological infrastructure, the nature-based equivalent to build infrastructure. Beaches, reefs, kelp forests and seamounts are marine ecosystems of limited extent that provide disproportionate benefits. Maintaining the health of marine biodiversity at the ecosystem species and genetic levels helps humans adapt to climate change. The continued supply of the many marine biodiversity benefits relies on healthy ecosystems and well managed species. Effective communication of the value of South Africa's marine biodiversity through improved co-ordinated messaging that articulates benefits is vital to mobilise people to sustainably use marine biodiversity. Increased research to improve social and economic statistics regarding marine biodiversity benefits should be prioritised. This chapter clearly illustrates that marine biodiversity is central to South Africa's national objectives of increased

economic growth and job creation, and plays a vital role in the wellbeing of coastal communities and South African society.

Advances in marine ecosystem mapping supports assessment, planning and management

Increased investment in research has improved ecosystem classification and mapping to support effective spatial assessment, planning and management



Whip and spiral wire corals found on the deep reefs of the Amathole Offshore MPA © ACEP Imida Project

A revised Marine Ecosystem Classification and Map showcasing South Africa's 150 marine ecosystem types in six marine ecoregions was produced. Key advances in the map of marine ecosystems included very fine-scale shore mapping with alignment between marine, terrestrial and estuarine realms in the coastal zone; the inclusion of kelp forests, bays, fluvial fans and stromatolite shores as distinct ecosystem types and the introduction of finer depth strata across shelves and on the slope. This was as a result of major efforts to collate or increase relevant historic and current data sets to support improved ecosystem classification and mapping. Marine ecosystem types that are coastal (including all shore types, ecosystem types on the inner shelf and all river influenced ecosystem types) were identified to produce the first ecologically determined map and assessment of coastal ecosystem types for South Africa. The development of an integrated map of ecosystems for all of South Africa's territory, including the terrestrial, marine and other aquatic ecosystem types in both mainland South Africa and the territory in the Southern Ocean is one of the major achievements of the NBA 2018. Key areas for future improvement include refined bathymetric data, updated wave-exposure data for shores, additional reef mapping, improved classification and mapping of bays and muds, and the collection of data to improve the understanding of biodiversity pattern in South Africa's deep-sea. Model-based approaches should be considered for future improvements, and validation of ecosystem types is a priority. Further data-driven approaches that can integrate large datasets covering multiple ecosystem components collected by multiple methods are encouraged.

Pressures impact all levels of marine biodiversity

Pressures are impacting marine biodiversity at all levels: ecosystems, species and genes

There is evidence that pressures on marine biodiversity exert impacts at the ecosystem, species and genetic levels. These impacts are most clearly demonstrated for fishing, the most established marine activity with the longest history in South Africa's oceans. Ecosystem effects from fishing range from impacts on the seabed, trophic changes and behavioural changes. These ecosystem changes impact on species. For example, seabirds are affected by food availability and there is commercial species and other species caught as bycatch or incidentally and (food availability, behavioural…d trophic effects. At the species level, dramatic declines in target and other species have been attributed to fishing in some cases leading to overexploitation and threatened status. Despite limited genetic research, there is evidence of impacts from fishing on several fish species.

Fishing, reduced freshwater flow, pollution, coastal development, mariculture and mining are key marine pressures (*well established*).

Marine ecosystems and species face pressures from an increasing range, extent and intensity of human activities, threatening the societal benefits from marine biodiversity. These pressures include 22 recognised fisheries sectors, petroleum activities, mining, shipping, freshwater flow reduction, coastal development, ports and harbours, mariculture, and pollution. The extent and intensity of pressures, and the impacted components of biodiversity, all warrant consideration in determining key pressures. Coastal development, mining, trawling and mariculture have the highest impact scores among the 31 pressures on marine ecosystem types included in this assessment. Fishing and shipping are pressures with the greatest extent. Emerging pressures of greatest concern include land-sourced pollution (e.g. plastic pollution and chemical runoff), increased underwater noise and desalination impacts. High levels of organochlorine pesticide accumulation in corals in the iSimangaliso were recently reported along with evidence that microplastics are no ubiquitous across the South African coastline. Fishing is the greatest cause of biodiversity degradation in the offshore environment whereas both coastal development and fishing are the greatest pressures on inshore ecosystems. A meta-analysis of the key pressures impacting on species of conservation concern revealed that fishing remains the greatest pressure on marine species. The impacts of key emerging pressures, including land-sourced pollution (e.g. plastic pollution and chemical runoffs), light pollution, increased underwater noise and desalination impacts require further research. Mapping of climate change impacts could strengthen future assessments.

Pressure distribution is uneven with hotspots in bays, bights and the shelf edge

The distribution of pressures is uneven with pressure hotspots in bays, bights and the shelf edge.
Pressures are unevenly distributed across the seascape with some areas experiencing high concentrations of pressures. A key pattern that emerged during the NBA 2018 marine assessment was the high cumulative pressures in bays and this is linked to the development of ports and harbours. These pressure hotspots require strategic planning and focused management. Other high pressure areas include the area offshore of the Orange River, the shelf edge on the west and south coast, large portions of the Cape inner and middle shelf, the Agulhas Bank and the KwaZulu-Natal Bight. The new Coastal and Marine Critical Biodiversity Area Map can support and inform Marine Spatial Planning in pressure hotspots.

Ports and harbours are drivers of cumulative impacts and degradation.

Ports and harbours are key drivers of cumulative impacts and ecological degradation by providing points of access to the sea, increasing coastal development, changing local shoreline orientation, and being pressure hotspots.

South Africa's coast is generally exposed to high wave energy; therefore, artificially constructed ports and harbours are necessary transport infrastructure, but are also key drivers of impacts to biodiversity. The development of ports and harbours and associate effects include the impacts of construction, concentration of pressures due to increased access, the introduction of alien and invasive species and the impacts of dredge disposal. As such port and harbours are drivers of significant cumulative pressures that require careful spatial planning and effective management. The highest cumulative pressure mapped in the NBA 2018 marine assessment was recorded in Saldanha Bay with all bays facing high cumulative pressures. Further, ports and harbours have high risks of biological invasions from ship fouling and ballast water, pollution from various chemicals and waste, and disasters such as oil spills. The main points of introduction and refugia for marine alien and invasive species are ports, harbours and marinas; which is where most introduced species (62 taxa)

have been recorded. In addition, harbour breakwaters interrupt the natural flow of sand in longshore currents in the surf and inner shelf around the country and contribute to the loss of sand on beaches. If not appropriately located and managed, the natural sand movement corridors ("sand rivers") that once supplied beaches with sand, can be cut off from their sand-bank reserves that beaches need during periods of heightened erosion. For these reasons, the location of ports and harbours should be carefully planned.

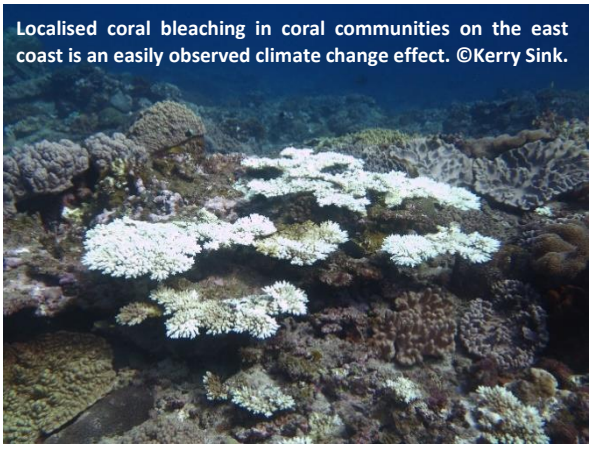
Marine invasive species are increasing despite limited survey effort

Marine invasive species are increasing in South Africa with 96 alien species and 55 invasive species reported, despite limited survey effort

In 2011, the NBA reported that the known number of marine alien species had expanded from 17 in 1992 to 84, only 8 of which were considered as invasive. Based on recent research, the number of marine alien species has been amended to 96 including 55 that are considered to be invasive. Invasive species were more prevalent in rocky shores than in other broad ecosystem groups, and in the Southern Benguela than in other ecoregions. Crustaceans and molluscs are the taxonomic groups most often recorded as invasive. The main points of introduction and refugia for marine alien and invasive species are ports, harbours and marinas as reported above. The main vectors of accidental introductions remain ship fouling and ballast water. Recreational boating has also been identified as a significant contributor to the intra-regional spread of invasive species, and the expanding aquarium trade is an emerging vector of introduction. Gaps in taxonomic knowledge, capacity and opportunities for systematic surveys limit the ability to detect and understand marine introductions and invasions in South Africa. The impacts of marine invasive species on global ocean economies and ecosystems signal the risks to South Africa's ocean economy, biodiversity and coastal communities. Ambitious plans to increase port and harbour development, maritime transport, oil and gas activities, aquaculture and coastal tourism in the interests of growing the ocean economy in South Africa, have the potential to increase the introduction and spread of alien species unless adequate biosecurity measures are implemented. A risk assessment protocol for transfer and introduction is needed to identify pathways that constitute the highest risk of introductions. Monitoring, early detection and rapid response protocols, that include clear roles and responsibilities and sufficient resources, are needed to ensure appropriate invasive species management for the marine realm. The highest priority action is to secure resources and develop capacity to enable rapid management action for preventing potential invasive species from becoming established when detected through monitoring programmes.

Climate change worsens pressure impacts, decreasing resilience of people and biodiversity

Climate change exacerbates impacts of pressures on marine ecosystems and species, decreasing resilience and threatening coastal communities and livelihoods.



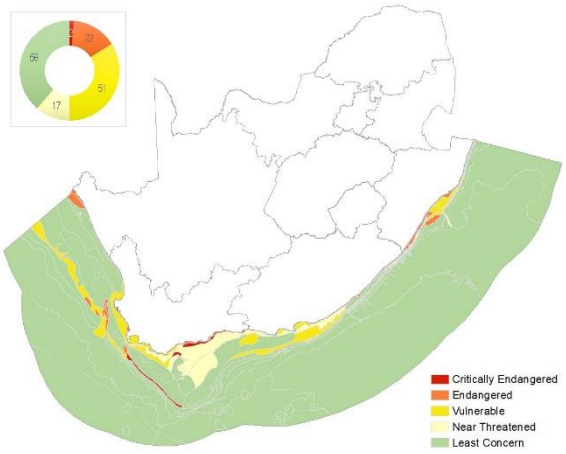
Localised coral bleaching in coral communities on the east coast is an easily observed climate change effect. ©Kerry Sink.

South Africa has experienced significant oceanographic changes over the past few decades. Parts of the Agulhas Current have warmed more rapidly than 90% of the world's oceans, while upwelling on the west and south coasts has increased due to intensified winds, leading to inshore cooling. These shifts are accompanied by increases in sea level, changes in ocean currents (which affect regional climate, energy transfer, and species dispersal), wave height, ocean acidification, low oxygen events and increasingly frequent storms. Such changes are already having marked impacts across a wide variety

of South Africa's marine taxa including sponges, kelp, fish, seabirds, molluscs, corals, crustaceans and foraminifera. Resulting shifts in species distribution, abundance, physiology and behaviour are causing changes in community composition, hybridisation, and the spread of alien species. Coastal fisheries most at risk in the short to medium term include those for small pelagics, linefish, netfish and West Coast Rock Lobster. Marine tourism may also be impacted. The complexity and variability of South Africa's marine systems, aggravated by anthropogenic stressors (including historical overexploitation of some marine resources), make future impacts difficult to predict. However, there is high certainty that impacts on biodiversity, ecosystem function, food security and economically valuable industries will continue to intensify. South Africa needs to maintain and increase research and consistent uninterrupted monitoring to track and understand climate change impacts on marine systems, including their interactions with the impacts of other pressures. Also, it is essential to assess the effectiveness of adaptive measures for both human communities and natural systems. South Africa's unique position and rich history of marine research, combined with the variety, speed and scale of predicted changes, offers a rare opportunity to facilitate global learning of the development and application of adaptation pathways.

Half of South Africa's marine ecosystem types are threatened

A first assessment of marine ecosystems using IUCN Red List Criteria found, that half of South Africa's marine ecosystem types are threatened (*established but incomplete*).



A systematic assessment of South Africa's 150 marine ecosystem types using a method aligned to that of the International Union for Conservation of Nature (IUCN) Red List of Ecosystems found that 50% are threatened. By area this equates to only 5% of the ocean space around South Africa, reflecting that many smaller ecosystem types are threatened, with larger deep ocean ecosystem types under less threat. More inshore and shelf ecosystem types are threatened than those of the slope and abyss. Only two ecosystem types (1% of types) are Critically Endangered; the Agulhas Muddy Mid Shelf and Browns Bank Rocky Shelf Edge. A further 22 types are Endangered (15%) and 51 types are Vulnerable (34%). The 2018 results are not directly comparable to the 2011 NBA results because of changes to the ecosystem maps and pressure data, and also differences in assessment methods. To improve this assessment, better data on ecosystem condition is needed, while further international collaboration is required to determine the appropriate spatial scale for ecosystem red listing and to refine thresholds for national assessments.

Bays, islands, muds and rocky shelves are most threatened

The most threatened broad ecosystem groups include bays, islands, muddy ecosystem types and rocky ecosystems on the shelf

To provide an overview of patterns in ecosystem threat status, ecosystems were grouped into several broad types. Bays, muddy ecosystem types and rocky ecosystems on the inner shelf and shelf edge experience amplified levels of threat due to cumulative pressures. Of the different ecoregions, the cold temperate Southern Benguela has more threatened ecosystem types than the warm temperate Agulhas ecoregion, and the ecoregions with the fewest threatened ecosystem types are the subtropical Natal and Delagoa ecoregions. Areas where pressures are concentrated such as bays are priorities for strategic spatial planning

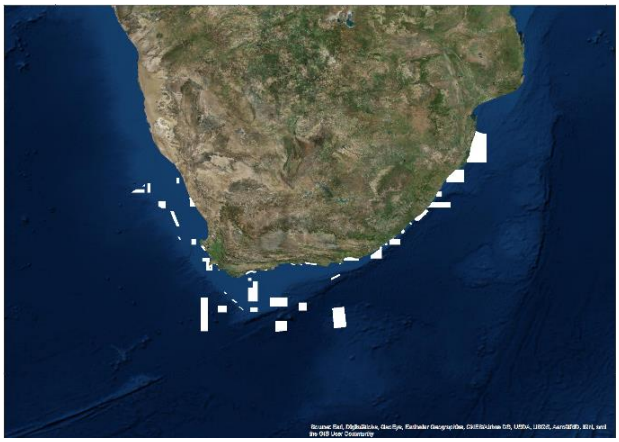
and focused management. To sustainably develop South Africa's ocean economy, the new maps of Coastal and Marine Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) can help inform planning and decision making. These are designed to be spatially efficient and to avoid conflict with non-compatible land and ocean uses wherever possible, and therefore align with the goal of growing South Africa's marine economy. It is possible to combine a range of economic activities and maintain healthy ecosystems through careful placing of intensive sea uses. Additional tools such as the Department of Environment, Forestry and Fisheries (DEFF's) recently developed Environmental Screening Tool can strengthen environmental impact assessment and environmental authorisations to avoid further impacts on threatened ecosystems. There are also opportunities to restore marine and coastal ecosystems and a coastal restoration program that strategically prioritises intervention to maintain and increase coastal biodiversity benefits is advocated.

Need for further cross-realm integration in shore assessments highlighted

Assessment of shores needs to improve in resolution and better account for cross realm connections

Although there has been excellent progress in mapping and alignment of ecosystems in the land-sea interface, a number of limitations were recognised in the mapping and assessment of shore ecosystems. In terms of ecosystem classification and mapping, the classification of mixed shores needs research attention and emerging new wave exposure data sets can improve mapping of rocky shore ecosystem types. Mismatches in the scale of ecosystem and pressure mapping limit the assessment of ecosystem types within the seashore and higher resolution and finer scale analyses may be needed. Considering the large extent of the terrestrial and marine realms, the current resolution of the assessments is generally appropriate except for the highly linear and small seashore ecosystem types. Coastal development impacts may have been underestimated and updated, improved data on recreational, subsistence and small scale fishing; invasive species and sea level rise are needed. Although there is evidence of beaches losing sand and eroding due to a legacy of poor management of connected beach, dune and estuarine systems, a lack of national scale data and a limited spatial understanding of degradation due to disruption of sediment movement corridors prevented consideration of these pressures in this assessment. As such, the ecosystem threat status of seashore ecosystem types, particularly sandy shores, is probably underestimated. In some places, South Africa is losing beaches as they erode to bedrock. Climate-change impacts are exacerbating these impacts, with increased frequencies and intensities of extreme storms eroding beaches further, and sea-level rise interacting with seawalls defending inappropriately located development, causing gradual inundation and loss of beaches through coastal squeeze. Losing beaches has the potential to impact tourism, especially because beach visiting is one of the most popular tourist activities, and favoured urban beaches are most at risk of habitat loss given that their resilience is undermined by inappropriate coastal development. The cross realm connections should be considered in the assessment of adjacent coastal ecosystem types where poor ecological condition could influence the status of adjacent linked coastal ecosystem types. Iterative improvements in cross-realm integration can improve the assessment of shores.

Marine ecosystem protection advanced from less than 0.5% in 2018 to 5.4% in 2019



In 2019, the South African government declared 20 new MPAs advancing marine ecosystem protection from less than 0.5% in 2018 to 5.4% in 2019 *(well established*).

South Africa's number of MPAs increased from 26 in 2018 to 42 in 2019, inclusive of the Prince Edward Islands MPA in the Southern Ocean and noting that some MPAs were expanded or merged and expanded in the new network. With this, protection of the marine environment around mainland South Africa increased from less than 0.5% (approximately 4 900 km^2) in 2018 to 5.4 % (57 900 km^2) in 2019 with the addition of approximately 53 000 km^2 of protected area estate. This expanded MPA network is helping to sustain South Africa's emerging ocean economy, protect marine ecosystems, rebuild fish stocks and support climate resilience.

Protected area expansion provides first protection for 51 ecosystem types

South Africa's MPA expansion provided the first protection for 51 previously Not Protected ecosystem types reducing the number of ecosystem types within this category from 47% to 13%.

The proclamation of 20 new MPAs in 2019 significantly improved marine ecosystem protection levels with 51 types receiving their first protection. Most of the ecosystem types that are Not Protected are located in the deeper offshore environment, particularly on the slope, with most of the slope and abyssal ecosystem types still Poorly Protected. Thirteen previously Not Protected and 4 Moderately Protected ecosystem types advanced to Well Protected, an improvement from 20% to 31% of ecosystem types in this category, and 87% of the 150 marine ecosystem types now have at least some representation in the MPA network. The MPA expansion translates into higher levels of protection for the marine realm than for any other realm in terms of ecosystem type representation. The placement of these new MPAs not only resulted in a marked improvement in ecosystem protection levels for many ecosystem types but also contributed to better representation of all ecoregions in the MPA network. A total of 41 marine ecosystem types were downgraded from Well Protected to Moderately Protected because although 20% of the extent of these ecosystem types are protected, insufficient area is in good ecosystem condition within MPAs due to legal and illegal fishing, flow reduction, waste water discharge and historical cumulative pressures. To increase the number of Well Protected ecosystem types, improvements in MPA governance are urgently needed. These include the development and implementation of management plans, innovative MPA financing arrangements, and improved stakeholder liaison and compliance. Also, degradation inside MPAs must be reduced to improve ecosystem condition, particularly for bays, kelp forests and shallow rocky shelves.

Seven priority marine ecosystem types are threatened and Not Protected

There are 7 priority marine ecosystem types that are both threatened and not protected

Although South Africa has significantly improved ocean protection, there are still seven threatened but unprotected ecosystem types that need protection. The highest priority are the Endangered ecosystems: two muddy ecosystem types on the shelf off the Orange River and a reef complex in the mid-shelf of the KwaZulu-Natal Bight. Reef mosaic and deep coral habitats in the trawl grounds of the Agulhas ecoregion are Vulnerable and need protection. In the Southern Benguela ecoregion, St Helena Bay, a unique ecosystem type that faces

cumulative pressures as well as the slope component of the Cape Canyon need representation in South Africa's MPA Network. This assessment identified priority ecosystem types for improved protection through MPA expansion and by improving condition in existing and new MPAs.

Stock status is known for less than 10% of harvested species: 39% are overfished


Dageraad is one of South Africa's Collapsed Linefish stocks and is a Critically Endangered species. © Denham Parker.

Updated stock assessments are available for less than 10% of South Africa's harvested marine species and more than a third (39%) of the assessed resources are Overexploited or Collapsed *(established, incomplete).*

South Africa's oceans provide a high diversity of marine resources with more than 770 marine species that are harvested. Updated stock status is available for only 54 stocks covering at least 42 species. Of these, 39% stocks are Overexploited or Collapsed. Effective science-based management has supported recovery of Deep Water Hake *Merluccius paradoxus* and some linefish species, such as Carpenter *Argyrozona argyrozona*. The recovery of Red Steenbras *Petrus rupestris* and Dageraad *Chrysoblephus cristiceps* should be prioritised. Improved data collection and data management systems and strategic focused research to address critical knowledge gaps can help streamline and update stock assessments.

Abalone and West Coast Rock Lobster are in crisis with escalating poaching

Abalone and West Coast Rock Lobster resources are severely overexploited with escalating poaching preventing recovery of these valuable resources *(well established).*

High value inshore resources are in crisis with illegal and unregulated fishing contributing to the drastic declines in stocks of Abalone *Haliotis midae* and West Coast Rock Lobster *Jasus lalandii.* Illegal Abalone trade is estimated to be almost double the volume of legally caught abalone or that produced by aquaculture operations**.** Resource recovery plans need to be implemented and fishing quotas need to be allocated in line with scientific recommendations that account for the realities of resource abundance.


Abalone stocks are in crisis. ©Steve Benjamin.

Approximately 18% of marine species are threatened


The African Penguin is one of South Africa's Endangered seabirds. © Peter Chadwick

Despite limited effort in assessing marine species threat status in South Africa, 376 species have been assessed using IUCN criteria, of which approximately 18% are considered threatened.

To date, 376 South African marine species have been assessed by a combination of national, regional and global assessments using the IUCN redlisting approach. Of these, 70 taxa were assessed to be threatened. While this is a relatively high percentage, it may not be truly representative of actual threat patterns because the selection of taxa for redlisting assessment was biased towards taxa that were perceived to be under threat. Seabirds**,** endemic sparids and marine reptiles are particularly threatened. Fishing remains the greatest driver of extinction risk in marine species. Climate change, underwater noise, alien species, problematic native species and plastic pollution constitute significant threats to marine mammals, birds and reptiles. Poor catchment management resulting in freshwater flow reduction and reduced estuarine function is increasing the extinction risk of many commercially important estuarine-dependent fish species. The development and implementation of science based fisheries management plans that account for ecosystem effects and impacts on threatened species can help improve marine species status and avoid extinctions in the future.

Marine species are most Data Deficient

Marine species have the highest levels of data deficiency across all realms (*well established*).

Thirty-four percent (34%) of 121 commercially important bony fish and 50% of 26 cartilaginous fish were assessed as Data Deficient. The high level of data deficiency for fish is due to knowledge gaps in life history, lack of long-term fisheries catch and effort data, impaired data integrity and challenges in data management. The lack of IUCN assessments for marine invertebrates is due to inadequate taxonomic knowledge, limited distribution data, a lack of systematic surveys and limited capacity to advance species' redlisting. Knowledge gaps in taxonomy, long-term population trends and life history limit our understanding of marine species' status and threatened species may be undetected. Strategic research to address key knowledge gaps, improve species monitoring and assess priority taxa can reduce uncertainty and support early warnings to guide management interventions.

Knowledge gaps limit the assessment of genetic biodiversity

A lack of knowledge and techniques limits our ability to assess the risks to the genetic component of marine biodiversity


Kingklip are a high value resource species with fisheries impacts on genetic diversity ©SAEON

The maintenance of genetic diversity is important for retaining evolutionary potential and the ability of species or populations to adapt to change. Risks to genetic diversity include genetic erosion through overfishing and reduced population sizes, loss of connectivity, hybridization and inbreeding and the disruption of co-adapted gene complexes and disease epidemiology through translocations. South Africa has increasingly invested in genetic research and is establishing a baseline understanding of spatial patterns, particularly inshore. There is evidence in South Africa of fisheries impacts on the genetic diversity of some fished species such as Cape Hakes *Merluccius* spp., Kingklip *Genypterus capensis* and Dusky Kob *Argyrosomus japonicus*. There is an absence of temporal genetic data sets and a lack of genetic diversity indicators and thresholds against which the state of genetic diversity can be assessed. A genetic monitoring framework is required that outlines a strategic approach to prioritise species for monitoring, identifies appropriate genetic markers and metrics, and specifies the frequency of monitoring. High priority resource species, overexploited and threatened taxa, endemic species, species identified as being especially sensitive to climate change and species farmed in mariculture are priorities for genetic monitoring. Spatial patterns in genetic biodiversity need to be taken into account in marine spatial planning and protected area design.

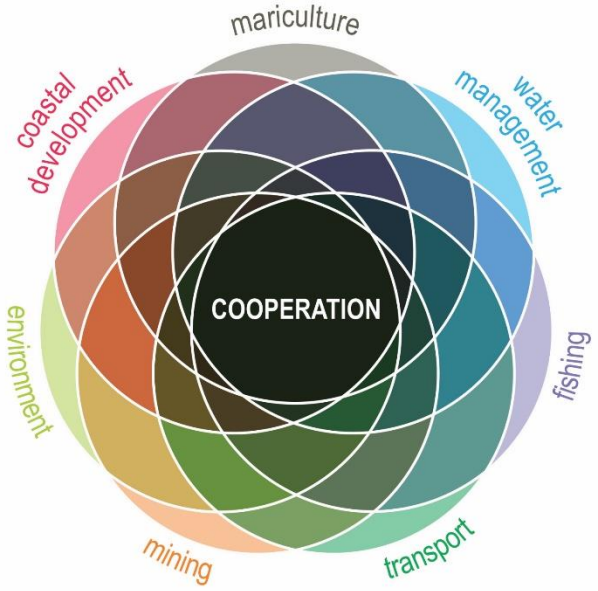
Priority Actions and Knowledge Gaps

The last chapter of this report distils the priority actions to address the key findings of this assessment with links to existing policy, plans and frameworks. The links between the NBA, the National Biodiversity Strategy and Action Plan (NBSAP) and the National Biodiversity Framework (NBF) are explained. Key priority actions related to each finding are presented, drawing from a review of progress against priority actions reported in the NBA 2011 and three expert workshops. Priority actions span the knowledge-action continuum and cover a wide range of actions to improve ecosystem and species status and avoid further ecosystem degradation and impacts on priority species. A key biodiversity response is the emerging first marine Critical Biodiversity Area (CBA) map that can inform Marine Spatial Planning, environmental authorisations and future protected area expansion. The top 10 priority actions to improve the state of marine biodiversity are identified and linked to the strategic objectives of the NBSAP and the NBF. Building on a brief review of progress against research priorities identified in the NBA 2011 marine assessment, key gaps and limitations from the NBA 2018 marine assessment are identified and discussed. Additional monitoring and research priority actions to address these knowledge gaps are communicated. Research priorities span foundational marine biodiversity research at the ecosystem, species and genetic level, to applied research for improving our understanding of the impacts of key pressures on ecosystem condition.



The top 10 Priority Actions to improve the state of marine biodiversity are:

- **Apply the Coastal and Marine Critical Biodiversity Area Map** in Marine Spatial Planning and Environmental Impact Assessments to mitigate pressures in priority areas.
- **Enhance co-operative governance** for improved, coordinated compliance and marine biodiversity management.
- **Modernise and integrate data collection, storage and access** to improve marine biodiversity, fisheries, and climate data for better assessment, analysis, and monitoring, and to improve compliance with and evaluation of management actions.



- **Restore marine biodiversity assets** to strengthen climate resilience and sustain key benefits.
- **Ensure sufficient quantity and quality of fresh water flow** to marine ecosystems.
- **Strengthen MPA financing and governance** to enhance MPA protection and the equitable flow of benefits from South Africa's MPA network.
- **Develop and implement effective fisheries management plans** to secure food and job security and reduce ecosystem impacts of fisheries.
- **Catalyse research to address critical knowledge gaps** that limit the assessment of marine biodiversity and decision-making for a sustainable oceans economy.
- **Effectively communicate the value of South Africa's marine biodiversity** through improved co-ordinated messaging that articulates benefits, in order to build support for marine conservation, mainstream biodiversity into key production sectors and mobilise people to sustainably use marine biodiversity.
- **Prevent new marine invasions** through response planning, ring-fenced resources and rapid action.

1. INTRODUCTION AND APPROACH

Chapter Citation: Sink KJ, Skowno AL, Green A, Landschoff J, Lamont T, and Franken M. 2019. Chapter 1: Introduction and Approach. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



South African marine biodiversity is globally recognised with many endemic species.

Chapter Summary

This Chapter presents the purpose and background of South Africa's National Biodiversity Assessment, introduces key indicators and provides an overview of the marine environment. The primary purpose of the NBA is to provide a high-level summary of the state of South Africa's biodiversity at regular points in time, with a strong focus on spatial information. It aims to inform policy, planning and decision making in a range of sectors for the management and sustainable use of biodiversity. The NBA relies on two headline indicators that can be applied to both ecosystems and species; threat status and protection level. Threat status is based on the IUCN risk assessment framework for species and ecosystems. Protection level was developed in South Africa for national reporting and addresses the extent to which ecosystems and where feasible, species are protected. These headline indicators provide a way of comparing results meaningfully across the different realms and provides a standardised framework that links with policy and legislation in South Africa, thus facilitating the interface between science and policy. There is growing recognition within government and other institutions of this framework and the need to respond to these headline indicators in planning and decision making. The marine realm covered by this report is defined from the dune base, effectively a decadal scale high water mark, to the outer boundary of South Africa's Exclusive Economic Zone, an ocean area of 1.1 million km^2. The overview of South Africa's marine environment highlights South Africa's wide range of oceanographic, bioclimatic, topographical and geological settings which have not only resulted in high species diversity and endemism, but also high ecosystem diversity. The three different margin environments of the west, south and east coasts are described with their contrasting oceanographic and current regimes and a brief overview of the Atlantic and Indian Ocean Basins is provided. South Africa's marine ecosystems support more than 13 000 species with estimates of marine endemism ranging between 26 and 33%. South Africa is reported as having the third highest marine endemism after New Zealand (51%) and Antarctica (45%). Highest marine endemicity has consistently been reported for the warm temperate Agulhas ecoregion on the south coast which lies entirely within South Africa's territory and is geographically very isolated from other warm temperate regions. Although there have been more than 170 new marine species described since the previous assessment, significant challenges in marine taxonomy are still prevalent. The underlying foundation of species knowledge has not kept up with the demands of modern biodiversity assessments and South Africa needs to integrate molecular tools into taxonomy, biodiversity assessment and planning. Given the unique South African marine environment, biodiversity and endemism patterns, it is important that local taxonomic expertise is strengthened to capitalise on strategic research opportunities that can strengthen biodiversity science, research outputs and marine biodiversity management.

1.1 Introduction

The National Biodiversity Assessment (NBA) is a collaborative effort to synthesise and present the best available science on South Africa's biodiversity. It aims to inform policy, planning and decision making in a range of sectors for the management and sustainable use of biodiversity.

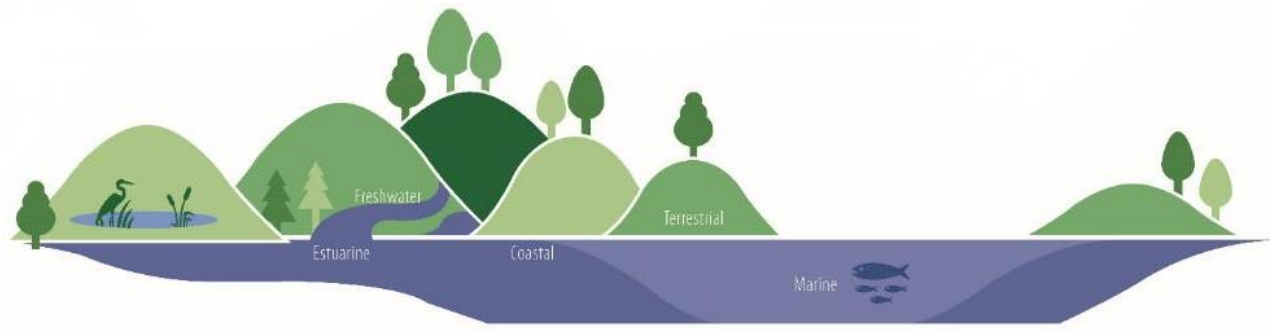
The NBA is a platform for reporting on the **current state of biodiversity** within South Africa. It describes the key pressures on biodiversity and, where possible, identifies important trends. It covers the terrestrial, inland aquatic[1], estuarine and marine realms, as well as the coast and South Africa's sub-Antarctic territory as cross-realm zones. The NBA is used to illustrate the benefits that biodiversity and intact ecosystems provide to the economy, society and human wellbeing. Finally, the systematic approach of the NBA allows us to identify important national knowledge gaps and research priorities linked to biodiversity.

Biodiversity is defined as the 'variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and across ecosystems' (Convention on Biological Diversity).



Biodiversity incorporates diversity at the genetic, species and ecosystem level – which together form the foundation of ecosystem services and are integrally linked to human wellbeing.

The National Biodiversity Strategy and Action Plan (NBSAP) and the National Biodiversity Framework (NBF) are two overarching national policy tools. They set out **South Africa's strategic objectives** for managing and conserving biodiversity and are the primary reference points for related priority actions. The NBA both informs the development of the NBSAP and NBF, and supports their implementation. below for more information.



The NBA covers all four realms: terrestrial, inland aquatic (freshwater), estuarine and marine; and the coast.

[1] Inland aquatic realm refers to rivers and inland wetlands. The term 'freshwater realm' is regularly used in the biodiversity sector but since numerous inland saline wetland ecosystems occur in South Africa the term 'inland aquatic' is preferred. The term 'inland wetland' is used to distinguish these ecosystems from estuarine or marine wetlands which are considered part of the estuarine and marine realms respectively.

1.2 Purpose and structure of the NBA

The NBA is the primary tool for monitoring and reporting on the state of biodiversity in South Africa. It is prepared as part of the South African National Biodiversity Institute's (SANBI) mandate[2] *to monitor and report regularly on the status of South Africa's biodiversity, and is a collaborative effort from many institutions and individuals. The NBA focusses primarily on assessing biodiversity at the ecosystem and species level, with efforts being made to include genetic level assessments. Two headline indicators that are applied to both ecosystems and species are used in the NBA: threat status and protection level. The products of the NBA include seven technical reports, a technical synthesis report and several popular outputs.*

The primary **purpose** of the NBA is to provide a high-level summary of the state of South Africa's biodiversity at regular points in time, with a strong focus on spatial information. Each NBA builds on decades of research and innovation by South African scientists and makes that science available in a useful form to users both inside and outside of the biodiversity sector. As a body of work the NBA is not prescriptive; it presents important information that can be adopted by government and civil society in various decision making processes to support socio-economic imperatives, human wellbeing, and the best management and conservation of South Africa's biodiversity.

Like the previous assessments in 2004 and 2011, this third iteration of the NBA will feed into a range of processes within the environmental sector and beyond (Figure 1). Key applications include:

- Informing policies and strategies in the biodiversity sector (e.g. National Biodiversity Framework (NBF), National Protected Area Expansion Strategy), and other key sectors responsible for natural resources utilisation and/or protection, such as the water, agriculture, fisheries, and mining sectors (e.g. Mining and Biodiversity Guidelines).
- Providing information to help prioritise the often limited resources for managing and conserving biodiversity; including datasets that feed into site and regional level planning and assessment (e.g. Strategic Environmental Assessments and Environmental Impact Assessments) and provincial and municipal Bioregional Plans and Marine Spatial Plans (i.e. systematic biodiversity planning).
- Creating a key reference and educational work for use by scientists, students, consultants, decision makers and funders.
- Serving as an effective national level platform for encouraging and facilitating collaboration, information sharing and, importantly, capacity building in the biodiversity sector in South Africa.
- Providing information for a range of national and international level monitoring, reporting and assessment processes such as state of environment reporting and reporting on commitments to international conventions (e.g. linked to the United Nations Convention on Biological Diversity [CBD], the Sustainable Development Goals [SDGs] and the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services [IPBES]).

[2] SANBI's mandate is outlined in the National Environmental Management: Biodiversity Act (10 of 2004), hereafter referred to as the 'Biodiversity Act'.

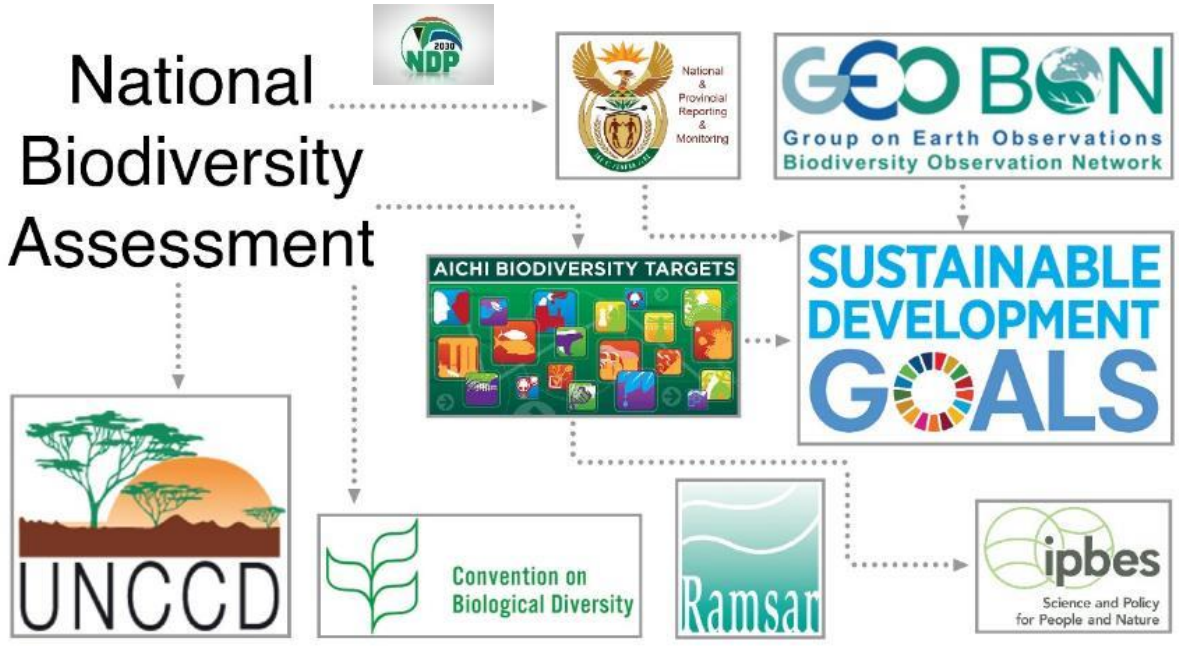


Figure 1. International reporting processes and channels into which the NBA is a key informant. This includes international conventions signed by the South African Government and voluntary processes.

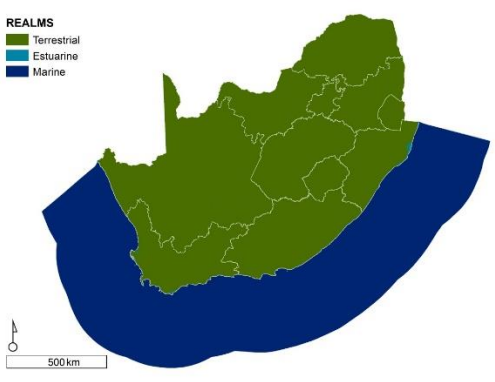
1.3 Navigating the NBA products

The NBA has a varied audience each with different needs, hence the NBA is presented in various forms. The NBA website is the primary portal through which you can access all information and products [http://nba.sanbi.org.za/]. The NBA website also provides factsheets and presentations summarising the NBA for non-technical audiences, using graphics and accessible language.

The NBA 2018 has ***seven technical reports***: one for each realm (marine -this report), terrestrial, inland aquatic, and estuarine); two cross-realm technical reports (the coast and South Africa's sub-Antarctic territory); and a technical report on genetic diversity. The technical reports are comprehensive volumes covering all input data used for the assessments, detailed explanations of methods and approach, full results and discussion, key messages for decision makers, limitations and knowledge gaps, and priorities for the future. These reports are for a scientific and technical audience and are fully referenced and peer reviewed. The technical reports refer to various supplementary technical documents, maps and datasets; all of which are available through the NBA website with accompanying metadata. The marine report covers the entire **marine realm** defined as the area from the dune base which is effectively a decadal scale high water mark (Harris *et al.* 2019b) to the outer edge of South Africa's Exclusive Economic Zone. The coastal report also includes content from the marine realm and there is deliberate overlap in material where this is relevant to the marine realm and the integrated perspective that the cross realm coastal report provides (Box 1). The coastal report examines the coastal components of marine, estuarine and terrestrial ecosystem types to provide a uniquely coastal perspective for South Africa's new ecologically determined coast (Harris *et al.* 2019b). The primary results for marine ecosystem types in the coastal zone are reported in the marine realm report.

Box 1. A Guide to the NBA 2018 Marine Realm Report with notes on the Coast Report

What is a realm?



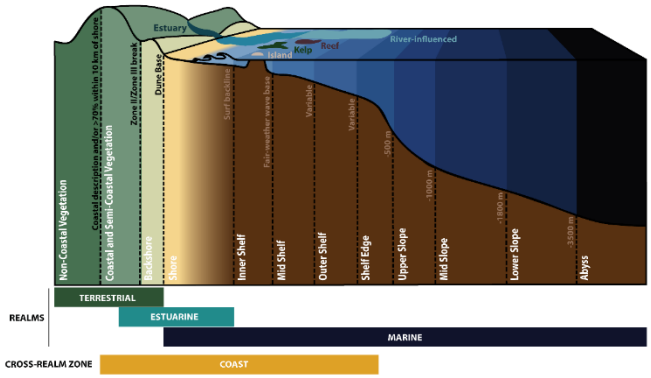
The realms reflected in their relevant colurs i.e terrestrial (green), marine (blue) and estuarine (teal) Only the largest estuary , St Lucia is visible at this scale. Various ecosystem types from each of these realms constitue the coast.

The NBA assesses biodiversity in four realms: (1) terrestrial (all land up to the dune base), (2) inland aquatic (rivers and wetlands), (3) estuaries (estuarine functional zone: water and surrounding floodplain), and (4) marine (dune base to the EEZ). The extents of the realms are shown in the map.

The **coastal zone** in NBA 2018 was determined ecologically, by identifying terrestrial and marine ecosystem types with strong coastal affinities. In addition, all estuarine ecosystem types were considered coastal. It is recognised that this is different to the definition of coastal zone in the Integrated Coastal Management Act.

Coast used to be part of the marine report – what is different now? Which report should I read?





Previously, "coastal" biodiversity was included in the marine report, but this referred only the marine portions of the coastal zone; estuaries and dunes are as much part of the coast as beaches and rocky shores. In NBA 2018, the coast is more appropriately defined as a cross-realm zone spanning the coastal terrestrial and coastal marine realms, and including all estuaries. It is not a realm, nor an independent assessment; it is an ecologically determined zone within which all results from the constituent realms are presented and discussed with a coastal, cross-realm lens. All ecosystem types that fall within the coastal zone are still reported on in each realm assessment. For example, if readers are interested in reading about dune vegetation or estuaries, these are still assessed and presented in the terrestrial and estuarine reports, respectively. The coast report focusses on analyzing the status of biodiversity across the land-sea interface and makes comparisons with the non-coastal parts of the country. The decision to do this was for three reasons: (1) coastal ecological processes operate across realms, and by restricting assessments of biodiversity to the separate realms, key insights about the cross-realm coastal zone may have been missed; (2) there is a target audience of readers who are interested in only the coastal portions of each realm and (3) the results of the more expansive non-coastal marine and terrestrial ecosystem types overshadow the smaller coastal ecosystem types. As a result, there is a lot of deliberate and unavoidable overlap in content among the realm reports and the coast report. Where issues, methods or findings are better discussed in the coastal report, this is noted in the marine report. Therefore, in choosing which report to read, readers should base this on their primary perspective: are you interested mainly in the realm, or the coast?

Key for text in different colored boxes

NBA 2018 KEY MESSAGES

The NBA 2018 summarized and integrated results across all realms in a **Synthesis Report**, from which 19 key messages were distilled in three themes (A: benefits; B: pressures and solutions; C: knowledge gaps). Where these are relevant in the Marine Report, they are given in green text boxes like this and the synthesis report is cited (Skowno *et al.* 2019).

MARINE HIGHLIGHTS

Key notes, highlights or definitions relevant to the marine report are included in blue text boxes. These are typically authored by one of the chapter authors unless otherwise acknowledged. There are also some longer contributions in full text boxes providing more detailed information on recent research, key issues or new advancements in methods. A list of boxes is provided in the front section of this report.

COASTAL HIGHLIGHTS

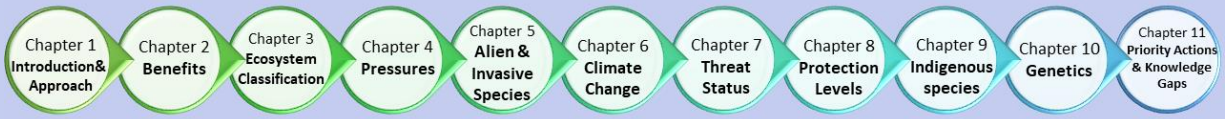
Important information from the cross-realm NBA 2018 Coast Report (Harris et al. 2019) are shown in yellow boxes that reflect this component. Marine content is shown in blue boxes.

PRIORITY ACTIONS

In Chapter 11 the top ten priority actions to improve the state of marine biodiversity are presented in white text boxes.

Marine Realm Report Overview

Chapters in the marine realm report



Annexures to the marine realm report

Annexure 1 - Sink *et al.* 2019. South Africa's New Marine Protected Areas.

Annexure 2 - SANBI. 2018. Marine Protected Areas Factsheet: How South African MPA's benefit people.

Annexure 3 - Sink *et al.* 2019. Ecosystem Classification and Pressure References.

Annexure 4 - Franken *et al.* 2019. Increasing Benefits from Marine Protected Areas.

Annexure 5 - van der Bank *et al.* 2019. Harvested species in the marine realm.

Annexure 6 - van der Bank *et al.* 2019. Progress against the NBA 2011 Priority Actions.

Conventions used in this report

This report follows the IUCN standard of reporting SPECIES COMMON NAMES with capital letters.

As the marine technical report is extensive and it can be difficult to locate key aspects in the lengthy text, **bold text assist readers in navigating by highlighting main topics and points** within paragraphs.

The **marine realm** covered by this report is defined from the dune base, effectively a decadal scale high water mark, to the outer boundary of South Africa's Exclusive Economic Zone, an ocean area of 1.1 million km^2. This report covers the ecosystem, species and genetic levels of marine biodiversity, the pressures and threats to this biodiversity and the key actions to maintain the benefits from South Africa's marine biodiversity. The threat status of both ecosystems and species is reported and progress in ecosystem protection levels is examined. Trends in threat status between previous assessments and 2018 are not examined due to differences in ecosystem classification and mapping, pressure mapping and the assessment methodology. For details on estuaries, refer to the estuarine report

The **synthesis report** focuses on the main findings and key messages from each technical report. As the technical reports give full details of the methods and input data used for the NBA, the synthesis report only briefly discusses the building blocks and approach used on a broad level.

1.3.1 The NBA process

The NBA 2018 required more than 135 000 person hours, contributed by more than 465 individuals, from approximately 90 institutions. The Council for Scientific and Industrial Research (CSIR) led the inland aquatic and estuarine components, and Nelson Mandela University led the coastal component.

The breadth and scope of the NBA make collaboration between multiple institutions and individuals an essential part of the process. SANBI plays the lead role and facilitates contributions by a large pool of experts. The **collaboration** ensures that the best available science underpins the NBA, promotes collective ownership of the NBA products by the biodiversity community in South Africa, and helps ensure a common vision for action following the assessment. The vast majority of contributions to the NBA are voluntary, and the few formal funded contributions involve significant co-financing. Without these voluntary contributions from experts and institutions outside of SANBI, the NBA would not be possible. While the reliance on experts to contribute voluntarily does present significant risks to the process, paid alternatives bring their own challenges and budget constraints. SANBI draws substantially on contributions of time and other in-kind resources from a wide range of partners over the course of the NBA. This is important not only for completing the work, but also for the collective ownership of the NBA by the biodiversity science community in South Africa. The NBA is a multi-author and multi-institution effort, and the authors of each section and subsection are indicated and acknowledged in all the various volumes and chapters of the NBA 2018. In addition to authorship, a large number of individuals and institutions have made their information available to this national assessment; wherever possible the source of the information used in the NBA is clearly attributed. The co-production of knowledge for the NBA also assists scientists, practitioners and decision makers to work towards a common vision for action following the assessment.

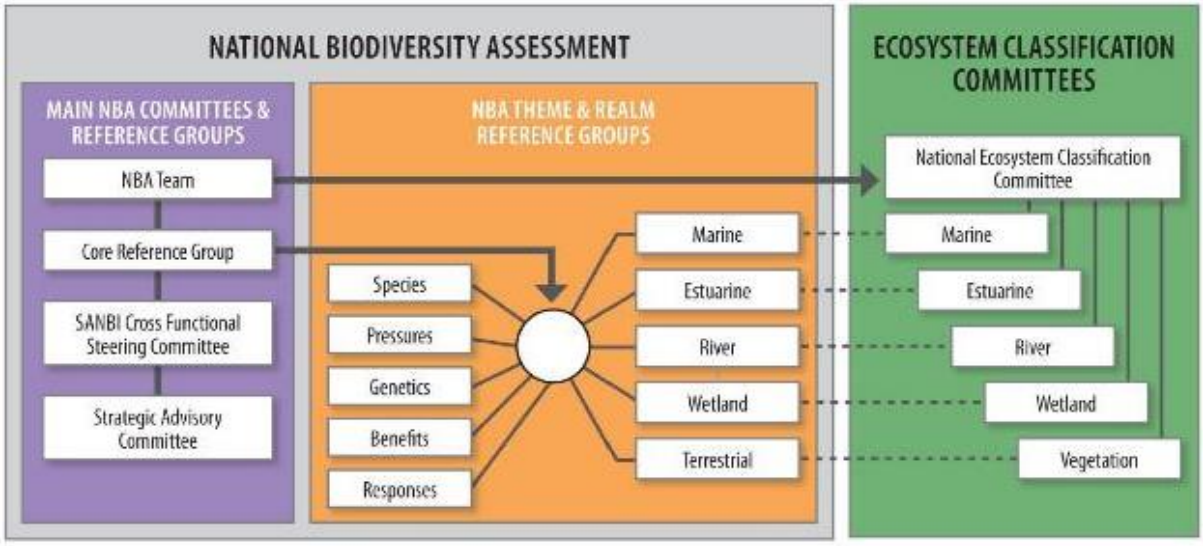


Figure 2. Committees and reference groups established for the NBA 2018. The purple panel includes the oversight structures for the NBA management team, the orange the reference committees for the technical elements. The green panel shows a group of ecosystem related committees that oversee the National Ecosystem Classification System. They exist in parallel to the NBA and are intended to continue work between assessments.

Various internal and external **governance structures** were put in place in 2015 to guide the NBA 2018, ensure the project received adequate oversight, and provide structures for the consultation of a wide range of experts in each specific biodiversity field (Figure 2). Reference groups were set up for each realm consisting of key technical and scientific experts. In the case of the marine assessment, the Marine Biodiversity Working Group convened by the Oceans and Coasts Branch of the former Department of Environmental Affairs served this role. The reference group therefore included researchers, experts and officials with technical roles, while the steering and advisory committees included senior officials. The Marine Ecosystem Committee also played a key role including several task teams (see Chapter 3, the Vulnerable Marine Ecosystem Working Group and many experts convened during many workshops held to facilitate this assessment (Table 1)). Note that Ecosystem Classification Committees have been permanently set up for each realm consisting of ecosystem classification and mapping experts – these will continue to be facilitated by SANBI and are not specifically linked to the NBA cycle of reporting. The NBA 2018 also included a focus on increasing cross-realm collaboration, which led to better alignment between realms for input data, assessment approaches and explanation of areas for improvement.

Table 1. Key Marine NBA workshops and meetings to convene input from scientists, managers and relevant working groups or committees.

Workshop or meeting date	Key NBA Workshops and Meetings
23 Jul 2015	Marine Ecosystem Committee Meeting (MEC)
12 Nov 2015	NBA Marine Component Inception Workshop
29 Aug 2016	Freshwater dependent coastal and marine ecosystem meeting (MEC subgroup)
30 Aug 2016	Coastal Think-tank
13 Sept 2016	Condition Workshop
15 Sept 2016	NBA Marine Reference Group Meeting,
23 Nov 2016	Targets Workshop
17 Aug 2017	Marine Ecosystem Committee Meeting (MEC)
30 Aug 2017	Kwazulu-Natal ecosystem mapping, biogeography and pressures meeting
14 Sept 2017	Coastal assessment alignment & fluvial fan mapping
5 Sept 2017	Team Deep meeting to collate geoscience data and information
30 Oct 2017	Kelp condition Workshop
20-22 Nov 2017	Pressures Workshop
24 Nov 2017	Marine Ecosystem Committee Meeting (MEC)
6 Mar 2018	Kelp assessment review
14 May 2018	Marine Ecosystem Mapping Meeting
8 Nov 2018	NBA Marine Review Workshop
21 Nov 2018	Marine Alien Invasive Species Working Group
6 Dec 2018	NBA Marine Reference Group Meeting
10 Dec 2018	Marine Responses Workshop
19 Mar 2019	Taxonomy Working Group to collate progress and identify taxonomic priorities
19 Jul 2019	Priority Actions Workshop



Dr Natasha Karenyi and Luther Adams examining seabed images from over 400 survey sites, during a workshop held to inform ecosystem classification.

1.3.2 Units of assessment and headline indicators

Headline indicators: threat status and protection level for species and ecosystems

Biodiversity indicators have received renewed attention recently amid calls to slow global losses of biodiversity (Nicholson *et al.* 2012, Tittensor *et al.* 2014, Geijzendorffer *et al.* 2015b). Indicators in general, are a tool to i) improve general awareness and gain public attention for biodiversity; ii) meet international reporting requirements; iii) monitor conservation actions; and iv) inform policy and decision making by governments (Nicholson *et al.* 2012, Keith *et al.* 2013a, Geijzendorffer *et al.* 2015b, Keith *et al.* 2015, Nicholson *et al.* 2015, Tanentzap *et al.* 2017a).

The NBA relies on two **headline indicators** that can be applied to both ecosystems and species; **threat status and protection level**. The first indicator (threat status) is based on the IUCN risk assessment framework for species (Red List of Species) (IUCN 2012a) and ecosystems (Red List of Ecosystems) (Bland *et al.* 2017a). The IUCN Red List of Species is well established globally and in South Africa and has formed a part of the NBA reporting since 2005 (Driver *et al.* 2005a). The IUCN Red List of Ecosystems (RLE) is relatively new (v1.0 released in 2016) and prior to its development South Africa developed its own ecosystem threat status assessment framework between 2004 and 2008 (RSA 2011). The second indicator, protection level, was developed in South Africa for national reporting

(Driver *et al.* 2005a) and addresses the extent to which ecosystems and species are protected. In the 2004 and 2011 national assessments protection level was only applied to ecosystems, but over the last two years SANBI's Threatened Species Unit has applied the indicator to terrestrial and some aquatic (freshwater) species and this is reported on for the first time in the NBA 2018. These headline indicators provide a way of comparing results meaningfully across the different realms and provides a standardised framework that links with policy and legislation in South Africa, thus facilitating the interface between science and policy. There is growing recognition within government and other institutions of this framework and the need to respond to these headline indicators in planning and decision making.

Ecosystem indicators

Ecosystem threat status tells us about the degree to which ecosystems are still intact or alternatively losing vital aspects of their structure, function and composition, on which their ability to provide ecosystem services ultimately depends (Figure 3). The conceptual 'end point' of decline for an ecosystem is termed collapse and is equivalent to extinction in the species red listing framework. Ecosystem types are categorised as Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Least Concern (LC), based on the proportion of each ecosystem type that remains in good ecological condition relative to a series of thresholds. For the NBA 2018 the IUCN Red List of Ecosystems was used as the risk assessment framework for terrestrial ecosystems (Bland *et al.* 2017a). The previous national assessments (2004 and 2011) predated the development of the IUCN RLE and used the South African Threatened Ecosystem Framework was used (Driver *et al.* 2005a, RSA 2011, Driver *et al.* 2012); making South Africa one of the pioneers globally of this approach to ecosystem assessment.

Ecosystem protection level tells us whether ecosystems are adequately protected or under-protected. Ecosystem types are categorised as Not Protected, Poorly Protected, Moderately Protected or Well Protected, based on the proportion of each ecosystem type that occurs within a protected area recognised in the National Environmental Management: Protected Areas Act (Act 57 of 2003)[3].

[3] Hereafter referred to as the 'Protected Areas Act'

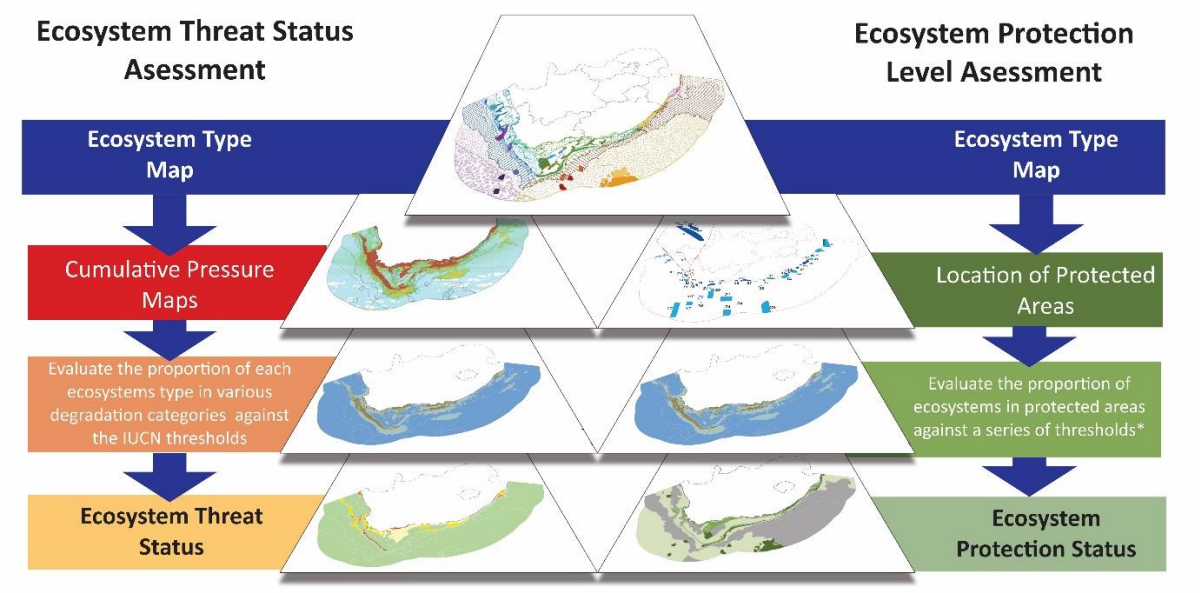


Figure 3. Steps in assessing ecosystem threat status and ecosystem protection level. Note the link between ecosystem condition and protection level for an ecosystem type to be considered Well Protected, the targets must be met in natural (undegraded) condition area.

The ability to map and classify ecosystems into different ecosystem types is essential in order to assess threat status and protection levels and track trends over time. South Africa has an emerging national ecosystem classification system, including vegetation types, river ecosystem types, wetland ecosystem types, estuary ecosystem types, and marine and coastal ecosystem types, which provides an essential scientific basis for ecosystem-level monitoring, assessment and planning.

Species indicators

Threat status of species tells us which species in South Africa are at risk of extinction. Threatened species are those with high risk of extinction and are classified in three categories of increasing risk of extinction Vulnerable (VU), Endangered (EN) and Critically Endangered (CR). Levels of threat are determined against quantitative threshold-based criteria. South Africa uses the latest version of the IUCN Red List Categories and Criteria, version 3.1. (IUCN 2012a).

Protection level of species is presented for the first time in this NBA, although not for marine species, and has no global equivalent indicator. Protection level measures progress towards effective protection of a habitat or population conservation target for each species. The indicator consists of two components. The first measures how well represented each species is within the protected area network, based on the conservation target for the species. This component allows the identification of which species require further protection, where species not represented or poorly represented within protected area network are prioritised for inclusion in spatial planning for protected area expansion. Component two includes a measure of management effectiveness within each protected area and when combined with protected area representation provides an overall (effective) protection level measure for each species.

Both the threat status and protection status indicators for species allow South Africa to report against Aichi Target 12.

Table 2. Links between NBA headline indicators and Aichi Targets and SDGs

NBA indicator	Aichi target	Sustainable Development Goal	Comment
Ecosystem threat status	5	15.1	This powerful indicator of threat to ecosystems is not adequately captured in Aichi and SDG related indicators
Ecosystem protection level	11	15.1	A version of protection level is used in SDG 15.1 reporting
Species threat status	12	15.5	Good links between national indicators and the Aichi and SDG indicators
Species protection level	12	15.1	Not captured in the Aichi and SDG indicators
Ecosystem extent / habitat Loss	5	-	Not captured in Aichi and SDG indicators
Biological Invasion Indicators (species, Areas and Pathways)	9	15.8	Reasonable links between national indicators and Aichi and SDG indicators

Indices of change

The headline indicators of the NBA can form the basis for an index that tracks change over time. Note that in the marine environment, the mapping of ecosystems and biodiversity lags behind terrestrial biodiversity mapping. More progress in marine ecosystem classification and assessment is anticipated thus limiting the use of the NBA as a monitoring tool until the marine ecosystem map is more stable. One such index, developed by the IUCN, is the **Red List Index** for species (Butchart *et al.* 2007). The Red List Index tracks genuine changes in extinction risk across entire species groups (i.e. it is based on only changes in extinction risk between Red List assessments due to actual improvements or deteriorations in extinction risk). It is used to generate 15 of the indicators used to track progress towards the Aichi Targets (UNEP/CBD/SBSTTA/20), mobilised through the Biodiversity Indicators Partnership as well as serving as the official UN Indicator 15.5.1 for Sustainable Development Goal 15.5 (Brooks *et al.* 2015).

Global biodiversity indicators

The **Aichi Biodiversity Targets** were structured around the CBDs 2011-2020 Strategic Plan for Biodiversity. Strategic Goals B (*Reduce the direct pressures on biodiversity and promote sustainable* use; Aichi targets 5-10) and Goal C (*Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity; Aichi targets 11-13*) are the most closely linked to the NBA 2018. Table 2 shows the links between the NBA headline indicators and the indicators for the Aichi Targets and **Sustainable Development Goals**. Ecosystem threat status, in particular, is not well captured in the Aichi Targets or SDGs. The SDGs linked to biodiversity propose Key Biodiversity Areas (KBAs) as a possible focal 'unit of assessment' for various indicators and it is likely that assessing the status of KBAs will become a global indicator of biodiversity that can be added to the NBA headline indicators. To facilitate this SANBI has initiated a project in partnership with BirdLife South Africa and co-funded by the WWF Nedbank Green Trust to identify and delineate a preliminary KBA network for the South Africa based on the species and ecosystem information gathered in the NBA.

Other indicators

Recent work in South Africa describes **indicators** for biological invasions, and international literature is expanding for indicators that track ecosystem extent and health. Indicators for assessing genetic diversity at a national scale are also being explored. Additional data will need to be collected to meaningfully compute some of these new indicators. Future assessments may also track Key Biodiversity Areas (KBAs) and Ecologically or Biologically Significant Marine Areas (EBSAs), which will allow for improved alignment with emerging global biodiversity indicators linked to the SDGs and future iterations of CBD targets in the post 2020 agenda for biodiversity.

1.4 About the Marine Environment

South Africa is a maritime nation with approximately **1.1 million km^2 of ocean territory** around mainland South Africa and an additional 470 000 km^2 around the Prince Edward Islands. In total this represents an area of about 1.5 million km^2 compared to our 1.2 million km^2 landmass (Skowno *et al.* 2019a). The coastline is a 3113-km long, microtidal (<2 m tide range) interface between land and sea that has mostly high wave energy (Harris *et al.* 2011b) and semidiurnal tides (two tidal cycles per day). It is generally exposed or very exposed to oncoming waves, except inside large log-spiral bays and in the wave-shadow of other rocky headlands and promontories that provide isolated areas of relative calm. Most of the shoreline is subject to strong wave action, with significant wave heights mostly between 2–3 m.

South Africa is unique in **having sharply contrasting geological and oceanographic settings** on the west and east coasts and is uniquely positioned at the confluence of the Atlantic and Indian Oceans. The divergent topographical, sedimentological and oceanographic environments interact to produce three very distinct environmental settings that have led to distinct marine biodiversity patterns at the broadest scale. South Africa's climate is strongly influenced by our adjacent oceans (Dingle *et al.* 1987, Reason and Godfred-Spenning 1998, Lutjeharms 2006b, Reason *et al.* 2006, Hutchings *et al.* 2009b, Beal *et al.* 2011) and in turn, varying rainfall and river flow patterns across the country also affect the marine environment. The eastern coast and adjoining interior have much higher rainfall than on the west coast as heat and moisture are transferred from the ocean to the atmosphere and much higher river input is a key feature of the eastern area compared with a much drier west coast (Dingle *et al.* 1987).

The variable **bathymetry and topography** of South Africa's ocean environment (Figure 4) are major drivers of broad scale biodiversity patterns with substantial differences in the geology and topography playing a key role in broad scale marine biodiversity patterns. The bathymetry and topography interact with the different oceanographic features (Figure 5) to create distinct environments on the western, southern and eastern coasts and continental margins. Similarly, differences in tectonic history, sediment supply and regional oceanography are key drivers of differences between the Southwest Indian and Southeast Atlantic Ocean Basins. The bathymetry and topography of the Southern Ocean is discussed in a separate report (Whitehead *et al.* 2019) but the influence of the Southern Ocean is also exerted in the deep southern component of South Africa's mainland Exclusive Economic Zone (Dingle *et al.* 1987, Best and Folkens 2007). The Indian and Atlantic Oceans also interact for example, large Agulhas rings or eddies that are shed from the retroflection of the Agulhas Current travel across the Atlantic Ocean (Figure 5). Generally, there are three distinct ocean margin environments in South

Africa with different physical characters and their shelves are mantled by sediment of differing composition. Beyond the shelf, the deep Indian Ocean and Atlantic Ocean environments also differ (Shannon and Nelson 1996, Lutjeharms 2006a, Schlüter and Uenzelmann-Neben 2008, Wiles *et al.* 2013, Palan 2017, Fischer and Uenzelmann-Neben 2018) and a summary of the ocean basins with their abyssal plains and seamounts is provided below.

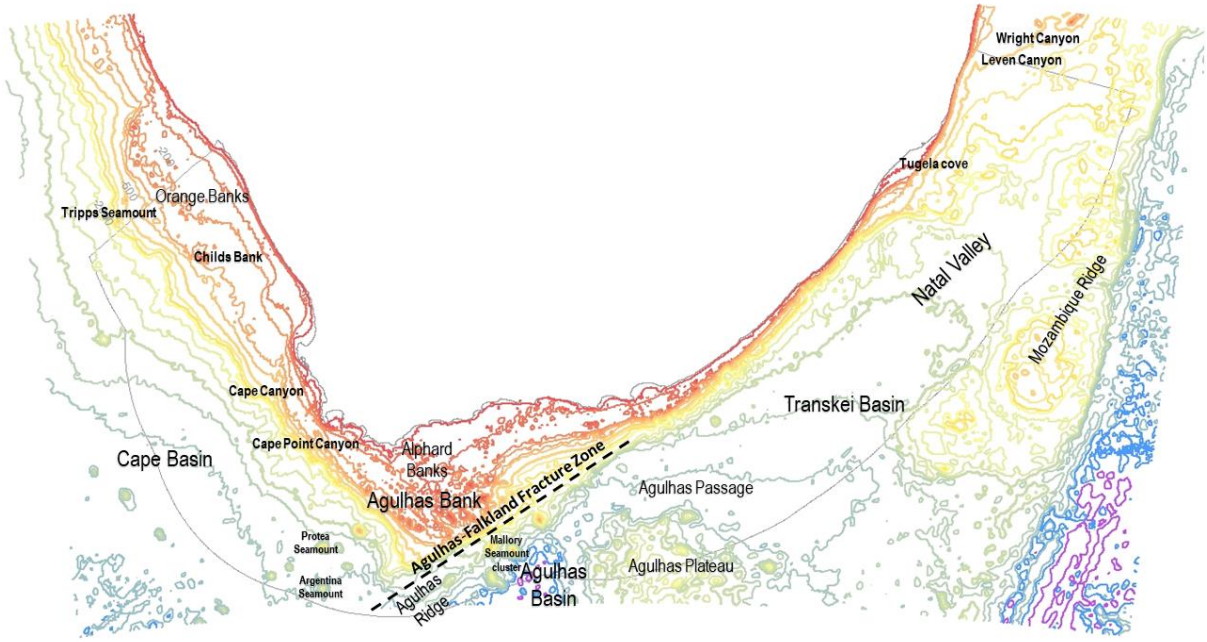


Figure 4. Main ocean basins and key marine features in the marine realm of South Africa (See further detail in Chapter 3: Sink *et al.* 2019)

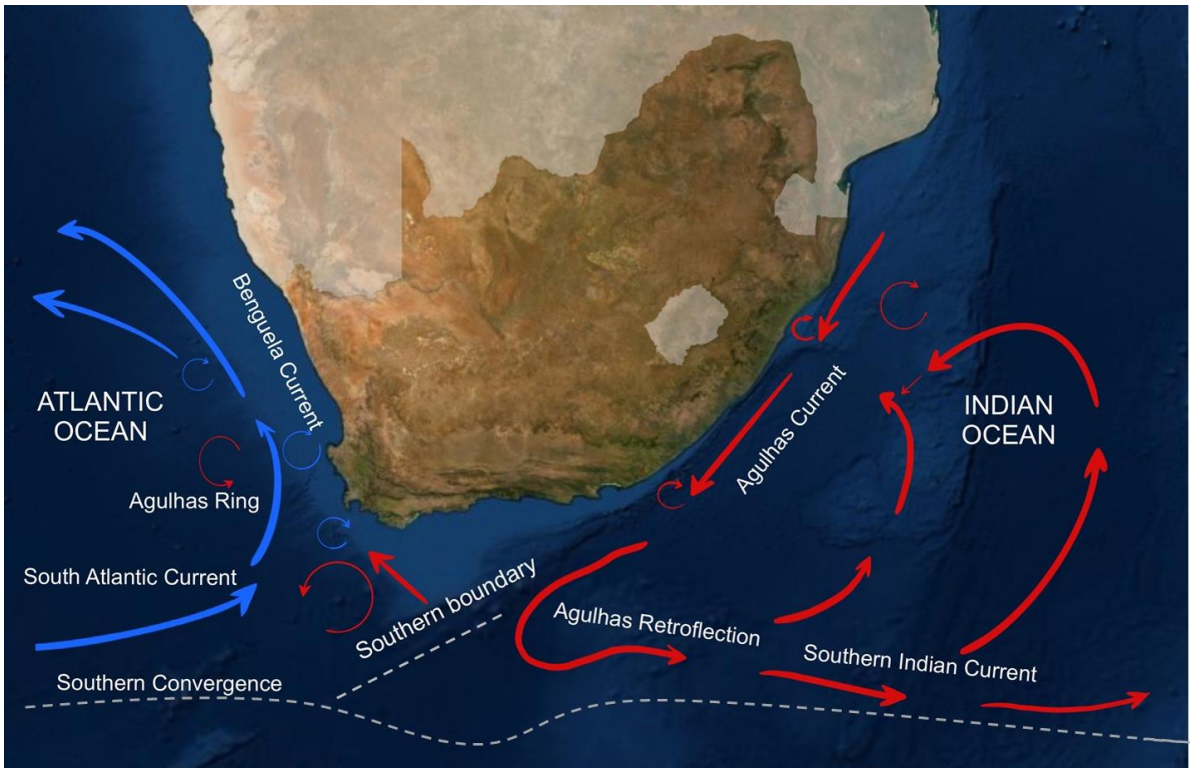


Figure 5. Schematic of major oceanographic processes that occurs off southern Africa

1.4.1 Ocean Basins

The **Agulhas-Falkland Fracture Zone** is a major feature where the Africa, Antarctica and South American plates separated during the breakup of western Gondwanaland of the Early Cretaceous (Ben-Avraham *et al.* 1997). This feature can the considered to separate the deep Indian and Atlantic Oceans. The southwest Indian Ocean has a more complex seafloor morphology due to the more complicated plate tectonic history than the south-east Atlantic.

Dingle *et al.* (1987) further describes how **sedimentation** in the deep ocean basins off southern Africa has been shaped by our geological history; injection of allochthonous material (i.e. rock fragments which have been transported to a site of deposition) from basin margins through tectono-sedimentary mass movements, benthic currents and pelagic sedimentation from the water column. Autochthonous inputs (deposits that are produced locally and contains biogenic sediment) that occur include in situ carbonate production and authigenic mineralisation through glauconite and phosphatic precipitation. Authigenisis is favoured by high sea levels and often linked to high productivity in zones of upwelling (Parker and Siesser 1972, Summerhayes 1973, Birch 1979).

The abyssal plain of the **Cape Basin** lies beyond the western margin. This extends offshore of our Exclusive Economic Zone (EEZ) and north into Namibia, bounded by the Walvis Ridge to the north and west and the Cape Rise and Agulhas Ridge to the south (de Wet 2013). The Cape Rise comprises a group of NE-SW trending seamounts that include the **Protea and Argentina Seamounts**. In 1986, a geoscience survey using a deep water camera (Rogers 1986) sampled the lower bathyal and abyssal zones, including the seamount flanks, of the Cape Basin. Bergstad, Gil, *et al.* (2019) and Bergstad, Høines, *et al.* (2019) describe the adjacent Erica and Schmitt-Ott Seamounts but no biodiversity surveys are known to have been conducted at Protea and Argentina seamounts.

The **Agulhas Ridge** is a positive relief feature that separates the Cape Basin and the Agulhas Basin (Schut *et al.* 2002). The ridge rises more than 3 km above the surrounding seafloor (Uenzelmann-Neben and Gohl 2004) and forms part of the Agulhas-Falkland Fracture Zone (Ben-Avraham *et al.* 1997). It is as an approximately 2500 km long linear feature, located between the southern margin of South Africa and the northern edge of the Falkland Plateau (Ben-Avraham *et al.* 1997, Uenzelmann-Neben and Gohl 2004) and as such is a substantial feature, most of which lies outside of the South African EEZ. The abyssal plain south of the Agulhas-Falkland Fracture Zone is known as the Agulhas Basin. The **Mallory, Davie, Shackleton and Natal Seamounts** lie within this area. Mallory is reported as the shallowest seamount but there is limited information about seamount ecosystems within South Africa's EEZ and there are no known biodiversity surveys that have sampled these seamounts. This deep and expansive basin is considered similar to the Cape Basin and is generally deemed featureless except for the occasional occurrence of seamounts. The only significant bathymetric feature that disrupts the otherwise featureless Agulhas Basin is the Agulhas Plateau. It is a remnant of the original Falkland Plateau that was sheared away during the break-up of Western Gondwana and is situated to the southwest of the Agulhas Bank, reaching depths of less than -2300 m in the surrounding Agulhas Basin to the west and Transkei Basin to the east (Schlüter and Uenzelmann-Neben 2008). The Agulhas Passage (Figure 4) is a deep-water passage (between -5000 and - 5400 m deep) situated between the Agulhas Bank and the Agulhas Plateau (Dingle *et al.* 1983). The Transkei Basin lies east of the Agulhas Plateau and is bounded by the South Coast continental shelf, the Agulhas Plateau and the Mozambique Ridge to the east. Between the Agulhas-Falkland Fracture Zone and the Tugela cone is the deep ocean basin known as the **Natal Valley** (Dingle *et al.* 1978, Martin 1981).

Two **deep current regimes** affect the erosion and dispersal of seabed sediments in our deep ocean (Ewing *et al.* 1971, Camden-Smith *et al.* 1981, Dingle *et al.* 1987, Miramontes *et al.* 2019, Thiéblemont *et al.* 2019). Along the South African west coast, a deep poleward-flowing boundary current transports **North Atlantic Deep Water** (NADW) from the Atlantic into the Southern and Indian Oceans (Kersalé *et al.* 2019). Along the South African east coast, a well-defined narrow undercurrent is one of the pathways allowing transport of NADW northward into the Indian Ocean (Bryden and Beal 2001). Sediment thickness and current velocity at the seabed are generally higher in the south-west Indian Ocean Basin and lower in the south-east Atlantic basin (Dingle *et al.* 1987). The Natal Valley and Transkei Basin receive an appreciable amount of terrigenous sediment whereas the Cape Basin and northern Agulhas Basin are sediment starved (Dingle *et al.* 1987).

1.4.2 Western margin

On the western margin of South Africa, the **Benguela Current System** comprises a general equatorward flow of cool water on the eastern limb of the South Atlantic gyre, with dynamic wind-driven upwelling on the shelf, enhanced at particular locations by local bathymetry (Shannon 1985, Shannon and Nelson 1996, Shillington 1998, Hutchings *et al.* 2009b, Kirkman *et al.* 2016, Verheye *et al.* 2016). The atmospheric circulation responsible for the upwelling also helps to sustain the low-rainfall Namib Desert, which extends northwards through Namibia and southern Angola. The water on the continental shelf is characterised by high nutrient supply to the upper layers, dense plankton blooms, which can reduce light levels, and rich fisheries based on a few, dominant species such as Anchovies, Sardines, Horse Mackerel and Hake (Payne *et al.* 1989). Organic-rich matter sinks onto the sea-floor, where decay processes reduce the dissolved oxygen content of the bottom waters to extremely low levels on the mid- and inner shelf (Monteiro *et al.* 2008, Pitcher *et al.* 2014, Lamont *et al.* 2015, Pitcher and Probyn 2017). Occasional harmful algal blooms develop which independently, or in combination with low oxygen water, can result in mass mortalities of rock lobster, fish and invertebrates (van der Lingen *et al.* 2016, Branch and Branch 2018). River input is via the Orange-, Olifants- and Berg River with less than 5% of the terrigenous sediment input reaching the western margin although katabatic winds sweep fine sediment off the continental interior onto the west coast shelf (Dingle *et al.* 1987). River flow is intermittent and generally weak, except for occasional flood events such as in 1988 and 2011, when millions of tons of freshwater and silt were transported onto the shelf (Van Niekerk *et al.* 2013).

The passive continental margin of the west coast is wide and flat, the gradient towards the shelf edge is relatively low (1-2 degrees) (de Wet 2013). The **Western Margin** is mantled by glauconite and foraminiferal sandy sediments (Birch *et al.* 1986, Dingle *et al.* 1987). The inner shelf north of St Helena Bay is blanketed by sand that extends offshore (Birch *et al.* 1986). There is a mudbelt between Saldanha Bay and the shelf near Cape Town, with sand more typical of the middle shelf. Sediment becomes finer seawards towards the outer shelf and continental slope, grading from muddy sand, to sandy mud, and finally to sand. Terrigenous debris is reported to cover the inner shelf north of St Helena Bay, but extends across the entire shelf and upper slope southwards from there as far as Cape Town. Biogenic material is almost entirely foraminiferal and covers the middle and outer shelves and upper slope north of St Helena Bay, and South of Cape Town. Extensive deposits of glauconitic sand are present on the middle and outer shelves of Saldanha Bay and West of Cape Town. Siesser *et al.* (1974) conducted bottom-sampling and used shallow seismic-reflection techniques to examine the

distribution, composition and origin of potentially economic deposits such as marine phosphorite and glauconite.

Key features on the western margin include the **Cape Canyon and Cape Valley** (Simpson and Forder 1968, Dingle 1986, Wigley 2004, Wigley and Compton 2006) in addition to numerous new canyons that are being discovered through recent research (Palan 2017). The Cape Canyon is the largest canyon on the western margin, trending in a south-westerly direction and cutting obliquely across both the continental shelf and slope, spanning a distance of approximately 200 km in length and a maximum depth of -3600 m (de Wet 2013). The head of the Cape Canyon is located roughly 23 km off Cape Columbine, at -168 m water depth, where it starts off parallel to a rocky inner shelf terrace and carries on as a shallow, indistinguishable feature for nearly 27 km to the southwest before deepening quickly and forming the northern segment of the Cape Canyon (de Wet 2013). The smaller Cape Point Valley is about 25 km south-west of Cape Point.

1.4.3 Eastern margin

The Eastern Margin is morphologically and sedimentologically distinct from the western margin. In contrast, this margin is a product of shearing during the margin development process, related to the extraction of the Falkland Islands along the Agulhas-Falklands Fracture Zone between 135 and 115 million years ago (Watkeys 2002). When coupled to a different current regime, productivity and climate, the result is a complex seafloor morphology that includes a very **narrow shelf, high terrigenous input and high energy benthic boundary conditions** (Dingle 1986). The shelf edge is mostly shallow (~ -100 m), fronted by a steep slope characterised by numerous mass wasting features (Dingle and Robson 1985, Green and Uken 2008). North of Richards Bay, the shelf narrows considerably, forming one of the World's narrowest shelf systems (Green 2009b). Occasional shelf protuberances exist, which are marked by coastal offsets and debouchments of large fluvial systems. The fan-shaped Tugela Cone features off the uThukela River (Dingle 1977, Dingle *et al.* 1983, Martin and Fleming 1988), between Cape St. Lucia and Durban is an asymmetrical sedimentary feature with a steep, south-west trending southern face and a gentler sloping eastern side, due to a change from a sheared margin to a short rifted section (Martin 1984, Martin and Fleming 1988). It is characterised by terraces and valleys including the prominent Tugela Canyon (Dingle 1977, Martin 1984, Martin and Fleming 1988, Wiles *et al.* 2013).

Up to 24 **submarine canyons** exist along the East Coast continental margin, with the majority of them only indenting the outer shelf margin and disrupting the adjacent continental slope, unlike the well-developed submarine canyons dissecting the West Coast margin (Flemming 1981, Hay 1984, Green *et al.* 2007, Green and Uken 2008, Green 2009a, 2009b, 2011). Despite the number of canyons in the region, strong sweeping of the seafloor in the abyssal areas and continental rise by North Atlantic Deep Water has resulted in a sediment-denuded seafloor (Wiles *et al.* 2014a). Seafloor topography is mostly a function of relict volcanic features formed during Gondwana breakup (Wiles *et al.* 2014b). The largest canyon recognised to date, the Tugela Canyon, does not have an associated fan. The current sweeping of the shelf by the Agulhas Current limits sediment input to the system, and further whittling in deeper waters by the North Atlantic Deep water has limited submarine fan development.

The warm western boundary **Agulhas Current** flows strongly southward along the east coast, bringing nutrient-poor tropical and subtropical surface waters from the equatorial and subtropical regions of

the western Indian Ocean (Lutjeharms 2001, 2006b, Beal *et al.* 2011). The Agulhas current is fully constituted along the north east coast of South Africa and is a wide (up to 100 km), intense current with peak surface speeds of more than 2m/s in the core (Lutjeharms 2006a, 2006b). It is very stable between northern KwaZulu-Natal and Port Elizabeth, meandering less than 15 km either side.

The behaviour of the Agulhas Current is strongly influenced by the underlying topography. As most of the east coast is narrow, the Current is found close to the coast, except off the uThukela Banks in the **KwaZulu-Natal (KZN) Bight**, and south of East London, where the shelf widens (Fennessy *et al.* 2016, Guastella and Roberts 2016, Roberts and Nieuwenhuys 2016, Roberts *et al.* 2016). Where large offsets in the coast (such as the KZN Bight) occur, cyclonic lee eddies often form and propagate downstream, interrupting the stable pathway of the Agulhas Current (Lutjeharms and Roberts 1988, Roberts *et al.* 2010). Within the Agulhas Current, the waters are typically blue and clear, considered to be **oligotrophic** with low nutrient levels, but these waters carry diverse biota from the rich Indo-Pacific region. On the eastern shelf regions, nutrient levels are usually slightly higher due to the interaction of the Agulhas Current with the continental slope, and shelf waters considered to be mesotrophic (Barlow *et al.* 2010). However, as cyclonic lee eddies propagate downstream along the inshore edge of the Agulhas Current, they can result in substantial upwelling of cold, deep, nutrient-rich water onto the shelf, which stimulates considerable increases in phytoplankton biomass and subsequent productivity on the shelf (Barlow *et al.* 2010, Russo *et al.* 2019). Many more rivers outflow on the east coast compared to the west coast, with increasing recognition of the importance of **river outflow** on the marine environment (De Lecea *et al.* 2013a, Porter *et al.* 2014, De Lecea *et al.* 2016, De Lecea and Cooper 2016, Scharler *et al.* 2016). There is increased outflow during the rainy (summer) season (Hutchings *et al.* 2010) and the freshwater input is often stratified , concentrated in the upper few metres of the water column and then dispersing often within 2-3 km of the outflow (Goschen and Schumann 2011, Russo *et al.* 2019). However, on the KwaZulu-Natal shelf, freshwater inputs from the uThukela River have been observed to influence the shelf waters up to 27 km away from the river mouth (Lamont *et al.* 2016). For more information on the effect of fluvial input see Chapter 3 where the seabed classification component integrated fluvial fan mapping and notes the influence of riverine input on offshore sediments.

The **sediment** of the Eastern margin is characterised by terrigenous sand and shelly gravel (Birch *et al.* 1986, Flemming and Hay 1988). North of Durban, the shelf is mantled by mixed terrigenous and bioclastic sediment, ranging from mud to gravel in size (Flemming and Hay 1988, Green 2009a, Green and Mackay 2016). In the KwaZulu-Natal Bight, muddy-sand predominates off the uThukela Bank. South of Durban, terrigenous sand is restricted to the inner shelf, and the middle and outer shelves are covered with shelly sand and gravel (Birch *et al.* 1986). On the Middle and Outer shelf between Port St Johns and the Great Fish River where the velocity of the Agulhas Current exceeds 2 knots, gravely sand and sandy gravels predominate (Flemming 1981, Flemming and Bartholomä 2012). Terrigenous sand and mud extend across the entire shelf off Port St Johns, off the mouth of the Mzimvubu River, and further south off the Great Fish River (Dingle and Robson 1985, Birch *et al.* 1986).

1.4.4 Southern margin

The Southern Margin includes the **Agulhas Bank** east of Cape Agulhas and is considered to be a transitional area exhibiting topography and sedimentological characteristics of both the Eastern and the Western Margins. This Agulhas Bank is a broad triangular section of the shelf extending nearly 100

nautical miles south of the coastline. The inner shelf of the southern Margin is covered by terrigenous sand and mud and shelly sand mantles the middle and outer shelves (Parker 1975, Birch 1979). Glauconite and phosphatide occurs as several individual deposits at or near the junction of the latter two sediment types and a mud belt, rich in faecal pellets is located on the middle shelf west of Cape Agulhas (Birch 1979).

The swift **Agulhas Current** moves offshore along the edge of the Agulhas Bank (Lutjeharms *et al.* 2000a). Most of the Agulhas Current then retroflects (bends back) eastwards into the western Indian Ocean and heads towards Australia (Lutjeharms and Van Ballegooyen 1988). Occasionally huge rings of warm water break off and slowly spin off into the South Atlantic, carrying heat, salt and some pelagic plants and animals characteristic of the Agulhas Current far into the South Atlantic Ocean (Bass 1970, Owen 1981, Gründlingh 1988, Luschi *et al.* 2003, Lutjeharms 2006a). This movement of surface waters from the Indian Ocean to the Atlantic is an important component of the global circulation of water which maintains the input of heat and salt into the Atlantic Ocean (Beal *et al.* 2011) and long-term variations in this input have been linked to global changes in glacial and inter-glacial periods (Peeters *et al.* 2004). One of the final outflows of the Agulhas Current, the Agulhas Return Current, must navigate a number of shallower features such as the **Agulhas Plateau**, which causes the current to carry out wide meanders in the direction of the equator (Lutjeharms 2006a). Upwelling of nutrient-rich sub-photic water occurs along the shelf break and at promontories along the southern coastline, creating an intensive, dynamic mixing region on the Agulhas Bank, intermediate in terms of temperature and productivity between the Benguela and Agulhas regimes (Jackson *et al.* 2012, Goschen *et al.* 2015). The south coast is an extremely important area for pelagic fish spawning, as eggs and larvae are swept westwards and northwards onto the west coast shelf, which the young fish utilise as a productive nursery area before returning to spawn on the Agulhas Bank (Hutchings *et al.* 2002).

1.4.5 Biodiversity and biogeography

The strong oceanographic variability and in particular the contrasts in temperature, productivity and dissolved oxygen are reflected in the division of the marine biodiversity into at least three broad biogeographic provinces, the cool temperate west coast, the warm temperate south coast and the subtropical east coast (see Chapter 3). There are also complex interactions between the oceans and the atmosphere on a regional scale, combined with the effects of latitude, topography and soil types, which affect the rainfall patterns in South Africa. It is therefore not surprising that South Africa displays such high levels of marine and biodiversity within such a small area.

1.4.6 Endemism

The rich marine biodiversity of South Africa has been recognised for a long time with a current estimate of 12 914 (Griffiths *et al.* 2010) marine species reported from South Africa's mainland marine territory. The addition of algae, fungi and parasites mostly accounted for the increase in species richness from the estimate of 11 130 species reported by Gibbons (1999). The addition of at least 170 new marine species descriptions (see Table 3) brings the total number of marine species in South Africa to **more than 13 000 species**. Estimates of endemism range between 26 and 33% (Gibbons 1999, Awad *et al.* 2002, Costello *et al.* 2010a, Griffiths *et al.* 2010, Griffiths and Robinson 2016) with South Africa reported as having the third highest endemism after New Zealand (51%) and Antarctica (45%) (Costello *et al.* 2010a). Griffiths and Robinson (2016) provide an excellent review of marine

endemicity in South Africa highlighting the limitations, biases, confounding factors and the value of such estimates particularly in the absence of more detailed assessments of range restricted taxa. There is considerable variability reported between taxa with estimates ranging between 0% (mammals and birds) to more than 90% (chitons). Highest marine endemicity has consistently been reported for the cool temperate Agulhas ecoregion on the south coast which lies entirely within South Africa's territory and is geographically very isolated from other warm temperate regions.

1.5 Foundational Marine Biodiversity Knowledge and the Taxonomic Impediment

Foundational marine and coastal biodiversity databases for most marine taxa lag well behind that of terrestrial, freshwater and estuarine ecosystems (Driver *et al.* 2012). This **lag in marine biodiversity knowledge** exists for four main reasons: 1) the environment is generally less accessible and more expensive to sample; 2) many existing biodiversity data are not digitised or are inaccessible; 3) capacity is limited with few mechanisms to engage civil society in the collection of primary marine biodiversity data; and 4) data management within the marine research community is poorly co-ordinated (Sink *et al.* 2012a).

Taxonomy is the science of describing, naming and classifying groups of biological organisms. This discipline stands at the core of all biological research and is the foundation for the assessment of biological diversity. In the NBA 2011 marine report a dedicated section provided an overview of the Status of marine taxonomy (Sink *et al.* 2012a). These authors highlighted the **critical limitation of taxonomic expertise** in South Africa. At the time Costello *et al.* (2010a) showed that South Africa has a 'state-of-knowledge index' for marine biodiversity that is only 'average', which in relative terms is moderately good for a developing country. The authors however also found that of 26 global regions analysed for the Census of Marine Life, South Africa had the lowest number of taxonomic experts per taxonomic group. Griffiths *et al.* (2010) added that the vast majority of the already limited local taxonomic experts are either graduate students or only part-time employees. This absence of employed local experts is particularly concerning considering the national biodiversity levels with high rates of endemism (see section 1.4.6 on endemism).

The deviation between South Africa's moderate biodiversity knowledge on the one hand, and lack of local taxonomic expertise on the other hand, can be explained by the **history of marine biological explorations** in the country. Griffiths *et al.* (2010) briefly outlined three eras of marine biodiversity explorations in South Africa: **1)** A "colonial" state from the late 1700s lasting to the late 1800s, during which ship-based expeditions such as *Challenger, Deutsche Tiefsee* or *Discovery* visited the Cape region. **2)** The "descriptive taxonomy" state spanned from around 1900-1970. In this time marine taxonomists such as J.D.F. Gilchrist, K.H. Barnard, and their followers, described a big bulk of the common fauna using morphology only. The species knowledge from this time still forms majority of biodiversity knowledge in South Africa at a species level. **3)** From 1970 onwards the "modern" state of marine research in South Africa shifted towards biological questions of ecological understanding, and during this time and until today, taxonomic research has been grossly neglected.

Gibbons *et al.* (1999) first collated information to report on the **richness of South Africa's marine fauna** and the status of taxonomic knowledge across various marine groups. Griffiths *et al.* (2010) evaluated and updated the status of knowledge of South African marine biodiversity. These authors calculated that 7,590 more species need to be described to bring the South African knowledge to

current European levels. In 2014, the SeaKeys project (funded by the NRF-FBIP) was initiated to help collate knowledge and address key gaps in South African foundational marine biodiversity knowledge. The project aimed to unlock marine biodiversity knowledge through the co-ordinated capture and dissemination of data, limited and focused new research and innovative knowledge generation, capacity building and information flow approaches. See Box 2 progress regarding the SAIAB fish collection.

Box 2. SAIAB Collections Platform
By Ryan Palmer

The South African Institute for Aquatic Biodiversity (SAIAB) Collection facility was completed in 2007 to house the **National Fish Collection**, the largest wet collection of fishes in the Southern Hemisphere. Since then, SAIAB has diversified its holdings to include, amphibians, diatoms, aquatic invertebrates, cephalopods, tunicates and marine mammals. The collections are growing annually and now include a range of other bio-materials, such as tissues for genetic isotope analyses. The Biobank is an area of major growth for SAIAB with catalogued holdings of more than 20,000 lots.



SAIAB's Collections Platform offers state-of-the-art facilities, equipment and processes, accommodation for multiple users, and provides teaching platforms for students. In addition to the wet collections, their services include a range of specialised laboratories including X-Ray facilities, otolith preparation and molecular preparation laboratories and genetics laboratories. All of these facilities are available to local, regional and international researchers and are used for training of students in the fields of taxonomy and genetic research, the critical underpinning of marine biodiversity knowledge.

The **SAIAB Collection facility** is essential for fish taxonomy and biogeography research in South Africa, which forms the foundations for ecology, biodiversity research and fisheries management. Researchers making use of the facility have produced several seminal works including: "Coastal Fishes of South Africa – Phil and Elaine Heemstra", "Fishes of the Southern Ocean – Ofer Gon & Phil Heemstra", "Groupers of the World – Phil Heemstra", and the much anticipated new "Coastal Fishes of the Western Indian Ocean – Heemstra and Heemstra *et al.* (in press)".

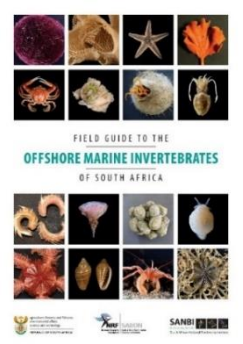
SAIAB's collections are becoming more accessible and are being loaned with higher frequency, new collections are being developed, more scientists are visiting the collections and systems within the Collections Division are being improved.

The **SeaKeys Project** made advancements in collating species checklists and records (Box 3). National inventories (species checklists) for various groups were compiled covering over 9700 species. A total of 6 data sets were digitised and new work undertaken to advance distribution data for fish and benthic invertebrate species. The completion of a guide to offshore marine invertebrates was a highlight in marine biodiversity science requiring substantial collaboration from many local and international taxonomists over the last decade (Atkinson and Sink 2018). The guide covers 410 species and described 20 new species discovered through associated offshore research initiatives.

However, during SeaKeys the lack of local taxonomic knowledge and expertise was a main limitation in collating accurate and validated information. It also became very apparent that the state of taxonomic knowledge for the marine fauna has only slightly improved since the 1970s end of phase 2 of "descriptive taxonomy". For example, the specialized taxonomic guides to the local fauna are mostly the same as listed by Griffiths *et al.* (2010), and at the time these authors already noted that most of the guides were severely out-dated.

Box 3. The SeaKeys project and Field Guide to the Offshore Marine Invertebrates

The SeaKeys Project was a large collaborative project (2012-2018) that aimed to collate and increase marine biodiversity information and translate this information into products to support decision making and the development of new biodiversity benefits for South African society. The project aimed to unlock marine biodiversity knowledge through the co-ordinated capture and dissemination of data, limited and focused new research and innovative knowledge generation. The Iziko Museums of South Africa played an important role in the curation of backlog museum specimens and unlocking historical records. Key products that were generated included many new animal checklists that collectively list more than 9 500 species, the SeaKeys monitoring report that collated all marine monitoring efforts in South Africa, over 32 000 species distribution records and the Dive SA Project. The Dive SA project aimed to increase scuba diving based tourism and knowledge of dive guides (highly qualified divers who serve as underwater tour guides) to improve diver experience and appreciation of marine biodiversity through a series of courses (see http://southafricandiver.co.za/ for full list of available courses) . This project also led to the development of a specialised course on Nudibranchs and more than 50 participants have successfully qualified from this course and have been actively participating in local nudibranch searches (#branching). Specialised courses like these can aid in promoting South Africa's marine biodiversity assets to attract more tourists. The SeaKeys team contributed to the first ever identification guide to South African offshore marine invertebrates (Atkinson and Sink 2018).



Since 2011, the offshore biodiversity team at the SAEON Egagasini Node have implemented and maintained a long-term, invertebrate monitoring programme in collaboration with the former Department of Agriculture, Forestry and Fisheries (DAFF) and the Department of Environmental Affairs (DEA) and the South African National Biodiversity Institute (SANBI). Between 2011 and 2018, a team of 22 co-authors from 16 institutions, along with many local and international collaborators, have compiled information for 410 offshore invertebrate species (Atkinson and Sink 2018). This programme also led to the discovery of 21 species and 16 new species records for the country. This long-term monitoring programme has enabled a rapid increase in local knowledge of offshore invertebrates and the guide lays the foundation for better assessing benthic offshore ecosystem communities in the future.

Some promising developments have been achieved in the historically understated but ecologically important groups of sponges and polychaetes. A total of 57 species of South African **sponges** have been described as new to science since the year 2000, and 23 since the NBA 2011 (R. Payne, University of the Western Cape, pers. comm.). A further number of 8 species of **polychaetes** have been described since 2011, and four more species descriptions are in the line of being published (Simon, pers. comm.). Descriptions of new species in other groups tend to be single events (Table 3). Advancements with holistic taxonomic treatments made in the past years are in the groups of **barnacles** (Biccard and Griffiths 2016), **brittle stars** (Olbers 2016), **anemones** (Laird and Griffiths 2016), **echinoids** (Filander and Griffiths 2017, Filander *et al.* 2019), **nudibranchs** (Toms 2017), bryozoans (Boonzaaier 2017), **hermit crabs** (Landschoff 2018), and **sponges** (Payne 2019 in prep). Once more, all of these studies were or still are however carried out as postgraduate student projects. They can generally not directly be compared to work done by international taxonomic authorities with decades of experience. None of the authors mentioned above are currently employed for taxonomic work within their respective group.

While some advancement has been made in marine biodiversity knowledge it is becoming clearer that biodiversity research in South Africa is almost entirely based on the taxonomy done during the descriptive era in the first two thirds of the 1900s. The very basic underlying foundation of species knowledge has therefore not kept up with the demands of modern biodiversity assessments. Meanwhile, biodiversity research has entered a new phase in which molecular tools are able to pick up much more detailed signals of population and species patterning. Modern taxonomic studies integrate molecular tools, but such **integrated taxonomy** is not reflected in the historic descriptive knowledge and is required to update these historic databases. Through SeaKeys and other initiatives, some positive first steps have been made in this direction, e.g. using a barcoding approach (see Chapter 10). But on a broader basis this type of taxonomic work is generally absent in the country. The Foundational Biodiversity Information Programme (a joint initiative of the Department of Science and Technology (core funder), the NRF and SANBI) provides an important opportunity to expand this work and other innovative approaches are needed for collaborative work that can address this shortcoming (see Chapter 11).

Box 4. Spider crab named after South Africa's Oceanographic Research Institute (ORI)



The discovery and description of the ORI Spider Crab *Pleistacantha ori* was a collaborative effort by South African scientists and a team of international experts. Due to the lack of local taxonomists the formal taxonomic description was carried out by overseas taxonomists but the species was discovered by Sean Fennessy, a scientist at the Oceanographic Research Institute (ORI) in Durban. The species was named after ORI in honour of this institute's more than 65 year history of research in advancing the knowledge of South Africa's marine diversity on the east coast of Africa and beyond. Photo: ACEP Spatial Solutions project.

Given the unique South African marine environment, biodiversity and endemism patterns, the lack of taxonomic expertise and the lack of funding for this work is a major concern – see Box 4 where international expertise was required. To address this issue SANBI established a **National Marine Taxonomic Working Group** to review historic efforts and collate information from recent taxonomic endeavours, building on taxonomic efforts from the SeaKeys project. A first working group meeting was held in 2019 to review progress, discuss challenges and work towards addressing the critical gaps that limit our ability to assess marine biodiversity in South Africa. See Chapter 11 for the taxonomic research and management priorities identified by this working group. An updated list of local and international experts with marine taxonomic research interest in South Africa (not shown) and list of species new to science since 2011 was produced. Table 3 shows that some good taxonomic work is being done in the country, with a 170 new species being described & more than a 100 new distribution records documented since NBA 2011, however the weight of this work is carried by a few specialized research groups. These efforts have not been able to do justice to South Africa's wealth of marine life. A priority ranking system was developed to highlight groups that are in high demand of taxonomic work. This ranking system considered measures such as the size of the group, the ecological and economic significance, the state of knowledge and endemism rates. Considering the many talented students that have graduated from taxonomic theses there was also strong agreement to build on this capacity in prioritising groups. Further detailed and recommendations are given in Chapter 11.

Table 3. Newly described South African marine species since 2011

Taxonomic group			No. new species described (since 2011)	No. new species currently being described	No. new records	Ref	Working Group or Expertise in SA
PLANTAE							
			11	9	5	John Bolton and Gavin Maneveldt pers. comms. Numerous papers	J. Bolton UCT & G. Maneveldt UWC
ANIMALIA							
Porifera			25	1		Robyn Payne pers. comm., Parker-Nance *et al.* 2019	T. Samaai DEA
Bryozoa				12		Boonzaaier *et al.* (in prep)	W. Florence IZIKO
Cnidaria	*Anthozoa*				12	(Laird and Griffiths 2016)	C.L. Griffiths lab UCT
	Myxozoa		1			Cecile Reed pers. Comm.	C. Reed (parasites) UCT
	Scyphozoa			3		Mark Gibbons pers. Comm.	Gibbons lab UWC
	Staurozoa		1			(Miranda *et al.* 2017)	C.L. Griffiths lab UCT
Annelida	*Polychaeta*		11	4		Simon *et al.* various papers, pers. Comm.	
Arthropoda (Crustacea)	*Amphipoda*		3		13	(Milne and Griffiths 2013, Griffiths 2019)	C.L. Griffiths lab UCT
	Cirripedia	*Thoracica*			14	(Biccard and Griffiths 2016)	C.L. Griffiths lab UCT
		Acrothoracica		2	3	(Botha 2019)	C.L. Griffiths lab UCT
	Decapoda	*Anomura (Paguroidea)*	3		12	(Landschoff and Lemaitre 2017, Landschoff 2018, Landschoff and Rahayu 2018, Landschoff *et al.* 2018)	C.L. Griffiths lab UCT
		Brachyura	3			(Dawson and Griffiths 2012)	C.L. Griffiths lab UCT
	Mysida		5			(Wittmann and Griffiths 2014, 2017, 2018)	C.L. Griffiths lab UCT
Mollusca	*Cephalopoda*		1			(Lipinski and Leslie 2018)	
	Gastropoda		115		2	David Herbert pers. comm. (taken from MolluscaBase *note that most species are described by amateurs and not by taxonomic experts)	
Echinodermata	*Asteroidea*		2			(Mah 2017)	
	Echinoidea				23	(Filander and Griffiths 2017, Filander *et al.* 2019)	C.L. Griffiths lab UCT
	Ophiuridae				24	(Olbers 2016)	C.L. Griffiths lab UCT
			170	**22**	**103**		

2. BENEFITS OF BIODIVERSITY IN THE MARINE REALM

Chapter Citation: van der Bank MG, Poole CJ, Sink KJ, Perschke M, Franken M, Rylands S, Miza SA, Majiedt PA, Sibanda SM, Harris LR, Whitehead TO, Dunga LV, Adams R. 2019. Chapter 2: Benefits of Biodiversity in the Marine Realm. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



South Africa's marine realm provides benefits to the economy, society and human wellbeing

Chapter summary

South Africa's marine realm has globally exceptional biodiversity that provides a wide array of benefits to the economy, society and human wellbeing. These benefits include those that are tangible such as the direct harvesting of food and medicinal resources, and the recreational, tourism and educational benefits of the marine realm. Less tangible benefits include the spiritual and cultural values of South Africa's oceans and coasts that include the likely role of marine resources in modern human evolution. Naturally functioning ecosystems that generate or deliver valuable services to people and thereby enhance human wellbeing are referred to as ecological infrastructure, the nature-based equivalent to built infrastructure. Beaches, reefs and kelp forests are marine ecosystems of limited extent that provide disproportionate benefits. The continued supply of these benefits relies on healthy ecosystems and well managed species. An overarching theme to this chapter is how the marine realm already provides numerous job opportunities and could potentially provide even more if marine ecosystems are maintained in a good ecological condition and the status of key species is improved. This chapter demonstrates the importance of marine biodiversity to fisheries and hence food and job security in South Africa. Similarly, the importance of apex predators such as marine mammals, birds and sharks for tourism in our growing ocean economy is established. Well managed marine species and ecosystems is therefore essential to secure long-term ecological and socio-economic benefits. Effective communication of the value of South Africa's marine biodiversity through improved co-ordinated messaging that articulates benefits is vital to mobilise people to sustainably use marine biodiversity. Increased research to improve social and economic statistics regarding marine biodiversity benefits should be prioritised. This chapter clearly illustrates that marine biodiversity is central to South Africa's national objectives of increased economic growth and job creation, and plays a vital role in the wellbeing of coastal communities and South African society.

2.1 Introduction

At the global scale the oceans have been estimated to contribute approximately US$24.2 trillion (R327.6 trillion) per year to human welfare (Hoegh-Guldberg 2015), and to contribute 60% of the total economic value of the biosphere (Costanza *et al.* 1997). Coastal services have been estimated to directly contribute 35% to the South African Gross Domestic Product (GDP) (WWF SA 2016).

A **Compendium of Benefits of Biodiversity** (SANBI 2019) has been produced for the NBA 2018 that explores the range of ways in which biodiversity supports human wellbeing. While this work is by no means comprehensive and includes limited work on marine benefits, it demonstrates the importance of biodiversity and outlines a number of examples of how biodiversity contributes to the objectives in South Africa's National Development Plan 2030. Objectives such as improving the economy and employment, building an inclusive rural economy, health care for all, and many others rely on biodiversity assets, ecological infrastructure and environmental sustainability and resilience. This chapter explores some of these objectives from the perspective of the marine realm.

South Africa's marine realm has extremely diverse and unique biodiversity (see Chapter 1), and this diversity provides an array of benefits to South Africans as well as to people beyond the national borders. These benefits include those that are tangible such as the direct harvesting of food and medicinal resources, and the recreational, tourism and educational benefits of the marine realm. Less tangible benefits include the spiritual and cultural value of our ocean, and the value of its ecological

infrastructure to South Africans' safety and wellbeing. An overarching theme to these benefits is how the marine realm already provides numerous job opportunities and could potentially provide even more if marine ecosystems are maintained in a good ecological condition and the status of key species is improved. There are opportunities to build on and diversify benefits from marine biodiversity.

2.2 Marine biodiversity is crucial for food security in South Africa

> ***Food security***: A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO 2017).

In 2016, global marine fisheries provided 108 million tonnes of fish, of which 79.3 million tonnes was from capture fisheries and 28.7 million tonnes (worth US$67.4 billion) was from marine and coastal aquaculture (FAO 2018a). These substantial fisheries and aquaculture sectors are crucial for **food security and human nutrition** (Béné *et al.* 2015, Roos 2016, Bennett *et al.* 2018) and play a key role in the fight against hunger, as articulated in the 2030 Agenda for Sustainable Development (FAO 2018a). Fish and fish products are excellent sources of high-quality protein and in 2015 fish accounted for 17% of animal protein consumed by the global population and provided 3.2 billion people with almost 20% of their average per capita intake of animal protein. Per capita global food fish consumption increased from 9.0 kg in 1961 to 20.2 kg in 2015 (FAO 2018a).

Archaeological evidence suggests that anatomically modern humans (*Homo sapiens*) first began to use marine resources for food along the southern African coastline approximately 160 000 years ago (Marean 2010, 2014). This adds a novel perspective to our realisation of the importance of marine resource use in human evolution. Fishing is a key part of our global and South African heritage and provides food security for many of our citizens. Approximately 312 000 tonnes of seafood are eaten annually in South Africa with an annual average per capita seafood consumption estimated at 6 kg in 2015 (Hara *et al.* 2017), with more than 770 marine species harvested in South Africa (see Chapter 9 for more detail).

> ***Small-scale fishing*** means the use of marine living resources on a full-time, part-time or seasonal basis using predominantly low-technology fishing gear to ensure food and livelihood security through direct consumption and/or sale or barter of catch (Policy for the small scale fisheries sector in South Africa. Department of Agriculture, Forestry and Fisheries, Pretoria. Government Gazette 20 June 2012).

More than 3 000 **commercial fishing** right holders (across 22 commercial fishing sectors) deploy approximately 1 700 fishing boats annually in South Africa's Exclusive Economic Zone (EEZ) (Moolla and Kleinschmidt 2008, DAFF 2013a). It is estimated that annual commercial fisheries production is 600 000 tonnes (DAFF 2013a, 2015a) valued at approximately R6 billion (DAFF 2015a). In 2013, the demersal hake trawl and small pelagic fisheries were ranked as having the highest economic value and landed tonnage and jointly accounted for 85%, 65% and 54% of South Africa's total catch, total tonnage and total direct employment respectively (Brick and Hasson 2016). Fisheries contribute at least 0.5% of South Africa's GDP and play an important role in providing livelihoods for more than 100 000 people (CLA Report 2010, DAFF 2013a, 2015a), more so in the Western Cape where fisheries are estimated to contribute up to 5% of the Gross Provincial Domestic Product (DAFF 2015a).

Although large-scale fisheries land more fish, only 80% is used for direct human consumption with the remainder being used for secondary products – for example, fishmeal for use in the agricultural sector (Chuenpagdee *et al.* 2006, Bennett *et al.* 2018). **Small-scale fisheries** account for about half of the global fisheries' catch and 90% of the world's fishers (Msangi *et al.* 2013). In 2016, South Africa's emerging small-scale fisheries sector had participation from approximately 147 coastal communities, which translated into approximately 29 000 individual fishers (DAFF 2013a). The total value of **subsistence fishing** is estimated to be around R16 million, with the vast majority (approximately 85%) derived from linefishing (Hara *et al.* 2008). In addition to fish, Rock Lobster, Abalone, bait organisms and other intertidal resources are also harvested. Although small-scale fisheries contribute less than 1% to South Africa's GDP, the importance of this sector is in its provision of employment and food security – particularly protein – to poor coastal communities (Isaacs and Hara 2015). **Recreational fishing** in South Africa includes participation from approximately 1.32 million fishers, of which approximately half are marine (Saayman *et al.* 2017) targeting mainly linefish and rock lobster. The total economic impact of marine recreational fishing is estimated at R9.82 billion and this estimate is an underestimation as it excludes light tackle boat angling and artificial lure angling (Leibold and van Zyl 2008).

NBA 2018 KEY MESSAGE A3

Water flowing into the sea provides multiple benefits to people

Freshwater flowing from rivers through estuaries into the sea is *not* wasted, and is essential for coastal and marine food production, livelihoods, tourism and future climate change resilience. Through appropriate management, South Africa can maintain the vital freshwater flows that reach the coast.

Skowno *et al.* 2019.



Apart from species that are directly harvested for food, **ecological processes** are also important in providing food and job security. For example, sediment-rich water flowing from rivers into the sea provides benefits, such as nutrients for fish and sand for beaches. Fisheries associated with muddy ecosystem types (e.g. prawns, sole and several other fish species groups) are supported by mud delivery and the maintenance of land–sea connections required for the completion of their life cycles. Freshwater flow and associated sediment inputs maintain key tourism assets such as sandy beaches and reduce the risks of long-term erosion of beaches and dunes – thereby decreasing coastal vulnerability to natural hazards like sea storms currently and in future with increasing climate change impacts. If the volume of freshwater reaching the sea is reduced, for example by dams and irrigation schemes upstream, negative impacts can include erosion of beaches and decline in productivity of fisheries. Prawns, for example, are a favourite South African seafood that depend on freshwater flow into the marine environment. See the coastal report for more examples of the benefits of coastal biodiversity (Harris *et al.* 2019).

In comparison to commercial fisheries, commercial **marine aquaculture** in South Africa is in its infancy. However, marine aquaculture has been identified as one of the key growth sectors for the ocean economy under Operation Phakisa (DAFF 2015b, 2017a), with production having increased by 240.16% between 2000 and 2015 (DAFF 2017a). In 2015, the total marine aquaculture production for direct human consumption was estimated at 3 590 tonnes (DAFF 2017a). Key species cultivated in

marine aquaculture include South African Abalone (*Haliotis midae*), mussels (*Mytilus galloprovincialis*, *Chromomytilus meridionalis*), Oyster (*Crassostrea gigas*), Dusky Kob (*Argyrosomus japonicus*) and seaweed (*Ulva sp., Gracilaria sp*.) (DAFF 2017a).

Both the wild harvesting of various fish species and the production of food via marine aquaculture depend on ecosystems in a good ecological condition. Despite the importance of fish for food security, 33% of global fish stocks were considered overexploited in 2015 (FAO 2018a). Similarly, in South Africa many of our fishery resources are considered overexploited/collapsed (see Chapter 9 for more detail), which undermines the potential for wild capture fisheries to support food and job security in South Africa.

Marine Protected Areas (MPAs) which aim to safeguard marine biodiversity, also supports food security. MPAs support fisheries sustainability by protecting breeding and nursery areas, providing areas for resources to recover form overuse and through spillover (Kerwath *et al.* 2013b) or flow of benefits to adjacent areas. In a developing ocean economy, MPAs can help maintain food and job security (Annexure 1 and Annexure 2).

2.3 Marine biodiversity offers numerous opportunities for employment

Globally, capture fisheries provided employment for 40.3 million people in 2016 while aquaculture (marine, coastal and inland) provided employment to 19.3 million people (FAO 2018a). The marine realm however provides far more jobs than just those in fishing and aquaculture (see Table 4).

Table 4. Summary of types of employment in the South African marine realm and approximate employment numbers.

Employment sector	Direct employment
Commercial fisheries (22 sectors)	43 000
Small-scale fisheries	29 000
Mariculture	3 800
Tourism	~1 300 (considered an underestimate as this figure only considers a few activities)
Coastal and marine protection and management	Probably >2 000
Total	**~79 000**

South Africa's exceptional marine biodiversity provides a wide range of employment opportunities through activities like tour guiding, scuba diving, shark cage diving, bird and whale watching, coastal protection and protected area management.

South Africa's commercial **fisheries** (22 sectors) have been estimated to employ approximately 43 000 people directly (Moolla and Kleinschmidt 2008, WWF-SA 2011) and provide between 80 000 and 100 000 indirect employment opportunities (Brick and Hasson 2016). The emerging small-scale commercial fishery currently includes approximately 29 000 fishers (DAFF 2013a) (see Section 2.5 for a description of South Africa's fishing cultures), but these numbers are rapidly growing and may provide job opportunities to many though the establishment of co-operatives. South Africa's estimated R9.82 billion (total economic impact but likely an underestimate) marine recreational fishery (Leibold and van Zyl 2008) likely creates economic stimulus for many coastal towns.

The South African **marine aquaculture** industry (see Box 5) employed 3 826 individuals in 2015 (DAFF 2017b). Through government support programmes, such as Operation Phakisa and the Aquaculture

Development and Enhancement Programme (ADEP), the employment rate in the marine aquaculture sector is estimated to be increasing at an average rate of 17.5% per annum (DAFF 2017b).

It is not entirely clear how many jobs are in the marine realm that relate directly to **tourism** because research has been conducted for only a few sub-sectors, with limited statistics available. For example, the Simon's Town penguin colony is projected to create 885 jobs (van Zyl and Kinghorn 2018) over the next 30 years; while boat-based whale watching is said to provide employment to 184 people and shark diving employs about 250 people (DEA 2015a). Scuba diving is a growing leisure activity with an estimate of more than 28 million active scuba divers globally (Garrod and Gössling 2008), although this activity has had limited recent growth in South Africa. Scuba diving can be an important factor in promoting foreign investment through tourism activities (Burke *et al.* 2011) to create local job opportunities. The scuba diving industry created approximately 540 jobs in 2013 (DEA 2015a), including direct employment (scuba diving operators, charter operations, scuba diving education and training) and through associated services and supporting tourism industries (accommodation, transport, retail and food services for scuba divers).

The need for effective management and compliance with regulations to ensure long-term conservation benefits is increasingly being recognised globally (Byers and Noonburg 2007, Guidetti *et al.* 2008, Kelaher *et al.* 2014, 2015). Job opportunities are created by MPAs and include **field rangers and section rangers** who are responsible for compliance and enforcement, as well as **MPA managers** who are responsible for the overall effective management to ensure MPA objectives are met and positive ecological outcomes are achieved. With the establishment of the new MPAs (see Chapter 8 for more detail) there is potential for further employment opportunities and benefits (Annexure 1 and Annexure 2) although budget constraints demand innovation to reduce management costs. Employment opportunities may include involvement in long-term monitoring programmes, for example, iSimangaliso Wetland Park has an active long-term turtle monitoring programme and employs people from local communities thus providing sustainable income to many rural families and contributing directly to the local rural economy (Harris *et al.* 2018)



Marine biodiversity creates numerous employment opportunities. Here rangers from Ezemvelo KZN Wildlife are undertaking routine monitoring activities on the shoreline.

Working for the Coast (WftC) is an initiative established under the Department of Environmental Affairs' Environmental Protection and Infrastructure Programme (EPIP) and forms part of government's broader Expanded Public Works Programme. The WftC initiative provides employment and training for unemployed individuals in coastal communities. WftC aims to create and maintain a cleaner and safer coastal environment to help address government objectives of responsible coastal management and the successful implementation of the Integrated Coastal Management Act. The WftC workforce contributes to the development and maintenance of infrastructure along the coast,

supports municipalities and management authorities in regular coastal clean-ups, rehabilitation of coastal ecosystems, monitoring and compliance, the removal of invasive alien vegetation and assisting with coastal access control (DEA 2014).

Box 5. About South Africa's marine aquaculture industry

The aquaculture sector in South Africa can be divided into freshwater and marine aquaculture (mariculture). Species farmed differ largely between the two sectors, with freshwater aquaculture farming: Rainbow and Brown Trout, Common Carp, crocodiles, ornamental fish, Catfish, Tilapia, Marron and Waterblommetjies; and mariculture culturing: Abalone, prawns, various seaweeds, Mussels, Oysters, Dusky and Silver Kob, Yellowtail, Atlantic Salmon, Clownfish, White Margined Sole, Scallop and Bloodworm (DAFF 2017a, AgriSETA 2018). The abalone sub-sector accounted for the greatest proportion of aquaculture-related employment in 2015, followed by the Tilapia and Mussel sub-sectors respectively (DAFF 2017b). As aquaculture in South Africa is still a growing industry, it is reported to have a low number of employees with many employed as seasonal or temporary workers (AgriSETA 2018). There are unique employment opportunities in the aquaculture sector, with jobs ranging from farm managers and engineers, through marine biologists and food scientists, to production foremen, machine operators and fishing hands. However, there is still a big gap in terms of key scarce skills and skills needed to grow this industry. For example: food and beverage scientists with specialised skills in food processing, safety standards and protein development technology; veterinarians; aquaculture systems builders; and technical drivers of specialised aquaculture mobile equipment (AgriSETA 2018).



The abalone sub-sector is a key employer in the marine aquaculture sector. © Peter Chadwick

Marine aquaculture has been identified as a priority sector for growth and development of South Africa's ocean economy (Operation Phakisa Lab Report 2014). There are numerous opportunities for job creation, especially in rural areas and marginalised coastal communities (Operation Phakisa Lab Report 2014, AgriSETA 2018). Through Operation Phakisa, various initiatives have been undertaken to accelerate growth and development in the aquaculture sector and it is envisioned that this sector will increase revenue from R6 billion to R3 billion, production by 20 000 tons and provide 15 000 jobs by 2033 (Operation Phakisa Lab Report 2014).

Also under the Expanded Public Works Programme is the Department of Agriculture, Forestry and Fisheries' **Working for Fisheries Programme** (WfFP) established in 2004. The WfFP focuses on undertaking projects related to monitoring of fisheries catches, protecting marine resources, monitoring fish landings, waste management and aquaculture infrastructure development and creating job opportunities for unemployed individuals. The WfFP created approximately 1 189 full time jobs in the 2016/2017 financial year (DAFF 2017c).

The above-mentioned examples demonstrate that the marine realm, especially coastal ecosystems, can provide a variety of **opportunities for economic growth and job creation**. Many of those jobs may be in the poorest parts of the country with the least access to other employment opportunities (Sims-Castley *et al.* 2005, Snyman 2012). Therefore, investing in naturally functioning ecosystems presents

an opportunity to strengthen the socio-economic development, and investing in well-managed fishery stocks is essential to long term food and job security.

2.4 Marine and coastal tourism is of large economic value to South Africa

South Africa is recognised for its scenic beauty and its diverse land and seascapes, beautiful coastal vistas and popular beaches that play a key role in attracting visitors. South Africa's seascapes include beautiful coasts, reefs, underwater forests, important cultural and historic sites and even sub-marine canyons home to 'pre-historic' coelacanths. Shipwrecks and other sites of archaeological and historical interest help diversify tourism opportunities. In 2013, the direct value of South Africa's **marine ecotourism** sector was estimated at R400 million and the indirect value estimated at R2 billion (DEA 2015a). Coastal tourism contributed an estimated R26 billion to South Africa's national income (Turpie and Wilson 2011). Global estimates of the value of coastal and marine tourism exceed R426 billion (Wynberg and Hauck 2014). Recognising the role that tourism can play in accelerating South Africa's economic growth, the Coastal and Marine Tourism Lab was established in 2016 as part of Operation Phakisa to identify specific initiatives aimed at accelerating growth, development and transformation in the sector. This initiative aspires to increase jobs by 52 000 to 116 000 and to contribute to a GDP growth rate of 9% p.a. To encourage repeat visits by foreign tourists who may first consider South Africa as a 'Big 5 Destination', there has been recently initiated development of the **Indi-Atlantic Route**. The Indi-Atlantic Route is a proposed tourism route that covers the four coastal provinces, intended to link existing tourism routes, create a major route that will cover the entire South African coastline, and aim to benefit local communities and Small, Medium and Micro Enterprises (SMMEs). See (Harris *et al.* 2019d) for futher detail on the Indi-Atlantic Route .

Beach activities are the most popular biodiversity-related tourism activity for domestic overnight tourists and among the most popular for domestic day travellers, with 3.2 million overnight trips to beaches and around 460 000 day trips in 2016 (Bac and Tlholoe 2017a). Visiting a beach ranks similar in popularity to undertaking wildlife activities for foreign tourists (Bac and Tlholoe 2017b). Beaches provide a diversity of tourism activities, such as bathing, swimming, fishing, surfing, kayaking, walking, sunbathing, picnicking, beach-related sports, and observing marine life, birds and mammals. Healthy beaches are a prerequisite for growth in coastal tourism. As a testament to the excellent beach-visiting opportunities and conditions in South Africa, the country was the first outside of Europe to be awarded Blue Flags in 2001. Blue Flags are awarded annually, ensuring that high tourism standards are maintained at the sites. For 2018, South Africa had 66 Blue Flags, 46 of which were for beaches (the others are for marinas and boats). Most of the Blue Flag beaches are in the Western Cape (30); the rest are in the Eastern Cape (7) and KwaZulu-Natal (9) (WESSA 2018). The suspension of blue flag status of beaches in Durban as a result of deteriorating water quality, led to a loss of an estimated **R100 million** per year (Lucrezi and van der Merwe 2015).

Tourism associated with the marine wildlife economy includes tour guiding, scuba diving, shark cage diving, and turtle, bird and whale watching. South Africa's oceans have species that occur nowhere else on earth and offer incredible encounters with marine wildlife that local and international tourists want to experience. The Simon's Town penguin colony, found within the Table Mountain National Park, is valued at around R311 million per annum and projected to generate **R6.8 billion** over the next 30 years while creating 885 jobs (van Zyl and Kinghorn 2018). The estimated direct value of land-based

whale watching sector was valued at R80 million (overall value of R400 million) in 2013. Boat-based whale watching provided employment to 184 people and attracted 42 812 tourists with a direct value of R21 million (overall value of R105 million) in 2013. Tourism centred on seals (viewing and snorkelling) employed at least 30 people in 2013 and had a direct value of R5 million (estimated overall value R25 million). In the same year, shark diving created approximately 249 jobs and had a direct value of R113 million (overall value estimated around R571 million) (DEA 2015a). The contribution of the Tiger Shark (*Galeocerdo cuvier*) diving industry in Aliwal Shoal MPA was estimated at over R12 million per annum in 2008 (Dicken and Hosking 2009). White shark cage diving in Gansbaai alone was estimated to generate R3.5 million of income to operators in 2003 (Hara *et al.* 2003), while diving in Sodwana Bay, one of South Africa's most popular diving destinations, is valued at approximately R75 million annually (Dicken 2014). These figures show that these species not only play an important role in ecosystem function, but are crucial tourism assets that need to be protected to secure economic benefits.

2.5 The spiritual and cultural value of the marine realm

The sea is a place of cleansing and spiritual renewal for many South Africans and a powerful spiritual connection to our ocean enhances our lives and sustains us emotionally. Many marine species are used for traditional medicine, and many places along the coast are important cultural and spiritual sites – such as the Hole-in-the-Wall (see Box 6). In addition, South Africa's coastline showcases several different traditional fishing practices of cultural and historical significance.

Traditional healing uses a variety of tools from man-made objects to those found in nature. Herbalists derive medicines from wild-harvested species, and diviners use these organisms in their divining sets or regalia (Herbert *et al.* 2003). Some marine organisms are commonly used in **symbolism**, for example: helmet and cowrie shells are often used with the large one representing the paternal ancestry and the small one representing maternal ancestry. Helmet shells with black spots particularly represent the spirits of grandfather and grandmother (Sizakele Sibanda, University of Cape Town, pers. comm.).

Many marine animals play a key role in **traditional medicine**, providing a wide range of natural remedies commonly used in many cultures (Herbert *et al.* 2003). Historical documents and archaeological research indicate the use of marine animals in traditional medicines since ancient times (Lev 2003, Voultsiadou 2010). Marine organisms are being used to encourage fertility in animals, for example crayfish eggs mixed with certain herbs are given to cows, ewes and hens to increase their chances of becoming fertile. A diet that contains a large proportion of shellfish is reportedly useful in helping a woman conceive (Sobekwa 1995). Cuttlebone that is reduced to a powder is used in cases of sore-eyes in humans and animals (Sobekwa 1995). Some species of chitons are reported to help prevent bed-wetting in children and alert partners to infidelity (Herbert *et al.* 2003). Starfish are dried and ground into a powder which is used for healing ailments such as sores or in magic to attract economic success (Sizakele Sibanda, University of Cape Town, pers. comm.). Similarly, sea water, sediment and rock are some of the common objects harvested from the sea and used in traditional healing. For example, sea water is mainly used for the purposes of ridding one of bad luck, also known as cleansing, and it is used as is or mixed with herbs or sediment (Sizakele Sibanda, University of Cape Town, pers. comm.).

Box 6: The Hole-in-the-Wall



The Hole-in-the-Wall is one of the most imposing landmarks along the entire South African coastline. Standing at the mouth of the Mpako River in the Eastern Cape, the cliff consists of dark-blue shales, mudstones and sandstones dating back ~260 million years. The local Bomvana people named the formation 'EsiKhaleni', or the Place of the Sound. Local legend has it that the Mpako River once formed a landlocked lagoon as its access to the sea was blocked by the mighty cliff. One day, a beautiful girl living in a village near the lagoon was seen by one of the sea people (semi-deities who look like humans but have flipper-like hands and feet) who became overwhelmed by her beauty and was determined to win her. But the village was horrified at the match, and when the girl's father found out he forbade her to see him again. So, at high tide one night, the sea people came to the cliff and, with the help of a huge fish, rammed a hole through the centre of the cliff. As they swam into the lagoon they shouted and sang, causing the villagers to hide in fear. In the commotion, the girl and her lover were reunited and disappeared into the sea. At certain times of the year or when a certain wind blows, the music and singing of the sea people can still be heard. See the Compendium of Benefits of Biodiversity, available on the NBA website, for more information.

South Africa has globally significant coastal cultural and heritage sites and it is recognised that South Africa's diversity does not just lie in its biodiversity, but also in its history, cultural diversity and heritage. Palaeontological evidence of well-preserved fossils dating back about 5 million years on the west coast have enabled scientists to study the climate and how it has changed over time, and archaeological evidence shows the presence of humans through well preserved footprints (called Eve's Footprints) dated 117 000 years before present and associated with a critical period of human evolution (Roberts and Berger 1997). Marean (2010, 2014) highlighted the global significance of coastal resource use in South Africa in human evolution. Skeletal remains of earlier humans dated 110 000 years before present were found in **Klasies River Mouth caves** near Mossel Bay and there are several additional coastal sites of significance to human evolution (Jerardino and Marean 2010, Marean 2010, Loftus *et al.* 2019). Ideal environmental conditions on the tip of Africa are believed to have given rise to modern humans, as the remains of tools and ornaments (including Abalone shells, cutting stones, ochre and shell necklaces, engraved stones) tell the story of early humans who are believed to have evolved large brains in this region (Marean 2010, Cunnane and Crawford 2014, Loftus *et al.* 2019). Consumption of highly nutritious, omega-3 oil-rich marine resources may have played a substantial role in the development of the increasingly sophisticated cognitive abilities of modern humans. Areas around Mossel Bay have caves, such as **Pinnacle Point and Blombos Cave**, which are still being excavated with well-preserved evidence of the rise of modern humans (Parkington 2006, 2010, Marean 2010, Loftus *et al.* 2019).

On the east coast, 15 km southeast of East London Cove Rock, also known as **Gompo Rock**, holds the history of early inhabitants the Khoikhoi through remains of shell middens, and of Xhosa people who narrate the story of Makhanda ka Nxele, a famous Xhosa prophet, philosopher and warrior. Makhanda led Xhosa warriors in The Battle of Grahamstown on 22 April 1819. Apparently, after the successful defence of the town by the British garrison aided by a group of Khoikhoi marksmen, Makhanda

retreated to Gampo Rock. Makhanda believed that if he could jump from one section of the rock across a large gully to another, the ancestors would respond by emerging through the wide chasm to destroy the colonial powers. Crowds waited to see the phenomenon, which never happened. Makhanda handed himself over to the British colonial forces and was imprisoned on Robben Island, later dying in the cold Atlantic waters trying to escape. On 2 October 2018, Grahamstown was officially renamed as Makhanda in memory of Makhanda ka Nxele.

Other examples of sites and practices of historical importance on the east coast are found further north. High Rock, in a suburb known as **Shaka's Rock** near Ballito, about 40 km north of Durban, is believed to be where the infamous Zulu King Shaka dealt with his enemies by throwing them over the cliff and into the ocean. Legend has it that the red seaweeds that thrive on these shores were produced by the blood of the fallen Zulus. Further north, near the border of South Africa and Mozambique is the **iSimangaliso** Wetland Park, which is a terrestrial reserve and Marine Protected Area, Ramsar Site, and the first United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Heritage Site in South Africa. The area represents an important fishing area for the Tsonga people who fish using traditional estuarine fish traps and harvest intertidal resource from beaches and rocky shores.

South Africa's rich variety of marine resources is reflected in a wide diversity of fisheries practices of **fishing cultures** that have developed with different resources, methods and fishing cultures across the seascape (Figure 6). Fishing is one of the most ancient forms of hunting and there is an amazing variety of innovative methods and equipment used to outwit fishes and harvest marine resources (Bruton 2016). The historical caves and middens show that South Africans' ancestors harvested limpets and mussels much like existing coastal communities do today in Pondoland and iSimangaliso (Parkington 2006). Today, intertidal and subtidal resources including seaweeds, mussels, abalone, rock lobsters and redbait are harvested by subsistence, recreational, small–scale commercial, and commercial fishers (DAFF 2016). In addition, indigenous fishing technologies span a range of methods with evidence of bone fishing hooks, spears, stone fish traps, fish poisons and a host of trap, linefish, net and other methods employed (Bruton 2016). The targeted resources, fishing method, bait used, catch preparation and cooking methods all reflect the multitude of cultural influences that exist in South Africa, and how these cultures evolved and replicate the astonishing variety of South Africa's marine biodiversity.

Figure 6. (Next page) The wide diversity of fisheries practices across South Africa reflect the rich variety of marine resources.


FISHING CULTURES IN SOUTH AFRICA
Port Nolloth fishermen catch West Coast Rock Lobster using traditional traps.
© Jaco Barendse
©Peter Chadwick
Harder (locally known as Bokkoms) are caught by fishermen in Velddrift using several types of nets and lines.
©Peter Chadwick
Kelp harvesting has a long history of traditional and commercial use.
©BrandSA/ Rodger Bosch
One of the oldest fishing methods, handlining, is still used across South Africa.
©Peter Chadwick
Fishing skills are passed down through generations– for both subsistence and recreation.
A fisherman collects fish in traditional woven fish traps that have been used in the Kosi estuary for >700 years.
© iSimangaliso Wetland Park
©Kerry Sink
Recreational rock and surf angling is entrenched in many cultures across South Africa.
©Peter Chadwick
The fishing community at Strandfontein typically catch a variety of inshore shoaling species using treknetting.
©Pauline Rowles
Remnants of historical fishing traps in Skilpiesbaai show how fish were trapped using the tides.
©Oswald Kurten
Cast netting for small bait fish is common practice in estuaries like the Gouritz estuary.
©Peter Chadwick
Red Steenbras is a sought after linefish species caught by recreational anglers in East London.
©Roger de la Harpe/ Afripics
Mussel collecting is a common subsistence practice on the east coast of South Africa.

2.6 Marine ecological infrastructure is crucial to South Africans

NBA 2018 KEY MESSAGE A4.

Small high-value ecosystem types take up just 5% of South Africa's territory but provide multiple benefits to people

Certain small ecosystem types function as crucial ecological infrastructure and, despite their small footprint, provide multiple benefits to society (established but incomplete). Kelp forests, reefs and seamounts are examples of marine ecological infrastructure. Managing, protecting and restoring these small high-value ecosystems gives a large return on investment.

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Naturally functioning ecosystems that generate or deliver valuable services to people and thereby enhance human wellbeing are referred to as ecological infrastructure (SANBI 2016). Ecological infrastructure is put forward as the nature-based equivalent to built infrastructure (SANBI 2014). Some of the tangible ecosystem services like **food provisioning**, **recreation and tourism**, and the **spiritual, cultural and educational values** delivered by South African coastal and marine ecological infrastructure are described in detail in other sections of this chapter. The underlying ecological infrastructure features that ensure the delivery of those important services include, for example, important fish habitats like kelp forests or nearshore reefs that offer the opportunity to harvest food (Blamey and Bolton 2018). Ecological infrastructure that supports tourism activities include beaches used for recreational outdoor activities (Lucrezi and van der Walt 2016) or ecosystems that provide habitat for iconic species that in turn support ecotourism, e.g. African Penguins at Boulders Beach (Lewis *et al.* 2012) and turtles in iSimangaliso Wetland Park (Hughes 2010). Beaches that support spiritual or religious activities of South African coastal communities are another example of valuable ecological infrastructure (Lucrezi *et al.* 2016). This highlights that coastal ecosystem types in the marine realm are particularly valuable in terms of ecosystem service provision. See (Harris *et al.* 2019d) for futher detail.

Naturally functioning marine and coastal ecosystems serve the South African society in many intangible ways as well. One of the most significant contributions of marine and coastal ecosystems such as near-shore reefs, kelp forests (Blamey and Bolton 2018), seagrass beds (Fonseca and Cahalan 1992) and sandy beaches (Hanley *et al.* 2014) to human wellbeing is their ability to act as a buffer against environmental changes. They provide **protection from the impacts of climate change** (Spalding *et al.* 2014, Musekiwa *et al.* 2015, Rao *et al.* 2015) such as sea-level rise (Mather *et al.* 2009, Wang *et al.* 2014) and an increase in extreme storm events (Mather and Stretch 2012). A national study in the United States showed that the number of people that are most vulnerable to natural hazards in the coastal zone can be reduced by half if the optimal functioning of marine and coastal ecosystems can be maintained (Arkema *et al.* 2013). Kelp forests, for example, have great potential to buffer the intensity of storm events as they can attenuate waves and reduce current velocity by up to 85% (Jackson and Winant 1983, Mork 1996) (see Box 7). Sandy beaches can also effectively attenuate waves and protect the coast from erosion through dynamic sediment flux between beaches, sand banks, coastal dunes and other sediment transporting systems like estuaries (Hanley *et al.* 2014).

Harris *et al.* (2019d) provide further detail on the role of coastal Ecological Infrastructure (EI) on **disaster-risk reduction**, which is becoming increasingly important in the face of climate change. The intensity and frequency of extreme storms is increasing and predicted to increase further (IPCC 2014, Sobel *et al.* 2016), and global wind speeds and wave heights have increased in the last three decades, particularly for the extreme events (Young *et al.* 2011, Young and Ribal 2019). Superimposed on these

effects is sea-level rise, the rate of which is variable around South Africa but is recognised globally to be an accelerating phenomenon (Houston and Dean 2011, Chen *et al.* 2017, Nerem *et al.* 2018). This means that both pulse (storm) and press (sea-level rise) disturbances are increasing (IPCC 2014), which will produce synergist impacts for coastal systems. A preview of future conditions like this was given in March 2007, when the high astronomical tide (the peak of an 18.6-year tidal cycle resulting in higher sea levels than usual) coincided with a cut-off low pressure storm that pounded the KZN coastline (Smith *et al.* 2007). But natural coasts are well able to absorb these impacts: EI such as nearshore reefs (Barbier *et al.* 2011), kelp forests (Blamey and Bolton 2018), seagrass beds (Fonseca and Cahalan 1992), rocky shores, sandy beaches and dunes (Biel *et al.* 2017, Feagin *et al.* 2019) protect the hinterland from high-energy wave events by buffering and tempering the wave energy. Further, these effects can be substantial; for example, kelp forests can attenuate waves and reduce current velocity by up to 85% (Jackson and Winant 1983, Mork 1996).

Box 7. The value of kelp forests as Ecological Infrastructure

Kelp forests are among the prolific primary producers on the planet, supporting productivity per unit area that resembles that of tropical rainforests (Krumhansl *et al.* 2016, Teagle *et al.* 2017). Dominating approximately 25% of the world's coastlines, they deliver services that are not only crucial in the shallow sub-tidal area, but also the adjacent deep-sea and beach ecosystems (Filbee-Dexter and Wernberg 2018). Kelp play an instrumental role in the process of climate regulation by contributing to the global carbon sink and serving as a protective coastal barrier to storms and harsh wave action that increase sedimentation and intensify impacts from coastal squeeze (Smale *et al.* 2016, Pfister *et al.* 2018, Wernberg and Filbee-Dexter 2018). Kelp also plays an ecosystem engineering role, as the wrack that accumulates on the driftline and supralittoral zones of beaches serves as a sand trap, which can form the basis for new foredunes to develop (Nordstrom *et al.* 2011) and thereby contributing further to coastal protection. Beach-cast wrack with kelp often underpins the food webs of sandy beaches (Gómez *et al.* 2018, Rodil *et al.* 2018). The services derived from South African kelp forest ecosystems and associated reefs contribute about R5.8 billion year, with direct services including recreational, commercial and exploratory fisheries (Blamey and Bolton 2018).



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Undoubtedly, though, dunes are the most important EI in terms of **coastal protection and adaptation to climate change (sea-level rise and storms)**. Coupled, intact dune-beach-surf systems effectively attenuate wave energy and protect the hinterland from wave damage through dynamic movement of sand between the dunes, beach and sand bars in the surf zone, with erosion during periods of heightened wave energy and accretion during periods of relative calm. However, the most critical thing is that the littoral active zone (coupled dune-beach-surf zone as a single geomorphic unit) has to be intact for it to deliver the benefits of coastal protection. A national study in USA, for example, showed that the number of people that are most exposed to natural hazards in the coastal zone can be reduced by half if the marine and coastal ecosystems remain functioning (Arkema *et al.* 2013).

Beaches and dunes are crucial ecological infrastructure in South Africa providing numerous benefits to people. Trips including beach activities rank as the most popular for domestic tourists, while visiting a beach ranks similar in popularity to undertaking wildlife activities for foreign tourists (see tourism section in Compendium of Benefits of Biodiversity). Visiting a beach allows a diversity of activities to suit every taste (e.g. bathing, fishing, surfing, kayaking, swimming, walking, sunbathing, picnicking, beach-related sports, and observing birds and mammals). Many cultural and spiritual ceremonies are performed on beaches; and beaches are a key place for environmental education and citizen science initiatives. The harvesting of marine flora and fauna for food, medicine and bait is common practice along beaches. Beaches filter about 10 000 litres of water per 1 m strip of beach per day, keeping the surf clean for the enjoyment and health of both humans and fishes. Beaches and dunes also protect nearby settlements from wave damage, wind stress and flooding (see Harris *et al.* 2019d).



Even in South Africa, periods of heavy surf or extreme wave events (e.g., from storms) most impacts areas where built infrastructure is located inappropriately close to the shore. Often these areas are then defended by seawalls, which exacerbates erosion because it cuts off the natural sand reserves in the dunes to replenish that which is lost off the beach, and it reflects the wave energy causing addition wave scouring at the foot of the wall and at its edges. Often, especially on urban beaches, hard defences need to be coupled with sand nourishment to replace the eroded sand, artificially replacing the function of the dunes (at a high cost) to maintain beaches for tourism. Soft engineering (such as geofabric sandbags) is generally a better option but is not always feasible. Ultimately, the best solution is to ensure our giant sandy buffer to the pounding waves and rising seas is kept intact by: constructing development behind scientifically determined setback lines; ensuring the **natural sand flows** between rivers, estuaries and the coast are maintained; and rehabilitating degraded dunes. Although there is a legacy of poor coastal dune management in South Africa, this was largely due to a limited understanding of dune systems; better information is now available, and South Africa is in a strong position to protect and restore this critical EI.

The world's oceans and coastal ecosystems have absorbed 30% of anthropogenic carbon dioxide (CO_2) emitted into the atmosphere since the pre-industrial era (Sabine *et al.* 2004). By **capturing and storing atmospheric carbon** in marine plants and sediments – also known as *Blue Carbon* – these ecosystems regulate the Earth's climate (Nellemann *et al.* 2009, Harris *et al.* 2019a, van Niekerk *et al.* 2019). It is estimated that 93% (40 teratonnes) of CO_2 is stored and cycled through the world's oceans (Nellemann *et al.* 2009). In the open oceans, phytoplankton are the main drivers of the biological carbon pump, converting CO2 into organic matter via photosynthesis, which then sinks to the seabed where it is stored. Areas of nutrient upwelling enhance this process by promoting phytoplankton growth. South Africa's west and south coasts are major upwelling regions that drive high rates of primary productivity, however, these are only modest carbon sinks because much of the carbon is remineralised (Waldron *et al.* 2009, Gregor and Monteiro 2013). In shallow seas, macroalgae such as kelps and seaweeds convert CO2 into organic matter that may later be transported to the deep oceans (Krause-Jensen and Duarte 2016). The expansion of South Africa's kelp forests along the south coast (Bolton *et al.* 2012, Reimers *et al.* 2014) may have increased the efficiency of **carbon sequestration** in these waters. Continental slopes, canyons and deep-sea fans are important sinks for organic carbon (de Haas *et al.* 2002), which highlights the importance of these features in South Africa's carbon budget. Vegetated coastal habitats such as mangroves, saltmarshes and seagrasses are the most efficient carbon sinks, as they cover less than 1% of the total ocean area but are responsible for 50% of the total carbon stored in ocean sediments (Nellemann *et al.* 2009). When these ecosystems are in good ecological condition, they are effective carbon sinks, but when degraded they become carbon sources (Pendleton *et al.* 2012). To secure the carbon storage potential of South Africa's coastal ecosystems and oceans, it is important to rehabilitate degraded ecosystems, regulate coastal development, create buffer zones to allow inland migration of coastal carbon sinks, and maintain and expand MPAs.

Pollution impacts the South African marine and coastal environment, and the users thereof, through waste-water discharge, agricultural fertilizers and industrial effluents (Mead *et al.* 2013). The May 2019 sewage spill in Durban harbour, for example, lead to the suspension of several coastal activities like bathing, angling and diving as well the cancellation of one of South Africa's major international surf events (Kockott 2019, Singh 2019). Marine and coastal ecosystems help to **regulate water quality**. They buffer the effects of pollution by purifying seawater through processes of filtration through sediments, and nutrient uptake and remineralisation by various biota. For example, kelp and seagrass beds take up nutrients from the sediment and the water column, thereby decreasing the concentration of suspended particles in the surrounding water (Barbier *et al.* 2011). The nutrient uptake can be as much as 35% of the total nitrogen input from land originating mainly from sewage and industrial discharges (Fernandes *et al.* 2009). Of all the ecosystems that contribute to water filtration and nutrient cycling, sandy beaches are the flagship ecological infrastructure for these services. Beaches have been recognised for decades as a 'great digestive and incubating system' (Pearse *et al.* 1942), 'sites of accelerated organic matter turnover' (Rocha 2008) and a 'biogeochemical reactor' (Anschutz *et al.* 2009). As each swash runs up the beach, seawater is forced horizontally through the interstitial spaces between the sand grains (Riedl 1971). The amount of water filtered depends on the sand grain size (and thus beach morphodynamic type). Consequently, fine-sand dissipative beaches filter 100–7 000 litres of seawater per 1 m strip (across-shore) of the beach per day (McLachlan 1989), intermediate beaches filter 3 000–15 000 $L.m^{-1}.d^{-1}$ (McLachlan 1989), whereas coarse-sand reflective beaches can filter as much as 10 000–91 000 $L.m^{-1}.d^{-1}$ (McLachlan *et al.* 1985),

which roughly averages about 10 000 $L.m^{-1}.d^{-1}$ per beach. Although some nutrients are processed by macrofauna, the bulk of the nutrients is processed by the interstitial fauna that live in the small spaces between the sand grains or on the sand grains themselves (McLachlan 1980, McLachlan *et al.* 1981a), particularly by bacteria (Koop and Griffiths 1982).

Coastal systems are strongly connected. To strengthen provision of benefits from marine ecosystems in the coast thus often requires a holistic 'catchment to coast' approach, where chains of adjacent terrestrial, freshwater, estuarine and marine systems need to be maintained in a healthy state in order to achieve maximum service flow.

See Harris et al. 2019d for more detail on coastal biodiversity benefits.

Biogeochemical (re)cycling on beaches extends well beyond the contribution to water purification. Beach biota can process other allochthonous inputs to make nutrients available to other beach fauna, and even for export to adjacent terrestrial and marine systems. For example, beach meiofauna respond rapidly to nutrients from sea turtle eggs (Le Gouvello *et al.* 2017), with turtle-derived nutrient export to both marine and terrestrial systems serving particularly as a nutrient source for dune plants (Le Gouvello *et al.* 2017). Similarly, beach communities are exceptional at wrack processing, with similar exports to adjacent systems (Gómez *et al.* 2018, Rodil *et al.* 2018) and contributions to carbon cycling as well (Rodil *et al.* 2018). In fact, the rate of carbon efflux in beach wrack piles is twice as high as that in tropical rainforests (Coupland *et al.* 2007). Although bacteria play the biggest role in wrack processing and nutrient cycling, macrofauna play a key role in fragmentation and break-down of the material, enhancing the process (Koop *et al.* 1982:1982, Gómez *et al.* 2018) and resulting in increased macrofauna abundance. Although many of the services provided by beaches may be overlooked, beaches are key ecological infrastructure promoting maintenance of healthy coastal ecosystems that support and enhance a myriad of related benefits, such as coastal protection, food production, and safe conditions for recreation and tourism. For case studies on the benefits on coastal EI, see Box 8.

Box 8. Coastal Ecological Infrastructure (EI) case studies - Kosi Bay and Cape Flats

Two case studies examined the benefits of coastal Ecological Infrastructure (EI) (Perschke *et al.* 2019) in two geographically distinct areas. These were the rural communities of KwaDapha and eNkovukeni in Kosi Bay, KwaZulu Natal and the urban communities of the Cape Flats in Cape Town, Western Cape. Although the socio-economic context of these two study areas is radically different, the residents of all communities highly benefit from the EI in their reach. The communities situated in Kosi Bay for example have a strong cultural connection to coastal ecosystems and still depend to a great extent on marine and other coastal resources delivered by the EI for basic needs like food, shelter and warmth. The residents of the Cape Flats, even though situated in an urban context, also still partly depend on the harvest of food and wild medicine from coastal ecosystems. In addition, the Cape Flats residents enjoy recreational opportunities like fishing, swimming, walking, bird watching or picnicking offered by coastal EI. In addition, the flow of regulating services such as the protection of people and development from storm events or the purification of polluted seawater by several coastal EI features is of great importance for the local communities of Kosi Bay and the Cape Flats alike. In both cases, there are opportunities to increase the non-consumptive benefits from coastal biodiversity through nature-based education programmes, innovative ecotourism initiatives and EI restoration projects.

Effectively communicating the benefits from marine biodiversity is a key element in building understanding among decision makers and the public to build support for sound management (Jobstvogt *et al.* 2014). This is often more difficult for marine ecosystems that are out of sight and is especially challenging for **deep sea ecosystems whose services are poorly appreciated** (Thurber *et al.* 2014). Ecosystem services in the deep sea include many of those articulated from coastal and near

shore ecosystems including food provision, genetic resources, pharmaceuticals, cosmetics, nutrient cycling and carbon storage and sequestration (Jobstvogt *et al.* 2014, Thurber *et al.* 2014, Niner *et al.* 2018). In addition, deep sea ecosystems may support chemosynthetic primary production which constitutes both a regulating and supporting service (Thurber *et al.* 2014). South Africa is likely to have seep ecosystems on its continental margin although these have yet to be discovered. Cultural and artistic values from deep sea ecosystems and species are also being increasingly realised (Thurber *et al.* 2014, Niner *et al.* 2018) with new insights emerging through transdisciplinary research in South Africa (Dylan McGarry, Rhodes University, unpublished data). There is also an increasing understanding of the connectivity of deep sea ecosystem services to those from coastal zones as ecological connectivity and ocean circulation connectivity cause activities in the deep sea (including the high seas) to impact on coastal waters (Popova *et al.* 2019).

2.7 The marine realm is an outdoor classroom with opportunities for citizens to become involved in science

Marine ecosystems and species are important educational tools and provide learning opportunities for people of all ages. Outdoor classrooms can be valuable for raising awareness on environmental issues and human impacts, fostering an environmental ethic, developing an understanding of sustainability, and promoting action to address environmental problems. **Environmental education** activities have also shown to help build some basic science skills including observation, classification, measuring, communicating and inferring skills (Rios and Brewer 2014). South Africa's rich marine environment has various educational opportunities led by local aquaria, government and private sector organisations to provide first-hand experiences to professionals, students and communities.

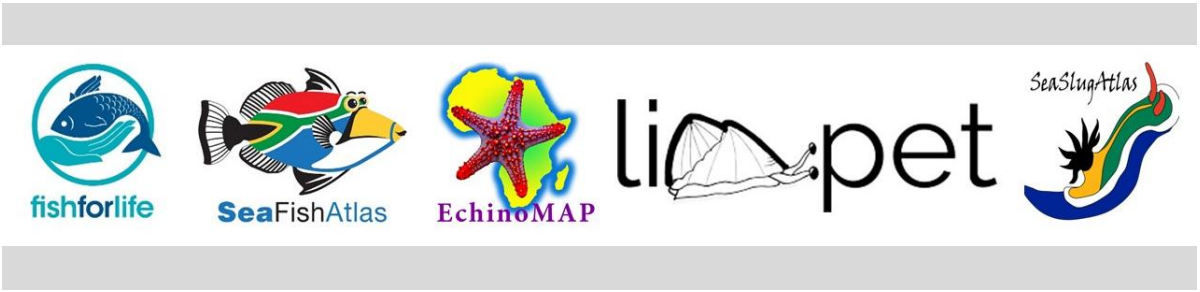


Outdoor classroom environments provide first-hand learning experiences and the opportunity to foster a greater environmental appreciation © South African Association for Marine Biological Research (SAAMBR)

South Africa's unique and diverse marine environment provides the perfect platform for a thriving **citizen scientist** community, allowing non-professional scientists to voluntarily participate in research activities to support scientific projects. Citizen scientists have increasingly been contributing to a range of South African marine projects, including the distribution mapping of various marine animal groups (Potts *et al.* in prep).

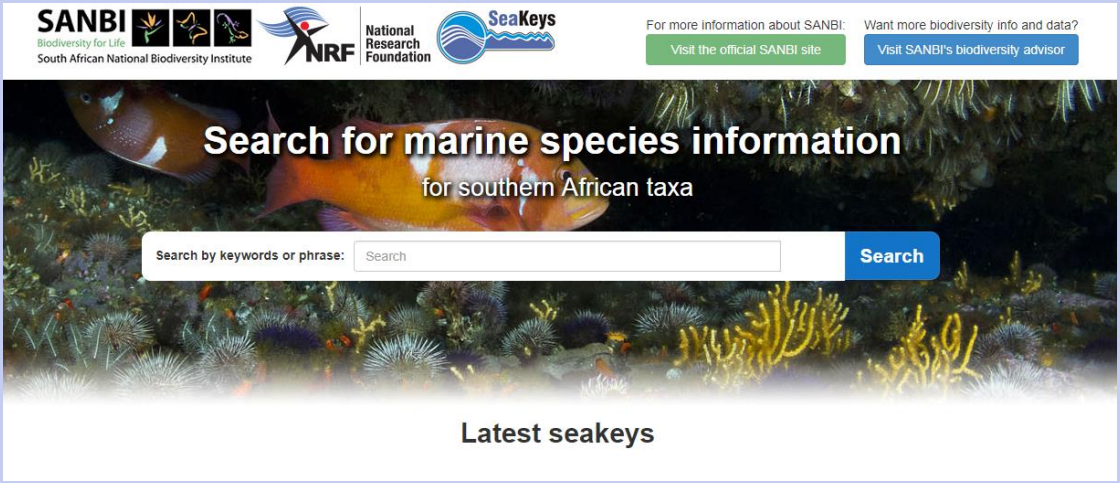
In terms of geographical distribution, citizen science research is dominated by developed nations, with far fewer examples of successful citizen science projects in the developing world (Loos *et al.* 2015). South Africa is likely an exception amongst developing nations, as it has a relatively long history and wide range of active citizen science projects, dating back to the Oceanographic Research Institute's conventional fish tagging program (ORI-CFTP) and Southern African Bird Atlas Project (SABAP), which began in 1984 and 1987, respectively. The contributions from citizen scientists can be substantial and,

in addition to providing crucial information for species red listing processes, can lead to the discovery of new species and bio-discovery opportunities (see Box 9 for the example of the SEAKEYS project).



Fish for Life, Sea Fish atlas, EchinoMAP, Limpet, and the Sea Slug Atlas are just a few examples from several local projects, aimed at inclusion of citizen scientists to help monitor and/or map the distribution of various marine species groups.

Box 9. Citizen scientist contributions to marine foundational science via the SEAKEYS project



The SeaKeys Project was a large collaborative project (2013 - 2018) that aimed to collate and increase foundational marine biodiversity information and translate this information into products to support decision making and the development of new benefits for South African society. Citizen scientists contributed substantially to the outcomes of the project. Contributions via the platforms iSpot and iNaturalist provided more than 41 000 new marine biodiversity records. The National Fish Atlas was established under this project and provided >8 000 fish records from citizen scientists. Over the course of the project, 1 683 images were submitted to the Echinomap Virtual Museum and 118 species with distribution records have been identified from these submissions (some are still unidentified and probably represent new records). Some of the records submitted by citizen scientists also included new distribution and/or species records, including records added to our starfish, crustacean, and anemone fauna.

2.8 Bio-discovery could bring further economic growth to South Africa

More than 70% of the planet's surface is covered by the oceans and it is estimated that a further 91% of species in the marine environment still await description (Mora *et al.* 2011). **Bio-discovery** is the exploration of biodiversity for new or alternate resources that are of social or commercial value (Beattie *et al.* 2011), and considering the undescribed and unexplored nature of the marine

Bio-discovery is often referred to as bioprospecting is defined in the National Environmental Management: Biodiversity Act (Act 10 of 2004) as 'research on, or development or application of, indigenous biological resources for commercial or industrial exploitation'.

realm, it is likely that bio-discovery based on South African marine species is a potential area for economic opportunity.

A range of **natural products** and other materials have been derived from marine organisms for use as medicines, agrochemicals and antifouling coatings (Davies-Coleman and Sunassee 2012) by the pharmaceutical, manufacturing and agriculture, bioremediation, biomining, biomimetic engineering and nanotechnology industries (Beattie *et al.* 2011). The introduction of modern snorkelling, SCUBA, the use of manned submersibles and remotely operated vehicles enabled the expansion of marine biodiversity exploration and bio-discovery (Dias *et al.* 2012).

Marine algae are major contributors in the bio-discovery field, with natural products being sourced from both microalgae and macroalgae. **Microalgae**, such as plankton, live in highly dynamic environments are adapted to tolerate a range of conditions (such as temperature fluctuation, wave action). These adaptations may be associated with the production of novel compounds which can be used by humans. For example, because the planktonic environment is nitrogen-scarce, plankton have developed effective mechanisms for increased nitrogen uptake. By transferring these planktonic genes into terrestrial plants, scientists can improve nitrogen uptake (Abida *et al.* 2013). Some phytoplankton are proficient at producing triacylglycerols which can be processed into biodiesel blends, and certain bioactive compounds from microalgae can protect the skin against aging, photo damage and micro-abrasion, which are essential properties in the cosmeceutical industry (Abida *et al.* 2013, Jaspars *et al.* 2016).

An estimated 3 129 natural products were isolated from **macroalgae** globally between 1965 and 2012 Leal *et al.* (2013). Many macroalgae present a natural source of compounds with bioactive metabolites such as polyunsaturated fatty acids, vitamins, carotenoids, polyphenols, dietary fibre, polysaccharides and proteins that may be used as nutraceuticals that can benefit human health overall and treat diseases (Hoosen 2016). Algae are also effective anti-fouling agents due to their ability to deter marine bacteria (Eghtesadi Araghi *et al.* 2017). Many red algae are industrially processed for the extraction of thickening agents such as agar and carrageenan (FAO 2018a). Seaweeds have long been considered as a healthy food source by countries such as China, Japan and Korea (FAO 2018a) and studies have shown that the Eastern Hemisphere reported a much lower number of cancer and degenerative diseases as a result of their high seaweed diet (Kim 2013). In South Africa, red algae *Gelidium* spp. are harvested by hand in the Eastern Cape and is exported overseas for the extraction of agar. Similarly, wash-up of brown kelp is harvested and exported for alginate extraction (Blamey and Bolton 2018). The harvested Kelp *Ecklonia maxima* is used to produce plant growth stimulants Kelpak® and Afrikelp® (Amosu *et al.* 2013). Box 10 explains the estimated value of the South African kelp industry.

Box 10. The application of marine natural products

Fresh kelp is harvested at an annual average of 4 500 tonnes for its use as abalone feed in aquaculture (Blamey and Bolton 2018). The market value of this industry is estimated at over **R6 million annually** (DAFF 2016).

The beach-cast harvest of brown kelp constitutes an annual average of approximately 700 dry tonnes (DAFF 2016). One tonne of dry *E. maxima* can produce about 250 kg of alginate, which is worth US$320 (approximately R4 700) (Blamey and Bolton 2018).



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South Africa's oceans, with their rich marine biodiversity and endemism, have the potential to offer a variety of marine natural products to bio-discoverers in search of secondary metabolites that can be of medicinal use. As a result of our high species richness, **marine invertebrates** present a unique collection of biomolecular diversity (Davies-Coleman and Sunassee 2012). Because marine invertebrates are often vulnerable due to their soft-bodied or sessile nature, they produce a vast array of secondary metabolites as chemical mechanisms to aid in predator-defence, overcome competition for space, reduce antifouling, inhibit overgrowth and for protection from ultraviolet radiation (Davies-Coleman 2010, Hoosen 2016).

Natural products derived from marine organisms form the backbone of **medical research** in global drug discovery, especially against cancer (Davies-Coleman 2010, Jaspars *et al.* 2016). In the global market there are currently seven pharmaceuticals derived from marine taxa that are approved by the US Food and Drug Administration and one approved by Specialised Therapeutics Australia. Five of the eight approved drugs are anticancer drugs (Midwestern University 2019). Globally, 16 617 novel compounds have been isolated from marine organisms between 1985 and 2012, of which 4 196 compounds were bioactive, and the discovery of novel compounds from marine organisms is increasing every year (Hu *et al.* 2015). Over the past three decades, a research team from Rhodes University has been investigating South African marine invertebrates for the isolation and examination of new natural products for their potential use in the medical field. Three South African marine invertebrates, the endemic hemichordate worm *Cephalodiscus gilchristi*, the ascidian *Lissoclinum* sp. and the endemic sponge *Topsentia pachastrelloides*, show significant potential for the development of their **bioactive properties** for commercial purposes and have attracted international attention (Davies-Coleman and Veale 2015) (see Box 11).

Although South Africa's oceans are a rich source of bioactive compounds with medicinal potential, only a small percentage of our biodiversity has been explored for medicinal purposes. Despite the vast number of new natural products being isolated from marine species on a global scale, few have been marketed or are currently being developed. Drawbacks in bio-discovery include a general lack of taxonomic knowledge of marine species, difficulties in accessing marine organisms, attaining relatively low concentrations of the natural product from the producing organism, difficulties in isolating the natural product and costly procedures taken to reach the market (Mans 2016).

Biomimicry is an exploratory field like bio-discovery that could provide further opportunities for economic growth in South Africa. It is the science of applying nature-inspired designs in human engineering and invention to solve human problems (https://biologydictionary.net/biomimicry/). It is the practice of learning from (not just about) nature and then emulating its forms, processes, and ecosystems to create more sustainable products, processes and systems. A few international examples of biomimicry of marine species are included in Box 12, and the Compendium of Information about Benefits of Biodiversity has more details on biomimicry (SANBI 2019).

Box 11. South African marine invertebrates and their potential for application in the pharmaceutical and medical industry



a) *Cephalodiscus gilchristi* – endemic hemichordate that occurs predominantly on the south coast in depths up to 1 000 m (Atkinson 2018). It produces one of the most potent compounds that have been tested against the National Cancer Institute's leukaemia cell line (Rudy *et al.* 2008, Davies-Coleman and Veale 2015).
b) *Topsentia pachastrelloides* – endemic marine sponge that inhibits the growth of the 'superbug' methicillin-resistant *Staphylococcus aureus* – a drug-resistant pathogenic bacterium that causes fatalities in many health care facilities (Davies-Coleman and Veale 2015). Alkaloids isolated from *T. pachastrelloides* showed significant antibacterial activity against the 'super bug' enzymes (Zoraghi *et al.* 2011). Clinical trials are still in process.
c) *Lissoclinum sp*. – colonial ascidian that exhibits potent cytotoxicity against lung cancer cells (Sikorska *et al.* 2012).
d) *Leminda millecra* – endemic frilled nudibranch produces cytotoxic activity that causes death of cancer cells from a type of oesophageal cancer particularly common in the Eastern Cape Province (Davies-Coleman 2010).

Box 12. A few examples of biomimicry from South African marine species

Shark skin: Sharklet Technologies has a surface coating that helps the prevention of biofilm formation without the need for chemicals, through diamond-shaped microscopic surface ridges inspired by the denticles on shark skin. Sharks move slowly in the ocean, but nothing attaches to them (unlike whales or turtles). Sharklet Technologies has found a way to fabricate a surface coating that mimics shark skin and resists the growth of organisms such as bacteria. Sharklet may be used in healthcare environments and on medical devices to help prevent the development of biofilms and hospital-acquired infections.

Humpback whale's flippers: WhalePower has developed a fan and wind turbine blade design using Tubercle Technology inspired by the flippers of humpback whales (*Megaptera novaeangliae*), which have tubercles or bumps on the leading edges. Despite their large size, humpback whales swim in circles tight enough to produce nets of bubbles less than 2 m across to corral their prey. The whale's dexterity is due primarily to its non-conventional flippers allowing better 'grip' on the water as opposed to smooth flippers. WhalePower is applying these lessons to the design of wind turbines and fans to improve their efficiency, safety, and cost-effectiveness.

Abalone shell: Various researchers (see article from LiveScience here) have been investigating the toughness of the abalone shell to see if ceramics could be made stronger. The abalone lays down sheets of calcium carbonate material between sheets of protein, which results in a shell that is 3 000 times stronger than its materials alone and is twice as tough as high-tech ceramics. Products of the future will likely mimic the way the abalone creates its nano-scale architecture of hard mineral and soft polymer.

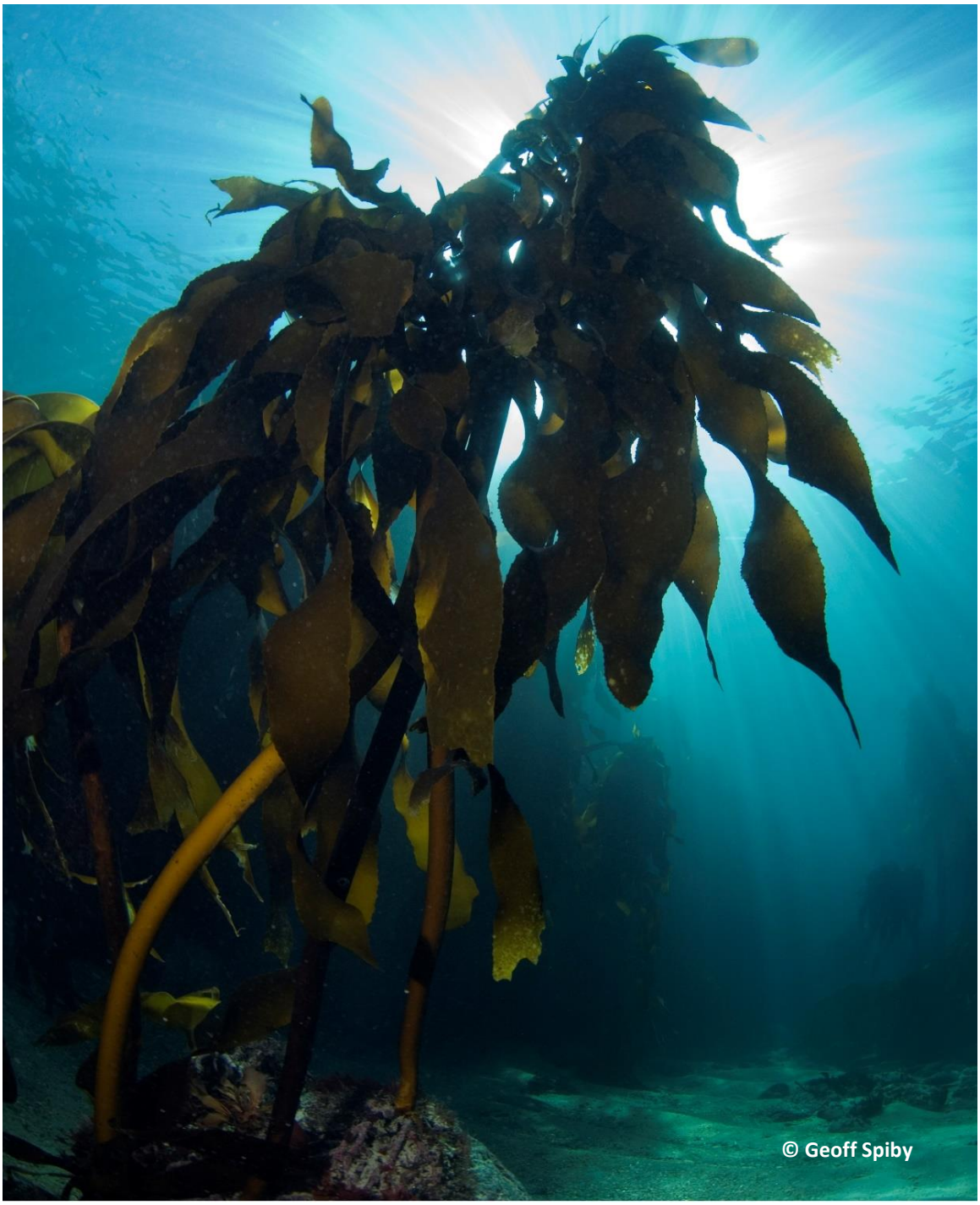
2.9 Conclusion and knowledge gaps

This chapter clearly illustrates that marine biodiversity is central to South Africa's national objectives of **increased economic growth and job creation**, and plays a vital role in the wellbeing of coastal dwellers and visitors to the marine realm. However, declining ecosystem condition (see Chapter 7) affects ecosystem functioning and ultimately the delivery of many valuable ecosystem services (Barbier *et al.* 2011, Isbell *et al.* 2017). As with built infrastructure, ecological infrastructure requires

careful management to maintain service delivery (Cumming *et al.* 2017). It is essential that all sectors (e.g. fisheries, tourism, aquaculture, etc.) that operate in the marine realm better integrate this understanding into their policies and practices to mitigate pressures and threats, and to provide for appropriate protection. Such investment can mean rehabilitation, protection and management interventions to maintain or restore the integrity of the ecological infrastructure feature (Nel *et al.* 2014, SANBI 2014, Lucrezi *et al.* 2016, Cumming *et al.* 2017). Trends in the economic value of the marine environment was not possible for the 2018 assessment but should be prioritised for future assessments. Regular update of the economic value (economic output and value-add potential of marine based sectors) of South Africa's marine environment will not only enable the evaluation of trends in economic value, but will also allow comparison with other sectors of the South African economy (see for example AIMS (2018)). Well-designed and effectively managed Marine Protected Areas can help protect the economic, environmental and social benefits of the marine realm for future generations, supporting fisheries sustainability, and help South Africans adapt to climate change.

3. ECOSYSTEM CLASSIFICATION AND MAPPING

Chapter citation: Sink KJ, Harris LR, Skowno AL, Livingstone T, Franken M, Porter S, Atkinson LJ, Bernard A, Cawthra H, Currie J, Dayaram A, de Wet W, Dunga LV, Filander Z, Green A, Herbert D, Karenyi N, Palmer R, Pfaff M, Makwela M, Mackay F, van Niekerk L, van Zyl W, Bessinger M, Holness S, Kirkman SP, Lamberth S, Lück-Vogel M. 2019. Chapter 3: Marine Ecosystem Classification and Mapping. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



Advances in marine ecosystem mapping supports assessment, planning and management

Chapter Summary

A revised marine ecosystem classification system and map of the distributions of 150 marine ecosystem types was produced in 2018. More than ten years of research was consolidated to inform the revised map. Updated biogeographic information was used to refine marine provinces and ecoregions, and sub-regions nested within ecoregions were introduced, such as the KwaZulu-Natal Bight, to better represent marine biodiversity patterns. Key advances in the map include: very fine-scale shore mapping with alignment and seamless integration of terrestrial and estuarine systems at the land-sea interface; the inclusion of kelp forests, bays, stromatolites and fluvial fans as distinct ecosystem types; and the introduction of higher resolution depth strata across the shelf and on the slope. These advances are a result of a major effort in collating and increasing relevant historic and contemporary abiotic and biological datasets for ecosystem classification and mapping. Key spatially referenced abiotic data included seven new bathymetric datasets, multi-beam and side-scan sonar data, a consolidated sediment dataset providing more than 5000 sediment-classification data points, data from a national dredging survey and a large oceanographic dataset. Analyses of patterns in benthic fauna from grab, trawl and remotely operated vehicle surveys and other types of visual seabed survey including submersible, tow camera and baited underwater video were used to inform the ecosystem map. More than 2000 visual surveys of the seabed were used to help classify seabed type and to provide information about biological assemblages. Kelp forests and the surf zone were mapped by contemporary remote sensing. Ecosystems were grouped into 15 broad groups to assess and report on patterns of threat and protection level. Key areas for future improvement include refined bathymetric data, updated wave-exposure data for shores, additional reef mapping, improved classification and mapping of bays and muds, and the collection of data to improve the understanding of biodiversity pattern in South Africa's deep-sea. Model-based approaches should be considered for future improvements, and validation of ecosystem types is a priority. Three-dimensional classification and additional work to improve the understanding of pelagic biodiversity also needs to be considered. Further data-driven approaches that can integrate large datasets covering multiple ecosystem components collected by multiple methods are encouraged.

3.1 Introduction

The classification and mapping of ecosystem types is foundational to their assessment and management. On land, South Africa is fortunate to have a long history of vegetation science to support the mapping and classification of terrestrial ecosystems. This work was initiated in 1936, and over the years, the focus of the maps has shifted from mapping rangeland types for agricultural planning, to mapping vegetation communities. The current National Vegetation Map was first published in 2006 using a combination of existing maps, field plot data, local expertise and remote sensing (Mucina *et al.* 2006) with recent refinements based on advances in knowledge and mapping tools (Dayaram *et al.* 2017, 2019). The **classification and mapping of marine ecosystems** is more challenging because of the inaccessible nature of the ocean, technological challenges and high associated costs. For these and other reasons, marine ecosystem classification and mapping lags behind that in other realms. Nevertheless, there is a long history of efforts to classify marine regions and ecosystem types (Gregr and Bodtker 2007, Longhurst 2007, Howell 2010, Last *et al.* 2010, Gregr *et al.* 2012) and in South Africa, considerable effort has been expended to advance marine ecosystem classification and mapping in the last 15 years.

South Africa's **first National Spatial Biodiversity Assessment in 2004** (Lombard *et al.* 2004) used an expert-based approach to assess ecosystem status for 35 marine biozones rather than at the level of ecosystem or habitat types. A hierarchical habitat classification was developed in the 2004 assessment to clarify terminology used and this provided a foundation for further classification and mapping in 2011. The 2004 assessment focused on the identification and description of bioregions but also mapped 5 broad intertidal habitat types; sandy beaches, pebble beaches, boulder beaches, mixed shores and rocky shores in each of the 5 inshore bioregions. Mixed and rocky shores were further classified by wave exposure. Lombard *et al.* (2004) developed GIS layers for marine benthic sediments drawing from existing geological and sediment maps (Birch *et al.* 1986, Dingle *et al.* 1987). Three other offshore features were mapped: seamounts and banks; untrawlable grounds on the Agulhas Bank (data provide by DAFF); and submarine canyons, drawing from (Dingle 1986) with additional unpublished canyon maps from off Port Elizabeth to Durban provided by Pete Ramsay (University of KwaZulu-Natal). Canyons were the only offshore feature to be sub-classified and this was done according to bioregion with 2 canyons mapped on the West Coast and more than 20 canyons on the East Coast.

In the **NBA 2011**, 136 marine ecosystem types including 58 coastal, 62 offshore benthic and 16 offshore pelagic habitat types, all grouped into 14 broad ecosystem groups, were classified and mapped into a first national marine "habitat" map (Sink *et al.* 2012a). The classification units were referred to as habitat types but noted to include interacting assemblages of species, their physical habitat, and trophic structure as ecological communities that could also be referred to as ecosystems in line with the definition of ecosystems, which can be recognised at multiple scales. This work from the previous NBA was used as a starting point for the NBA 2018 with additional historical and contemporary data, knowledge and literature informing the new work.

3.2 Classification Approach

A revised map of 150 marine ecosystem types was produced for the NBA 2018 marine realm, drawing from new abiotic and biotic data (Table 5) with an attempt to align with emerging global classification efforts. Recent (i.e. post-2010) literature on drivers of biodiversity pattern and methods in marine ecosystem classification were reviewed Annexure 3 data and publications on local marine biodiversity patterns were collated, and a draft classification approach was developed through the national **Marine Ecosystem Committee** (MEC). The MEC was established to guide classification, support identification and collation of relevant datasets and literature, and support improvements in the marine ecosystem classification and map. Several task teams were established in 2017 to advance key areas including coastal integration, inclusion of fluvial fans and plumes, reef mapping, and deep-sea diversity pattern. A Vulnerable Marine Ecosystem working group was also established to improve mapping of potential indicator taxa and co-ordinate efforts to map these sensitive ecosystem types.

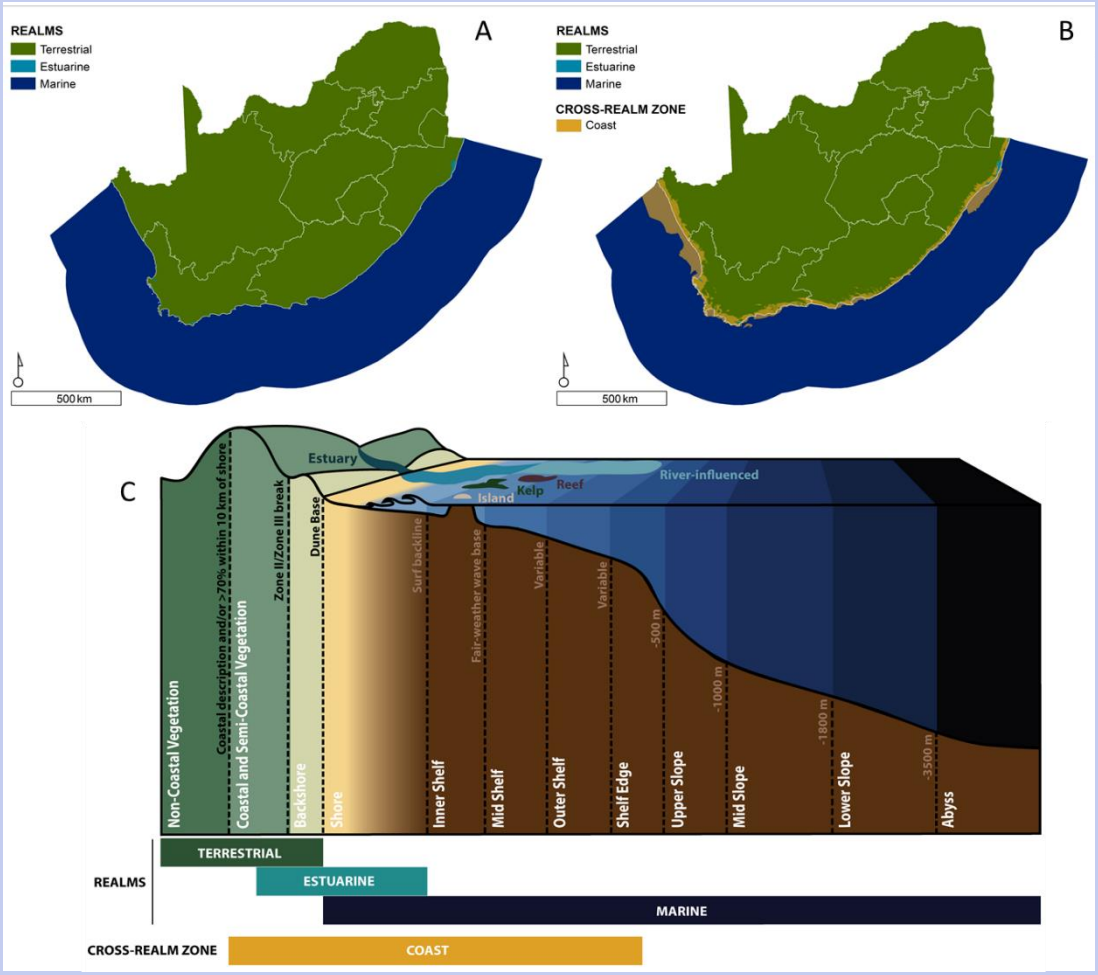
The **2018 Marine Ecosystem Classification and Map** built on the 2011 ecosystem map, with many refinements and incorporation of newly collated historical and current datasets. Three MEC meetings were held to assist with the collation and review of scientific information and data to support revisions to the marine ecosystem type map. A review of literature covering other marine ecosystem classifications and key drivers of marine biodiversity pattern was conducted (Annexure 3) to improve the mapping of marine ecosystem types in South Africa and ensure that key recognised drivers of marine biodiversity pattern were captured in the revised classification. In addition, new references were sought to update the review of Broad Ecosystem Groups (Annexure 3) completed in the 2011 Assessment and these helped to guide both the classification of ecosystem types and also the work to assess the potential impact of each pressure on each broad ecosystem group (see Chapter 7).

The most significant difference between the 2018 and 2011 classifications was the **merging of the separate benthic and pelagic components** recognised in 2011 in response to feedback from scientists working on the ecosystem-pressure matrix and assessment (Chapter 7) and managers who expressed that consulting two or more map layers overly complicates spatial planning in the marine realm. In the case of the former, challenges arose in trying to uncouple benthic and pelagic ecosystem considerations on the shelf and shelf edge. The pressure impact scoring of the Hake fisheries exemplified this challenge. Hake are caught by demersal and midwater trawl fisheries. The trawl fishery targets Hake during the day when they are on the seabed, an activity that includes impacts on benthic ecosystems (see Chapter 4) but Hake are considered to feed mostly in the water column and can be considered to play a key role in pelagic ecology. Hake are caught by the midwater trawl fishery mostly at night. Trying to separate the impacts of these respectively benthic and pelagic activities on benthic and pelagic ecosystem components was a challenge, particularly in considering biomass removal. Trophic impacts of fishing of small pelagic fish, reef fish and large pelagic fisheries are also difficult to separate in ecosystems where there are significant relationships between benthic and pelagic ecosystem components.

A further dramatic improvement was the ecologically determined coast – See Box 13.

Box 13: Achieving a seamless map of South Africa

In NBA 2018, there was a key focus on aligning the extent of the realms to produce a seamless map of ecosystem types, and thus a seamless assessment of South Africa's biodiversity (Harris *et al.* 2019b, Skowno *et al.* 2019a). Therefore, as shown in panel A and C, the extent of the marine realm was taken to be from the dune base (equivalent to a decadal scale high-water mark) to the full extent of South Africa's EEZ. Note that the coast, as defined in NBA 2018, is an ecologically determined cross-realm zone illustrated in panel B and C, which includes coastal terrestrial, estuarine and coastal marine ecosystem types (with the farthest offshore extent including river-influenced ecosystem types that in some places extend just beyond the shelf edge). Therefore, although some marine ecosystem types are also considered coastal, the classification, mapping and assessment of all ecosystem types in the NBA 2018 marine realm (both coastal and non-coastal) are presented in this report.



Key **drivers of marine biodiversity patterns** included in the 2018 classification and map were similar to those used in the previous assessment, with depth recognised as the greatest driver of pattern, and many other variables, including temperature, light, oxygen and wave energy also associated with it (Annexure 3). A nested hierarchical approach was followed in order to enhance the utility of the map of ecosystem types, making it more appropriate as a basis for assessment and prioritisation at a range of spatial scales (see Figure 7) (SANBI and UNEP-WCMC 2016) For the purpose of alignment with other international and regional classification schemes, a set of large marine Provinces was agreed on that overarch the classification hierarchy used here (Figure 7), with three main Provinces recognised in the marine realm (see Section on Regional Patterns). This allowed for the three established main biogeographic provinces in South Africa to be recognised and accommodated at the top of the

classification system, with ecoregions recognised at the next level in the classification hierarchy (and the first level actually used in this assessment). The approach is similar to that of (Last *et al.* 2010), with five levels applied to define a set of ecosystem types but with recognition that there is scope to further classify habitats, biotopes or facies (communities) within ecosystem types.

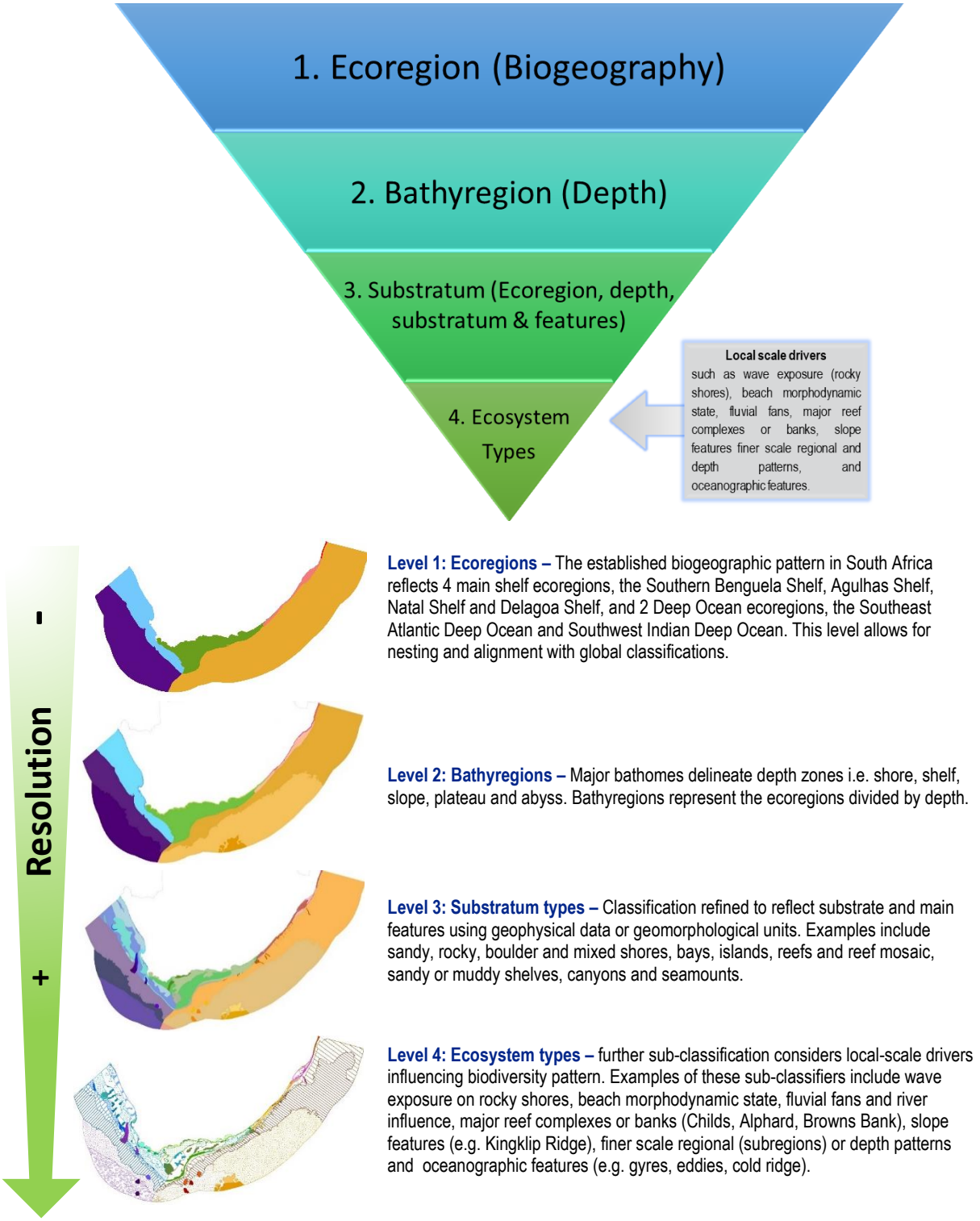


Figure 7. Schematic showing the hierarchical classification approach used to classify 150 marine ecosystem types around South Africa.

At the largest spatial scale of **Level 1 (Ecoregion)**, four shelf ecoregions and two deep ocean ecoregions were defined. These are the Southern Benguela, the Agulhas, the Natal and the Delagoa, and the Southeast Atlantic Deep Ocean and the Southwest Indian Deep Ocean respectively. This level allows for nesting and alignment with global classifications. Although most broad coastal ecosystem groups classify within these four ecoregions (Southern Benguela, Agulhas, Natal and Delagoa, see Section on Regional Patterns), there is no evidence of differences in sandy beach biodiversity between the Natal and Delagoa Ecoregions (McLachlan *et al.* 1981b, Hockey *et al.* 1983, Turpie *et al.* 2000, Harris *et al.* 2010, Harris 2012) necessitating a broader coastal province within the classification, termed the Natal-Delagoa Province. This was not actually used in the classification, but it is recognised at a potential higher level that may be of service. Current work is underway to develop a broader bioregionalisation of the Indian Ocean and these international efforts may help resolve this discrepancy. In addition, dedicated examination of beach biodiversity patterns is recommended to further investigate beach biogeography by sampling further north into Mozambique. However, given that this is the only anomaly in the ecoregional classification, the Natal-Delagoa Province is referred to as an ecoregion for simplicity.

Major depth boundaries constitute **Level 2 (Bathyregions)** with the shore, shelf, slope, plateau and abyss comprising the five major bathomes. At **Level 3 (Substratum types)**, the primary substratum types (sandy, rocky, mixed or mosaic) and main geomorphological units (submarine canyons and seamounts) are recognised. These were further sub-classified at **Level 4 (Ecosystem types)** to define ecosystem types, with these sub-classifications varying within different bathomes and substratum types in accordance with local-scale drivers influencing biodiversity pattern. Examples of these **sub-classifiers** include wave exposure on rocky shores, beach morphodynamic state, fluvial fans, major reef complexes or banks (e.g. Childs, Alphard and Browns Bank), slope features (e.g. Port Elizabeth Ridge), finer scale regional and depth patterns (inner versus mid shelf), and oceanographic features (presence of gyres, eddies and the cold ridge). Biotopes or distinct biological assemblages were also used to further sub-classify ecosystem types (see Section on Biotope Input Data). In many cases, such quantitative analyses of biodiversity pattern were used to inform finer scale depth patterns in different ecoregion or subregional boundaries.

A **limitation to this hierarchical classification approach** is that some types of ecosystems (e.g. canyons) or broad ecosystem types (e.g. kelps) do not nest neatly within the hierarchy. Canyons are an ecotype that stretch over multiple bathomes and kelp forests span two ecoregions. These groupings are however useful units for practical analysis of fine-scale ecotypes in order to examine and report on patterns in threat and protection level for similar ecosystem types. The distribution of kelp also spans two bathomes, with most kelp occurring in the shore (to the back of the surf zone) but some kelp lying further offshore in the inner shelf. To allow kelp forests to nest within the classification, kelp was assigned to the shore zone.

3.3 Input data and mapping methods

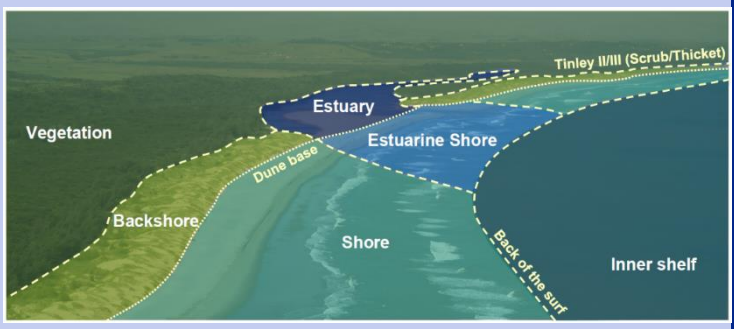
Building on previous approaches and in line with international efforts, **key elements in the classification** include biogeography, depth, geomorphology, topography and geology (Last *et al.* 2010, Briggs and Bowen 2012, Spalding *et al.* 2012, Douglass *et al.* 2014, Sutton *et al.* 2017) and additional references reflected in Annexure 3, and other fine-scale drivers of biodiversity pattern (Figure 7). Boundaries for biogeographic provinces, ecoregions and depth boundaries were determined by the MEC but informed by the datasets described below and are described in the Section on Regional Patterns.

Key differences between the classification and map of marine ecosystem types developed in 2018 and that presented in the 2011 Assessment include:

- amalgamation of offshore benthic and pelagic habitat types into a single ecosystem type;
- improved fine-scale shore mapping with alignment and integration between estuarine, marine and coastal vegetation types in the coastal zone (Harris *et al.* 2019b)
- the inclusion of kelp forests (LV. Dunga, University of Cape Town MSc thesis in prep.), bays and stromatolites (Perissinotto *et al.* 2014)
- the introduction of finer-scale depth strata across shelves (inner, mid and outer shelf) and on the slope (upper, mid and lower slope);
- improved bathymetric data and refinement of boundaries between bathomes (depth zones);
- refined biogeographic information including the introduction of a new KwaZulu-Natal Bight sub-region and an extension of the Cape ecoregion;
- recognition of ecosystem types that are mosaics of repeating patterns of both consolidated and unconsolidated habitats on the shelf
- consideration of fluvial fans, plumes and river-influenced ecosystem types in the offshore environment; and
- consideration of substantial new datasets to inform the subtidal classification of ecosystems.

The **land-sea integration** and mapping of shore types (dune base to the back of the surf zone) are described in detail by Harris *et al.* (2019b) and in the Coast Technical Report of the NBA 2018 (Harris *et al.* 2019c) – see Box 14 for a short overview. Beyond the shore, data that were used to inform the classification and map included historical abiotic and biodiversity data, new bathymetry data, new sediment data, remotely sensed data, and recent biodiversity records and information from visual surveys of the seabed. The broad ecosystem types unit used to group similar ecosystem types in 2011 were considered as **Broad Ecosystem Groups** and were adapted to include kelps, bays and fluvial fans, mosaics of mixed habitats and to distinguish muddy ecosystems from those characterised by coarser sediments. Langebaan Lagoon was included in the National Estuary Map and Assessment, and both vegetated and un-vegetated dunes were mapped and assessed in the Terrestrial component. The coast is recognised as a cross-realm zone (including coastal terrestrial, estuarine and coastal marine ecosystem types) rather than a separate realm, as outlined further below and as detailed by Harris *et al.* (2019a).

Box 14: Stitching the land to the sea, and everything in between



A detailed description of how the 2018 NBA considered land-sea integration and the mapping of shore types is outlined in Harris *et al.* (2019b) and the coastal component of the NBA Harris *et al.* (2019c). Briefly, the integration facilitated seamless alignment between the terrestrial, estuarine and marine realms at the land-sea interface. The landward boundary of the marine realm is at the dune base (effectively a decadal-scale high water mark), which marks that inland extent of the shores that extend seaward to the back of the surf, but excludes estuarine shores (which are now part of the estuarine functional zone and not the marine realm). The dunes (backshore) mark the start of the terrestrial realm.

Inshore ecosystem types included those more influenced by wave energy and light, with the fair weather wave base (the depth at which waves influence or agitate the seabed under normal conditions), at a depth ranging between -30 to -50 m (see Section 3.6.2 on depth patterns) used to determine the outer limits of this zone in South Africa. **Offshore ecosystems** were those beyond this zone, with the shore, shelf and shelf edge (extending to -500 m) all considered part of the shelf, and the slope, plateau and abyss recognised as part of the deep ocean. Figure 8 and Table 5 provides an overview of the key datasets that informed the 2018 marine ecosystem classification with further details on seafloor classification in Table 6 (side-scan sonar and multi-beam data), Table 7 (sediment data), and Table 8 (visual surveys).

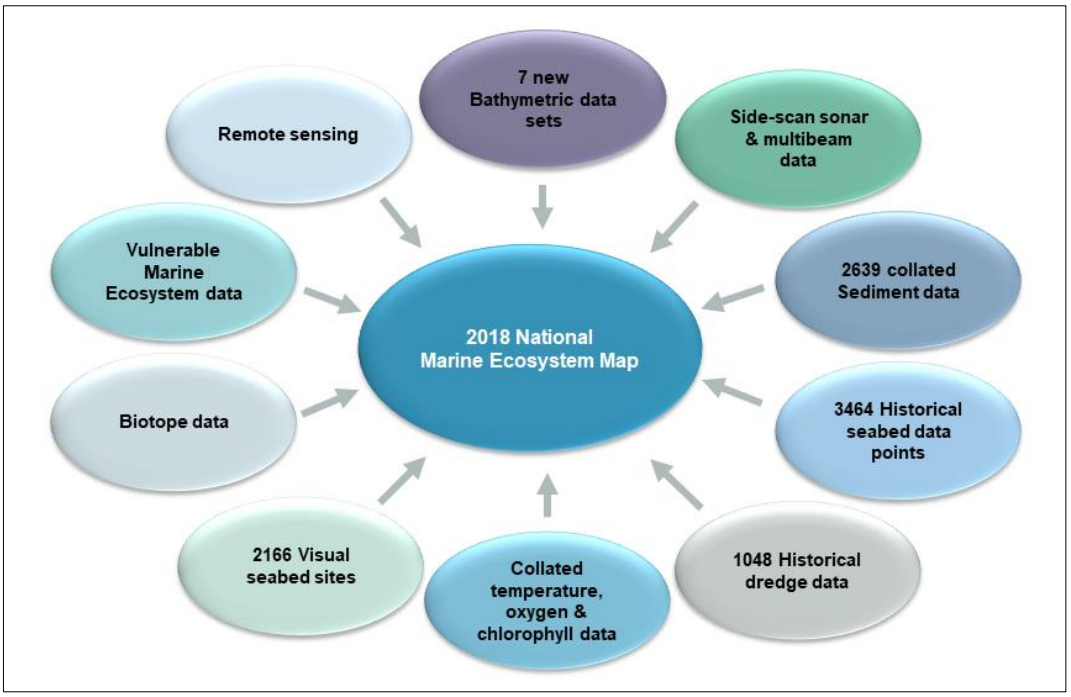


Figure 8. Schematic illustrating the various data that were used to inform the revised map of marine ecosystem types. Increased investment in research has improved the marine ecosystem classification and map to support spatial biodiversity assessment and management.

Table 5. Overview of datasets that informed the subtidal components of the 2018 Marine Ecosystem Classification and Map.

Data type and period	Data overview	Data sources
Bathymetric datasets 1991-2016	Collated single-beam data and multi-beam bathymetry data covering the South African shelf and slope. Research vessel single-beam data collected between 1991 and 2011. Resolution is better on the West and South Coast with less data north of East London. Single-beam data (2016) for the slope off Cape St Francis supported mapping of the Kingklip Ridge. Multi-beam data from petroleum companies and research mapping covering several submarine canyons (Cape Canyon, Chalumna (Gxulu), Kei and East Coast canyons were used to supplement the de Wet (2013) dataset.	Raw collated data provided by de Wet (2013) from data provided by government research vessels. Unpublished data for West Coast shelf edge, slope and canyons provided by Anadarko to Kerry Sink and Andrew Green, unpublished data for shelf edge, canyons and slope provided by Exxon Mobil to Kerry Sink for the Amathole and uThukela Banks areas. Multibeam data from ACEP surveys in KwaZulu-Natal (Ramsay and Miller 2002, 2006, Environmental Mapping and Survey 2015) and in the Amathole Area (provided by Andrew Green from the geoscience component of the ACEP Imida project). The Kingklip Ridge data provided by ACEP Deep Secrets cruise 2016. GEBCO data were used below 2000 m.
Side-scan sonar and multi beam data 1987 - 2016	Processed side-scan sonar and multi-beam data covering 46 survey areas between Port Nolloth and Kosi Mouth. Existing GIS layers where such data were classified into seabed types including several reef types, scattered reef, sand, gravel, bioclastics and coarse sediments. In some cases, geology and rock type is specified.	GIS layers collated from the Council of Geoscience, marine geologists and ACEP research projects (Table 5). Data were further processed in some cases by Tamsyn Livingstone (EKZNW). Reef polygons were extracted whereas other sediment information, scattered reef and mixed substrate was used to delineate mosaic ecosystem types.
Sediment data 1967 - 2016	A total of 2639 historical and new sediment type data points derived from benthic grab or core and analysed to assign sediment type using Folk or Wentworth scale	Compiled from records held by the Council of Geoscience & from geologists /benthic ecologists who have collected & analysed sediment samples in the last 7 years. See Table 6.
Historical seabed data 1897-1949	3464 Data points from grab, dredge and sounding lead samples. Of these, 3289 are within South Africa with other sites falling in Namibian territory. The data spans depths of 4 to 924 m and Namibia to north of Richards Bay. There is a hiatus in the data from 1905 to 1919.	The historical research survey database (Currie *et al.* 2013) is housed by SAEON. It contains the records of government-led marine surveys collected from three research vessels. Data were further classified by SANBI and a new GIS layer was produced to support application in the NBA.
Historical dredge data 1991-1993	Data from historical dredge surveys at 1048 sites covering the 12-800 m depth range between Cape Columbine & Kosi Bay. Seabed information indicating substrate and noting coral, coral rubble, sponge rubble, shell grit or shells.	Data provided by the Natal Museum Dredging Program (via Dai Herbert) and described in Kilburn and Herbert (1994). Data were further classified by SANBI and a new GIS layer was produced to support application in the NBA.
Oceanographic data 1985 - 2005	Temperature, salinity and oxygen data collected by CTD. Data were averaged per grid cell and interpolated over the spatial extent of the cruises to create a climate rather than using the original value.	Data collected by fisheries research vessels (former government departments of Marine and Coastal Management and Department of Agriculture Forestry, Fisheries). Accessed from https://robert-schlegel.shinyapps.io/CTD_project/
Visual seabed surveys 1986-2018	2166 visual seabed surveys by Baited Remote Underwater Video (BRUV), Remotely Operated Vehicle (ROV), submersible, tow or drop camera. Coverage spans from the Namibian to Mozambican border and from 7- 4560 m.	See Table 8 for detail. Imagery was collated from geoscientists, petroleum companies and researchers from ACEP, SANBI, SAIAB, SAEON and the Oceans and Coasts Branch of the former Department of Environmental Affairs.

Data type and period	Data overview	Data sources
Biotope data 2014-2018	Georeferenced biotope maps provided from 4 studies that processed biological datasets to define and map biotopes. Karenyi (2014) defined 7 soft sediment biotopes on the West Coast shore and shelf. Shah (2018) defined 14 and 7 offshore biotopes off the West and South Coast respectively. A total of 3 soft sediment, 1 mixed and 3 reef biotopes were defined from the KwaZulu-Natal mesophotic.	West Coast benthic macrofauna (Karenyi 2014, Karenyi *et al.* 2016), West and South Coast epifauna (Shah 2018) and biotopes of reef, mixed (Makwela 2017), and unconsolidated sediment habitats (Franken 2015) from the East Coast ACEP Surrogacy project. See section below for details of other published literature that informed classification and mapping. This includes museum and research trawl surveys of potential Vulnerable Marine Ecosystem (VME indicator taxa).
Remote sensing 1984-2018	Mapping of the outer boundaries of the surf zone at national scales using a time series of multispectral Sentinel-2A satellite imagery. Kelp mapping relied on Sentinel 2 (A & B) remote sensing at 10 m resolution. River influence informed by a series of processed Landsat images (1984–2017) for five systems.	Remote sensing of the surf zone was undertaken by Mariel Bessinger and outputs used by Linda Harris to map the outer boundary of the surf zone (see Harris, Bessinger, *et al.* (2019) for details). Kelp mapping was conducted by Loyiso Victor Dunga (SANBI and University of Cape Town) as part of an MSc study to inform the NBA 2018. The CSIR (Melanie Lück-Vogel) provided unpublished products to support mapping of river plumes.

Bathymetric data

Single-beam data and multi-beam bathymetry data covering the South African shelf and slope were collated with a major contribution provided by de Wet (2013) who manually processed, gridded and exported ±7 million single-beam echo-sounding data points to produce a detailed bathymetric map of the entire South African continental shelf (See Figure 9). The de Wet (2013) dataset was collected by the government research vessels *F.R.S. Africana II* and *F.R.S. Algoa* which used *SIMRAD EKS-38*, *EK 400*, *EK 500* and an *EK 60* single-beam echo-sounder along with a *SIMRAD ES38B* split beam transducer. Improved bathymetric mapping included the northern extension of the Olifants Valley submarine canyon, details of the rocky inner shelf related to glacial period sea level low stands, coast parallel wave cut terraces and paleo-dune ridges on the middle shelf between Cape Seal and Cape Recife (de Wet 2013). Other prominent bathymetric features such as Childs Bank, Cape Canyon, Cape Point Valley, the offshore submerged river valleys of the Breede and Gouritz Rivers and the east-west trending anticlinal ridges on the Agulhas Bank were also revealed in greater detail. Note that bathymetric data are much better on the West and South Coast, with less data north of East London due to the focus of government research vessels in the former areas. Bathymetric data were also provided from several **other sources** that mapped submarine canyons, the petroleum industry, and from projects funded through the DST NRF African Coelacanth Ecosystem Program (ACEP) conducted on the East Coast (Table 5). The Kingklip Ridge off Cape St Francis was mapped using single-beam bathymetry collected during the ACEP Deep Secrets cruise. The GEBCO dataset was used to cover the seafloor beyond 2000 m, noting that ship coverage and the underlying data are very poor in these areas. Updated government research vessel data could further improve bathymetric mapping around Childs Bank, the Amathole Offshore area and KwaZulu-Natal due to more recent efforts in these areas. Ideally, all government (including Navy data) and other research and industry data should be consolidated to produce a new publicly available bathymetric dataset of enhanced quality.

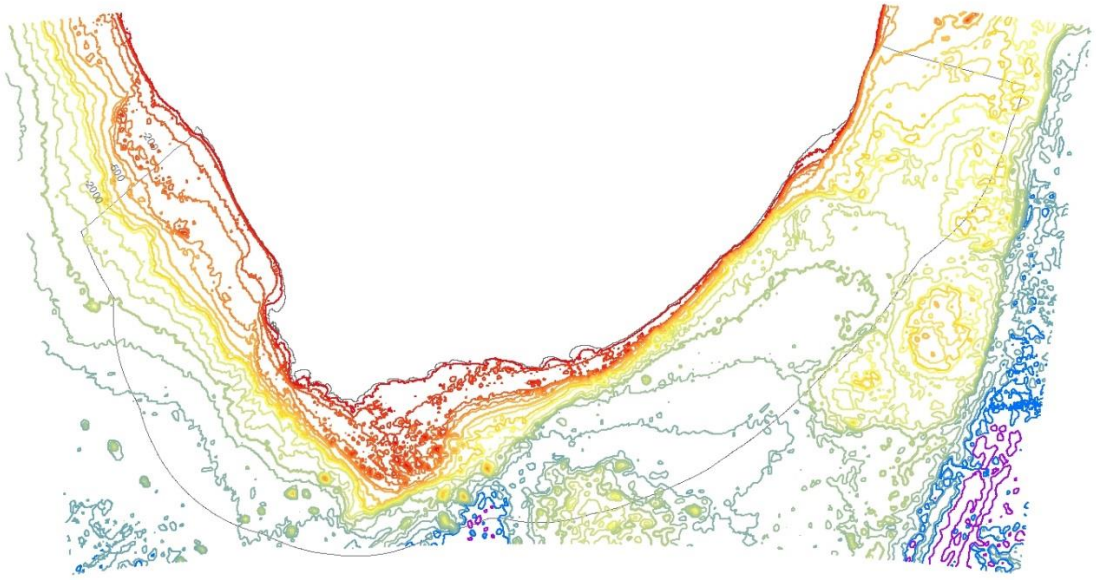


Figure 9. Bathymetric data used in the NBA 2018 produced from de Wet (2013) and other sources noted in Table 1.

Multi-beam and side-scan data to support seabed classification and mapping

To further improve the mapping of reef features, seabed types and mosaics of mixed rocky and unconsolidated sediment on the shelf, geoscience data from side-scan sonar and multi-beam surveys were collated (Table 6 and Figure 10). Although a substantial number of datasets were gathered, these represent a very small area overall (less than 1%) of the ocean around South Africa. Multi-beam data also improved the mapping of reefs, submarine canyons and other major features, as did the work of de Wet (2013).

Table 6. Data provided from geoscience surveys to contribute with seabed classification and reef mapping in the 2018 National Marine Ecosystem Type Map. Datasets listed from west to east.

Area	Survey method	Description	Citation or source	File name
Alexander Bay	Side-scan sonar	Polygons classified as bedrock, coarse and fine grained sediment and sediment with current marks.	(de Decker 1987)	g85111_dd_wgs84.shp
South of Port Nolloth	Side-scan sonar	Seabed classified as bedrock outcrop and sediment.	Unpublished data, De Beers	RockyOutcrop_IndustryProposedMpa.shp
Hout Bay to Table Bay, Cape Town	Side-scan sonar	Area off the West Coast of Cape Point classified as sediment, scattered granite reef and granite	Unpublished data, Council of Geoscience	Atlantic_SSS_interp.shp
Cape Peninsular	Side-scan sonar	Classifies and maps granites, Table Mountain Sandstone and Malmesbury shale from Cape Hangklip to North of Robben Island.	Unpublished data, Council of Geoscience	CapeTown_offshoreGeology.shp
False Bay West	Side-scan sonar	A small area in False Bay classified as reef and scattered reef.	Unpublished data, Council of Geoscience for SAEON	FalseBay_interp.shp
Simon's Town, False Bay	Side-scan sonar	Only the two eastern-most reef patches were extracted from this dataset as the reefs digitised in the FalseBay_interp reef dataset were more precise. Therefore, the FalseBay reef polygons were used rather than the TeHorts reef polygons in the areas where the two datasets overlapped.	Terhorst (1987)	TeHorts_interp.shp
Gansbaai	Side-scan sonar	Seabed polygons classified into gravel, rock and sand off Gansbaai.	Unpublished data, Council of Geoscience	Ganzbaai.shp

Area	Survey method	Description	Citation or source	File name
Tsitsikamma MPA	Side-scan sonar	Two areas where the seabed is classified into coarse sediment, reef, rippled coarse sediment and sand.	Unpublished data, Council of Geoscience	SSS_interp_west.shp & SSS_interp_east.shp
Port Elizabeth	Side-scan sonar	Classifies and maps gravel, rock and sand.	Unpublished data, Council of Geoscience	Summerstrand_SSS.shp
East London	Multi-beam	13 sets of multibeam data spanning the mid shelf between Mazeppa and Port Alfred. Baseline data used to delineate reef and reef mosaics.	Unpublished data, Andrew Green	1.Overlay1.tiff - 14.Overlay1.tiff (no 13)
Gxulu area south of East London	Multi-beam	Multi-beam data and video surveys used to classify and delineate Gxulu Canyon and reefs into flat reef with veneer, reef mosaic and rugged relief reef mosaic.	Unpublished data, ACEP Imida project digitised by Tamsyn Livingstone	Bathy1.shp – Bathy 14.shp
Southwest of Kei Mouth, East London	Side-scan sonar	Side-scan sonar data classified into flat reef with veneer, rugged relief reef, subdued reef and dolerite.	Unpublished data, Andrew Green	East_London_Geology_UTM35S
Kei Mouth, East London	Side-scan sonar	Side-scan sonar data, confirmed with visual surveys, were used to classify and delineate reefs into flat reef with veneer, rugged relief reef and subdued reef.	Unpublished data, Andrew Green, ACEP Imida project	Morgans_Bay_Geology_UTM35S
East of Kei Mouth, East London	Side-scan sonar	Side-scan sonar data used to classify and delineate reefs into flat reef with veneer, rugged relief reef, subdued reef and dolerite.	Unpublished data, Andrew Green	Mazeppa_Bay_Geology_UTM35S
Protea	Multi-beam	Multi-beam data used to classify and delineate canyon features and reefs into flat reef with veneer and rugged relief reef mosaic.	Pretorius *et al.* (2019), Pondoland NRF Grant, Green plus ACEP Surrogacy.	ProteaReefs_WGS84_36S
KwaZulu-Natal	Side-scan sonar	Side-scan sonar data used to classify and delineate reef and scattered reef.	Unpublished data, Council of Geoscience	Trafalgar_merge_utm
Aliwal Shoal	Side-scan sonar	Processed side scan data classified into high relief reef outcrop, sediment filled gullies, shelf sediment and subdued relief reef outcrop. Wreck of Produce included.	Unpublished data, Council of Geoscience	AliwalReefs_UTM36S.shp
Isipingo	Side-scan sonar	Reef polygon digitised from side-scan and reef points (comb_reefdata_tw_05) where absolutely certain.	Unpublished data, Andrew Green and digitised by Tamsyn Livingston	IsipingoReefs_WGS84_36.shp and comb_reefdata_tw_05
Durban Bight, KwaZulu-Natal	Side-scan sonar	Side-scan sonar data used to classify and delineate reefs into reef, scattered reef, bioclastics, sand and bioclastic gravel.	Richardson (2005)	RichardsonAllReef.shp
South of Richard's Bay	Side-scan sonar	Side-scan sonar data used to classify and delineate reef and scattered reef, mud, sand and submarine features	Unpublished data, Council of Geoscience	ThukelaReefs_WGS84_UTM36S
Umdhloti	Polygon	Reef delineated from side-scan sonar data obtained from Andrew Green.	Unpublished data, Andrew Green and digitised by Tamsyn Livingstone	UmhlodtiReefs_WGS84_36S.shp
iSimangaliso	Polygon	Reef digitised from side-scan sonar data by Andrew Green.	Unpublished data, Andrew Green	iSimangalisoReefs_WGS84_36S.shp
iSimangaliso	Side-scan sonar	Side-scan sonar data were used to classify the seabed into prominent reef, reef, sand, scattered reef and bioclastics.	Ramsay *et al.* (2006)	MaputalandGeologyDDJune2005

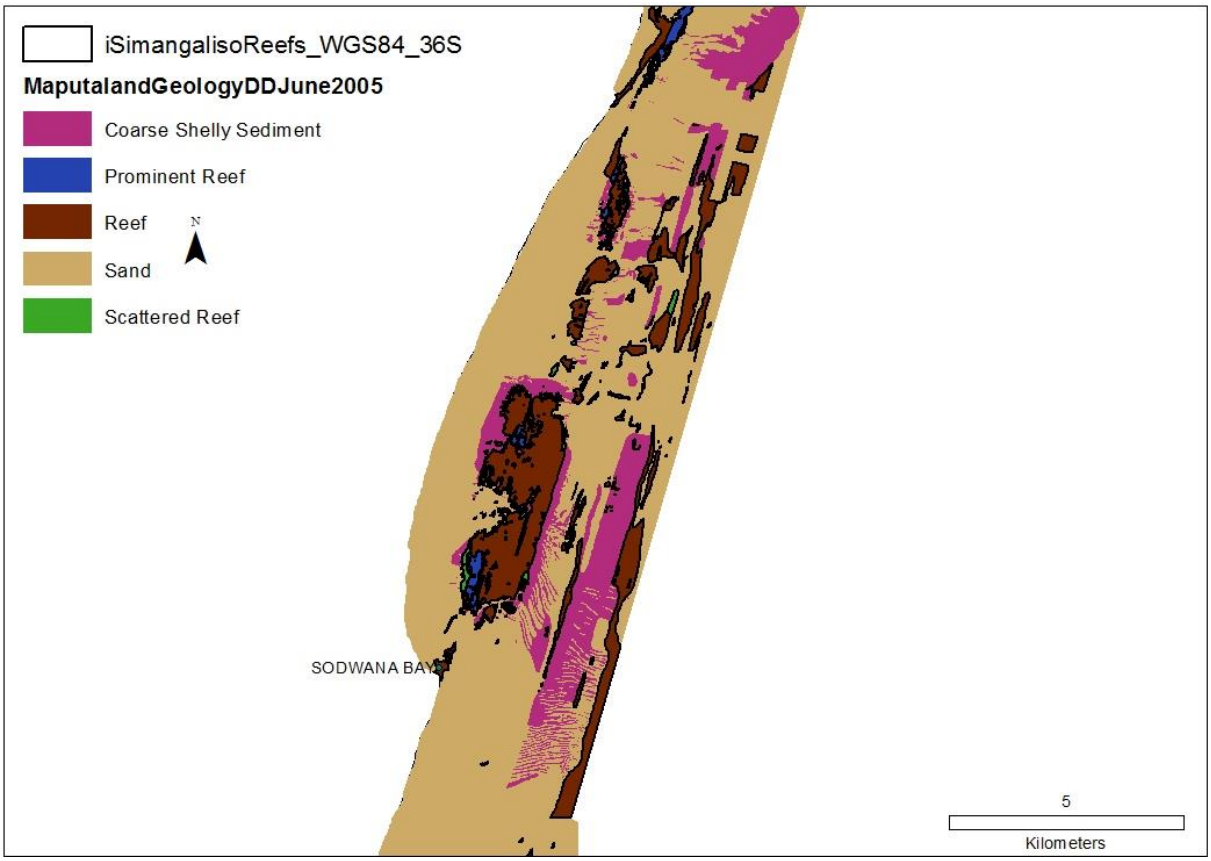


Figure 10. Selected sample of interpreted seafloor geology derived from single-beam and side-scan sonar data, used to improve reef and seabed mapping (Ramsay *et al.* 2006).

Sediment data

Substrate is recognized globally as an important primary determinant of community structure and biodiversity in coastal and offshore environments and has been applied to inform numerous local and international marine habitat classification efforts (Connor *et al.* 2004, 2006, Howell *et al.* 2010, Sink *et al.* 2012a). Sediment data from **13 different projects** were collated to inform 2018 marine ecosystem classification and mapping efforts (see Table 7). All datasets were classified according to the Folk (Folk 1954) or Wentworth scale (Wentworth 1922), or both where possible. Where both Folk and Wentworth classes were available, the Wentworth classification prevailed as it provides a finer scale of classification according to mean grain size. For purposes of mapping, all classified data were grouped into five broader biologically meaningful categories: Gravel, Mixed, Coarse sediment, Mud or Sand (Figure 11). This revised categorisation is based on the Folk category amalgamation developed for the UKSeaMap project (Connor *et al.* 2006). This approach was also adopted in the 2011 NBA (Sink *et al.* 2012a), where it was recognized that not all geological distinctions are appropriate in terms of surrogacy for biodiversity, and classes were assigned that would better reflect the broad substratum types used in seabed habitat classifications (Leslie *et al.* 2000, Connor *et al.* 2006, Howell 2010, Sink *et al.* 2012a).

The **seafloor** of the South African shelf is primarily composed of sand with a noticeable proportion of mud (Figure 12). Two areas previously thought to be predominantly gravel grounds (Birch *et al.* 1986) were investigated during the 2016 NRF ACEP–funded Deep Secrets research expedition. No gravel samples were collected, nor was any gravel observed on footage during the cruise. Currents also

influence sediment patterns (Dingle *et al.* 1987) and could have caused a shift from the gravel-dominated seabed as previously recorded to the more unconsolidated environment observed in 2016. A previously reported mud patch off East London was not located during the ACEP Imida surveys suggesting that sediment patterns are more dynamic than previously thought. One of the recent advances in sediment mapping (Figure 13) was the ACEP KZN Bight–funded research on the uThukela Banks (Green and Mackay 2016), these data providing both better coverage, in addition to multiple temporal scales, when compared to other previous datasets. These data were therefore used preferentially in this area.

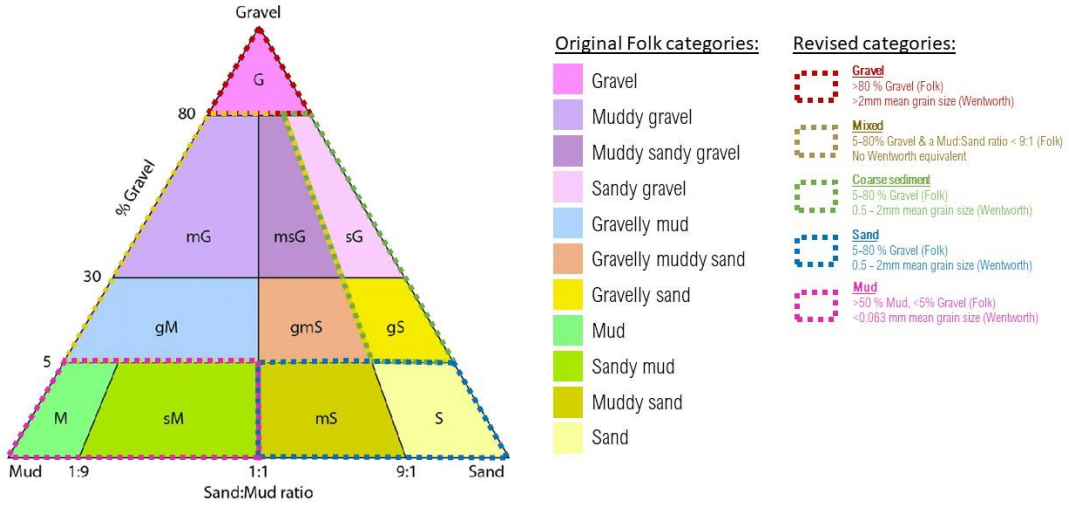


Figure 11. Folk sediment trigon, modified to show the aggregation of classes into five main sediment classes (gravel, mixed, coarse sand, mud and sand). Revised categorisation is based on the Folk category amalgamation developed for the UKSeaMap project (Connor *et al.* 2006). E.g. Gravel includes data classified with >80% gravel according to the Folk scale and sediment data with mean grain size of >2 mm from datasets classified according to the Wentworth scale. Mud includes all data with made up of >50% mud and <5% gravel in the Folk classification, and sediment data with a mean grain size < 0.063 mm on the Wentworth scale.

Table 7. Overview of data collated to produce a national layer of sediment types as classified by the Wentworth or Folk classification. Samples were acquired by grab or core.

Data coverage	Sample number	Data description	Data Provider
National coverage in the 7–3370 m depth range (1967-1976)	1683 data points	Folk classified (% Sand, Mud, Silt, Clay & Gravel). Sediment collected by grab, or core sampling.	Council for Geoscience - includes data from Richard Dingle and John Rogers, Birch *et al.* (1986)
Child's Bank area on the West Coast in the 192–515 m depth range (2014-2015)	32 sediment samples	Folk classified (% Sand, Mud, Silt, Clay & Gravel). Sediment collected by grab sampling.	SAEON Benthic Trawl Experiment (Principal Investigator Lara Atkinson, unpublished data)
West Coast in the 412–422 m depth range (2007-2008)	30 sediment samples	Folk classified (% Sand, Mud, Silt, Clay & Gravel). Sediment collected by grab sampling.	Atkinson (2010)
West Coast in the 25–103 m depth range (2009-2010)	41 sediment samples	Folk & Wentworth classified (Mean particle sizes & % Sand, Mud, Silt, Clay & Gravel). Sediment collected by grab sampling.	Karen Tunley, University of Cape Town, unpublished data
Port Nolloth to Cape Point on the West Coast in the 0–391 m depth range (2008-2010)	216 sediment samples	Folk classified (% Sand, Mud, Silt, Clay & Gravel). Sediment collected by grab, or core sampling.	Karenyi (2014)
Robben Island in the 15–53 m depth zone (2006)	55 sediment samples	Wentworth classified (Mean particle sizes. % Sand, Mud, Silt, Clay & Gravel)	(Van Den Bossche 2006)
Houtbay in the 10–60 m depth zone (2013)	57 sediment samples	Wentworth classified. Mean particle sizes. % Sand, Mud, Silt, Clay & Gravel	(MacHutchon 2012)
Robben Island to the Kei river mouth on the South Coast in the 77–1035 m depth range (2016)	28 sediment samples	Folk classified (% Sand, Mud, Silt, Clay & Gravel). Sediment collected by grab sampling.	ACEP Deep Secrets Project (Principal Investigator Kerry Sink, unpublished data)
Vleesbaai on the South Coast in the 9–20 m depth range (2011-2013)	41 sediment samples	PetroSA Vleesbaai monitoring work. Folk classified (% Sand, Mud, Silt, Clay & Gravel & Mean particle sizes). Sediment collected by grab sampling.	SAEON (Principal Investigator Lara Atkinson, unpublished data)
Algoa Bay on the South Coast in the 30–100 m depth range (2015-2016)	12 sediment samples	Folk classified (% Sand, Mud, Silt, Clay & Gravel). Sediment collected by grab sampling.	(Truter 2018)
Algoa Bay on the South coast in the 43–200 m depth range (2015-2016)	9 sediment samples	Folk classified (% Sand, Mud, Silt, Clay & Gravel). Sediment collected by grab sampling.	NRF Innovation project for Algoa Bay (Principal Investigator Charles von der Meden, unpublished data)
Durban Bluff on the East Coast in the 0–60 m depth zone (2010)	111 sediment samples	Folk & Wentworth classified (Mean particle sizes & % Sand, Mud, Silt, Clay & Gravel). Sediment collected by grab sampling.	Cawthra (2010)
KZN Bight in the 20–180 m depth range. (2010)	324 sediment samples	Areas sampled included: Richards Bay North, Richards Bay South, Durban Eddy & Thukela. Folk & Wentworth classified (Mean particle sizes & % Sand, Mud, Silt, Clay & Gravel). Sediment collected by grab sampling.	Green and Mackay (2016)

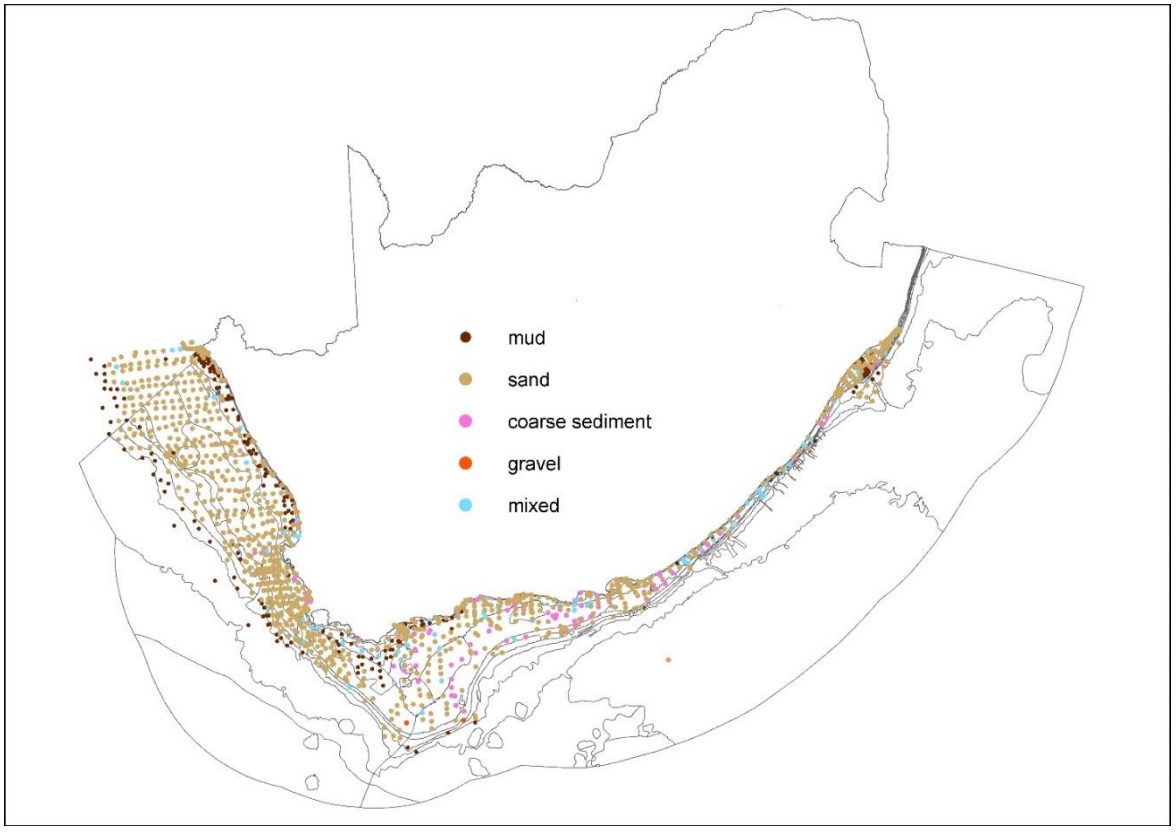


Figure 12. Map of sediment data collated to produce a national layer. All samples were acquired by grab or core.

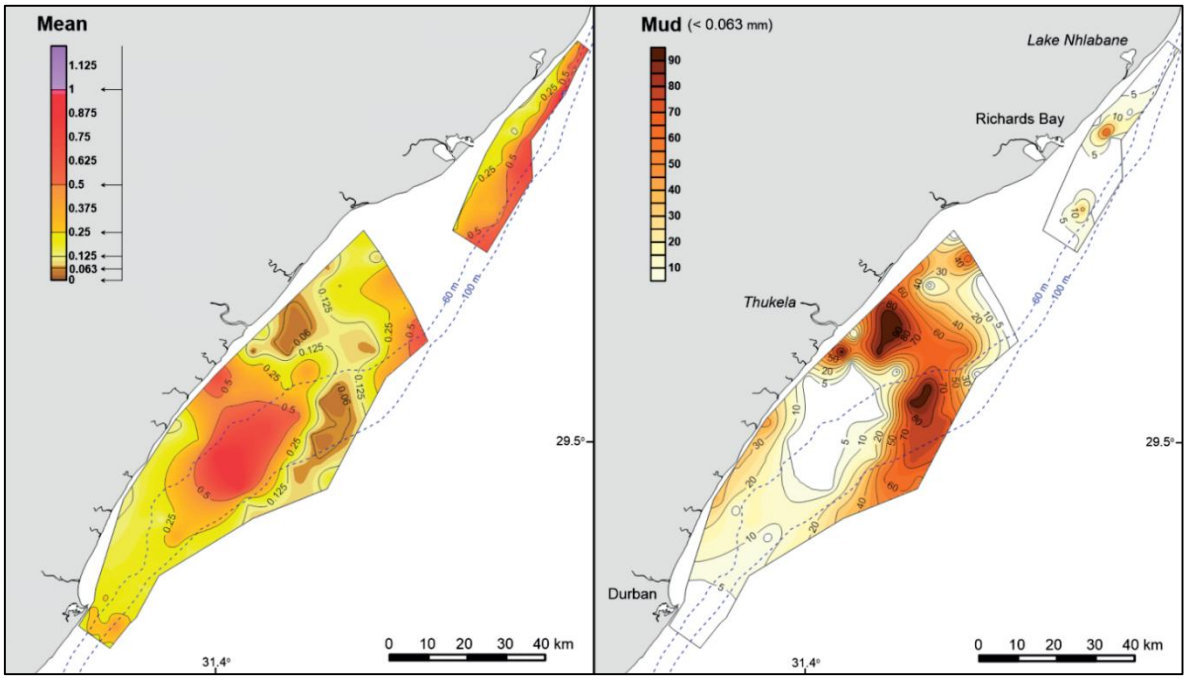


Figure 13. Fine-scale sediment classification was considered at a regional scale where available (Map produced by Green and Mackay (2016).

Historical seabed and dredging data

Historical fisheries research survey data from the database housed by SAEON (Currie *et al.* 2013) were used to provide further information on sediment, hard grounds and even the potential presence of reefs (through records of reef biota). Overall, the collection methods were dominated by trawl surveys but included other gear types such as dredge, grab and lead line with multiple gears employed at most stations. Seabed information was recorded in a station observation field and it was often unclear which gear was used as the basis for the observation. In contrast to the sediment data described above, sediment type was not assigned through any analysis and therefore is less reliable. Many of the stations reported as mud are more accurately described in samples where sediment is processed and analysed to examine grain size and silt and clay content. The records used in supporting ecosystem mapping for the NBA 2018 included those describing both the **physical aspects of the seabed and the presence of biota** including corals, sponges, bryozoans and molluscs. The original dataset included 335 different types of seabed covering grain size, colour, texture, presence of rock, various biota (coral, sponges, polychaete tubes, bivalves and other molluscs) and many combinations of these. These were reclassified by Kerry Sink into 7 categories, chiefly by grain size, into rock, gravel, coarse sand, fine sand, mud, globerigina and coral (Figure 14). Sediment colour was not used at this stage but should be further considered by benthic ecologists in the future. Where mud was noted, this took precedence over sand. The category "globerigina" refers to a muddy deep-sea sediment type where deposits from the microscopic tests of pelagic foraminiferans (including the genus *Globerigina*) constitute a large proportion of the sediment. This name was originally applied to mud sampled from the seabed of the deep Atlantic Ocean when planning the location of the first transatlantic telegraph cables (Murray and Renard 1891).

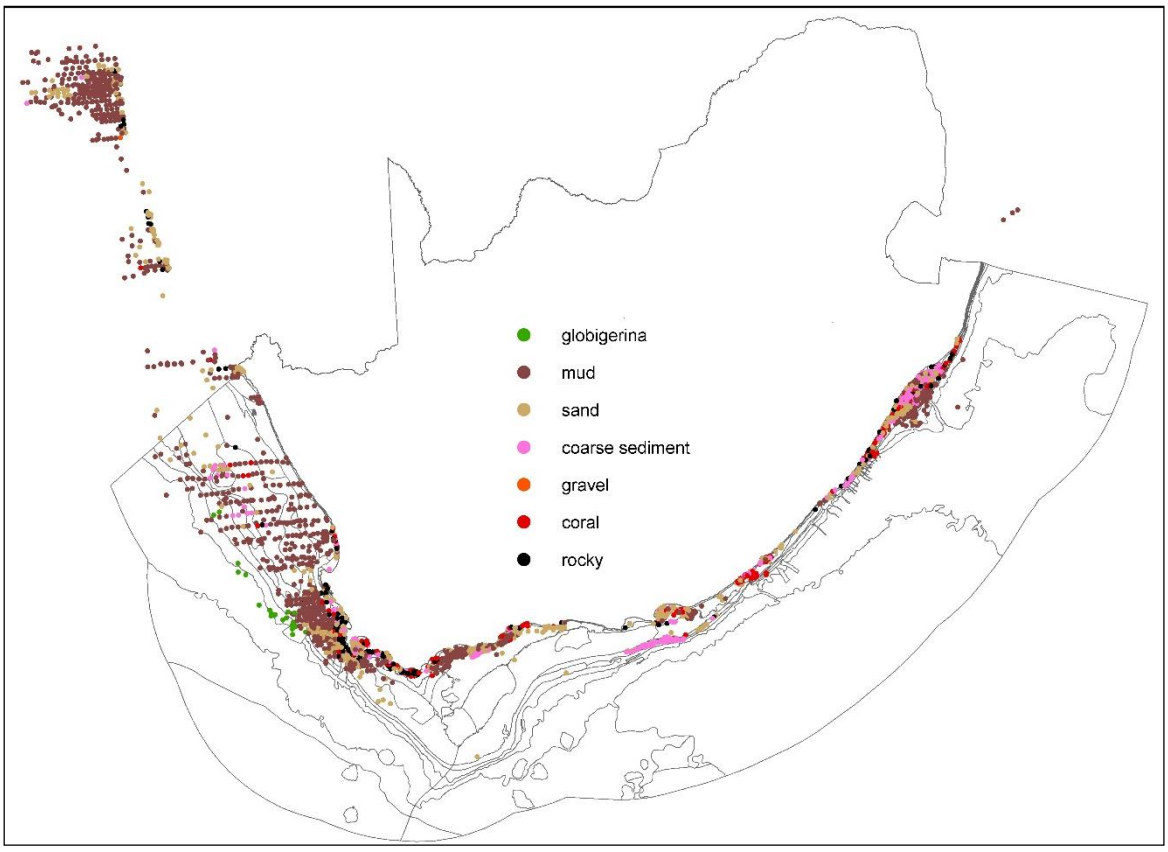


Figure 14. Map of historical seabed data records used to inform the 2018 NBA marine map of ecosystem types.

The historical dredging dataset (Figure 15) provided by the **Natal Museum Dredging Program** (Table 5, Kilburn and Herbert 1994) was also a very useful addition to support ecosystem classification and mapping. This georeferenced dataset includes notes on seabed type and biodiversity, such as the presence of coral, coral rubble, sponges, bryozoans, polychaete tubes and shells. Seabed categories included mud, sand, coarse sediment, shell grit, rock and stone. These historical datasets were used as a supplementary dataset where there were gaps in the more accurate, processed sediment and multibeam datasets and where there was conflicting information between different sources (e.g. side-scan sonar interpretations and sediment data).

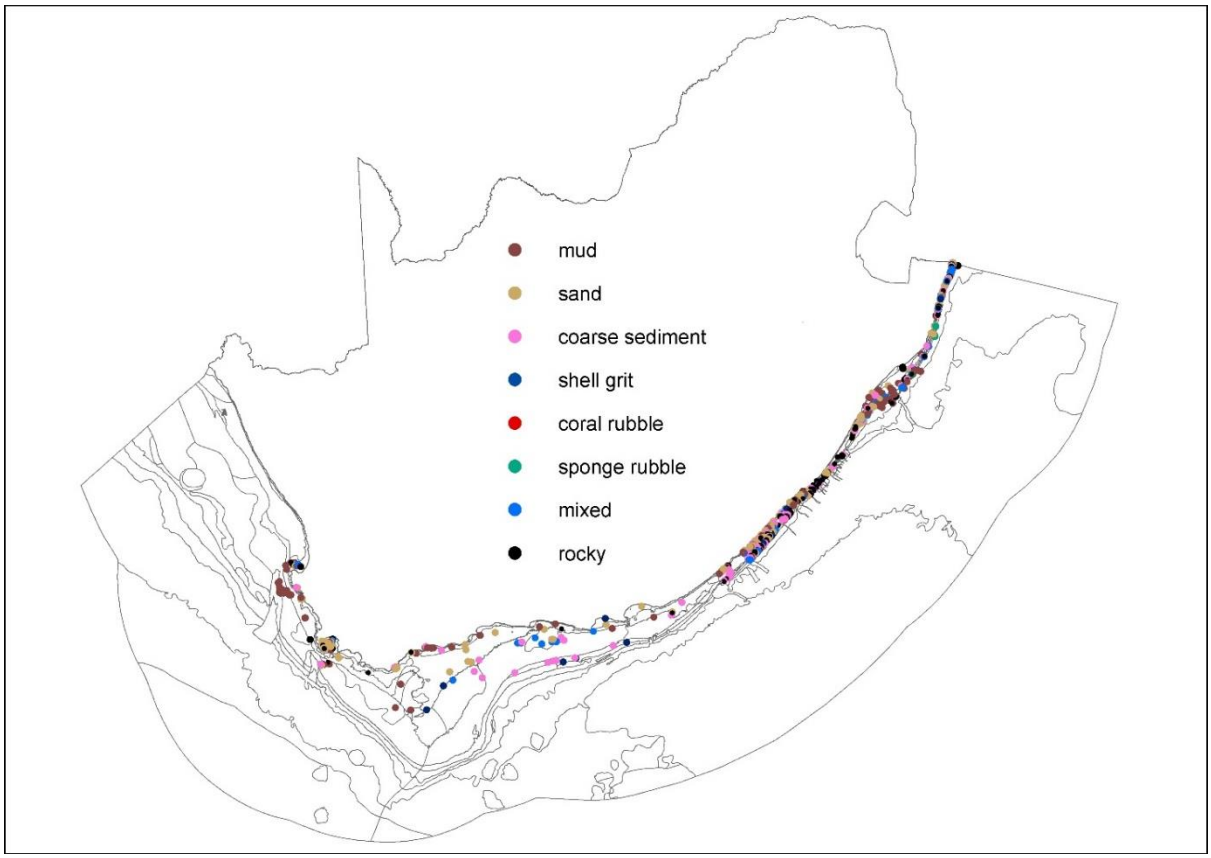


Figure 15. Map of historical dredging data used to inform the 2018 NBA map of marine ecosystem types.

Oceanographic data

The oceanographic data were compiled from CTD data collected by government research cruises between 1985 and 2005. Temperature (°C), salinity (‰) and oxygen (ml.l^{-1}) were measured at various stations and several depths within each station. These data extend across the continental shelf and slope from the Namibian border in the west to the border between the Eastern Cape and KwaZulu-Natal in the south east. For use in the NBA, the data for just above the seafloor were averaged over the entire period for each grid cell of 0.1 degrees in order to provide a **climatology** for each cell. Where no data were available for grid cells, values were linearly interpolated based on surrounding cells. The data were made available online through an application (visit https://robert-schlegel.shinyapps.io/CTD_project/ to access the data).

Remote sensing

Remote sensing data were used to produce a map of kelp forests, delineate the outer bounds of the surf zone, and to support the mapping of fluvial fans. The **surf zone** was mapped by Mariel Bessinger using a time series of multispectral Sentinel-2A satellite imagery drawing from 112 Sentinel-2 L1C images (acquired 31 August 2016 -16 July 2017). These images were converted to top-of-canopy reflectance. The surf zone was then extracted using the Normalised Difference Vegetation Index (NDVI) and the Tasseled Cap (TC) Transformation bands. Areas with NDVI values of less than 0 and TC_B values of greater than 0.3 were classified as surf. The resulting surf image was then converted by Linda Harris to a polygon shapefile, manually cleaned to remove noise, and smoothed and generalised to generate a contiguous line delineating the back of the surf (Harris *et al.* 2019b).

To produce the South African **kelp forest** map, contemporary remote sensing images were used by Dunga (*in prep*) to update the kelp forest map produced during the mid-2000s (Anderson *et al.* 2007). This mapping approach entailed extracting the vegetative index of kelp forests and subjecting the product to expert validation, visual observation, and comparison with the previous kelp map by Anderson *et al.* (2007). Making use of Geographic Information Systems, the spectral bands 4 (Red) and 8 (Near-Infrared) (at 10 m resolution) were isolated and used to calculate the NDVI. An NDVI threshold of -0.2 was set to detect both subtidal and surface-reaching kelp while excluding non-vegetative material. The results were subjected to Observational, Supervised Classification and an error matrix to determine the accuracy of the developed method and kelp NDVI detecting ability in both clear and turbid waters. At 76% overall accuracy the results depict a kelp map extending across 1200 km of South Africa's coastline along the West Coast and parts of the South-West Coast, including the kelp that was relatively recently established in De Hoop Nature Reserve approximately 70 km east of its previous limit. Kelp took precedence over other marine ecosystem types, including bays.

To support an improved understanding of **river influence** and mapping of fluvial plumes and fans, a series of Landsat images were collated for five of the larger catchments. It was difficult to identify the river signature as it consists of both the fan (seabed component) and the plume (pelagic component). River influence and fluvial plumes were examined based on a series of processed Landsat images (1984-2017) for the Orange, Breede, uThukela and greater uMthamvuna catchments. As there were not resources or time to achieve this for all major river systems, this area of work will need attention in the future. These preliminary products were useful but current efforts relied mostly on sediment data to map fluvial fans. This has likely led to an underestimate of river influence. Future research is needed on the more season component of river influence (i.e. the plume).

Visual surveys

A further data type to inform the ecosystem classification and map was the information collated from visual surveys of the seabed (overview provided in Figure 16 and Table 8 below). South Africa has made substantial progress over the last two decades in applying new technology to obtain photographs and video of the seafloor as reflected in the ten sets of visual data collated to improve ecosystem mapping. One of the most substantial datasets was that provided by SAIAB (Anthony Bernard supported by Elodie Heynes) who classified 1710 **Baited Remote Underwater Video** (BRUV) sites into one of 6 seabed types (patch reef high, patch reef low, reef high, reef low, sand inundated reef or sand). Four ACEP projects provided **ROV** imagery from 215 sites which were classified into one of six seabed types (reef, reef mosaic, sand, coarse sand, gravel or mud). The SAEON and DEA **tow cameras** provided similar data for a further 124 widely spread sites and detailed information in the vicinity of Childs Bank used to distinguish between the sandy plateau, rocky slopes and shelf edge. Historical **submersible** surveys conducted by the Jago team were helpful in classifying the seabed at a further 63 sites, although improved canyon mapping and tow camera footage provided improved information in many cases. The visual surveys provided information on seabed types but also contributed knowledge about biological communities.

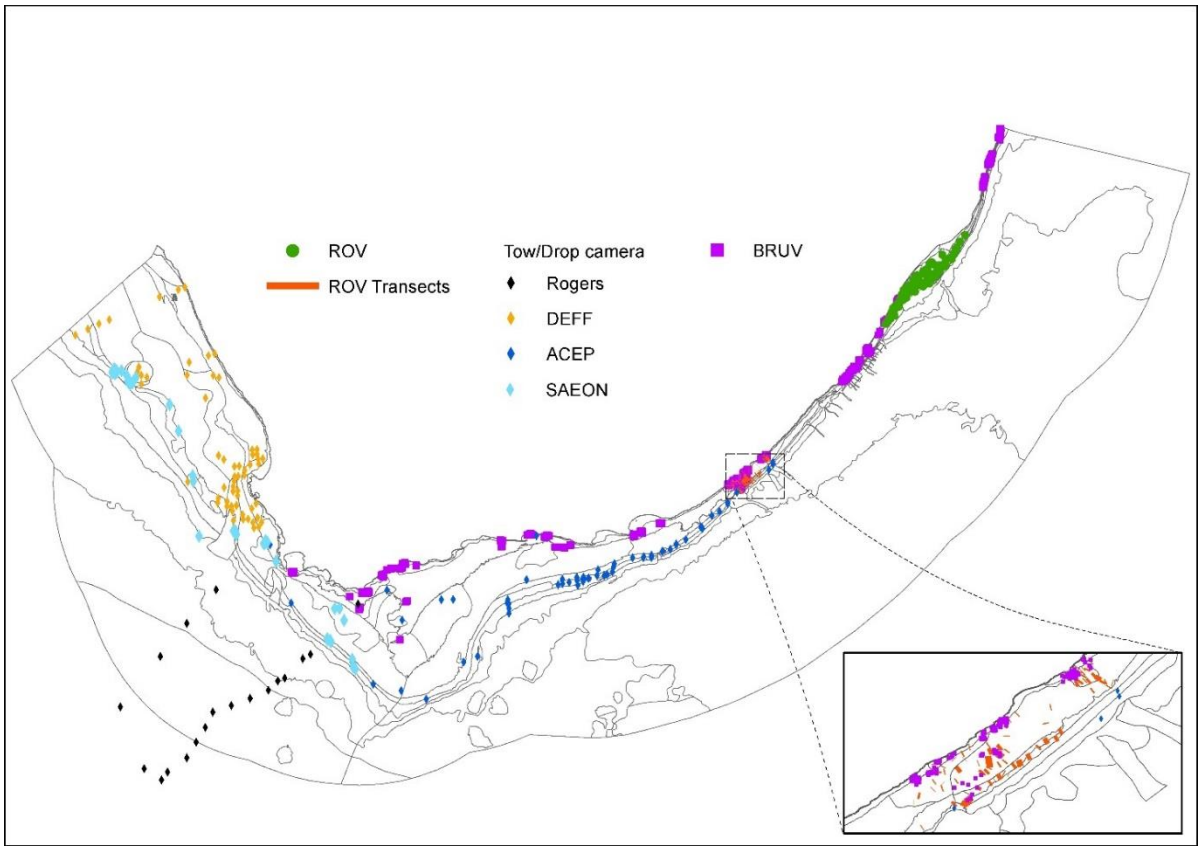


Figure 16. Overview of visual survey stations reviewed to inform 2018 ecosystem classification and mapping efforts. Visual surveys from 11 research projects (Table 8) were collated and were useful to provided information on seabed types and their associated biological communities.

Table 8. Overview of data and information provided by Baited Remote Underwater Video (BRUV), Remotely Operated Video (ROV), submersible, tow camera and drop camera surveys.

Survey method & number of sites	Data coverage (spatial and temporal)	Data description, provider and Project/ Institution
1710 BRUV sites	Cape Agulhas to Kosi Bay. Depth: -5 to -238 m (2013-2018)	Habitat descriptions from stereo BRUV locations classified as sand or various reef types (Anthony Bernard, SAIAB)
100 ROV survey sites	Keiskamma to Kei Mouth. Depth: - 23 to -225m (2017)	ROV footage and still images from ACEP Imida Project: Ecosystem mapping component (Kerry Sink, Principal Investigator Sven Kerwath, DEFF)
67 ROV sites	Aliwal Shoal to Richards Bay in KwaZulu-Natal. Depth: -34 to -248 m (2016, 2017)	ROV footage and still images from ACEP Spatial Solutions: Habitat component (Kerry Sink, Principal Investigator Andrew Green, UKZN)
86 Visual survey sites	Robben Island to Kei Mouth. Depth: -94 to -1050 m (2016)	Tow and drop camera footage and still images provided by ACEP Deep Secrets Project (Principal Investigator Kerry Sink, SANBI)
62 Tow camera sites	Kleinsee to Cape Town (2015, 2016, 2017)	Tow camera footage and still images provided by DEA Cape Canyon Project (Principal Investigator Zoleka Filander, DEA) and Integrated Ecosystem Program IEP line (Principal Investigator Zoleka Filander, DEA)
34 ROV sites	Zinkwazi to Pennington (33-88m) and Trafalgar Reef Complex and Protea Banks including 2 canyons. Depth: -30 to -160 m (2014, 2015)	ROV footage and still images from ACEP Surrogacy Project and associated Protea Canyon Survey: benthic component (Kerry Sink; Principal Investigator Jean Harris)
15 ROV sites	Algoa Bay (Riy Banks to Evans Peak). Depth: -30 to -65 m (2016, 2017)	ROV footage and still images provided by ACEP Algoa Bay Project (Shirley Parker-Nance, Principal Investigator Rosie Dorrington, Rhodes University.
13 Drop camera sites within the EEZ	Six Mile Bank to the Atlantic Abyss and 6 adjacent sites between the EEZ boundary (-45 to -4663 m) and adjacent high seas area including Wyandot Seamount. (-4619 to -4852 m)	Drop camera images from 13 sites within the EEZ ranging from and between the EEZ boundary and Wyandot Seamount. Images provided by John Rogers (University of Cape Town).
70 Tow camera sites	Child's Bank Area off Hondeklipbaai, West Coast. Depth: -190 to -527 m (2014-2018)	Tow camera footage and still images from the Benthic Trawl Experiment (Lara Atkinson, Principal investigator, South African Environmental Observation Network) (Attwood & Sink 2016; 2017, Sink *et al.* 2016;2017)
54 sites	Chaka Canyon (Cape Vidal) to Island Rock Canyon, -50 to -333m (2002-2013)	Video footage of submarine canyon and deep reef ecosystems captured during the 2002-2004 Jago submersible expeditions (Hissman *et al.* 2002), the 2005 ROV survey (Sink and Scott-Williams 2005) and the 2013 ROV coelacanth survey (Sink *et al.* 2013).
9 sites	Childs Bank Area, Cape Canyon, Rocky Bank and False Bay Depths not provided	Jago submersible footage from Cape Canyon and from additional footage from De Beers sites in the vicinity of Childs Bank, Rocky Bank and False Bay. Historical submersible footage (provided to Kerry Sink by Diamondfields International) and footage from 1991 East London expedition at Tsitsikamma and East London (SAIAB archives). Slides by Robyn Stobbs digitised by SANBI.

Biotope data

The final two types of data that informed the map were biodiversity data for benthic epifauna, macrofauna and fish (Figure 17), and unpublished data to indicate the presence of potential indicator species for Vulnerable Marine Ecosystems. Key recent **biological community** and associated habitat datasets and publications that informed the marine ecosystem map included the West Coast benthic macrofauna work by (Karenyi 2014, Karenyi *et al.* 2016), studies on macrofauna (Mackay *et al.* 2016) and fish (Fennessy *et al.* 2016) from the ACEP KwaZulu-Natal Bight project, patterns in epifauna from the West and South Coast (Shah 2018) and reef, mixed (Makwela 2017), and unconsolidated sediment biotopes (Franken 2015) in KwaZulu-Natal. The latter two studies were linked to the ACEP Surrogacy project, which also developed and tested new marine bioregions (Livingstone *et al.* 2018) but these were not used in the 2018 assessment due to their limited ability to represent observed marine biodiversity patterns (Franken 2015, Makwela 2017). Karenyi *et al.* (2016) used physical variables to define eight unconsolidated sediment seascapes on the West Coast but found that including expert knowledge and/or biological data produced more biologically relevant "habitats" (Karenyi 2014). In the shallow subtidal, several publications (Celliers *et al.* 2007, Olbers *et al.* 2009, Porter 2009, Porter *et al.* 2013, Schleyer and Porter 2018) informed ecosystem classification and mapping in the Delagoa and Natal ecoregions, including Pondoland.

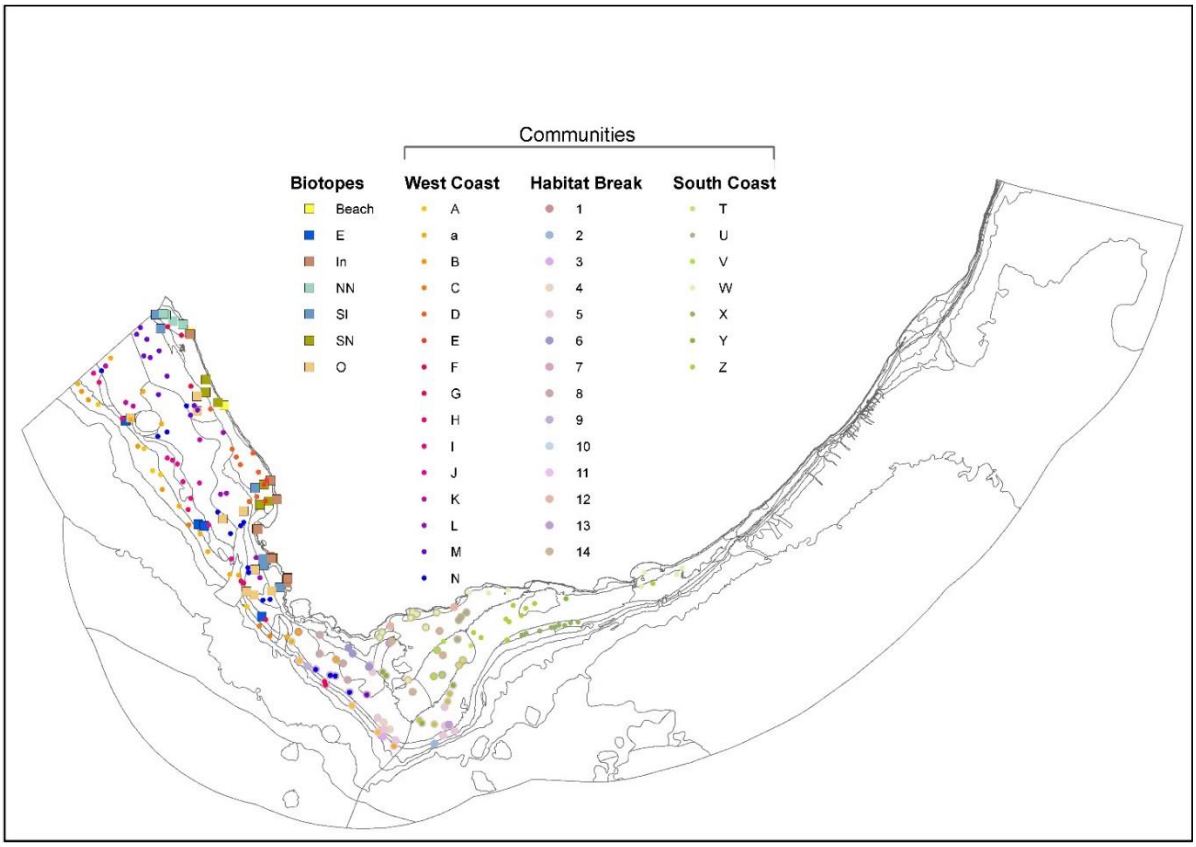


Figure 17. Map of distinct biotopes described in various research projects (Karenyi 2014, Shah 2018). Data provided by Makwela (2017) and Franken (2015) is not reflected here.

The distribution of potential **Vulnerable Marine Ecosystems (VMEs)** was also used to inform classification and ecosystem mapping efforts. VMEs are groups of species, communities or habitats characterized by their structural functionality and their vulnerability to physical disturbance (FAO

2009a). Vulnerability relates to the likelihood that a population, community or habitat will experience substantial alteration from short-term or chronic disturbance, and the likelihood that it would recover and in what time frame. The Identification of VMEs is based on five main criteria outlined in the 2006 Food and Agriculture Organization (FAO) guidelines for management of deep-sea Fisheries and includes; (i) uniqueness or rarity; (ii) functional significance of the habitat; (iii) fragility; (iv) live-history traits of component species that make recovery difficult; and (iv) structural complexity (FAO 2009a). Examples of indicator taxa of VMEs are also provided by the guidelines and includes reef-building corals, sponge-dominated communities, endemic or rare communities and structural biogenic habitats (e.g. those composed of large bryozoans, protozoans or hydrozoans (Auster *et al.* 2011). Mapping VMEs provides broad information about functional ecology and biodiversity even when using relatively sparse point-occurrence data and is useful to inform marine spatial planning.

The distribution of 22 potential VME indicator taxa (Atkinson and Sink 2018) were mapped drawing from invertebrate research trawl data and museum records for reef building Scleractinian corals (see Figure 18). These include stony corals (Scleractinia), bamboo (Isidae), stylasterine lace coals (*Errina*, *Errinopsis, Inferiobata* and *Stylaster* spp.) and soft corals (*Thouarella* spp.) and seafans (*Melithaea* genus); seapens of the genus *Anthoptilum* and habitat forming sponges and bryozoan. A total of 466 records were included, however data were not evenly distributed throughout the South African EEZ and increased efforts are needed, especially on the East Coast, to map these potential sensitive ecosystem types for the entire EEZ. Further work is underway to map fragile ecosystems and to incorporate data from visual surveys. In the interim, this map has advanced our understanding of the distribution of potential VME's over large areas and was useful in defining the *Suberites* sponge grounds on the West Coast (Samaai *et al.* 2017) and refining the map of hard grounds on the West and South Coasts. Together with seabed data described above, this allowed for the removal of the former "untrawlable grounds" layer and was used to assign the mosaic seabed type category when multiple datasets suggested a mix of consolidated and unconsolidated substrates. All taxa in Figure 18 suggest rocky habitat with the exception of seapens and *Suberites* sponges.

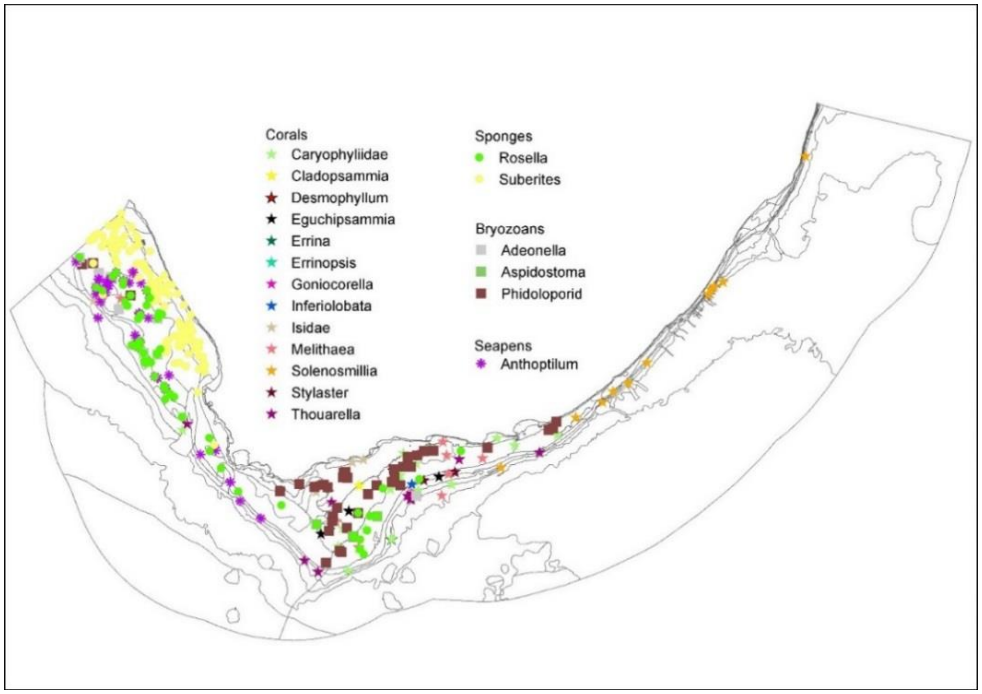


Figure 18. Map of potential indicator species for Vulnerable Marine Ecosystems.

3.4 Marine Ecosystem Mapping

The marine ecosystem types were mapped in Arc GIS 10.4 using a digitising tablet. **Shore mapping** was conducted mostly by Linda Harris and is described in detail in (Harris *et al.* 2019c) and the coast report for the NBA 2018 (Harris *et al.* 2019a). **Beyond the surf zone**, mapping was conducted in a single project where all the spatially referenced data were compiled and used to delineate polygons of relatively uniform seabed and oceanographic habitat and known biological community structure. Final polygons were digitised by Andrew Skowno and Kerry Sink, with reefs and canyons digitised by Tamsyn Livingstone, and kelp polygons provided by Loyiso Dunga (LV Dunga *in prep*). Bathomes were delineated first, drawing from datasets described above. Key boundaries are reported in detail below (see Section 3.6.2). Then ecoregions and sub-regions were delineated with boundaries informed by oceanographic datasets, recent literature and experts in consultation with the MEC and associated task teams. These are described in the section entitled REGIONAL PATTERNS below. Finally, polygons of different seabed type or reflecting distinct oceanographic features (such as the Agulhas Blues), or areas of riverine influence were created on the shelf and shelf edge, drawing from the datasets described in Table 6. Bays took precedence over other information such as seabed type, but the kelp layer was the last component to be added and superseded all ecosystem types, including bays.

3.5 Marine Ecosystem Map

NBA 2018 KEY MESSAGE C1

South Africa's new seamless map of ecosystem types paves the way for improved assessment, planning and monitoring

Substantial progress made in classifying and mapping ecosystem types seamlessly across all realms has unlocked comprehensive and systematic assessment and planning for all of South Africa's territory, providing improved information to inform policy and decision making.

Skowno *et al.* 2019.

South Africa's new marine ecosystem type map is shown in Figure 19. There are **150 marine ecosystem types** (Table 9). The map includes a total of 6244 polygons (including a disproportionate 3700 kelp polygons caused by the high-resolution remote sensing approach used to map kelps). An overview of these key **advances in the map of marine ecosystems** included the collation of substantial new datasets on bathymetry, sediment and seabed type, very fine-scale shore mapping with alignment and integration at the land-sea interface; the inclusion of kelp forests, bays and fluvial fans as distinct types and the introduction of finer depth strata across shelves (inner, mid and outer shelf) and on the slope (upper, mid and lower slope). This is a result of a major effort in collating and increasing relevant historic and current datasets for ecosystem classification and mapping.

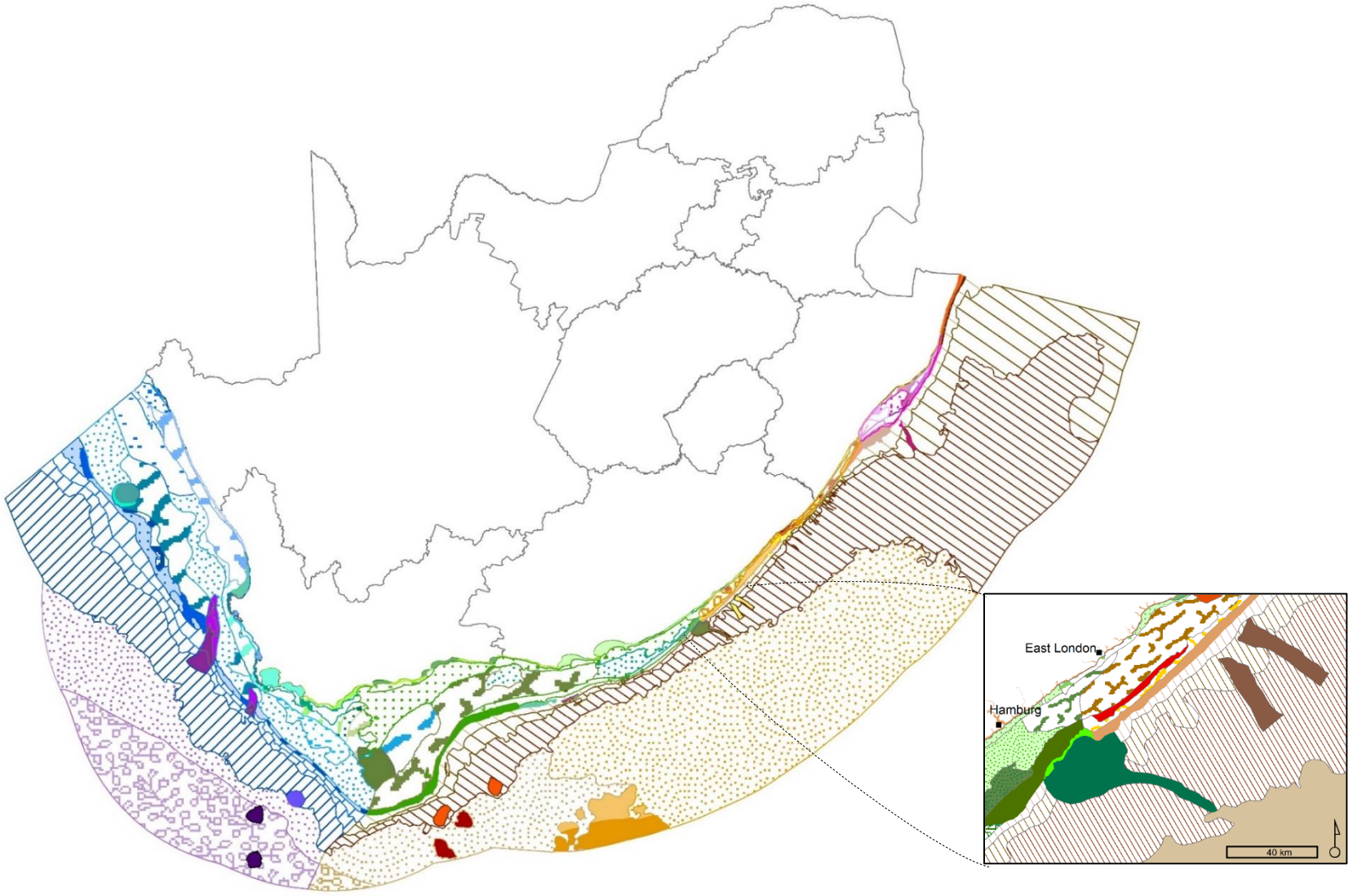


Figure 19. Map of the 150 Marine Ecosystem Types as classified during the 2018 National Biodiversity Assessment (see key below). The insert shows the boundary between the Agulhas (green colours) and Natal ecoregions (warm colours). The newly mapped Gxulu canyon (dark green), Amathole Lace Corals (red) and the Kwelera and Kei Canyons (brown) are visible. Key


Agulhas Basin Abyss
Agulhas Basin Complex Abyss
Agulhas Blues
Agulhas Boulder Shore
Agulhas Coarse Sediment Shelf Edge
Agulhas Dissipative-Intermediate Sandy Shore
Agulhas Dissipative Sandy Shore
Agulhas Exposed Rocky Shore
Agulhas Exposed Stromatolite Rocky Shore
Agulhas Inner Shelf Mosaic
Agulhas Inner Shelf Reef
Agulhas Intermediate Sandy Shore
Aghulhas Island
Agulhas Kelp Forest
Agulhas Lower Canyon
Agulhas Mid Shelf Mosaic
Agulhas Mid Shelf Reef Complex
Agulhas Mixed Shore
Agulhas Muddy Mid Shelf
Agulhas Muddy Outer Shelf
Agulhas Outer Shelf Reef Sand Mosaic
Agulhas Plateau
Agulhas Plateau Mosaic
Agulhas Reflective Sandy Shore
Agulhas Rocky Outer Shelf
Agulhas Rocky Plateau
Agulhas Sandy Inner Shelf
Agulhas Sandy Mid Shelf
Agulhas Sandy Outer Shelf
Agulhas Sheltered Rocky Shore
Agulhas Stromatolite Mixed Shore
Agulhas Upper Canyon
Agulhas Very Exposed Rocky Shore
Agulhas Very Exposed Stromatolite Rocky Shore
Aliwal Shoal Reef Complex
Alphard Bank
Amathole Hard Shelf Edge
Amathole Lace Corals
Browns Bank Rocky Shelf Edge
Cape Bay
Cape Basin Abyss
Cape Basin Complex Abyss
Cape Boulder Shore
Cape Exposed Rocky Shore
Cape Island
Cape Kelp Forest
Cape Lower Canyon
Cape Mixed Shore
Cape Rocky Inner Shelf
Cape Rocky Mid Shelf Mosaic
Cape Sandy Inner Shelf
Cape Sheltered Rocky Shore
Cape Upper Canyon
Cape Very Exposed Rocky Shore
Central Agulhas Outer Shelf Mosaic
Childs Bank Coral
Childs Bank Plateau
Delagoa Deep Shelf Edge
Delagoa Lower Canyon
Delagoa Lower Canyon
Delagoa Mixed Shore
Delagoa Rocky Mid Shelf
Delagoa Sandy Inner Shelf
Delagoa Sandy Mid Shelf
Delagoa Shelf Edge
Delagoa Upper Canyon
Delagoa Very Exposed Rocky Shore
Dumford Mid Shelf Reef Complex
Dumford Inner Shelf Reef Complex
Eastern Agulhas Bay
Eastern Agulhas Outer Shelf Mosaic
False and Walker Bay
Kei Fluvial Fan
Kei Reef Mosaic
Kingklip Koppies
Kingklip Ridge
Kosi Coral Community
KZN Bight Deep Shelf Edge
KZN Bight Mid Shelf Mosaic
KZN Bight Mid Shelf Reef Complex
KZN Bight Muddy Inner Shelf
KZN Bight Muddy Shelf Edge
KZN Bight Outer Shelf Mosaic
KZN Bight Sandy Inner Shelf
Leadsman Coral Community
Namaqua Exposed Rocky Shore
Namaqua Kelp Forest
Namaqua Mid Shelf Fossils
Namaqua Mixed Shore
Namaqua Muddy Sands
Namaqua Muddy Mid Shelf Mosaic
Namaqua Sandy Inner Shelf
Namaqua Sandy Mid Shelf
Namaqua Sandy Middle Shelf
Namaqua Sheltered Rocky Shore
Namaqua Very Exposed Rocky Shore
Natal Boulder Shore
Natal Deep Shelf Edge
Natal Delagoa Dissipative Intermediate Sandy Shore
Natal Delagoa Intermediate Sandy Shore
Natal Delagoa Dissipative Sandy Shore
Natal Delagoa Reflective Sandy Shore
Natal Exposed Rocky Shore
Natal Lower Canyon
Natal Mixed Shore
Natal Upper Canyon
Natal Very Exposed Rocky Shore
Orange Cone Inner Shelf Mud Reef Mosaic
Orange Cone Muddy Mid Shelf
Port St Johns Inner Shelf Mosaic
Port St Johns Muddy Shelf Edge
Port St Johns Muddy Mid Shelf
Protea Mid Shelf Reef Complex
Sodwana Coral Community
Southeast Atlantic Lower Slope
Southeast Atlantic Mid Slope
Southeast Atlantic Seamount
Southeast Atlantic Slope Seamount
Southeast Atlantic Upper Slope
Southern Benguela Dissipative Sandy Shore
Southern Benguela Dissipative Intermediate Sandy Shore
Southern Benguela Intermediate Sandy Shore
Southern Benguela Muddy Outer Shelf Mosaic
Southern Benguela Muddy Shelf Edge
Southern Benguela Outer Shelf Mosaic
Southern Benguela Reflective Sandy Shore
Southern Benguela Rocky Shelf Edge
Southern Benguela Sandy Outer Shelf
Southern Benguela Sandy Shelf Edge
Southern Benguela Shelf Edge Mosaic
Southern KZN Inner Shelf Mosaic
Southern KZN Mid Shelf Mosaic
Southern KZN Shelf Edge Mosaic
Southwest Indian Lower Slope
Southwest Indian Mid Slope
Southwest Indian Seamount
Southwest Indian Slope Seamount
Southwest Indian Upper Slope
St Helena Bay
St Lucia Mid Shelf Mosaic
St Lucia Sandy Inner Shelf
St Lucia Sandy Mid Shelf
Transkei Basin Abyss
Trafalgar Reef Complex
uThukela Canyon
uThukela Mid Shelf Mosaic
uThukela Mid Shelf Mud Coarse Sediment Mosaic
uThukela Outer Shelf Muddy Reef Mosaic
Western Agulhas Bays
Wild Coast Mid Shelf Mosaic
Wild Coast Inner Shelf Mosaic
Wild Coast Shelf Edge Mosaic

Table 9. An overview of the 150 marine ecosystem types included in the NBA 2018. A brief description, the total extent as calculated in ArcMap 10.4 using Albers Equal Area projection. The total number of polygons per type (n) is shown.

Ecosystem Type	Description	Polygons	Size (km2)
Agulhas Basin Abyss	Abyssal ecosystem in Agulhas Basin, depth of -3500 m to -6000 m.	1	56942,81
Agulhas Basin Complex Abyss	Abyssal ecosystem with hard substrate in Agulhas Basin. Extends to -5200 m.	1	3747,72
Agulhas Blues	Mosaic seafloor composed of sand and rocky outcrops and associated water column on the outer shelf (-100m and -150 m) in the Agulhas ecoregion. Unique pelagic feature where Agulhas current water is bounded by cold ridge feature. Both inshore and offshore trawlers target this feature.	1	8379,65
Agulhas Boulder Shore	Shore type characterised by boulders in the Agulhas ecoregion.	39	1,64
Agulhas Coarse Sediment Shelf Edge	Coarse sediment seafloor and associated pelagic habitat on shelf edge in the Agulhas ecoregion. High current environment -150 to -500 m.	2	3990,51
Agulhas Dissipative Intermediate Sandy Shore	Fine grained, sloping sandy shore with moderately wide beach and surf zone in the Agulhas ecoregion.	206	116,45
Agulhas Dissipative Sandy Shore	Fine-grained wide gently sloping sandy beach in the Agulhas ecoregion with a wide surf zone.	40	25,15
Agulhas Exposed Rocky Shore	Rocky shore type in the Agulhas ecoregion exposed to moderate wave intensity.	563	89,52
Agulhas Exposed Stromatolite Rocky Shore	Rocky shore with structures formed by lithified cyanobacteria in the Agulhas ecoregion, exposed to moderate wave intensity.	39	8,30
Agulhas Inner Shelf Mosaic	Mosaic seafloor and associated water column on the inner shelf in the Agulhas ecoregion. Extends from the back of the surf zone to fair weather wave base at -40 m.	26	1853,60
Agulhas Inner Shelf Reef	Stable high-profile reef on the inner shelf in the Agulhas ecoregion such as Grootbank off Natures Valley and shallow reef in Tsitsikamma.	36	17,68
Agulhas Intermediate Sandy Shore	Beach with medium grain size and moderate slope in the Agulhas ecoregion. Often with cusps on the shore and sandbars and rips in the surf.	60	14,45
Agulhas Island	Island and offshore area extending to the back of the surfzone in the Agulhas ecoregion. Includes Bird, St Croix and Jaheel Islands and Seal Island in Mossel Bay.	10	6,45
Agulhas Kelp Forest	Kelp forest in the Agulhas ecoregion as mapped from Sentinel 2 satellite imagery. Agulhas kelp forests are more grazer dominated and more diverse than those in the Southern Benguela.	1107	12,27
Agulhas Lower Canyon	Slope component of canyons in the Southwest Indian ecoregion extending below -500 m.	8	1152,52
Agulhas Mid Shelf Mosaic	Mosaic reef and sand seafloor and associated water column in -40 to -100 m on the mid shelf in the Agulhas ecoregion.	4	3632,56
Agulhas Mid Shelf Reef	Reef and associated water column on the mid shelf in the Agulhas ecoregion (-40 to -100 m).	7	51,87
Agulhas Mixed Shore	A shore with both rocky and sandy habitat in the Agulhas ecoregion.	766	188,08
Agulhas Muddy Mid Shelf	Muddy seafloor and associated turbid pelagic habitat in the Agulhas ecoregion (-40 to -100 m). This ecosystem includes the East Coast sole grounds.	2	1732,35
Agulhas Muddy Outer Shelf	Muddy seafloor and water column above on the outer shelf in the Agulhas ecoregion (- 100 to - 150 m).	1	1278,05
Agulhas Plateau	Unknown seabed type on the Agulhas plateau (-1500 to - 3500 m).	4	5469,13
Agulhas Reflective Sandy Shore	Steep sloped, narrow, coarse-grained beach with a narrow surf zone within the Agulhas ecoregion.	18	0,87
Agulhas Rocky Outer Shelf	Rocky seafloor and associated water column on the outer shelf in the Agulhas ecoregion (-100 to -150 m). Includes two prominent features that rise from -80 m to -50 m known as the Agulhas Arch anti-clines.	1	4214,82
Agulhas Rocky Plateau	Complex seabed habitat with hard substrate on the plateau between -1500 m to - 3500 m.	**2**	8592,86
Agulhas Rocky Shelf Edge	Rocky seafloor approximately -200 to -500 m (depending on shelf break depth) and associated water column on the shelf edge in the Agulhas ecoregion.	1	5232,98
Agulhas Sandy Inner Shelf	Sandy seafloor and associated water column on the inner shelf in the Agulhas ecoregion extending from the back of the surf zone to the fair weather wave base (approximately -40 m).	6	521,55

Ecosystem Type	Description	Polygons	Size (km2)
Agulhas Sandy Mid Shelf	Sandy seafloor and associated water column on the mid shelf in the Agulhas ecoregion (-40 to -100 m).	2	20233,09
Agulhas Sandy Outer Shelf	Sandy seafloor and associated pelagic habitat on the outer shelf in the Agulhas ecoregion (-100 to -150 m).	2	7058,51
Agulhas Sheltered Rocky Shore	Rocky shore type in the Agulhas ecoregion that is sheltered from high wave intensity.	34	1,32
Agulhas Stromatolite Mixed Shore	A shore with both rocky and sandy habitat with lithified cyanobacteria structures in the Agulhas ecoregion.	41	8,36
Agulhas Upper Canyon	Shelf-indenting component of canyons in the Agulhas ecoregion. Closely coupled benthic and pelagic habitats are a key feature of this ecosystem type.	5	101,99
Agulhas Very Exposed Rocky Shore	Rocky shore type in the Agulhas ecoregion that is exposed to high wave intensity.	62	9,07
Agulhas Very Exposed Stromatolite Rocky Shore	Rare rocky shore type with structures formed by lithified cyanobacteria in the Agulhas ecoregion, exposed to high wave intensity.	7	1,27
Aliwal Shoal Reef Complex	A 3 km long by 380 m wide major shallow reef on an aeolianite ridge on the inner shelf in the Natal ecoregion. Reef rises from -30 m to just 6 m below sea level. Algal dominated (brown and corallines) with soft and hard corals and sponges.	7	5,22
Alphard Bank	Rocky volcanic pinnacle in the Agulhas ecoregion rising from -80 to -14 m. Unique topography with kelp and cold-water corals. Fish and turtle aggregation area.	1	31,86
Amathole Hard Shelf Edge	Hard seafloor and coupled pelagic habitat on the steep shelf edge (-200 to -500 m) in the Amathole region of the Agulhas ecoregion. This ecosystem type is characterised by many octocorals (particularly *Anthomastis giganteus*), South Coast Rock Lobster and Windtoy *Spicara australis*. Water temperatures are cooler than adjacent areas to the north.	1	468,74
Amathole Lace Corals	Lace coral gardens in -80 to -200 m on the shelf edge in the Amathole region of the Natal ecoregion. This ecosystem type is influenced by the strong flow of the Agulhas current and water is warmer and clearer than the adjacent Amathole hard shelf edge. *Anthomastus giganteus* is absent.	1	131,64
Browns Bank Rocky Shelf Edge	Mosaic seafloor and associated pelagic habitat on the shelf edge of Browns Bank in the Southern Benguela ecoregion. Ecosystem type spans -350 to -500 m on the western edge of the Agulhas Bank and is within a zone of mixing between ecoregions.	**1**	2164,06
Cape Basin Abyss	Abyssal ecosystem in the Cape Basin, -3500 to -4600 m.	1	57854,97
Cape Basin Complex Abyss	Abyssal ecosystem with hard substrate in the Southeast Atlantic ecoregion. Depth < -5000 m.	1	73071,65
Cape Bay	Bays on the West Coast including Table Bay and Saldana Bay extending from the back of the surf zone to the outer edge of embayment at a depth of about -50 m. Unaffected by seasonal low oxygen.	2	254,37
Cape Boulder Shore	Shore type characterised by large boulders in the Cape ecoregion.	41	2,62
Cape Exposed Rocky Shore	Rocky shore type in the Cape region of the Southern Benguela ecoregion. Exposed to moderate wave intensity.	188	28,88
Cape Island	Island shore extending to the back of the surf zone in the Cape subregion of the Southern Benguela. Includes Robben Island and Dassen Island.	48	2,95
Cape Kelp Forest	Kelp forest in the Cape ecoregion as mapped from Sentinel 2 satellite imagery. Extends from Cape Point to south of Doringbaai.	989	9,78
Cape Lower Canyon	Lower canyon component (-500 m) in slope adjacent to the Southern Benguela ecoregion.	4	2838,08
Cape Mixed Shore	A shore with both rocky and sandy habitat in the Cape subregion of the Southern Benguela ecoregion.	303	33,74
Cape Rocky Inner Shelf	Rocky seafloor and associated water column on the inner shelf in the Cape ecoregion extending from the back of the surf zone to the fair weather wave base (approximately -50 m).	9	473,61
Cape Rocky Mid Shelf Mosaic	Mosaic seafloor habitat on the mid shelf (-50 to -150 m) in the in the Cape subregion of the Southern Benguela ecoregion.	1	3904,95
Cape Sandy Inner Shelf	Sandy seafloor habitat in the Cape ecoregion extending from the back of the surf zone to the fair weather wave base (approximately -50 m).	2	526,20
Cape Sheltered Rocky Shore	Rocky shore exposed to low wave intensity in the Cape subregion of the Southern Benguela ecoregion.	27	1,48
Cape Upper Canyon	Shelf-indenting component of the canyons in the Southern Benguela ecoregion.	4	2394,82

Ecosystem Type	Description	Polygons	Size (km2)
Cape Very Exposed Rocky Shore	Rocky shore exposed to high wave intensity in the Cape subregion of the Southern Benguela.	5	0,52
Central Agulhas Outer Shelf Mosaic	Mosaic seafloor (gravel, coarse and fine sand with some rock outcrops and associated water column in -100 to -150 m on the central Agulhas Bank.	1	2452,94
Childs Bank Coral	Steep rocky seafloor with cold water coral communities on a unique submarine feature (possible carbonate mound) in the Southern Benguela ecoregion.	1	505,48
Childs Bank Plateau	Relatively flat sandy top or sandy slope of a unique submarine feature (possible carbonate mound) known as Childs Bank off Hondeklipbaai in the Southern Benguela ecoregion (-180 to -250 m).	1	1620,28
Delagoa Deep Shelf Edge	Unknown seabed type and associated high current shelf edge in the Delagoa ecoregion (-200 to -500 m).	4	605,36
Delagoa Lower Canyon	Slope component of canyons that incise or are adjacent to the Delagoa ecoregion.	14	33,63
Delagoa Mixed Shore	A shore with both rocky and sandy habitat in the Delagoa ecoregion.	41	28,72
Delagoa Rocky Mid Shelf	Deep reef complex in -33 to -80 m on the mid shelf in the Delagoa ecoregion. Suspension feeders and algae dominate in the shallower portion.	291	22,99
Delagoa Sandy Inner Shelf	Sandy seafloor and associated pelagic habitat on the inner shelf of the Delagoa ecoregion extending from the back of the surf zone to the fair weather wave base (approximately -33 m).	136	172,70
Delagoa Sandy Mid Shelf	Sandy seafloor and associated water column on the mid shelf in the Delagoa ecoregion (-33 to -80 m).	32	274,20
Delagoa Shelf Edge	Unknown seabed type (probably sandy) and associated high currents -80 to -200 m on the shelf edge of the narrow shelf of the Delagoa ecoregion.	6	189,79
Delagoa Upper Canyon	Shelf indenting component of the canyons incising the shelf edge of the Delagoa ecoregion (-80 to -500 m).	27	13,60
Delagoa Very Exposed Rocky Shore	Rocky shore type in the Delagoa ecoregion exposed to high wave intensity.	1	0,27
Durnford Inner Shelf Reef Complex	Reef complex on the inner shelf in the warm, turbid KZN Bight subregion (-7 to -30 m).	1	460,54
Durnford Mid Shelf Reef Complex	Durnford reef complex in high turbidity mid shelf of the KZN Bight (-30 to -80 m).	1	431,84
Eastern Agulhas Bay	Eastern bays (Cape St Francis and Algoa Bay) of the Agulhas ecoregion (with narrow shelf) from the back of surf zone to outer edge of embayment which ranges between -50 to -70 m.	4	1631,19
Eastern Agulhas Outer Shelf Mosaic	Mosaic seafloor (reef, coarse sediment and some mud) and associated water column in -100 to -150 m on the current-influenced Eastern Agulhas Bank.	1	25966,23
False and Walker Bay	False Bay and Walker Bay extend from the back of the surf zone to the outer edge of embayment, a maximum depth of -80 m. These bays are in the Agulhas ecoregion.	11	1681,23
Kei Fluvial Fan	The shallow river-influenced fluvial fan off the Kei river mouth. Mixed substrate beyond the surf zone and extending to the fair weather wave base (approximately -40 m).	1	49,02
Kei Reef Mosaic	High profile reef complex with coarse sediment, rhodoliths and gravel off the Kei River on the mid shelf in the southern part of the Natal ecoregion.	1	93,69
Kingklip Koppies	A series of small, rocky hills in -300 to - 500 m in the Agulhas ecoregion. This area is part of the kingklip grounds and spawning aggregation area. Sensitive ecosystem characterised by stony and lace coral.	1	642,86
Kingklip Ridge	Unique 40 km long ridge feature on the upper slope in the Southwest Indian Deep Ocean ecoregion. Rises from -700 m to -350 m. Ridge higher in the northeast.	1	103,59
Kosi Coral Community	Subtropical coral communities on fossilised dune rock in -6 to -33 m forming the northern reef complex in the Delagoa ecoregion.	117	8,04
KZN Bight Deep Shelf Edge	Unknown seabed type on the shelf edge (-300 to -500 m) in the KZN Bight. Muddy in places and dependent on fluvial inputs.	1	1761,23
KZN Bight Mid Shelf Mosaic	Mosaic (reef, sand to coarse sand and some muddy areas that provide substrate for specific infaunal tube-builders) and associated current influenced pelagic habitat in -30 to -80 m on the mid shelf in the KZN Bight.	5	534,67
KZN Bight Mid Shelf Reef Complex	Deep reef complex (-30 to -80 m) of the mid shelf of the KZN Bight region. Less turbid than Durnford Mid Shelf Reef Complex.	132	22,99

Ecosystem Type	Description	Polygons	Size (km2)
KZN Bight Muddy Inner Shelf	Muddy seafloor and associated turbid water column on the inner shelf, (back of surf to approximately -30 m) in the KZN Bight.	1	328,75
KZN Bight Muddy Shelf Edge	Deep muddy seafloor and associated pelagic habitat on the productive shelf edge in the KZN Bight (-200 to -300 m).	1	515,73
KZN Bight Outer Shelf Mosaic	Mosaic of reef and coarse sand and associated warm current influenced pelagic habitat in -80 to -200 m on the outer shelf of the KZN Bight.	2	655,79
KZN Bight Sandy Inner Shelf	Sandy seafloor habitat in -7 to -30 m with associated turbid river influenced pelagic habitat on the inner shelf of the KZN Bight.	2	145,87
Leadsman Coral Community	Subtropical coral communities on fossilised dune rock in -6 to -33 m, forming the southern reef complex in the Delagoa ecoregion.	74	12,49
Namaqua Exposed Rocky Shore	Rocky shore type exposed to moderate wave intensity in the Namaqua subregion of the Southern Benguela Shelf Ecoregion.	340	42,49
Namaqua Kelp Forest	Kelp Forest in the Namaqua subregion (north of Doringbaai and extending into Namibia) as mapped from satellite imagery.	1028	7,36
Namaqua Mid Shelf Fossils	Rocky outcrops and associated highly productive pelagic habitat in -50 to -150 m on the mid shelf in the Namaqua ecoregion.	151	20,07
Namaqua Mixed Shore	A shore with both rocky and sandy habitat in the Namaqua subregion of the Southern Benguela.	461	60,66
Namaqua Muddy Mid Shelf Mosaic	Mosaic muddy and rocky seafloor in the highly productive zone (-50 to -150 m) on the mid shelf in the Namaqua ecoregion.	31	11762,51
Namaqua Muddy Sands	River influenced muddy sand and associated turbid, productive pelagic habitat in the northern outer shelf (-150 to -350 m) of the Southern Benguela ecoregion.	1	12168,95
Namaqua Sandy Inner Shelf	Sandy seafloor habitat on the inner shelf (extending from the back of the surf zone to -50 m) on inner shelf in the Namaqua subregion of the Southern Benguela Shelf ecoregion.	2	760,25
Namaqua Sandy Mid Shelf	Sandy seafloor and associated productive pelagic habitat in -50 to -150 m on the mid shelf in the in the Namaqua subregion of the Southern Benguela Shelf Ecoregion.	3	2853,16
Namaqua Sheltered Rocky Shore	Rocky shore type exposed to low wave energy in the Namaqua subregion of the Southern Benguela Shelf Ecoregion.	31	1,20
Namaqua Very Exposed Rocky Shore	Rocky shore type exposed to high wave intensity in the Namaqua subregion of the Southern Benguela Shelf Ecoregion.	24	3,15
Natal Boulder Shore	Shore type dominated by large boulders in the Natal ecoregion.	7	0,27
Natal Deep Shelf Edge	Unknown seafloor habitat on the shelf edge of the southern part of the Natal ecoregion extending approximately between -200 and -500 m, between Durban and East London.	8	1377,22
Natal Delagoa Dissipative Intermediate Sandy Shore	Fine grained, sloping sandy shore with moderately wide beach and surf zone width in the Natal-Delagoa Province (ecoregion).	100	32,85
Natal Delagoa Dissipative Sandy Shore	Fine-grained, flat sandy beach in the Natal-Delagoa Province (ecoregion) with a wide intertidal and surf zone where the wave energy is dissipated on the shore.	4	0,71
Natal Delagoa Intermediate Sandy Shore	Beach with medium grain size and moderate slope in the Natal-Delagoa Province (ecoregion). Often with cusps on the shore and sandbars and rips in the surf.	188	52,12
Natal Delagoa Reflective Sandy Shore	Steep sloped, coarse-grained sandy shore with a narrow surf zone within the Natal-Delagoa Province (ecoregion).	39	9,44
Natal Exposed Rocky Shore	Rocky shore type in the Natal ecoregion exposed to moderate wave intensity.	214	31,48
Natal Lower Canyon	Slope components of canyons in the southwest Indian ecoregion adjacent to the Natal ecoregion.	48	1481,39
Natal Mixed Shore	A shore with both rocky and sandy habitat in the Natal ecoregion.	397	69,52
Natal Upper Canyon	Shelf indenting component of canyons incising the shelf edge in the Natal ecoregion.	10	83,05
Natal Very Exposed Rocky Shore	Rocky shore type in the Natal ecoregion exposed to high wave intensity.	7	0,96
Orange Cone Inner Shelf Mud Reef Mosaic	River influenced mosaic seafloor habitat (mostly muddy) on the inner shelf (extending from the back of the surf zone to 50 m in depth) in the Namaqua ecoregion.	1	511,02
Orange Cone Muddy Mid Shelf	River-influenced muddy seafloor and associated highly turbid pelagic habitat in -50 to -150 m on the mid shelf in the Namaqua subregion of the Southern Benguela.	1	1925,36

Ecosystem Type	Description	Polygons	Size (km2)
Port St Johns Inner Shelf Mosaic	Mosaic rocky, sandy and muddy seafloor habitat on the inner shelf (to approximately -30 m) in the area between the Mbotyi and Mngazi Rivers in the Pondoland subregion of the Natal ecoregion. Dominated by suspension feeders).	1	48,54
Port St Johns Muddy Mid Shelf	Muddy seafloor and associated turbid pelagic habitat off the Mzimvubu River in -30 to -80 m one in the mid shelf of the Port St Johns area in the Natal ecoregion.	1	124,79
Port St Johns Muddy Shelf Edge	Muddy seafloor and associated turbid habitat in the -80 to - 200 m on the shelf edge offshore of the area between Mbotyi and Mngazi in the Pondoland subregion of the Natal ecoregion.	1	129,38
Protea Mid Shelf Reef Complex	Protea Banks reef complex in -30 to - 80 m on the mid shelf on the KZN South Coast.	2	15,54
Sodwana Coral Community	Subtropical coral communities on fossilised dune rock in 6 - 33 m forming the central reef complex (Jesser Point to south of Rabbit Reef) in the Delagoa ecoregion.	88	5,96
Southeast Atlantic Lower Slope	Unknown seabed type on the lower slope of Southeast Atlantic with a depth range of -1800 to -3500 m.	1	86412,91
Southeast Atlantic Mid Slope	Unknown seabed type on the mid slope in the Southeast Atlantic ecoregion, -1000 to -1800 m.	2	18140,11
Southeast Atlantic Seamount	Seamount arising from the Southeast Atlantic abyss (includes Protea and Argentina Seamounts).	2	1576,25
Southeast Atlantic Slope Seamount	Seamount arising from the Southeast Atlantic slope. Includes an officially un-named seamount we refer to as "Mount Marek".	1	887,91
Southeast Atlantic Upper Slope	Unknown seabed type and associated water column on the upper slope (-500 to -1000 m) in the Southeast Atlantic ecoregion.	3	15242,09
Southern Benguela Dissipative Intermediate Sandy Shore	Fine grained, sloping sandy shore with moderately wide beach and surf zone width in the Southern-Benguela ecoregion.	73	51,47
Southern Benguela Dissipative Sandy Shore	Fine-grained sandy beach in the Southern Benguela ecoregion with a wide surf zone where the wave energy is dissipated on the shore.	27	26,18
Southern Benguela Intermediate Sandy Shore	Beach with medium grain size and moderate slope in the in the Southern Benguela ecoregion. Often with cusps on the shore and sandbars and rips in the surf.	105	32,34
Southern Benguela Muddy Outer Shelf Mosaic	Mosaic muddy and rocky seafloor and associated pelagic habitat on the outer shelf of the western Agulhas Bank in the Southern Benguela ecoregion.	1	5574,43
Southern Benguela Muddy Shelf Edge	Muddy seafloor and associated pelagic habitat on the shelf edge (-350 - 500 m) in the Southern Benguela ecoregion.	2	814,04
Southern Benguela Outer Shelf Mosaic	Sandy and rocky seafloor and associated pelagic habitat on the outer shelf (-150 to - 350 m) of the West Coast.	3	19508,71
Southern Benguela Reflective Sandy Shore	Steep sloped, coarse-grained sandy shore with a narrow surf zone within the Southern Benguela ecoregion.	81	10,54
Southern Benguela Rocky Shelf Edge	Rocky seafloor and coupled pelagic habitat on the shelf edge (-350 to -500 m) depth in the Southern Benguela ecoregion. Occurs off the Orange River and north of Cape Canyon.	3	2380,69
Southern Benguela Sandy Outer Shelf	Sandy seafloor and associated highly productive benthic and pelagic habitat on the outer shelf in the Southern Benguela ecoregion.	3	36057,07
Southern Benguela Sandy Shelf Edge	Sandy seafloor and associated productive water column on the shelf edge (-350 to -500 m) in the Southern Benguela ecoregion.	3	7397,87
Southern Benguela Shelf Edge Mosaic	Rocky mosaic seafloor and associated productive pelagic habitat in - on the shelf edge (-350 to -500 m) in the Southern Benguela ecoregion.	1	2181,79
Southern KZN Inner Shelf Mosaic	Mosaic reef and coarse sandy seabed with high current and warm clear water on the shelf edge between Durban and Port Edward in the Natal ecoregion.	8	258,87
Southern KZN Mid Shelf Mosaic	Mosaic seafloor (rocky and sandy) and moderate turbidity warm pelagic habitat on the inner shelf (approximately -7 to -30 m) between Durban and Port Edward in the Natal Shelf ecoregion.	10	989,63
Southern KZN Shelf Edge Mosaic	Current swept mosaic seafloor comprised of rocky and coarse to very coarse sand, -30 to -80 m, between Durban and Port Edward in the Natal Shelf ecoregion.	4	669,56
Southwest Indian Lower Slope	Unclassified seabed, -1800 to -3500 m in the Southwest Indian Deep Ocean ecoregion.	2	197988,13

Ecosystem Type	Description	Polygons	Size (km2)
Southwest Indian Mid Slope	Unclassified seabed, -1000 to -1800 m in the Southwest Indian Deep Ocean ecoregion.	20	78270,72
Southwest Indian Seamount	Seamount rising from the Southwest Indian abyss (deeper than 3500 m). Includes Natal and Shackleton Seamount.	2	2072,41
Southwest Indian Slope Seamount	Seamount rising from the Southwest Indian slope (-1000 to -3500 m) Includes, Mallory and Davie Seamounts.	2	1614,36
Southwest Indian Upper Slope	Unclassified seabed, -500 to -1000 m in the Southwest Indian Deep Ocean ecoregion.	14	17527,17
St Helena Bay	St Helena Bay in the Cape ecoregion, extending from back of surf zone to outer edge of embayment (approximately -50 m). This bay is characterised by lower oxygen than other bays.	4	980,82
St Lucia Mid Shelf Mosaic	Mosaic seafloor habitat (reef and sand) on the mid shelf (-30 to -80 m) in the Delagoa ecoregion. Transition area between Durnford and KZN Bight with localised upwelling and deep *Ecklonia radiata* kelps.	2	4,76
St Lucia Sandy Inner Shelf	Sandy seafloor and productive pelagic habitat, -7 to -30 m on the mid shelf in the area between Nhlabane and Cape Vidal in the Natal ecoregion. Influenced by the St Lucia upwelling cell.	1	119,96
St Lucia Sandy Mid Shelf	Sandy seafloor and productive pelagic habitat in -30 to - 80 m on the mid shelf in the area between Mtunzini and Cape Vidal in the Natal ecoregion. Influenced by the St Lucia upwelling cell.	1	646,80
Trafalgar Reef Complex	Algal dominated photic reef in the Natal ecoregion. Red and green algae are dominant in this ecosystem type.	1	58,71
Transkei Basin Abyss	Unknown abyssal seabed type in the Transkei Basin spanning from -3500 m to approximately -4500 m in depth.	1	210710,40
uThukela Canyon	Deep canyon (deeper than -500 m) in the slope of the Southwest Indian ecoregion.	2	417,81
uThukela Mid Shelf Mosaic	Mosaic of coarse sand and reef and associated river influenced pelagic water column on the mid shelf (-30 to -80 m) in the KZN Bight region.	1	789,36
uThukela Mid Shelf Mud Coarse Sediment Mosaic	Mosaic mud and gravel seafloor and associated turbid water column on the mid shelf (-30 to -80 m) in the KZN Bight region.	1	1348,70
uThukela Outer Shelf Muddy Reef Mosaic	Mosaic muddy seafloor and associated turbid water with low profile reef outcrops in -80 to -200 m on the outer shelf of the KZN Bight.	1	531,75
Western Agulhas Bay	Western bays (St Sebastian, Vleesbaai, Mosselbay and Plettenberg Bay) of the Agulhas ecoregion from back of surf zone to outer edge of embayment which ranges between -40 and -70 m.	4	819,73
Western Agulhas Outer Shelf Mosaic	Mosaic seafloor (reef and sand) and associated warm temperate pelagic habitat in -100 to -150 m depth range in the Agulhas ecoregion. Extends from offshore of False Bay to offshore of Danger Point.	1	2786,45
Wild Coast Inner Shelf Mosaic	Mosaic seafloor and associated warm, moderate visibility pelagic habitat in -7 to -30 m depth zone on the inner shelf from Mbashe to Mngazi and from Mbotyi to Port Edward and in the Natal Shelf ecoregion. (Celliers *et al.* algal dominated community C with articulated corallines).	2	253,03
Wild Coast Mid Shelf Mosaic	Mosaic seafloor and associated warm, moderate visibility pelagic habitat in -30 to -80/100m depth zone on the shelf from East London to Mngazi in the Natal Shelf ecoregion.	2	2385,89
Wild Coast Shelf Edge Mosaic	Mosaic seafloor and associated warm high current pelagic habitat in -100 to -300 m depth zone on the shelf edge from East London to Port St Johns in the Natal Shelf ecoregion.	1	1435,24

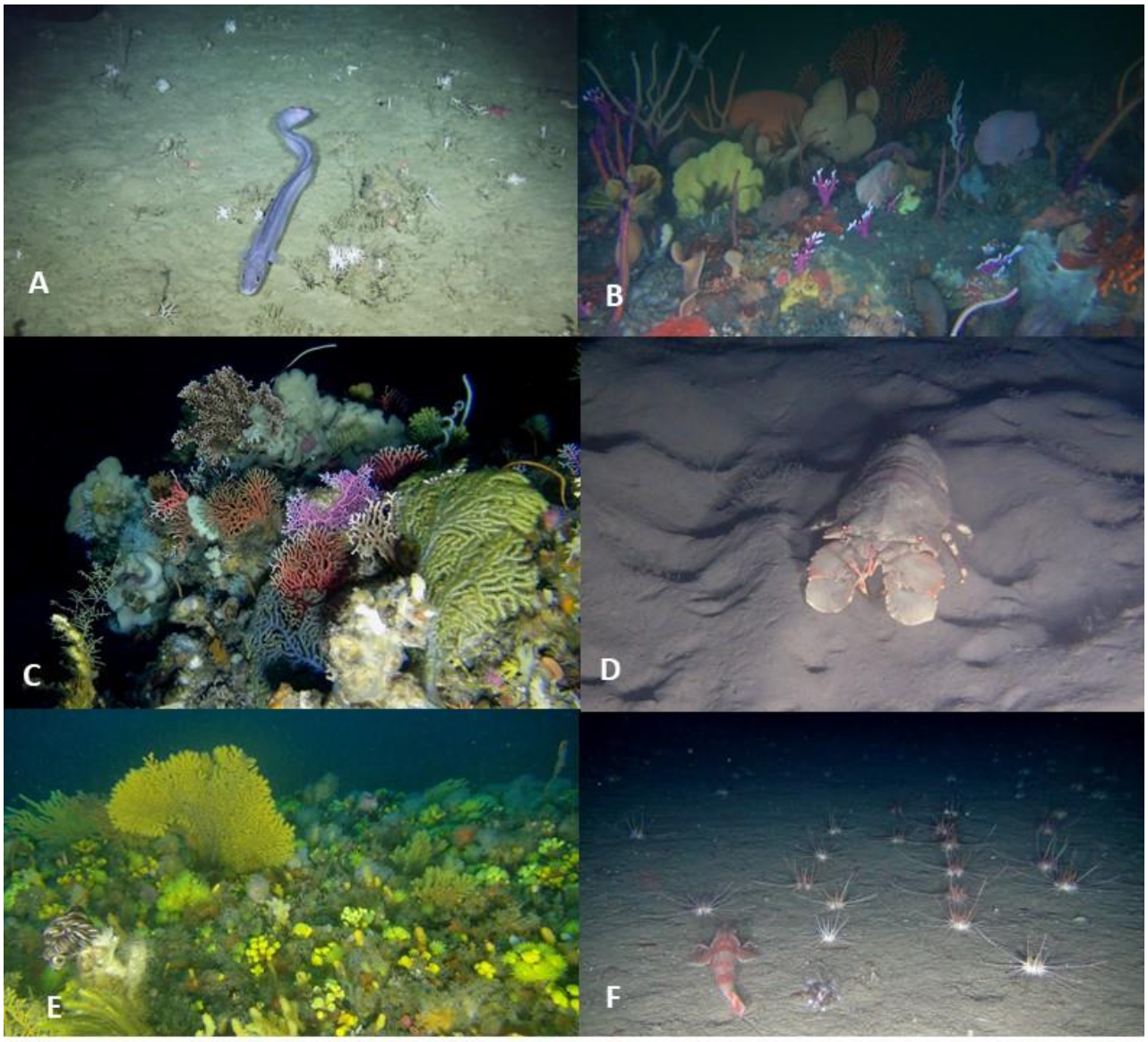


Figure 20. Plate showing a selection of marine ecosystem types. A .Southern Benguela Outer Shelf Mosaic (SAEON), B Eastern Agulhas Bay (ACEP), C. Amathole Lace Corals (ACEP), D. KZN Bight Muddy Shelf Edge (ACEP), E. Durnford Mid Shelf Reef Complex (ACEP) and F. KZN Bight Outer Shelf Mosaic (ACEP).

3.6 Overview of key elements in the marine ecosystem map

The main elements in the map include regional patterns, depth and seabed type, recognising that these incorporate multiple drivers of biodiversity pattern Annexure 3 It is challenging to distil this complexity into a neat hierarchy with many factors having multiple and interacting influences at different scales. The section below provides an overview of the main patterns that were used to partition South Africa's oceans into discrete ecosystem types for the purpose of ecosystem assessment. Regional patterns were applied at multiple levels of the classification to accommodate large-scale biogeographic patterns and finer scale regional patterns but are discussed together for ease of explanation.

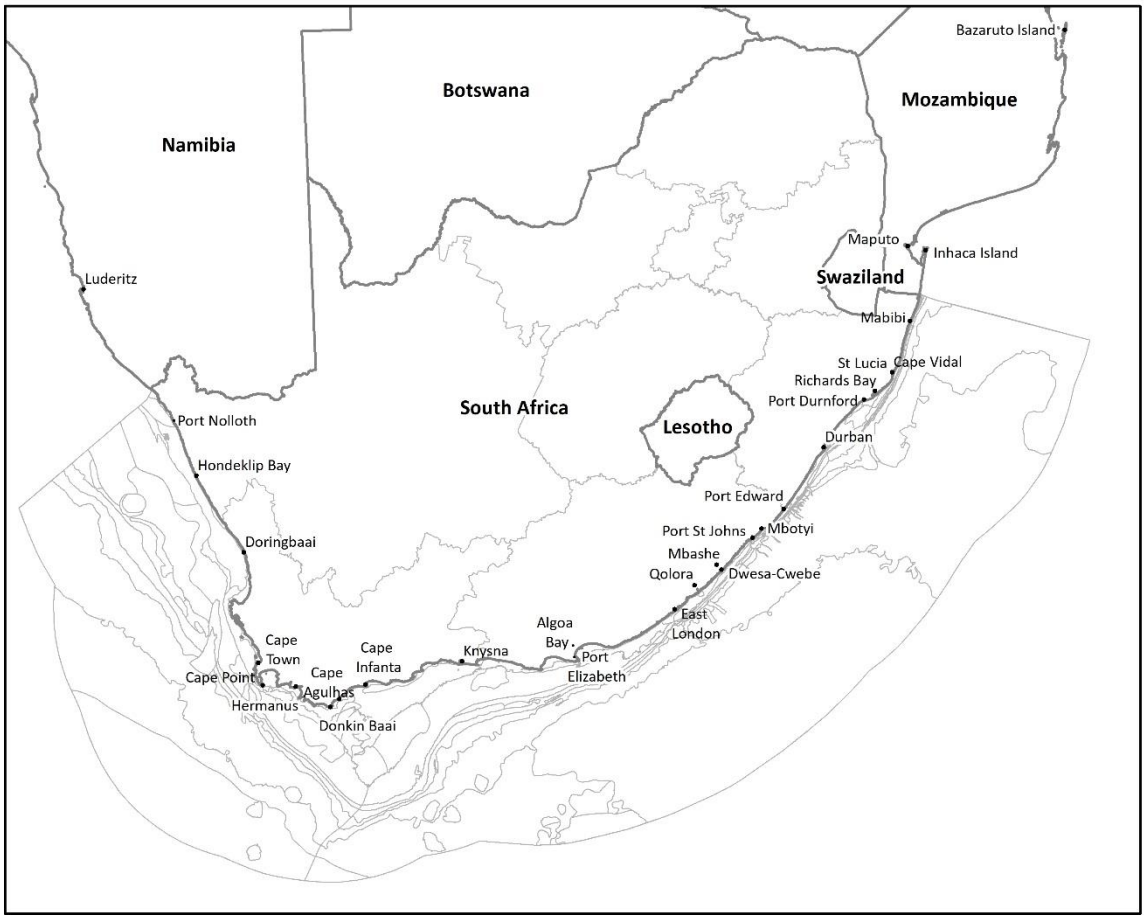


Figure 21. Coastal towns of Southern Africa mentioned in the review of biogeographic and other regional patterns references

3.6.1 Regional patterns

Achieving consensus in patterns of biogeographic regions, ecoregions and even regions is difficult for five reasons. Firstly, separate analyses of the distribution of different taxonomic groups and of species from different ecosystem types and habitats have yielded contrasting patterns, reflecting different species responses to environmental determinants. Secondly, there have been biases in sampling effort where some taxa or areas have been sampled more intensively and some areas or taxa are neglected. Thirdly, patterns are strongly influenced by the ocean depth sampled, with different processes operating at different spatial scales and different species turnover rates at different depths and in different types of ecosystems (e.g. intertidal versus subtidal). Fourthly, few studies cover the entire South African coastline or multiple ecoregions (Brown and Jarman 1978, Bustamante and Branch 1996a, Turpie *et al.* 2000). Lastly, there is a lack of consensus on defining critical terminology including biogeographic provinces, bioregions, ecoregions, overlap regions, subregions and in terms of pinpointing specific biogeographic breaks. Further work is needed to agree to criteria to define and delimit regional patterns. Despite the challenges in delimiting regional patterns, the MEC was able to agree on the broad patterns and key boundaries for ecoregions and subregions applicable to most groups of ecosystem types. Most place names referred to in the description of these patterns are shown in Figure 21. The 2018 Marine Ecosystem Map includes three levels of regional patterns from large-scale ecoregions to fine scale regional patterns

(subregions) with a fourth higher level (province) also recognised to accommodate beach biodiversity patterns.

Biogeographic provinces

Stephenson (1939, 1944, 1948) pioneered biogeographic research in South Africa and recognised three primary biogeographic provinces based on the distributions of intertidal species: (i) the **cool-temperate West Coast**; (ii) the **warm-temperate South Coast**, and (iii) the **subtropical East Coast** (Stephenson and Stephenson 1972). These three biogeographic provinces were also recognised by (Brown and Jarman 1978, Hockey and Buxton 1989, Emanuel *et al.* 1992, Stegenga and Bolton 1992, Hockey and Branch 1994, Bustamante and Branch 1996a, Hockey and Branch 1997, Turpie *et al.* 2000) for a variety of shelf organisms, but were often referred to by different names which has further complicated this topic. Estuarine fish distributions also reflect three provinces (Harrison 2002). Similarly sandy macrofauna and shorebird patterns reflect three major provinces (Hockey *et al.* 1983). A similar pattern is suggested for marine mammals despite their nomadic nature, as there are several small odontocetes confined to the West Coast (including Dusky and Heaviside's Dolphins) and some other species are confined to the East Coast (e.g. Indo-Pacific humpback dolphin) (Best and Folkens 2007).

Based on this and further considerations of the literature below, the Marine Ecosystem Committee for South Africa recognises a similar set of **three shelf biogeographic provinces** (with some modifications from those initially proposed by Stephenson and Stephenson (1972), which are termed the Southern Benguela (or western margin), the Agulhas (southern margin) and the Natal-Delagoa (eastern margin) Shelf Provinces. The boundaries between these three provinces are located at Cape Point in the Western Cape and at Mbashe in the Eastern Cape. These were not actually used in the marine ecosystem classification, which rather used the ecoregions described below as a starting point.

Although the concept of having boundaries between different marine provinces is rational for purposes of planning and biodiversity assessment, the idea of discrete marine provinces with clearly defined boundaries has been challenged for a variety of reasons and the concept of overlap or transition areas acknowledged. Many authors recognise **overlap regions** or transition zones between provinces, because biogeographic boundaries are challenging to pinpoint and may not necessarily show an abrupt change in nature. This is because available species data may indicate large sections of coast (>500 km) with few endemics, and even in comprehensive datasets, many species may have affinities with more than one province as not all species necessarily show similar patterns in their distributional ranges. This is further complicated by trying to reconcile spatial patterns of biodiversity from different ecosystem types, for example intertidal rocky versus sandy beach habitats.

Stephenson and Stephenson (1972) originally defined an area of overlap between what they called the cool temperate West Coast (Southern Benguela Shelf Province) and the warm temperate South Coast (Agulhas Shelf Province). This **western overlap** extends from Cape Point to Cape Agulhas with a rapid reduction of West Coast species between Hermanus and Arniston (Stephenson 1948). The recognition of this overlap region has been supported by further studies, particularly those looking at marine benthic flora (Jackelman *et al.* 1991, Stegenga and Bolton 1992) but also in recent work examining fish biodiversity (Solano-Fernandez *et al.* 2012). The MEC acknowledges this area of overlap and has incorporated this

western overlap area into the Agulhas Province because shores in this area are more similar to those on the far colder West Coast.

There is however less consensus regarding the eastern limit of the **Agulhas Shelf Province**, the existence or the position of an overlap region between it and the Natal-Delagoa Province, originally termed the subtropical East Coast province by (Stephenson and Stephenson 1972), and even the northern limit of the Natal-Delagoa Province. (Stephenson 1948) identified an eastern overlap area between East London and Durban, with a biogeographic break near Port St Johns. Stephenson and Stephenson (1972) considered the subtropical East Coast province to extend all the way from Port St Johns into Mozambique. Similarly, Turpie *et al.* (2000) reported that coastal fishes do not reflect a clear biogeographic break between the two regions, but show a gradual species turnover east of Cape Point.

Jackson (1976) however, proposed a marine province with a southern boundary between Port St Johns and Qolora in the Transkei and a northern boundary between Cape Vidal and Mabibi approximately 100 km south of the Mozambique border. Emanuel *et al.* (1992) however proposed that the division between the South Coast and East Coast was south of Port St Johns and recognised an additional break at Durban, similar to the location of the eastern extent of the overlap region transitioning between the original South and East Coast provinces identified by Stephenson (1948). Emanuel *et al.* (1992) also found no further biogeographic breaks north of Durban to at least as far as Ponta da Barra Falsa in Mozambique. However, Bolton and Anderson (1997) and Bolton *et al.* (2004) argued against the existence of a distinct East Coast province because the marine flora reflects an eastwardly decreasing number of temperate South Coast species, replaced largely by tropical Indo-West Pacific species. On these grounds, and that the overlap region has low endemicity, they suggested that there is an **extended overlap region** from East London on the South Coast, to Mozambique on the East Coast, thereby including the entire KwaZulu-Natal coast southwards to East London as an overlap region.

With the exception of Jackson (1976), a constraint of the findings of much of this work was that it was characterised by insufficient sampling in the extreme north-eastern part of the country in order to validate the existence of a distinct East Coast province and the potential of this province to extend into southern Mozambique. The aforementioned work (Stephenson and Stephenson 1972, Emanuel *et al.* 1992, Bustamante and Branch 1996a, Turpie *et al.* 2000, Bolton *et al.* 2004) overshadowed the findings of Jackson (1976), whose extensive sampling in the north-eastern part of the country found evidence of a **distinct region on the East Coast** but also the possibility of a fourth province, as there appeared to be a biogeographic break in the vicinity of Cape Vidal, KwaZulu-Natal.

Subsequent rocky intertidal analyses by Sink *et al.* (2005) in KwaZulu-Natal, and by Porter *et al.* (2013) on shallow reefs in KwaZulu-Natal and in Mozambique, detected a similar pattern in the region to Jackson (1976) and the possible existence of a fourth province too, also extending from Cape Vidal as initially suggested by Jackson (1976), into the Delagoa region of southern Mozambique (Evans 2005, Lawrence 2005, Sink *et al.* 2005). In addition, Solano-Fernandez *et al.* (2012) found a similar pattern in the distributions of 700 fish species, as samples north of Cape Vidal clustered independently as a distinct outlier further supporting the recognition of a fourth province or ecoregion extending into the **Delagoa region** of southern Mozambique. However, this potential fourth province extending from Cape Vidal northwards into southern Mozambique may not be considered distinct enough from other such provinces

as a similar general pattern is not shared by other organisms or habitats such as seaweeds and sandy beach fauna respectively (McLachlan *et al.* 1981b, Bolton *et al.* 2004, Harris 2012). Therefore, the Delagoa region from Cape Vidal northwards, rather than being considered a fourth distinct province, can be recognised as being a smaller subunit termed an ecoregion. This area is possibly an overlap zone between the subtropical East Coast and the tropical East Coast, and as such, has been incorporated as part of the East Coast province now referred to as the Natal-Delagoa Shelf Province by the MEC.

The idea of a transitional area or overlap region along this part of the shelf was also suggested by Bolton *et al.* (2004), and by Porter *et al.* (2013). Porter *et al.* (2013) even referred to this part of the shelf as the Delagoa Overlap Bioregion. This **potential overlap region** is further supported by sandy beach biogeography which recognises only a single shelf province on the East Coast of South Africa. The recognition of the East Coast as one biogeographic province called the Natal-Delagoa Shelf Province is to accommodate the reported absence of a difference in beach biodiversity patterns between the Delagoa Ecoregion and the Natal Ecoregion described below. The only difference between this high-level classification of provinces and that of smaller-scale ecoregions is that the Natal and Delagoa Ecoregions are merged into a single province, the Natal-Delagoa Shelf Province. However, some researchers do consider differences in beach biodiversity patterns between these two regions, with turtle nesting habitat and perceived differences in bird, crab and intertidal fish fauna north of Cape Vidal. Quantitative sampling of multiple sandy shore ecosystem components is needed to resolve this and this sampling should extend into central Mozambique.

Ecoregions and subregions

In the NSBA 2004 (Lombard *et al.* 2004), the majority of effort in marine ecosystem mapping was focused on expert identification and description of nine marine bioregions and 34 biozones (detailed by (Sink *et al.* 2004). The 2011 Assessment recognised the importance of including variation due to biogeographic differences and summarised the major differences linked to temperature, nutrients and productivity within South Africa's marine environment, updating the 2004 bioregions into six ecoregions based on revisions that emerged through investigation of offshore biodiversity patterns during work undertaken to support the identification of offshore MPAs (Sink *et al.* 2011). Different biogeographic patterns for different broad ecosystem groups were also accommodated. The 2011 Assessment used the terms 'ecoregions' and 'ecozones' to replace the similar, but revised 'bioregions' and 'biozones' used previously and to avoid confusion between the different map layers from 2004 and 2011. As the term bioregion has a legal association in terms of bioregional planning as governed by the Biodiversity Act, the term ecoregion was retained in 2018 to represent the agreed high-level national biodiversity pattern. A total of **six ecoregions** are recognised (Figure 22). Sub-regions (referred to as **regions**) were introduced to reflect areas with distinct biodiversity pattern within ecoregions but where differences in biodiversity pattern are less distinct than at the ecoregional level. These include the former Namaqua bioregion and Southwestern Cape bioregion, the name of the latter being simplified to the Cape region.

In 2018, updated information (e.g. new bathymetry data and new publications) was used to refine the map of marine ecoregions and various subregions nested within ecoregions. Each ecoregion including any finer scale regional patterns are described below. The shelf ecoregion boundaries are similar to those

described in 2011 which are similar to those described in 2004. Figure 22 shows the ecoregions used in the NBA 2018.

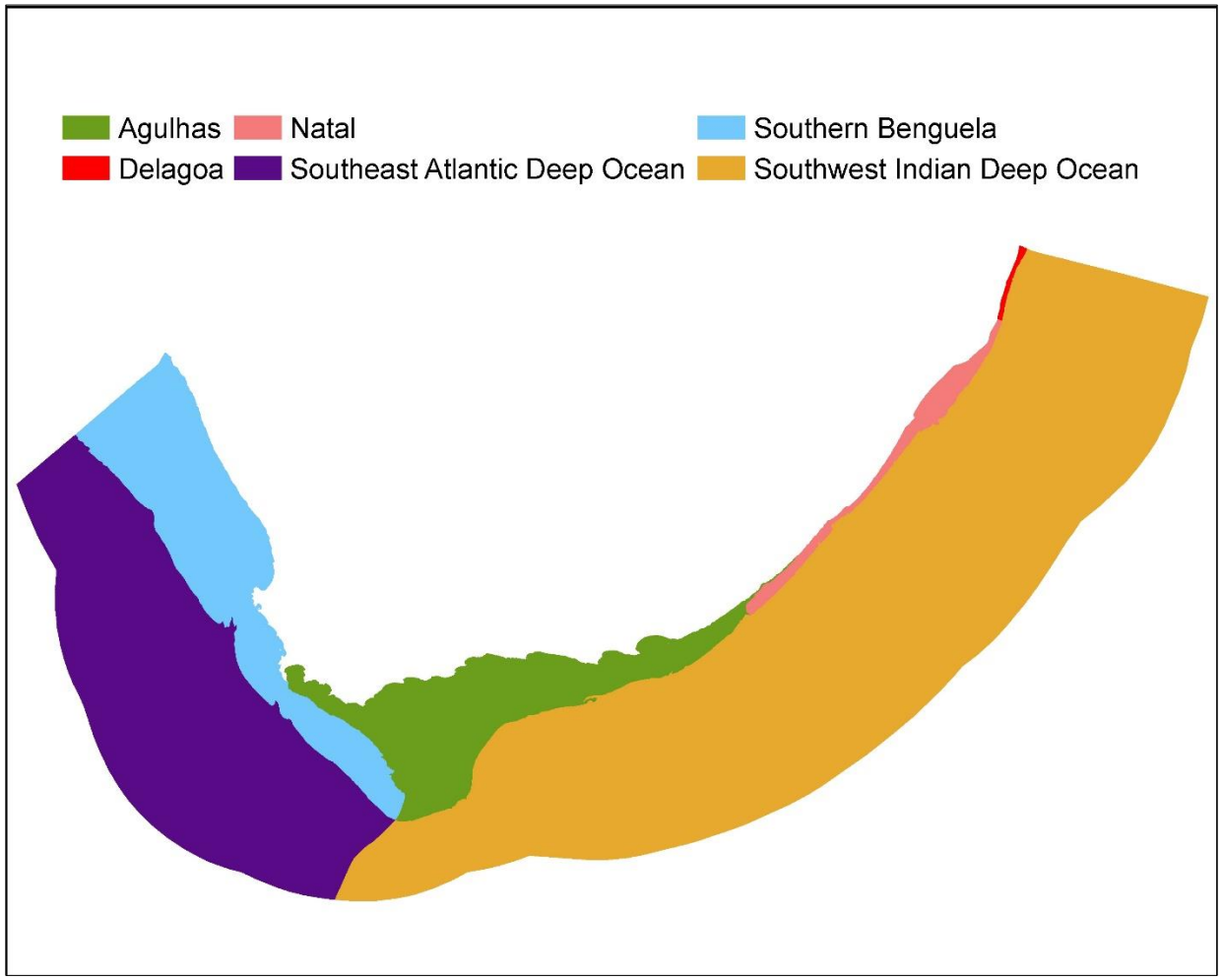


Figure 22. Marine ecoregions of South Africa.

Shelf Ecoregions

Southern Benguela ecoregion

This cold, temperate shelf ecoregion in the south east Atlantic extends from Namibia to Cape Point and offshore it includes the western Agulhas bank in South Africa. It is bounded by a deep shelf edge that ranges between depths of 200 to 600 m, making it one of the deepest in the world (de Wet 2013). The continental margin of the West Coast is passive (i.e. a relatively stable tectonic environment) and the gradient towards the shelf edge is relatively low (1-2 degrees) (de Wet 2013). The shelf is wide with the shelf break occurring at a maximum distance of 240 km off the Orange River and a minimum distance of 50 km off Cape Point. This is South Africa's **most productive ecoregion** and is characterised by the cold equatorward flowing Benguela Current and large-scale intensive upwelling with nutrient rich water (Shannon 1985, Field and Shillington 2006). Two major submarine canyons, the Cape Point Valley and Cape Canyon incise the shelf in this ecoregion (Simpson and Forder 1968, Dingle 1986, Wigley 2004, Wigley and Compton 2006), in addition to numerous new canyons that are being discovered through

recent research (Palan 2017). This ecoregion supports major commercial fisheries including hake trawl and longline fisheries, a small pelagic fishery, large pelagic longline fishing and commercial linefishing. The West Coast Rock Lobster fishery and an abalone fishery are key inshore fisheries. Low oxygen events are a feature of this region (Jarre *et al.* 2015a).

Sub-regions within this ecoregion include the Namaqua and Cape (formerly referred to as the southwestern Cape) regions which are considered to separate in the area between Cape Columbine and Donkin Bay. This division is considered to be most pronounced in seaweed communities (Engledow *et al.* 1992, Bolton and Anderson 1997, Sink *et al.* 2004) but intertidal invertebrate communities also reflect changes in this area (Emanuel *et al.* 1992, Wieters 2006, Wieters *et al.* 2009). The regional differences extend to the middle shelf as evident in the restriction of two muddy middle shelf biotopes to the Namaqua bioregion but no such division has been detected in deeper shelf bathomes (Karenyi 2014, Karenyi *et al.* 2016). Wieters (2006) sampled 27 rocky shores and detected a clear discontinuity in intertidal community structure at about 32 degrees south distinguishing a northern and southern region. Further support for this division is provided by important environmental differences in this area, between the northern and southern components of the West Coast Rock Lobster fishery. The area south of Cape Columbine is less prone to oxygen-deficient bottom water that extends close inshore at times causing hypoxic conditions and lobster walkouts. No further regional patterns in beach biodiversity pattern have been detected in this ecoregion.

Namaqua subregion

The Namaqua subregion is a cool temperate region that is considered to extend from Sylvia Hill in Namibia to Donkin Bay. The rationale for the break at Sylvia Hill just north of Lüderitz is that the area constitutes the northern edge of a large upwelling cell. This break is supported by seaweed and invertebrate data and for intertidal and subtidal habitats (Emanuel *et al.* 1992, Engledow *et al.* 1992, Bustamante and Branch 1996a, Bolton and Anderson 1997). The Namaqua subregion is characterised by **persistent strong and spatially homogenous upwelling**, high chlorophyll and is less variable in terms of temperature and productivity than the Cape subregion (Hardman-Mountford *et al.* 2003, Wieters *et al.* 2009). The Namaqua inner shelf has a narrower temperature range – with marked spring and summer temperature averages masking the daily rapid and wide temperature changes as upwelling periods alternate with down welling (Smit *et al.* 2013). Of note in this subregion is a peak in the densities of two limpet species (*Scutellastra argenvillei* and *S. granatina*) with a declining trend southwards (Bustamante *et al.* 1995, Wieters *et al.* 2009). There are also trends in two kelp species *Ecklonia maxima* and *Laminaria pallida*, with the latter also declining southwards (ref to be provided by Loyiso). Rocky shores have higher biomass of filter feeders and grazers with dense beds of mussels and limpets in this subregion (Wieters *et al.* 2009). Subtidally, extensive mud banks are an important characteristic of the Namaqua region, having high organic carbon in the southern muds and high sedimentation rates in the northern muds (Karenyi 2014, Karenyi *et al.* 2016). This subregion also experiences frequent seasonal to semi-permanent hypoxia (Jarre *et al.* 2015a).

Cape subregion

The Cape subregion has a narrower, rockier shelf with extensive inshore reef development and an absence of mud on the inner shelf (de Wet 2013). This cool temperate subregion is characterised by **high variability**

in the oceanographic environment. The Cape subregion is more species-rich in terms of seaweeds than the Namib Province (north of Lüderitz) (Engledow *et al.* 1992, Bolton and Anderson 1997). At the eastern end of this ecoregion, the inshore break at Cape Point is very distinct in the intertidal habitats (Stephenson and Stephenson 1972, Brown and Jarman 1978, Emanuel *et al.* 1992, Bustamante and Branch 1996a, Turpie *et al.* 2000, Harrison 2002, Wieters 2006), but in deeper waters this division is less distinct. It cuts obliquely south-eastwards so that at a depth of 150 m, the boundary is approximately south of Cape Agulhas. This angled line is more consistent with the mixing zone of the Benguela and Agulhas currents, and their associated fish and invertebrate communities (Shah 2018). The eastern Agulhas Bank is considered part of the Agulhas ecoregion, and the western area is part of the Cape ecoregion. Cetacean distributions also support the Cape Point boundary with Heaviside's and dusky dolphins occurring west of Cape Point, and the Indo-Pacific humpback dolphin occurring in the Indian Ocean, to the east of Cape Point (Best and Folkens 2007).

Agulhas ecoregion

The **warm temperate** Agulhas ecoregion incorporates the shelf area from Cape Point to the Mbashe River in the Eastern Cape and includes the central and eastern Agulhas Bank bounded by the Agulhas Falklands Fracture Zone (see Chapter 1). The continental shelf is at its widest in the Agulhas Shelf ecoregion, extending up to 260 km offshore at its widest point south of Cape Infanta on the Agulhas Bank (de Wet 2013). There is a series of reef complexes on the Agulhas Bank including the Alphard Banks, six-mile, twelve-mile, 45-mile and 72-mile Banks (also known as the Agulhas Arch Anti-clines (de Wet 2013) which constitute important linefishing grounds. This region has been widely recognised as an independent province and region (Emanuel *et al.* 1992, Stegenga and Bolton 1992, Bustamante and Branch 1996a) although the eastern boundary has been debated. The Agulhas Shelf ecoregion hosts the **greatest number of South African endemics** including sparid reef fishes, octocorals and algae and is a spawning and nursery ground for many species (Thandar 1989, Griffiths and Robinson 2016, Atkinson and Sink 2018). This region supports numerous important commercial fisheries including the pelagic fishery, trawl fisheries for hake and sole, a trap fishery for the endemic deep-water rock lobster (*Palinurus gilchristi*) and an abalone fishery. Pilchard and anchovy spawn on the Agulhas Bank and eggs and larvae are transported up the West Coast via the Benguela jet. This is also the only known *Loligo reynaudii* squid spawning area in South Africa and supports a commercial squid fishery. The horse mackerel stock of the Agulhas Bank is the mainstay of the midwater fishery in South Africa. A shark directed longline fishery also occurs in this ecoregion.

The area from Cape Point to Cape Agulhas has been considered to constitute an **overlap zone** where there is mixing of the Benguela and Agulhas currents (see discussion on overlap regions above). Fewer systematic quantitative surveys have taken place to further delineate regions for intertidal and subtidal biodiversity pattern in this region compared with the East Coast. **Bays** in this overlap zone were considered distinct from those further east with a further division in eastern and western bays based on expert knowledge of reef biota (Shirley Parker Nance, Rhodes University; Toufiek Samaai Department of Environment, Forestry and Fisheries and Maya Pfaff, Department of Environment, Forestry and Fisheries pers. comm.). Solano-Fernandez *et al.* (2012) reported reduced linefish diversity between Knysna and Algoa Bay which is attributed to frequent cold water upwelling events along this stretch of coast (Attwood *et al.* 2011) and noted that the Agulhas Shelf is more variable than the Southern Benguela Shelf and the more subtropical regions to the north.

The **Mbashe boundary** is supported by the work of Beckley and van Ballegooyen (1992) who found a strong inshore subsurface temperature front that maintains a fixed location in the vicinity of the Mbashe system. Upwelling cells are reported to still have a major impact south of the Mbashe and this river marks the distribution limit for abalone (confined to the area south of the Mbashe) and East Coast Rock Lobster (occurs to the north). There is also a clear break in estuarine ecoregion types at the Mbashe (Harrison 2002, van Niekerk *et al.* 2019). Fennessy *et al.* (2003) also found a clear difference in the species composition of linefish catches between the northern and southern Transkei with fish in the north being predominantly subtropical and those in the south comprising mainly warm temperate species.

Natal ecoregion

The Natal ecoregion is a **subtropical region** at the southern end of the Mozambique Channel (Stephenson 1939, Jackson 1976, Brown and Jarman 1978, Turpie *et al.* 2000, Bolton *et al.* 2004, Sink *et al.* 2005, Porter *et al.* 2013). It extends from the Mbashe River northwards to Cape Vidal and is bounded by the shelf edge which is steep and narrow, occurring 10-50 km offshore (Lutjeharms *et al.* 2000b). The strong Agulhas Current flows southwards through the province and interacts with the shelf resulting in a dynamic upwelling cell in the KwaZulu-Natal Bight (Lutjeharms *et al.* 2000, 2006; Meyer *et al.* 2002); The ecoregion is characterised by higher turbidity and riverine influence relative to the southern part of the adjacent Delagoa ecoregion to the north (De Lecea *et al.* 2013a, Porter *et al.* 2014, Scharler *et al.* 2016, Porter *et al.* 2017a). In the south, submerged coast-parallel palaeo-dune cordons form reef complexes that extend along most of the former Transkei coastline (Flemming 1978, 1980, 1981, Birch 1981, Ramsay 1991, 1996, Bosman *et al.* 2005). These submerged dune cordons constitute the substratum for the rich diversity of marine flora and fauna, and the relatively high percentage of endemic species found in the Natal ecoregion (Emanuel *et al.* 1992, Turpie *et al.* 2000, Mann *et al.* 2006). The **uThukela Cone** of the KwaZulu-Natal Bight between Cape St Lucia and Durban is an asymmetrical sedimentary feature that distinguishes this area (Martin and Fleming 1988), Fennessy *et al.* 2016 and associated references). The rocky intertidal shores are distinguished from Delagoa shores by the dominance of the filter feeders *Perna perna* and *Octomeris angulosa* (Sink *et al.* 2005) while shallow rocky reefs are dominated by algal, sponge and ascidian communities with small components of mainly azooxenthellate coral species (Celliers *et al.* 2007, Olbers *et al.* 2009, Porter *et al.* 2013). The distribution of benthic macrofauna is chiefly related to the distribution of sediment but unique mud ecosystem types are a key feature of this shelf (Mackay *et al.* 2016) and shelf edge which support crustacean trawl fisheries (Fennessy 1994a, Fennessy and Groeneveld 1997). Linefishing is also an important fishery in this ecoregion. The MEC recognised some finer scale regional patterns particularly in reef types that have been reflected below, and the KwaZulu-Natal Bight was also recognised as a distinct region.

Southern KwaZulu-Natal and Wild coast subregion

North of the Mbashe River, the former Transkei region of the Eastern Cape forms an aptly named coastal stretch known as the **Wild Coast**, considered in the NBA 2018 to extend from the Mtamvuna River, Port Edward southwards to the Mbashe River. This includes the **Pondoland** coast, considered by some to extend between the Mzimvubu and the uMthavuna Rivers (Mann *et al.* 2006) although some authors also refer to the broader region from the Mbashe to uMthavuna as Pondoland (Celliers *et al.* 2007). This is the narrowest shelf in South Africa and this narrow steep shelf edge with the powerful Agulhas Current are

key characteristics of the Wild Coast region. Mann *et al.* (2006) note that the marine biodiversity patterns are relatively distinct and other authors have noted higher endemism in this area (Turpie *et al.* 2000, Awad *et al.* 2002). Celliers *et al.* (2007) defined three relatively distinct reef communities in the Pondoland area with a change in reef communities at Mbotyi with water visibility declining south of Mbotyi, and this was also reflected by the absence of the coral genus *Stylophora*. Suspension feeders dominate reefs in the south and algal-dominated reefs occur in the north. This is probably related to higher turbidity and nutrient levels in the south. Jooste *et al.* (2018) however recently applied genetic techniques and argue that this area is not a distinct region. These varying perspectives are likely a result of the different study organisms, biodiversity components examined (reef communities versus genetics of an estuarine crab) and different interpretations of biogeography and ecosystem types. Celliers *et al.* (2007) attribute observed changes to river influence rather than the kinds of processes reflected in genetic data. More quantitative comparative research is needed to better classify and map ecosystem types and ascertain the **level of distinction** within this region. Sand and coarse sediment types were not subclassified by region within the broader Wild Coast but mosaic ecosystems were classified using the same patterns reflected in reef communities as reported by Celliers *et al.* (2007). For example, the Wild Coast inner shelf reef sand mosaic extends between Mbashe and Port Edward although it occurs in two stretches with clearer water from Mbashe to Mngazi and Mbotyi to Port Edward.

The area between Durban and Port Edward is referred to as **southern KwaZulu-Natal**. There is some evidence of distinct ecosystem types within this area particularly for reefs (Olbers *et al.* 2009, Porter *et al.* 2013, Franken 2015, Makwela 2017) and unconsolidated sediments (Franken 2015, Maduna 2018). This region also has a narrow shelf, high current and experiences relatively high riverine input although less than the KwaZulu-Natal Bight or southern Pondoland (Porter *et al.* 2017b).

KwaZulu-Natal Bight subregion

The **KwaZulu-Natal Bight** is an offset in an otherwise 1 300 km curvilinear coastline on the East Coast of South Africa (Harris *et al.* 2019a) within the oligotrophic/mesotrophic East Coast of South Africa (Bustamante *et al.* 1995, Barlow *et al.* 2008). This offset, and associated expansion in shelf width, was caused by a change in the tectonic origin of the continental shelf margin, from a sheared to a short-rifted section (Martin 1984, Martin and Fleming 1988), and is approximately 160 km long between Durban and Richards Bay. This shelf widening is in sharp contrast to the remainder of the province where the average position of the continental slope break is reported to be 11 km from the shore (Ramsay 1994, Porter *et al.* 2017b). The seaward boundary of the Bight can be considered to be broadly delimited by the shelf break at a depth of approximately 100 m, about 45 km offshore at its widest point (Martin and Fleming 1988), and the shoreward boundary of the Agulhas Current (Gründlingh 1983), which has a mean width of 100 km (Bang and Pearce 1976).

The KwaZulu-Natal Bight is recognised as an oceanographically important area (Lutjeharms 2006b) with recent work significantly advancing the understanding of this region (Fennessy *et al.* 2016). In addition to oceanic nutrient sources, the KwaZulu-Natal Bight region has many rivers and estuaries providing fluvial materials to the Bight (Porter *et al.* 2014, De Lecea *et al.* 2016, Scharler *et al.* 2016). The mesotrophic nature of the Bight means that it does not support large fisheries, as in other regions of the country, but it does host South Africa's only crustacean trawl fishery (Fennessy and Groeneveld 1997) and a significant

component of the line fishery, which is the most important fishery on the East Coast in terms of participation and catch (Lamberth *et al.* 2009).

Delagoa Shelf ecoregion

The Delagoa Shelf Ecoregion extends from Cape Vidal northwards to Bazaruto Island in Mozambique (Jackson 1976, Bolton *et al.* 2004, Sink *et al.* 2005, 2012a, Porter *et al.* 2013). It is considered to be a transitional area between subtropical and tropical coastal waters, as coral communities flourish here but rarely form true accretive coral reefs (Schleyer *et al.* 2018). The South African component of this ecoregion is characterised by a very narrow continental shelf, several submarine canyons and an absence of riverine inputs which together result in clear oligotrophic waters (Ramsay 1994, Porter *et al.* 2017b) whereas the Mozambican component has a wider shelf and increased riverine input resulting in increased turbidity and nutrients (Porter *et al.* 2017b). Warm eddies from the Mozambique Current interact with the East Madagascar Current to form the fast south-flowing Agulhas Current in the southern limits of this province (Lutjeharms 2006b). Algae and zooxenthellate corals, particularly soft corals, dominate shallow reefs in this ecoregion (Porter *et al.* 2013, Schleyer and Porter 2018).

Deep Ocean Ecoregions

The Southeast Atlantic Deep Ocean is separated from the Southwest Indian Deep Ocean by the Agulhas Ridge, a transverse ridge (Uenzelmann-Neben and Gohl 2004) that forms part of the **Agulhas Falklands Fracture Zone** (AFFZ) where the African and South American Plates separated in the break-up of West Gondwana in the early Cretaceous (Ben-Avraham *et al.* 1997). The AFFZ is globally one of the largest structural offsets between crustal segments (1200 km ridge-to-ridge) and stretches approximately 2500 km between the southern margin of South Africa and the northern edge of the Falkland Plateau which lies east of South America. It is a clearly defined linear feature that includes the prominent Agulhas Ridge which rises more than 3 km above the surrounding seafloor and acts as a divide between the Cape Basin and the Agulhas Basin (Schut *et al.* 2002). It should be noted that the biodiversity patterns in the deep ocean ecosystems are not well understood.

Southeast Atlantic Deep Ocean ecoregion

The Southeast Atlantic Oceanic Ecoregion extends from the shelf edge of the Southern Benguela onto the slope and into the abyssal plain of the **Cape Basin**. The Cape Basin comprises a relatively monotonous plain, interrupted by sporadic seamounts of the Cape Rise; Protea, Argentina and an unnamed seamount on the slope (de Wet 2013). John Rogers (University of Cape Town) conducted some visual sampling of the seabed in the 1980's with seabed imagery of the slope and sandy and more complex abyssal habitats (Table 8). This region extends into Namibia and is bounded by the prominent Walvis Ridge which separates the extensive Angola Basin and abyssal plain to the north, from the smaller Cape Basin and abyssal plain. The ridge is a linear feature that extends in a north-easterly direction, with increasing relief, from the island of Tristan da Cunha for almost 3000 km to link with the continental margin near Cape Fria in Namibia (Simpson 1971). It is suggested that the Walvis Ridge originated from rifting and likely acted as a barrier to circulation in the deep ocean since the time of the formation of the Atlantic Ocean at the beginning of the Cretaceous. This allowed for relatively unhindered sedimentation leading to the subdued topography

of the continental margin in the Southern Benguela (Leyden *et al.* 1971, Francheteau and Le Pichon 1972, Dingle and Scrutton 1974, Siesser *et al.* 1974).

Southwest Indian Deep Ocean ecoregion

This region includes the continental slope and abyss of the Southwest Indian Ocean including the **Agulhas Basin, Transkei Basin, the Natal Valley** and the smaller Zululand and Durban Basins (de Wet 2013). The Agulhas and Transkei Basins are separated by the Agulhas Plateau, a remnant of the original Falkland Plateau which was sheared away during the break-up of Western Gondwana. It reaches depths of less than 2300 m in the surrounding more than 5000 m deep Agulhas Basin to the west and the Transkei Basin to the east. The Agulhas Passage is a deep-water passage (-5000 to -5400 m) between the Agulhas Bank and the Agulhas Plateau. The Transkei Basin lies east of the Agulhas Plateau and is bounded by the South Coast continental shelf, the Agulhas Plateau and the Mozambique Ridge to the east. The continental margin in this ecoregion is considered translational (i.e. characterised by shearing and ongoing neotectonic uplift (Green 2011), compared to the divergent margin of the West Coast. The AFFZ strikes Northeast-Southwest and is divided into three sections; (a) Mallory Trough Segment (b) Diaz Ridge Segment and (c) East London Segment (Ben-Avraham *et al.* 1997). The Mallory Trough is the steepest area in the South African seascape, with a 3000 m depth change over a distance of less than 30 km (de Wet 2013). The Diaz Ridge (or North-eastern Marginal Fracture Ridge (Robson and Dingle 1986) is a parallel sub-cropping ridge which is largely buried by sediments, but with occasional bedrock exposures between *24˚* and *26˚ E* at the base of the continental slope in depths of 3000 to 4000 m (Ben-Avraham *et al.* 1997). It bounds the southern margin of the Outeniqua Basin. The Agulhas Marginal Fracture Ridge is situated roughly 50 km south of the Diaz Ridge and stretches 470 km to the southwest along the AFFZ. The Natal, Mallory and Shackleton Seamounts occur along the AFFZ.

3.6.2 Depth patterns

Building on the 2011 Assessment, the 2018 Marine Ecosystem Classification and Map included finer scale patterns in the nearshore and shelf environments. The Marine Realm is considered to extend from the dune base to the abyss (Figure 23) with a neritic or shelf-associated zone where benthic and pelagic ecosystems are more tightly coupled and an oceanic or deep ocean zone beyond the shelf edge which includes the continental slope and abyss. The shelf edge is considered a distinct zone but is classified as part of the shelf as benthic and pelagic components of the ecosystem interact closely in this steeper zone (Karenyi *et al.* 2016). Within the shelf, four finer scale bathomes were recognised: an inner, mid and outer shelf and the shelf edge.

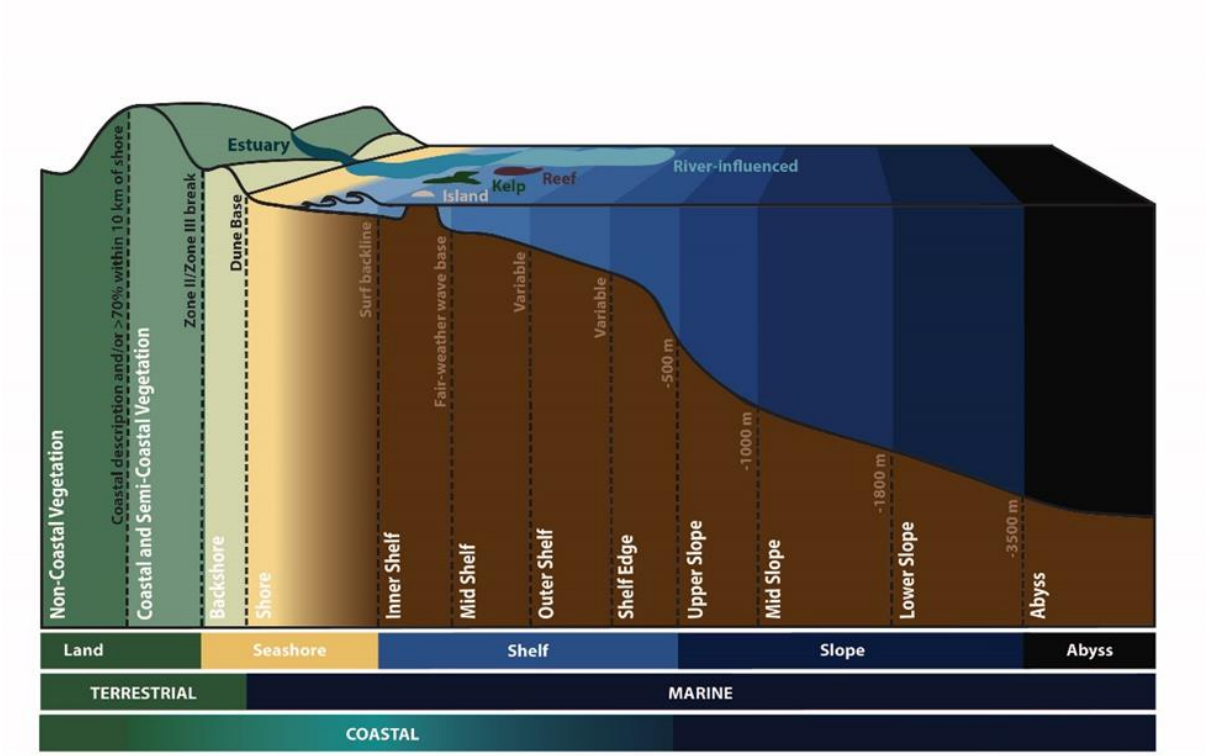


Figure 23. Bathomes used in the 2018 Marine Ecosystem Classification and Map. Major bathomes include the Shore, Shelf, Slope (and Plateau not shown) and Abyss with finer scale depth patterns in the shelf and slope.

Shore

The NBA 2011 advanced the mapping of coastal ecosystem types, particularly along the shore. The across-shore boundaries, however, were largely heuristic, and included a landward and seaward zone, respectively between the mid-shore and 500 m inland, and the mid shore and -5 m depth. In the NBA 2018, new boundaries were chosen to delineate ecologically meaningful zones across the land-sea interface, informed by the work of Tinley (1985), (McLachlan *et al.* 1984) and expert consultation. A core objective of the new delineations was to facilitate the creation of a seamless ecosystem-type map across realms (Terrestrial, Estuarine and Marine) that would allow for a robust coastal integration for both assessment and planning. See (Harris *et al.* 2019b, 2019c) for details.

The interface between land and sea is defined as the seashore, split into a backshore and shore zone at the dune base. The backshore essentially represents dunes, and has an inland boundary at the break between the scrub and thicket zones (the Zone II/Zone III break *sensu* (Tinley 1985). The backshore is represented in the Terrestrial Vegetation Map as Seashore Vegetation and classified in accordance with the National Vegetation Map (Harris *et al.* 2019a, 2019a). Both the scrub-thicket break and dune base lines were mapped in ArcGIS 10.5 off of the South Africa 50 cm colour imagery (2008-2012), which is freely available from NGI via ArcGIS Online. Both boundaries were mapped at a scale of <1:3000 (Harris *et al.* 2019b).

The shore zone extends from the dune base to the back of the surf zone, where the latter was found to be the start of a transition zone between surf and inner-shelf benthic communities (McLachlan *et al.*

1984). Recognising that the surf zone is variable depending on local weather conditions, this outer boundary was determined by a time series of remotely sensed images as described by (Harris *et al.* 2019c).

The ecosystem types that lie somewhat between the sandy and rocky extremes include boulder shores and mixed shores. There is very little information on these shore types, particularly for boulder (and cobble) shores. However, this is an area of active research (Griffiths and Robbins 2019), and thus will be better incorporated into the next National Biodiversity Assessment once more is understood about these ecosystems. What is known, however, is that their associated communities are sufficiently different from those on rocky shores for them to be classified as separate ecosystem types (Tucker *et al.* 2017). See the NBA Coast report for better information.

There is limited information on mixed shores in South Africa, particularly in comparison with the substantial amount of research done on purely rocky and purely sandy shores. Mixed shores in South Africa were first recognised by (Bally *et al.* 1984), with some early qualitative research that followed. However, the first truly quantitative work comparing mixed, rocky and sandy shores appears to have been conducted 20 years ago (Smith 1999), with few other quantitative studies since (e.g., Garner 2013). Mixed shore communities comprise species from both rocky and sandy shores that are tolerant of sand inundation and rock presence, respectively (Garner 2013; Smith 1999), and can be more, less or equally diverse compared to their adjacent rocky or sandy counterparts. Given the limited work on the ecology of these ecosystems, there is still no ecologically-based classification scheme for mixed shores that is based on national sampling, even though they comprise a third of the coast (Harris *et al.* 2011b).

The offshore islands around the South African mainland were also considered part of the national shore. These islands are generally small (two thirds are each <0.05 km^2 in area; one third, <0.5 km^2 each), with the largest being Robben Island (5 km^2). They were included as single polygons bounded by the back of the surf zone, except for the larger islands, where terrestrial vegetation was also mapped in the island's interior (Harris *et al.* 2019a).

Shelf and shelf edge

The offshore boundary of the surf zone is considered the start of the **inner shelf** which in turn extends offshore to the fair-weather wave base. Note that this zone was referred to as "inshore" in the 2011 assessment. The inner shelf was considered to extend to a depth of 33m in the Delagoa Ecoregion based on reef organisms (Schleyer and Porter 2018) and to a depth of 50 m in the Southern Benguela Ecoregion (Karenyi 2014). A depth of 30 m and 40 m was used to delineate this boundary in the Natal and Agulhas ecoregions respectively as informed by experts in geoscience (Hayley Cawthra pers. comm., (Bosman *et al.* 2005) and benthic macrofauna (Stephen Weerts, CSIR, pers. comm.).

The **mid shelf** is a new depth zone that was introduced on the strength of new evidence for distinct pattern in this area of shelf (Karenyi 2014, Fennessy *et al.* 2016, Green and Mackay 2016) but also recognising such patterns reflected in international studies (Cudaback 2005). Note that there is confusion in terminology and depth ranges referred to across studies and care needs to be taken when interpreting or comparing results across studies as different authors have used different depth ranges to define different depth zones even within the same study area. In the NBA 2018, the mid shelf is recognised to span

different depth ranges in different ecoregions due to the broad scale differences in shelf width, topography and oceanography described in Chapter 1 (see section 1.4).

On the broad shelf of the West Coast, three shelf zones are recognised following reported abiotic and biotic patterns (de Wet 2013, Karenyi *et al.* 2016). Patterns in fish fauna (Roel 1987, Shine 2008, Yemane *et al.* 2008, 2010), benthic epifauna (Atkinson *et al.* 2011a, Langejans *et al.* 2012, Shah 2018), and benthic macrofauna (Karenyi 2014, Untiedt and Mackay 2016) informed these shelf bathomes. The mid shelf extends from -50 to -150 m. The **outer shelf** is broad and wide and ranges from - 150 to - 350 m. The shelf edge extends to depths of between 350-500 m. The outer extent was delineated from the angle of maximum slope rather than a depth boundary, as mapped from data provided by de Wet (2013). In the Agulhas ecoregion, the **mid shelf** extends from approximately -40 m to -100 m and the outer shelf extends to -150 m. On the southern part of the East Coast the fair-weather wave base is considered to extend to approximately -30 m or -40 m. In the KwaZulu-Natal Bight, this is corroborated by recent patterns in benthic macrofauna (Mackay *et al.* 2016, 2016, Untiedt and Mackay 2016). This assessment considers the 40-80m depth range to constitute the mid shelf in the Natal ecoregion (Mackay *et al.* 2016, Untiedt and Mackay 2016). In the Delagoa ecoregion the mid shelf extends offshore from -33m (Schleyer and Porter 2018) to approximately -80 m.

The **shelf edge** is the zone that includes the shelf break as reflected in the dataset provided by de Wet (2013). The shelf edge is deepest on the West Coast spanning the -350 m to -500 m depth range. On the South Coast the depth band is more variable but follows approximately the -200 m to -300 m contour to -500 m. On the East Coast the shelf edge is mostly in the -100 m to -500 m range with a deep shelf edge included in Northern KwaZulu-Natal. For pragmatic reasons the shelf edge zone is considered and mapped to extend to -500 m throughout South Africa although it is recognised that in places on the West Coast the shelf edge is terraced and there are steeper sections beyond 500 m depth (de Wet 2013). Due to limited sampling in such areas, deeper and steeper areas were not further sub-classified at this stage.

Deep Ocean

The lower boundary of the **upper slope** (bathyal) at -1000 m and the lower boundary of the lower slope at - 3500 m were retained as per the 2011 Assessment but a new **mid slope** zone was introduced spanning the -1000 m to -1800 m depth range. This aligns with several international classification boundaries including the well recognised -1000 m boundary that is commonly used to delineate the mesopelagic (Costello *et al.* 2017, Sayre *et al.* 2017, Sutton *et al.* 2017).Thus the upper slope spans -500 to -1000 m and the **lower slope** spans -1800 to -3500 m. De Wet (2013) data were used to delineate the -1000 m boundary but GEBCO data were used to demarcate all deeper boundaries. The plateau depth range falls within the same depth range as the slope recognising that although it falls within this depth band, it is distinct in terms of geological history and possibly in terms of benthic fauna. There has been no studies examining connectivity between slope, plateau or abyssal ecosystems in South Africa and the benthic biodiversity of all three of these broad ecosystem groups (slope, plateau and abyss) has never been investigated in South African waters.

The **abyss** was delineated by the -3500 m contour as per previous assessments with no new sampling having being undertaken to inform changes in this bathome in South Africa. The ocean around mainland

South Africa doesn't include any hadal or trench habitats with a maximum depth of approximately 5700m in the Agulhas Basin (Dingle *et al.* 1987, de Wet 2013).

3.6.3 Substrate and features

Shores

As in the 2011 Assessment, other variables that are recognised drivers of shore patterns including beach morphodynamic state, wave exposure and substratum were used in the classification and map with a different approach employed in mapping shore ecosystems at a fine scale that **aligns at the land-sea interface** (Harris *et al.* 2019b) and the less visible and accessible marine environment beyond the surf zone.

The ecosystem types within the shore zone were **updated** from the NBA 2011. The shore is an inherently dynamic zone, with some sections naturally switching between ecosystem types during erosion-accretion cycles; the classification in 2011 did not account for this but recognised this gap. In 2018, multiple imagery sets were used to determine what the local shore type was as described by (Harris *et al.* 2019b) in order to include the temporal element in the classification. All shore type classification methods followed those used in the NBA 2011 and Harris *et al.* (2019b) where each broad type (e.g. rocky shore versus sandy beach) is split according to various physical characteristics (such as wave exposure and beach morphodynamic state) and ecoregions or in the case of rocky and mixed shores in the southern Benguela, regions. Part of this reclassification also included integrating the national and provincial classification of shore types in KwaZulu-Natal, where the latter was included as an additional time point, and was integrated into the national map based on a series of rules (Harris *et al.* 2019b). In some cases, ecosystem types were also updated because new, higher resolution imagery facilitated better distinction between rocky and boulder shore types, leading to the removal of a previously misclassified boulder shore type in the Namaqua region.

Overall, the map includes a total of **35 shore types** with 12 sandy shore types and 23 rocky and mixed shore types. The greater number of rocky and mixed shore types is driven by the finer scale regional patterns in rocky and mixed (five ecoregions/subregions) versus sandy shores (three ecoregions/provinces). Rocky shores included boulder shores and three categories of wave exposure, and both rocky and mixed shores also included some stromatolite-associated types (See NBA Coast Report Box 3). Sandy shores were classified by four categories of beach morphodynamic state (Harris *et al.* 2011b, 2019a). Improved data is now available for classification of wave exposure (see Box 15).

Islands

The offshore islands around the South African mainland were also considered part of the national shore (Harris *et al.* 2019a). South Africa has at least 30 rocky **coastal islands** distributed along the mainland's West and South Coasts that have suitable area for permanent breeding colonies of Cape fur seals *Arctocephalus pusillus pusillus* or substantial numbers of seabirds (Kirkman *et al.* 2013, Crawford *et al.* 2015). These islands are generally small (two thirds are each <0.05 km^2 in area; one third, <0.5 km^2 each), with the largest being Robben Island (5 km^2). They were included as single polygons bounded by the back

of the surf zone, except for the **larger islands**, where terrestrial vegetation was also mapped in the island's interior. Island mapping is described by (Harris *et al.* 2019a). Only two types of island are recognised; Cape and Agulhas due to the absence of islands in the Namaqua subregion and on the East Coast.

Seabed types on the shelf

To classify the seabed in the inner, middle and outer shelf, five main sets of data were used (Tables 1-4). The first major distinction was between unconsolidated or **soft** shelves and **hard** and **mixed** shelves. Soft shelf areas were further classified by grain size recognising sandy, muddy or muddy sand categories using a consolidated sediment dataset (Table 7). The 2018 classification included a new category of ecosystem types that are **mosaics** of repeating patterns of both consolidated and unconsolidated habitats on the shelf. In this case the reef and other sediment type (usually sand, sometimes mud) were reflected in the name of the ecosystem type. Coarse sand was also specified where this information is available and relevant, usually in current influenced reef mosaics. The previous untrawlable grounds layer (Sink *et al.* 2012a) was considered during mapping but was greatly refined by this newly collated data and was not incorporated in the previous form in the NBA 2018. There are 79 shelf ecosystem types including 17 sandy, 11 muddy, 27 rocky and 24 mosaic ecosystem type

Reefs, Ridges and Banks

Mapping of reef positions was a major focus of the NBA 2011 which relied on SANBI's **Reef Atlas Project**, a dedicated project that aimed to address a research priority that emerged from the 2004 NBA (Lombard *et al.* 2004) i.e. the classification and mapping of reefs. This was supplemented by a GIS layer from the fisheries department that mapped "untrawlable grounds". Several reef types were classified based on coastal biogeography with the first descriptions developed for any marine ecosystem types (Sink *et al.* 2012a) using a template derived from the National Vegetation book (Mucina and Rutherford 2006).

The datasets used to improve the mapping of reefs and other large bathymetric features are shown in Table 1 and Table 2. The **de Wet (2013)** dataset helped improve the resolution of Child's Bank, several reef complexes on the Agulhas Bank and coast parallel wave cut terraces and palaeo dune ridges on the middle shelf between Cape Seal and Cape Recife. Single beam echosounder data from the Research Vessel Algoa were used to map a ridge on the slope between Port Elizabeth and Cape St Francis (See Table 5 **Kingklip Ridge**). This ridge rises from a depth of more than 700 m to as shallow as 350 m and extends across approximately 40 km although it is only 500 m wide. Very strong currents occur on the outside of the ridge (DEFF and ACEP Deep Secrets unpublished data) and the area inside of the ridge forms part of the kingklip spawning aggregation area.

Childs Bank is a major feature on the West Coast margin. It is a rounded, flat topped, plateau, situated at a water depth of less than -260 m and lies approximately 125 km offshore, to the southwest of Hondeklip Bay (de Wet 2013). This feature has a very gentle northern, eastern and southern margin but a steep, slump-generated outer face which lies at the edge of the continental shelf (Birch and Rogers 1973, Dingle *et al.* 1983, de Wet 2013). At its southwestern edge there the continental slope drops down steeply from -350 to -1500 m over a distance of less than 60 km. The more recent work describing Childs Bank (de Wet 2013) is different from that depicted by previous studies (Dingle *et al.* 1983). These earlier studies indicate

Childs Bank to have a much more angular and elongated shape, tapering to a sharp point towards its western edge, and the adjacent westward slope was also thought to be more irregular than the new bathymetry data suggest (Figure 9). Childs Bank consists of resistant, horizontal beds of Pliocene sediments, similar to that of the Orange Banks, and represents another perched erosional outlier formed by Post-Pliocene erosion (Dingle 1973, Siesser *et al.* 1974). In 2015 and 2016 tow camera surveys and additional mapping work helped better define the ecosystem types in this area and the bathymetric data collected during those cruises should be added to the de Wet (2013) dataset for further improvement. The top of this feature is a sandy plateau with dense aggregations of brittle stars and the steeper slopes have dense invertebrate assemblages including unidentified cold-water corals/rugged limestone feature, bounded at outer edges by precipitous cliffs at least 150 m high (Birch and Rogers 1973).

The datasets listed in Table 2 were used for mapping **Reef Complexes** (larger consolidated reef polygons such as Trafalgar, Protea, Aliwal Shoals, Durban Bight, Durnford and iSimangaliso reefs) particularly on the East Coast. There is much less data on the West Coast but de Decker (1987) and De Beers (unpublished data) facilitated reef mapping off Alexander Bay and Port Nolloth. The Council for Geoscience are advancing mapping on the Atlantic Seaboard off the Cape Peninsula and other historical datasets were used to improve reef mapping in False Bay, off Gansbaai, Port Elizabeth and Tsitsikamma. Further effort is needed to collate any other geoscience data and better consolidate and provide access to such information. Datasets provided by the University of KwaZulu-Natal and the ACEP Imida project helped improve mapping of the seabed component of ecosystem types between Port Alfred and Richards Bay.

The Baited Remote Underwater Video **BRUV data** (1710 points classified into seabed types) provided by SAIAB were also used to support reef and seabed type mapping. The points classified as Patch-reef high (rugged high relief reef), Patch reef low (subdued reef) and sand inundated reef: Flat reef with thin sediment cover were extracted and added to the Reef Atlas point layer from NBA 2011. As in NBA 2011, reef and canyon (see below) polygons took precedence over reef points.

As in 2011, reef types were **classified by region**. The effect of geological rock types in defining reef types remains poorly understood in South Africa and national data are not available for classifying rock type in the marine environment. Anderson (2000) reviewed the status of knowledge of subtidal hard substratum in South Africa and concluded that “we know so little about rocky reefs on the southeast coasts that it is not possible to identify gaps in our knowledge”. The reefs of the Delagoa ecoregion are the best studied (Riegl *et al.* 1995, Schleyer and Celliers 2003a, 2003b, Glassom *et al.* 2006, Celliers and Schleyer 2008, Porter 2009, Porter *et al.* 2013, 2017a, 2017b, Schleyer and Porter 2018, Schleyer *et al.* 2018, Porter and Schleyer 2019) but quantitative information about reefs in the Southern Benguela is completely lacking. There is also little quantitative data to characterise and provide baseline data for reef ecosystems in the Agulhas ecoregion but some published information about reef communities off the South Coast (Goukamma and Tsitsikamma areas) (Götz *et al.* 2009a, 2009b, Heyns *et al.* 2016, Heyns-Veale *et al.* 2016). There is increasing information from the Natal ecoregion (Porter 2009) with no published information on the Port Durnford reef biota. The ACEP Surrogacy and ACEP Spatial Solutions projects have significantly advanced the available ROV footage for reefs in the 40-80 m range in KwaZulu-Natal with (Makwela 2017) characterising several reef biotopes there. Makwela (2017) motivated for the reefs of the KwaZulu-Natal Bight to be considered distinct from those in southern KwaZulu-Natal but notes the need for additional

sampling and analyses to better examine these patterns. Mann *et al.* (2006) and Celliers *et al.* (2007) advanced knowledge of reef ecosystems in the Pondoland area and the ACEP Imida and ACEP Deep Forests projects are further advancing information regarding reefs in the area between Kei Mouth and Cape St Francis. The area between Kei Mouth and Umzumbe is a high priority for improvement of reef mapping and classification particularly beyond -20 m.

Canyons

The **NBA 2011** included **21 submarine canyons** drawing from mapping conducted by (Lombard *et al.* 2004), augmented through the work conducted to design a network of offshore MPAs (Sink *et al.* 2011). In 2018, the mapping of canyons was informed by the updated bathymetric data that including the multibeam data collected by the African Coelacanth Ecosystem Program for iSimangaliso (Ramsay and Miller 2002), Protea Banks (Pretorius *et al.* 2019), the area near East London (unpublished data, ACEP Imida Project) and recent theses and literature. In **2018**, a total of **29 canyons** were included in the ecosystem map representing 9 different canyon ecosystem types. Canyons were classified by bathome into upper and lower canyon types and then by ecoregion. Only shelf-breaching canyons have an upper extent which falls within the shelf edge zone. Lower canyon components fall within the slope.

Cape Lower Canyons is the most expansive canyon ecosystem type (2 838 km^2) followed by Cape Upper Canyons (Table 9) due to the enormous size of the **Cape Canyon** off Cape Columbine and Cape Valley off Cape Point. These are the only mapped canyons in the Southern Benguela although new work has identified more canyons, most of which are less extensive and do not incise the shelf (Palan 2017). In the Agulhas ecoregion, there are three canyons known off Algoa Bay with the **Sundays and Addo Canyons** breaching the shelf (spanning an approximate depth range of -150 to -2000 m) and the deeper **Cannon Rocks Canyon** (off the Boesmans Estuary) being confined to the slope. Two potential canyons off Tsitsikamma were not included although they were included in the NSBA 2004 map. These canyons could not be located during the Deep Secrets cruise (see Sink (2016) Deep Secrets cruise report). The **Tyolomnqa** or Gxulu canyon is the northernmost canyon in the Agulhas ecoregion and appears to be the largest shelf-breaching canyon on the East Coast. There are more than 30 canyons on the eastern margin with at least 12 canyons between **Durban and Kwelera** and 12 mapped canyons in the **Delagoa** ecoregion. All the canyons in the Delagoa ecoregion combined tally less than 45 km^2 in area, compared to the more than 5200 km^2 of canyon ecosystem extent from just 2 canyons in the southern Benguela. The **uThukela** canyon is the only mapped canyon in the KwaZulu-Natal Bight but the canyon head is on the slope. Further information is needed to map the **Goodlad** Canyon which is currently excluded from the ecosystem map.

Seamounts

There are **4 seamount types** in South Africa's marine ecosystem classification and map. Seamounts were classified by Deep Ocean ecoregion and bathome. Protea and Argentina Seamount are Southeast Atlantic Seamounts with the un-named recently discovered seamount ("Mount Marek") on the slope considered a different ecosystem type, Southeast Atlantic Slope Seamount. In the Southwest Indian deep ocean, Mallory and Davie Seamounts were classified as slope seamount ecosystem types and Natal and Shackleton as abyssal seamount types. Note that there are finer patterns in biodiversity with depth

zonation patterns within these features but this is not captured within ecosystem types. Such finer zonation patters occur in most ecosystem types with rocky shores exhibiting the most extreme fine-scale zonation. The biodiversity of South African seamounts has not been sampled but there has been recent efforts in the adjacent high seas (Bergstad *et al.* 2019a, 2019b).

Bays

Bays are retentive and relatively sheltered coastal ecosystems and thereby fulfil important roles in the marine environment. The NBA 2018 is the first to classify bays as distinct ecosystem types due to their **high ecological importance**. Bays provide natural shelter from storms and swell, serve as refugia for coastal marine species that seek calm conditions, either permanently of during certain parts of their life cycles. The circulation in bays tends to trap and retain seawater, generating longer residence time of water parcels and for example larvae or pollution retention times in bays than on the open coast (Pfaff *et al.* 2011, 2019b). Bays in temperate regions are therefore areas of relative warmth and thermal stratification, fostering enhanced phytoplankton abundance and primary production. This productivity supports the entire food web, such that higher trophic levels, like zooplankton, fish and birds, aggregate in bays to feed or reproduce. Such abundance, in turn attracts fishing efforts and other extractive activities into bays (see for example (Pfaff *et al.* 2019b). South Africa's coastline features several large embayments. Throughout history, these bays have attracted sailors and settlers by providing natural shelter from storms and swells. Today, many bays have ports, harbours or marinas, and two of the three major coastal metropolitans are located alongside bays: Cape Town is spread between Table Bay and False Bay, and Port Elizabeth (or Nelson Mandela Metropolitan) around Algoa Bay. Although Durban Bay is generally considered to represent the estuarine environment and is not considered a major bay but rather part of the KwaZulu-Natal Bight, the sheltered bay is the site of a further major metropolitan. As such bays experience higher levels of cumulative pressures (see Chapter 4) and without mapping of bays and their pressures, their ecosystem status cannot be assessed.

Eleven major bays were mapped in this NBA 2018 (Figure 24) and further classified into five bay ecosystem types: the three bays in the Cape subregion were assigned to 2 types (with/without seasonal low-oxygen occurrence); and the seven bays in the Agulhas ecoregion were assigned to three types depending on their location and biogeography. Since circulation patterns in bays primarily affect pelagic ecosystems by retaining water and increasing nearshore residence time near the coast, bays were mapped as features of the inner shelf (and not the shore), reaching from the back of the surf zone to the outer edge of embayment at approximately 50-80 m depth, depending on the type of bay (see Table 9). Their along-shore extent was determined by boundary features such as headlands or capes or, in the case of open bays, by expert-opinion.

St Helena Bay, the most prominent bay on the West Coast of southern Africa, was delineated to incorporate a cyclonic (clock-wise) eddy that entrains water from the Cape Columbine upwelling plume into the bay (Shannon 1985, Penven *et al.* 2000), which drives the exceptional plankton productivity (Shannon and Nelson 1996, Pitcher and Nelson 2006) of this important nursery area for commercially exploited fish stocks (Hutchings 1992). It is characterised by lower oxygen (Pitcher *et al.* 2014, Lamont *et al.* 2015, Pitcher and Probyn 2017) than other bay types in South Africa and was therefore treated as a

unique bay ecosystem type within the region. **Table Bay and Saldanha Bay** were considered as another ecosystem type, as they were smaller and not affected by frequent low oxygen conditions. The offshore extent of all bays in the Cape subregion was determined as ca. 50 m depth.

In the Agulhas ecoregion, three different types of bays were distinguished. **False Bay and Walker Bay** are located on the western Agulhas Bank (the area around Cape Agulhas where the shelf is very wide), a known overlap region between the Cape subregion and the Agulhas ecoregions and thus a biodiversity hotspot (Pfaff *et al.* 2019b). These bays are bounded by prominent capes to their eastern and western sides and the outer edge of their embayment was therefore determined by a straight line between capes, which corresponds to a maximum depth of 80 m. Agulhas Western bays are situated on the Eastern Agulhas Bank and include **St Sebastian Bay** (extends to 60m), **Vleesbaai** (extends to 40 m), **Mossel Bay** (extends to 50 m) and **Plettenberg Bay**, for which the outer edge of embayment's extended between 40 - 60 m depth. Agulhas Eastern Bays are located upstream of the Agulhas Bank in an area where the shelf is narrower. They include **St Francis Bay** and **Algoa Bay** (extending to a depth of about 60 or 70 m respectively. Differences in bay types were based on oceanographic features, regional patterns and biogeographic context for the current assessment but will need to be validated by biodiversity patterns once such data exist. The inclusion of bays as distinct units of assessment in the NBA 2018 is, however, a key step towards recognising and addressing the pressures these important ecosystems experience (Pfaff *et al.* 2019b).

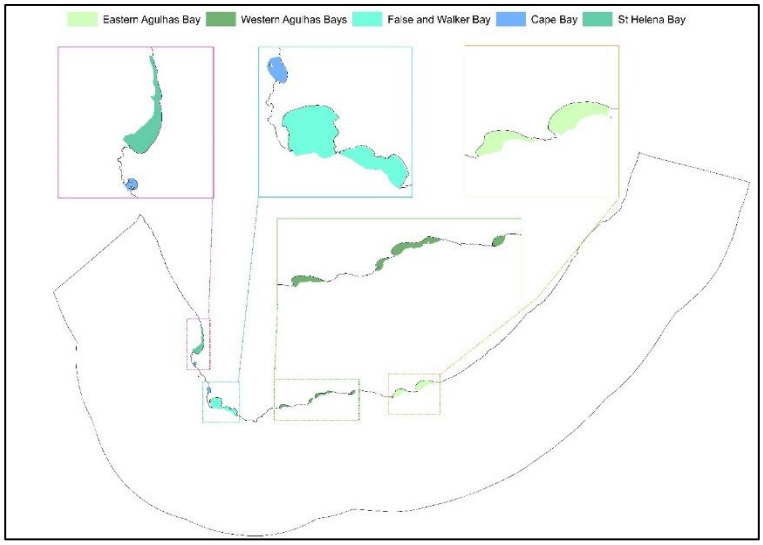


Figure 24. Location of the major bays along the South African south coast.

Kelp Forests

Kelp polygons were mapped using Sentinel 2 satellite imagery and classified into three kelp ecosystem types namely: Namaqua kelps, Cape kelps and Agulhas kelps (Dunga 2019 in prep). The Namaqua kelp forest ecosystem extends between Orange river and south of Doring Baai. As this mapping was undertaken for the South African NBA, it excluded the kelp that spans northwards into Namibia and Dunga (in prep) acknowledges a need for international collaborations to map the full extent of this ecosystem type. South of Doring Baai to Cape point is the Cape Kelp Forest. These two kelp ecosystem types share the same ecoregion, both occurring in the Southern Benguela. The Agulhas kelp forest ecosystem extends from Cape Point to west of Mossel Bay.

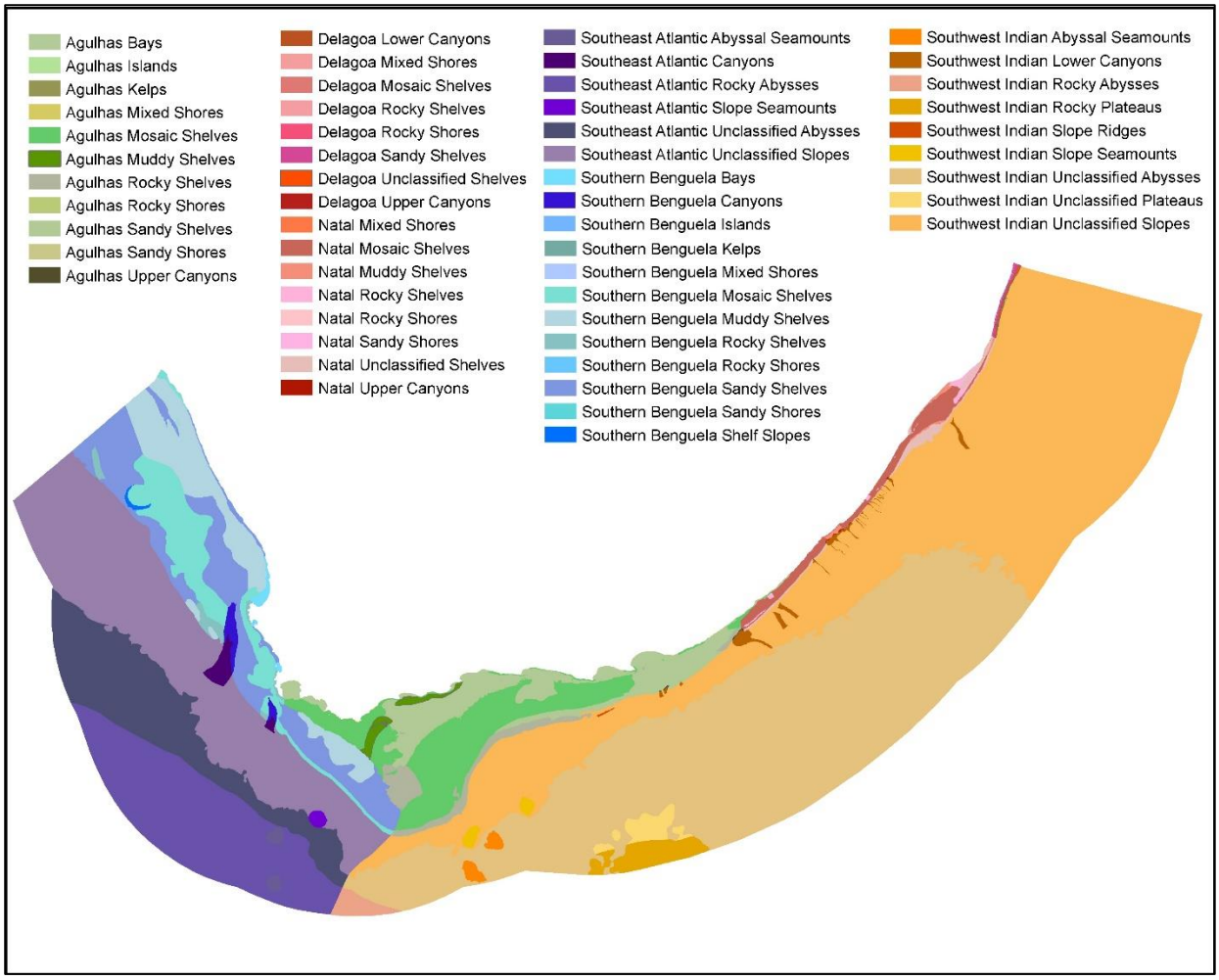


Figure 25. Substratum types map produced at the third level of the 2018 NBA Marine Ecosystem classification efforts. Classification refined to reflect substrate and main features using geophysical data or geomorphological units.

Substratum and main biophysical features were incorporated at the third level of the ecosystem classification. The 150 marine ecosystem types group into 54 types at this level (Figure 25) which does not include finer depth and regional patterns or other finer scale classification features such as wave exposure, beach morpho-dynamic state or local scale oceanographic features. Key elements incorporated at this level included sandy, rocky, boulder and mixed shores; bays, islands, reefs and reef mosaic, sandy or muddy shelves, canyons and seamounts and unclassified slope, plateau and abyss. Ridges, rocky abyss and rocky plateau ecosystems were also included. Kelp forests were treated as a biological feature. Further effort is needed in grouping and nesting of marine ecosystem types for analysis and reporting at coarser and finer scales. Functional ecosystems should be defined which should distinguish inshore and offshore ecosystems on the shelf with the former falling within the photic range. Trophic patterns and other key aspects of ecosystem functioning will need to be considered in such endeavours. This level might be appropriate for global biodiversity assessment and for other initiatives that may require broader patterns. For example, this level may be useful for ecosystem accounting.

3.6.4 Broad Ecosystem Groups

The **NBA 2011** introduced 14 Broad Ecosystem Groups into the classification and assessment methods building on the first report on the status of South African marine biodiversity (Durham and Pauw 2000). In 2018, as previously described, broad ecosystem types could not be neatly nested within the classification due to changes made to align with international classification efforts and because some types span major divisions in the classification. Some ecosystem groups (e.g. sandy shores, kelp forests and canyons) span bathomes or major regions and because, as detailed in NBA 2011, some groups of ecosystem types show different biogeographic or regional patterns to others e.g. beaches versus rocky shores see (Sink *et al.* 2005, Harris *et al.* 2010, Porter *et al.* 2013, Karenyi 2014). These groupings are useful however for reporting and management purposes and to examine patterns in threat and protection level for similar ecosystem types and so were retained but amended to include revisions (such as inclusion of bays and kelp forests) and to be of greatest use in reporting purposes.

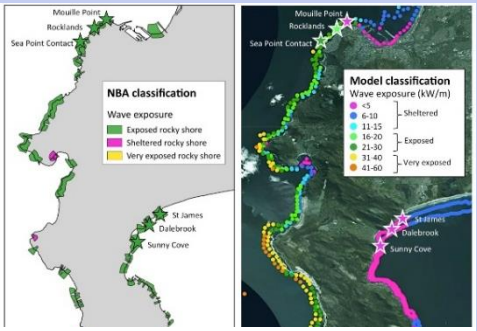
The 2018 assessment included **15 Broad Ecosystem Groups** with Bay, Kelp Forest, Canyon and Plateau being new additions, with Lagoon being excluded (as Langebaan was assigned to the estuarine assessment team by the National Ecosystem Committee) and with some former groups being amalgamated and others split based on advice of the MEC informed by data, literature and in alignment with other classifications. Rocky and mixed shores were grouped into one category in 2018, as were offshore rocky and soft sediment mosaics. Offshore pelagic was removed as a category as both benthic and pelagic elements were amalgamated in the 2018 classification and map. Shelf edge ecosystem types were considered as part of deep shelf types and inner, middle, outer and shelf edge ecosystems were only separated by seabed type. This led to 15 groups of broad ecosystem types.

Five of these are **shore typ**es with more types of rocky and mixed shores than sandy shores due to the inclusion of mixed shores and the finer scale biogeographic patterns reported for rocky versus sandy shores. A reasonable understanding of the effect of wave exposure and beach morphodynamic state allowed for classification of beaches and rocky and mixed shores although refinements in wave exposure measurements (see Box 15) are anticipated in the near future (Pfaff *et al.* 2019a). Only two types of **island** are recognised; Cape and Agulhas due to the absence of islands in the Namaqua subregion and on the East Coast. The three types of kelp forest; Namaqua; Cape and Agulhas are described above. Five types of **bays** were recognised driven by biogeography and expert advice on differences between bays in the Agulhas ecoregion. Four major divisions in broad ecosystem groups on the **shelf** were recognised; the shallow and deep shelf separated by the fair weather wave base and soft versus hard shelf. These differences are considered more substantial than the differences between depth zones in the middle, outer and edge of the shelf. **Canyons** were sub-classified into 9 types using ecoregion and upper (shelf breaching) and lower components. Delagoa canyons were assigned to the shelf they fall mostly within the deep shelf edge depth band. Other canyon ecosystem types were also assigned to the major bathome in which the majority of their extent was found. **Seamounts** were sub-classified into 4 types based on ocean basin and position on the slope or abyss.

Box 15. Wave exposure classifications of rocky shores benefit from a recently developed numerical model: evidence from a case study

by Maya C. Pfaff, Ndanduleni R. Malwela, Lauren Williams and Christo Rautenbach

Wave exposure strongly influences the ecology of intertidal rocky shores and is a key determinant of along-shore patterns of biodiversity (Stephenson and Stephenson 1972, Menge and Branch 2001, Branch and Branch 2018). This means that rocky shores that are in close proximity to each other but experience different wave exposures are occupied by entirely different organisms, while others that are further apart but have the same wave exposure feature similar biotic communities. Wave exposure has thus been used to define rocky shore habitats in National Biodiversity Assessments (NBA), by distinguishing among very exposed, exposed and sheltered types. In the absence of high-resolution measurements of wave force for the entire coast, wave exposure has been estimated by experts, assigning wave exposure levels to each rocky shore according to its shoreline orientation and - where known - its community attributes.



Two different wave exposure classification schemes for the Cape Peninsula, the National Biodiversity's (left panel) and a new model-based approach (right panel) (Malwela and Pfaff, unpublished data). Note the disagreement in wave exposures assignments on the eastern shores of the Cape Peninsula and the generally more detailed model-based approach. Study sites where community surveys were conducted are indicated by stars.

Very recently (and after the completion of data layers for the 2018 NBA) a more objective way to classify wave exposure was developed using modelled data (Rautenbach and Williams, unpublished data). In this approach, wave propagation was modelled using more than 20 years of swell data (1997–2013) obtained from the National Centre for Environmental Prediction (NCEP). To generate wave power data for coastal locations, the long-term offshore wave climate was refracted to the nearshore (7 m and 15 m depth) via a nested numerical model approach, rendering a data point every 500 meters along the entire South African coastline. Wave exposure levels were assigned by classifying each coastal data point (7 m depth) as sheltered (0–15 kW/m), exposed (>15–30 kW/m) or very exposed (>30 kW/m).

To assess whether modelled wave exposure levels reflect biodiversity patterns more appropriately than those previously determined by experts, a case study was done in the Cape Peninsula, where wave exposure levels diverged notably between the two methods (see figure above by Malwela and Pfaff). Rocky shore community surveys were conducted at six sites, where disagreements existed in wave exposure assignments. Observed differences in community structure were then compared to those expected according to known relationships (Blamey and Blanch 2009, Branch and Branch 2018), and the appropriateness of the two classification schemes evaluated in this context. The results of this study showed that the NBA classification did not provide the necessary level of detail in wave exposure classifications to appropriately capture observed differences in community types. The model-based wave exposures, however, managed to resolve differences in wave exposure more appropriately, reflecting real differences in biotic communities.

Based on these results, it is recommended that the wave exposure classification will be revised in futures NBAs by using the newly developed model-based wave exposure index, which is based on long-term wave climate and available at high spatial resolution around the whole South African coastline.

These broad ecosystem groups are both physically and functionally similar, although biogeographic differences account for significant differences in species composition, ecology and ecosystem functioning in many of these ecosystem types. For example, shallow reefs in the Delagoa ecoregion in northern KwaZulu-Natal have very little overlap in species composition with the shallow reefs in the Southern Benguela ecoregion. Nevertheless, reefs are more functionally similar across ecoregions than reefs and unconsolidated ecosystem types within the same ecoregion. It is because of these critical differences in ecosystem functioning that it is not considered appropriate to assess marine ecosystem types at this broad level but rather focus on the level of ecosystem types which is considered more appropriate for marine spatial planning.

3.6.5 Coastal ecosystems

The 2018 Assessment produced the first aligned and integrated map of South Africa's coast which is recognised as a cross-realm environment comprising terrestrial and aquatic components, including all estuaries and micro estuaries) (Harris *et al.* 2019a). Coastal ecosystem types in the marine realm include all shore and inner shelf ecosystem types and the full extent of bays, but also, where applicable, river-influenced marine ecosystem types that extend further offshore (Figure 26). Where river influence is greatest and the shelf edge is close to shore, this means that the coast, as defined here, extends to the mid or outer shelf, or even shelf edge in the case of the KwaZulu-Natal Bight (Fennessy *et al.* 2016, Scharler *et al.* 2016, Harris *et al.* 2019b).

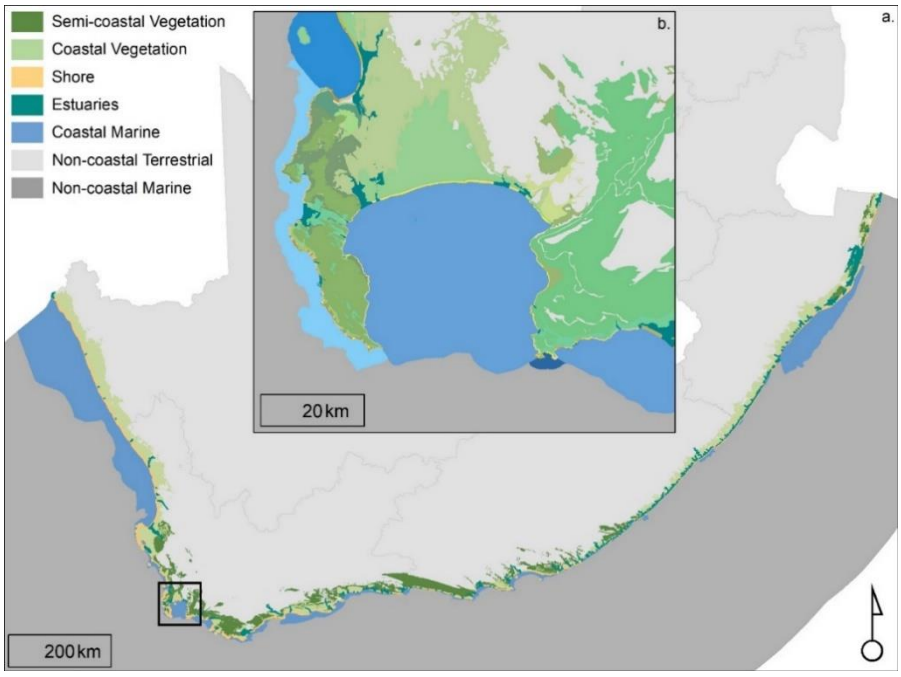


Figure 26. Map of coastal ecosystem types in the marine (blue and yellow in the case of shores), estuarine (teal) and terrestrial (greens) realms. The 20 km and 200 km inserts are scale bars.

3.7 Limitations and priorities for future improvement

Key areas for improvement of the classification and map of marine ecosystems in South Africa relate to the need for additional data coverage, particularly in deep water; a better understanding of benthic-pelagic coupling and pelagic biodiversity pattern; and work to address the limited sampling for those ecosystem types with limited sampling effort and on confidence (see Figure 27). A new national bathymetric dataset is a priority that should draw from research, navy and industry datasets to produce one publicly available bathymetric dataset that includes the best available data. An improved understanding of the role of freshwater flow in offshore environments, mapping of fluvial fans and the mapping and classification of mud habitats is needed. Updated wave exposure data should be incorporated into shore classifications as new innovations are improving spatial data (Harris *et al.* 2019a).

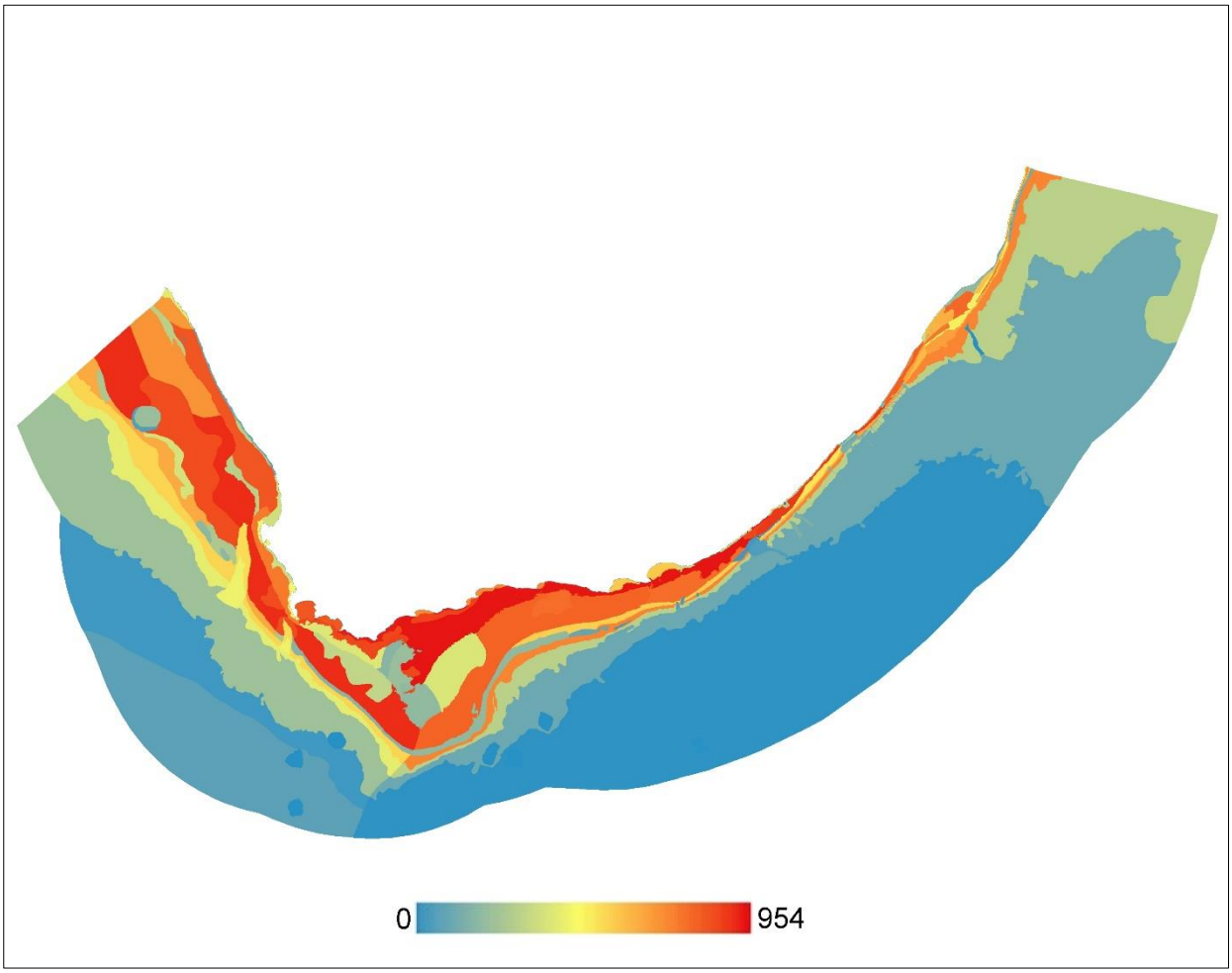


Figure 27. Heat map reflecting the number of data points per ecosystem type showing relative sampling effort per ecosystem type.

Differences in biodiversity between ecosystems characterised by terrigenous versus authigenic muds require further investigation. Research to improve the classification and mapping of bays is a priority. Current work underway in new ACEP projects should be incorporated inform future ecosystem classification efforts, for example progress reflected in Box 16. Further data-driven approaches that can integrate large datasets covering multiple ecosystem components collected by multiple methods are

encouraged. Three-dimensional mapping of marine ecosystem types can be considered but additional complexity in having multiple map layers requires consideration in terms of the application of assessment outputs in ecosystem accounting and ocean management.

In summary, **7 key research priorities** were identified to improve the National Marine Ecosystem Classification and Map

1. Integrative approaches to advance mapping to a **data driven** expert informed approach
2. Improved mapping of **bays, reefs, Vulnerable Marine Ecosystems and muds**
3. Advances in incorporation of **pelagic** biodiversity pattern and process into this map
4. Improvements in **shore** mapping (see Coastal report for details)
5. Shelf edge and deep ocean ecosystem sampling including slope, seamounts, canyons, plateau and abyssal research. More effort is needed to detect and map **chemosynthetic ecosystems**
6. Targeted research that addresses those ecosystem types with few data points
7. Improved mapping of important **carbon sequestration ecosystems** e.g. seaweeds

Box 16. Classification and mapping of mesophotic ecosystems in the Amathole region

By Luther Adams, University of Cape Town



Mesophotic ecosystems (-30m to -150m) worldwide are understudied and temperate mesophotic ecosystems are particularity poorly studied. Advancements in underwater camera technologies have increased the accessibility and affordability of these systems for conducting research in the mesophotic zone in South Africa. Current research, from the ACEP Imida Frontiers project, aimed to use Remotely Operated Vehicles (ROV) to study these ecosystems in an under-sampled stretch of the outer shelf and continental margin off East London. The new Research Vessel *Phakisa* with its propeller free jet engines allowed for the first georeferenced ROV transects providing an opportunity for more comprehensive ROV surveys for quantitative analysis of invertebrate communities in the temperate mesophotic ecosystems. This region has a narrow, steep continental shelf compared to the wider western shelf. It is also the location where the first coelacanth was discovered, the terminus of the Great Kei River and currently thought to constitute the transitional boundary between the Agulhas and Natal ecoregions. Ongoing research is needed to iteratively improve ecosystem classification and mapping in this area. Preliminary results show several distinct benthic epifauna communities exist off the Kei River and that depth has the greatest influence on biodiversity pattern in this region. Gathering foundational biodiversity information, understanding the underlying processes that shape ecosystems and biodiversity are of paramount importance if we aim to sustainably use our oceans natural resources for future research, bio-discovery and economic development.

4. PRESSURES ON THE MARINE ENVIRONMENT

Chapter Citation: Majiedt PA, Holness S, Sink KJ, Reed J, Franken M, van der Bank MG, Harris LR, Adams L, Perschke M, Miza SA, Currie J, Dunga LV. 2019. Chapter 4: Pressures on Marine Biodiversity. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



Increasing petroleum exploration is a key pressure on marine biodiversity

Chapter Summary

Marine ecosystems and species face pressures from an increasing range and intensity of human activities. Pressure data is a key input into ecosystem assessments including the new IUCN Redlist of Ecosystems. This chapter reviews pressures on marine biodiversity in South Africa drawing from the NBA 2011, literature, expert knowledge and updated data to support pressure mapping. These include 20 fisheries sectors, petroleum activities, mining, shipping, ports and harbours, coastal development, mariculture, freshwater flow reduction and pollution. Emerging pressures include plastic pollution, increased underwater noise and desalination. An overview of each pressure is provided summarising the known impacts on marine biodiversity. The spatial extent and intensity (where feasible) of the following 31 pressures were mapped to support the 2018 assessment of marine ecosystem status.

- Demersal Trawling (Inshore and Offshore)
- Crustacean Trawling
- Midwater Trawling
- Linefishing
- Recreational Fishing
- Demersal Longline Fishing
- Pelagic Longline Fishing
- Tuna Pole Fishing
- Small Pelagic Fishery
- Netfishing: Gillnet Fishing
- Netfishing: Beach-seine Fishing
- West Coast Rock Lobster Harvesting
- South Coast Rock Lobster Harvesting
- Squid Harvesting
- Abalone Harvesting
- Oyster Harvesting
- Kelp Harvesting
- Subsistence Fishing
- Shark Control
- Sea-based Aquaculture
- Coastal Development
- Coastal Disturbance
- Mining
- Petroleum Activities
- Invasive Species
- Port and Harbour Activities
- Shipping
- Wastewater Discharge
- Ammunitions Dumping
- Dumping of Dredge Material
- Freshwater Flow Reduction

4.1 Introduction

Pressure data is a key input in research to understand and evaluate ecosystem degradation which can be used to assess the state of marine ecosystems. SANBI used cumulative pressure mapping in the **NBA 2011** in a first data-driven assessment of ecosystem threat status (See Sink *et al.* (2012a)). This approach was based on work undertaken by other authors who examined both global (Halpern *et al.* 2008) and more localised (Halpern *et al.* 2009) impacts of cumulative pressures on marine ecosystems. South Africa is now aligning its ecosystem assessment approaches with the new IUCN guidelines for redlisting of Ecosystems (RLE) (Bland *et al.* 2017a). This is explained more fully in Chapter 7. The goal of the IUCN RLE is to identify ecosystems that are at risk of losing their constituent biodiversity (Keith *et al.* 2013b). The RLE encourages the use of all available information on ecosystem degradation, including rates of habitat loss, disruption of biotic processes and environmental degradation. Of these three components of degradation, the focus here is on environmental degradation but many pressures, particularly fisheries, lead to both environmental degradation and biotic disruption (Keith *et al.* 2013b). Halpern *et al.* (2015) show the value of a cumulative pressure mapping approach in tracking increasing pressures and in prioritising management interventions.

This chapter provides a summary of the current state of knowledge of pressures on marine biodiversity in South Africa to inform the assessment of ecosystem threat status. A brief history of previous work in this context is provided and then each pressure is reviewed, providing a description of each pressure and a map of the relative intensity of each pressure for which spatial data were available. Patterns in the extent and intensity of pressures are noted. The known biodiversity impacts of each pressure are presented and discussed, noting any known mitigation measures or current relevant work that is underway. The main informants for these pressure overviews were the NBA 2011, expert knowledge, recent literature, and updated data to support pressure mapping. While this chapter includes information on the impact of pressures on species, it is not intended be a comprehensive assessment of impacts on marine species. Rather, this chapter collates the knowledge on biodiversity impacts of pressures to inform ecosystem (i.e. species and habitat) threat status. For an overview of the state of marine species in South Africa, refer to Chapter 9.

4.2 Processing of pressure data

4.2.1 Previous NBA assessments

The **2004 National Spatial Biodiversity Assessment** employed expert assessment to map the relative impact of 9 major categories of resource use and other influences on the marine environment. The **NBA 2011** drew from Sink *et al.* (2011) and Harris (2011) to map human use in offshore and coastal environments respectively and produced 27 GIS layers reflecting the relative intensity of 27 drivers of ecosystem change. In 2011, data on each of the pressures were summarised to 5' grids (approximately 8 x 8 km) to facilitate the spatial assessment. This scale represented a compromise between the finer-scale data available for some coastal pressures and coarser-scale offshore fishing data, and corresponded with the data collation scale of the major base data source for the assessment (Sink *et al.* 2012a). For most pressures, pressure values were converted to a 0-1 range using the formula p=d1/d80, where d1 is the raw pressure data in a 5' grid, d80 is the 80th percentile of the pressure values for that data set, with

resultant values over one being assigned a value of one. This method was required as some of the datasets contained some very high values which would have masked the potential impact of moderate levels of pressure. The compilation of the individual pressure layers into this consistent format and range was necessary to allow spatial patterns of intensity of different pressures to be compared and cumulative pressures to be calculated.

4.2.2 2018 NBA

In comparison, the NBA 2018 has covered 31 pressures. Key **additions and improvements** include finer scale mapping of pressures, the inclusion of additional pressures and differences in pressure data variables (e.g. catch versus effort). The pixel resolution of pressure maps was improved from a 5' grid (approximately 8 × 8 km) in 2011 to 30 × 30 m pixels in 2018. This does not imply improved accuracy but rather a better match in the resolution of ecosystem and pressure mapping. In many cases, data were still provided at a coarse resolution and was re-sampled to the pixel level. Of the 31 pressures included, six are new, including abalone fishing (South African abalone *Haliotis midae*), port and harbour activities, disposals of ammunition and dredge material, beach seine netfishing, gillnet fishing and oyster harvesting. Source data and an overview of pressure data processing steps are detailed in Appendix 2. In summary, updated data were collated and cleaned for each pressure. The most appropriate measure (i.e. units such as effort or catch in the case of fisheries) to represent each pressure in the context of ecosystem degradation were selected. This was then summarised across the seascape using the 30 x 30 m pixels described above to produce a national map of intensity for each pressure. These raw values were normalised to deal with skewed distributions (especially where some extremely high values may mask the overall picture) and converted to a standardised range (0-100). For some datasets, additional steps were taken to further normalise data. In some cases, pressures were split into ten quantiles (such as small pelagic seine net fishing) and in other cases pressures were categorised into equal intervals (such as wastewater discharge). Further detail on the rationale and processing of individual pressure intensity and impact layers is provided in Appendix 2.

Note that invasive species (briefly discussed in this chapter) and climate change (although not mapped in this assessment) are considered as threats to marine biodiversity and discussed in detail in Chapter 5 and Chapter 6 respectively.

4.3 Overview of Pressures in the NBA 2018 Assessment

4.3.1 Demersal Inshore Trawling

Pressure Description

South Africa's inshore trawl fishery uses **demersal otter trawls** (Box 17) to catch a variety of fish species in shallower areas near the coast. This fishery targets Agulhas Sole (*Austroglossus pectoralis*) and Shallow-water Hake *Merluccius capensis* (Durholtz *et al.* 2017) but may be considered a multi-species fishery due to the diversity and volume of bycatch including Silver kob *Argyrosomus inodorus*, Panga *Pterogymnus laniarius* and several other commercial linefish species, much of which adds value to this sector (Walmsley *et al.* 2007a, Attwood *et al.* 2011). A description of trawling and the trawl gear is provided in Box 17.

Distribution of Pressure

The inshore trawl fishery operates in **Agulhas Bank** waters shallower than 110 m or within 20 nautical miles of the coast, whichever is the greatest distance. Its western and eastern boundaries are approximately Cape Agulhas and the mouth of the Kei River respectively (Figure 28). However, (Booth and Hecht 1998) report that the eastern boundary contracted from East London to Port Alfred in 1972, due to declining hake catches on the East London grounds. A map of the commercial trawl footprint (Wilkinson and Japp 2005a) shows Port Alfred to represent the eastern-most point of operation. In the last three decades highest fishing effort occurred between Cape Infanta and Mossel Bay, and to a lesser degree east of Algoa Bay (Currie 2017). Effort is focused on muddy and sandy ecosystem types in the mid shelf.

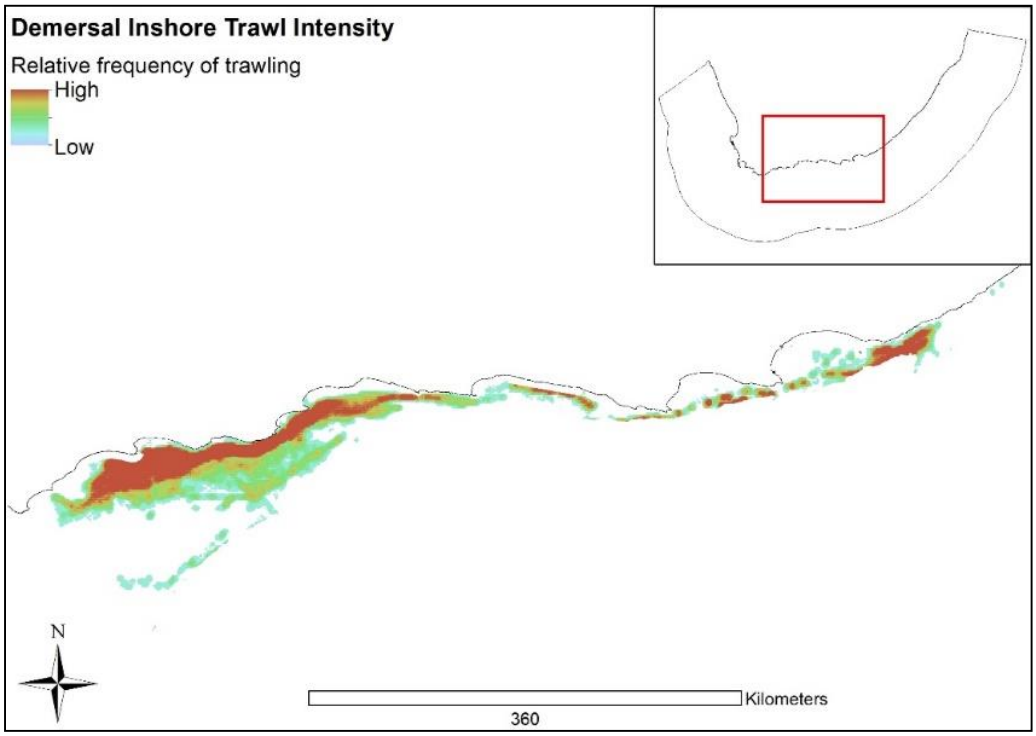


Figure 28. Scaled pressure values reflecting relative fishing effort measured as frequency of trawling for the inshore demersal trawl sector in South Africa for the period 2008-2016.

The **frequency of trawling events** was used as a proxy for effort and therefore degradation in this assessment. This was to account for the cumulative impact of multiple trawling events within the revised assessment framework. The high values in Figure 28 represent areas most often trawled, with low values reflecting areas that were sporadically trawled.

Biodiversity concerns and potential ecosystem impacts of the inshore trawl sector include:

- Damage to seabed habitats and potential vulnerable marine ecosystems (Auster *et al.* 1996, Attwood *et al.* 2000, Leslie *et al.* 2000, Kaiser *et al.* 2002, Tillin *et al.* 2006, Atkinson and Sink 2008, Sink and Samaai 2009, Atkinson *et al.* 2011a, Ragnarsson *et al.* 2016, Rijnsdorp *et al.* 2016, Currie 2017, Hiddink *et al.* 2017).
- The diverse and substantial proportion of bycatch, which includes overexploited linefish species (Wilkinson and Japp 2005b, Walmsley *et al.* 2007b, 2007a, Attwood *et al.* 2011, Winker *et al.* 2012,

2014) and chondrichthyans (Walmsley *et al.* 2007a, 2007b, Attwood *et al.* 2011, da Silva *et al.* 2015).

- Catches of juveniles of Hake and linefish species such as Silver Kob and Geelbek (Walmsley *et al.* 2007b, Attwood *et al.* 2011, Winker *et al.* 2017a)
- Impacts on squid egg beds on the seabed (Sauer 1995)
- Discarding of low value and small fish (Attwood *et al.* 2000, 2011, Walmsley *et al.* 2007b, 2007a)
- The uncertain stock status of Agulhas Sole (DAFF 2016, Currie 2017, Yemane 2017, Glazer and Butterworth 2018).

The two principal ecological concerns of South Africa's inshore demersal trawl sector are **benthic habitat damage** and the large bycatch of diverse fauna (Walmsley *et al.* 2007a, 2007b, Atkinson and Sink 2008, Atkinson *et al.* 2011a, Sink *et al.* 2012b, Rijnsdorp *et al.* 2016). There has been no research aimed at understanding the impacts of the inshore trawl fishery on the seabed with substantial challenges in finding representative untrawled areas to examine such effects. Although several closed bays were established to protect areas and young fish from trawling (Buxton *et al.* 1984), these typically represent distinct ecosystem types (see Chapter 3) and the effectiveness of these closures has not been investigated (Attwood *et al.* 1997b). The importance of bays is being increasingly realised (Pfaff *et al.* 2019b) and these retentive and productive areas no doubt benefit from closures, some of which were implemented prior to 1930 in response to high bycatch and competition with linefishers. It is likely that such areas would have a far greater bycatch than the primary target species but it is also likely that these bay systems harbour different benthic assemblages from the equivalent depths outside of such closures.

A recent comparative trawl survey study compared the fish composition on inshore trawl grounds of the Agulhas Bank where inshore trawling has persisted since its onset more than 111 years ago (Currie 2017). This study used meticulously-documented trawl survey data from 1897-1904 and repeat surveys based on re-construction of historical trawl gear (Currie *et al.* 2019), and detected **substantial changes in demersal fish assemblages** and hence the ecosystem structure on the inshore trawl grounds. These changes included the heavy depletion of kobs *Argyrosomus* spp. (absent in resurveys), Panga *Pterogymnus laniarius* (2.4% of historical catch abundance) and East Coast Sole *Austroglossus pectoralis* (4.6% of historical catch abundance), which had jointly comprised 70-84% of historical catch composition (Currie 2017). In contrast, Hake *Merluccius capensis* had substantially increased in abundance (558% of historical abundance) along with gurnards (*Chelidonichthys* spp.; 3 792% of historical abundance), dogfish (*Squalus* spp.; 3 121% of historical abundance) and White Sea Catfish *Galeichthys feliceps* (13 863% of historical abundance). These results suggested that trawling-induced alteration of benthic habitats is likely and warrants further investigation. The recent proclamation of 20 new MPAs provides some protection to some of the ecosystem types previously identified as requiring protection in this Marine Stewardship Council eco-certified fishery (Sink *et al.* 2012b, 2013). Chapter 7 provides an updated assessment of ecosystem threat status and Chapter 8 updates protection levels. Ecosystem types such as the muddy mid shelf and outer shelf remain as ecosystem types of concern although there has been progress in their protection levels.

The diverse and substantial **bycatch** remains a concern in South Africa's inshore trawl fishery. A total of 137 nominal species were documented by observers monitoring this fishery between 2003 and 2006

(Attwood *et al.* 2011). There is substantial species overlap between the inshore trawl bycatch and target species from the commercial linefishery, many of which are overexploited (Winker *et al.* 2012, 2014, Boyd 2017, Winker *et al.* 2017a). A voluntary program to **limit bycatch** impacts was applied in 2014 in collaboration between the inshore trawl fishery, NGOs and researchers (Greenston and Attwood 2013), although its implementation stalled in 2017 due to legal challenges. If successfully implemented, this program could help limit the trawl impact on species included in the program. Broader impacts on benthic habitats and species have not been accounted for in this initiative and may be difficult to mitigate without reducing the footprint or fishing effort of the inshore trawl sector (Attwood 2011).

4.3.2 Demersal Offshore Trawling

Pressure Description

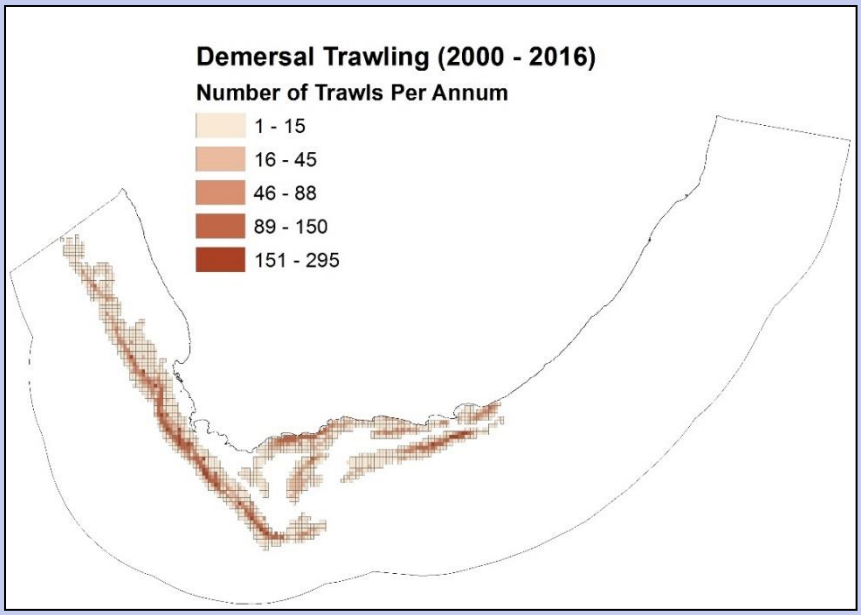
South Africa's offshore trawl fishery uses demersal **otter trawls** to target primarily two hake species, namely Shallow-water Cape Hake *Merluccius capensis* and Deep-water Hake *M. paradoxus.* The shallower species occur from the coast to about 400 m depth, whereas the deeper species ranges from about 150 m to 900 m off the South African continental shelf (Payne 1986, Payne and Punt 1995). Valuable bycatch species of the offshore demersal trawl fishery include Monk *Lophius vomerinus*, Kingklip *Genypterus capensis*, Angelfish *Brama brama*, Snoek *Thyrsites atun* and Horse Mackerel *Trachurus trachurus capensis* (Atkinson and Sink 2008). In west coast waters deeper than 500 m, the bycatch includes additional species such as oreos and slimeheads *Hoplostethus* spp., of which some are commercially valuable (Atkinson and Sink 2008). The market value of bycatch species (e.g. Kingklip and Monk) is sometimes higher than that of Hake, which can lead to targeted fishing of bycatch species. A description of trawling and the trawl gear is provided in Box 17.

Box 17. Gear and fishing methods of South Africa's trawl fisheries

By Jock Currie and Jodie Reed

Trawling is the act of dragging a fishing net (trawl) behind a vessel, or between two vessels. In South Africa, the nets used are predominantly 'otter' trawls, which means the shape of the mouth of the net is maintained by the outward shearing force of a pair of 'otter' trawl doors that act like underwater kites (FAO 1974). The trawl doors are connected to the vessel via steel cables ('trawl warps') and to the cone-shaped net by lengths of cables (the 'bridles') (Fonteyne 2001). The mouth of the net is created by a 'headline' and a 'groundrope', which consist of chains, cables or ropes in various configurations. The back end of the net where the catch accumulates is referred to as the codend.

South Africa has both an **inshore** and an **offshore demersal trawl** sector targeting hake and other fish species on the Agulhas Bank and off the west coast. Demersal trawling means the trawl is dragged on the seafloor, with the 'ground' gear, consisting of the trawl doors, bridles and net (especially the groundrope) making contact with the sediments and fauna living there. Accessory gear such as bobbins, rollers and discs attached to the ground-rope of the net (Sink *et al.* 2012b) help to lift the net over features on the seafloor, while providing a barrier to fish that might escape under the net opening. Fishing depths range from just below 30 m to approximately 800 m, although offshore licensed vessels are not permitted to fish in depths less than 110 m. The demersal inshore trawl sector tends to have smaller vessels and smaller nets than the offshore sector, with drag durations of 1-6 hours (median=3 hours) and towing speeds of 2.5-4 knots (Currie, unpublished data). Their nets have a minimum mesh size of 75-90 mm, dependant on target species. Although not restricted to a certain depth, inshore licensed vessels tend to fish shallower areas closer to shore. Offshore trawl sector depths are predominantly between 230 m and 630 m. Drag durations tend to range from 1 to 6 hours (median=3 hours) and towing speeds from 3 to 4 knots (Currie, unpublished data). The effort distribution for these inshore and offshore demersal trawling sectors is shown in the map provided below.



Map of demersal fish trawling effort for the inshore and offshore sector presented as the 2000-2016 mean annual hours of trawling on a 5 min grid.

The **crustacean trawl** fishery also uses demersal otter trawls. As described by Fennessy and Groeneveld (1997) and Everett *et al.* (2015b) , the fishery uses variable trawl configurations, that might include a single net or boom-operated twin or triple nets, with trawl sizes ranging from 25 – 60 m footrope lengths. The stretched mesh size tapers from 70 mm in the wings to 50 mm in the codend where the catch is retained. Trawl drag duration averages four hours at speeds between 2-3 knots, with trawling taking place on a 24 hour basis.

Midwater trawling is a method of trawling where the gear is designed to 'fly' in the water column and tends not to interact with the seafloor. Nets are usually considerably larger than the nets used by bottom trawl fisheries and are designed to target pelagic rather than demersal species. This includes fishing of surface water. Horse mackerel are targeted in the water column at night as they exhibit a distinct diurnal vertical migration, being found close to the seabed during the day and ascending into the water column at sunset (Reed *et al.* 2017). Midwater trawls operate at speeds of approximately 5 knots with trawl durations ranging between 1 and 9 hours and averaging 2.5 hours (Norman *et al.* 2018).

Distribution of Pressure

The offshore trawl grounds extend in an unbroken band along the west coast of South Africa, from approximately 300 m depth off Hondeklipbaai to the southern tip of the Agulhas Bank (Figure 29). Effort diminishes closer to the Namibian border due to greater fuel costs associated with increasing distances from port. Offshore trawling is concentrated on the **shelf edge**. Little offshore trawling occurs between the southern tip of the Agulhas Bank and offshore of Plettenberg Bay, due to rocky terrain (Wilkinson and Japp 2005a). On the south coast, offshore trawlers concentrate fishing effort on the chalk line grounds, which span the edge of the Agulhas Bank and yield relatively high catches of Kingklip. Trawling effort in this area is concentrated offshore of Port Elizabeth (Figure 29).

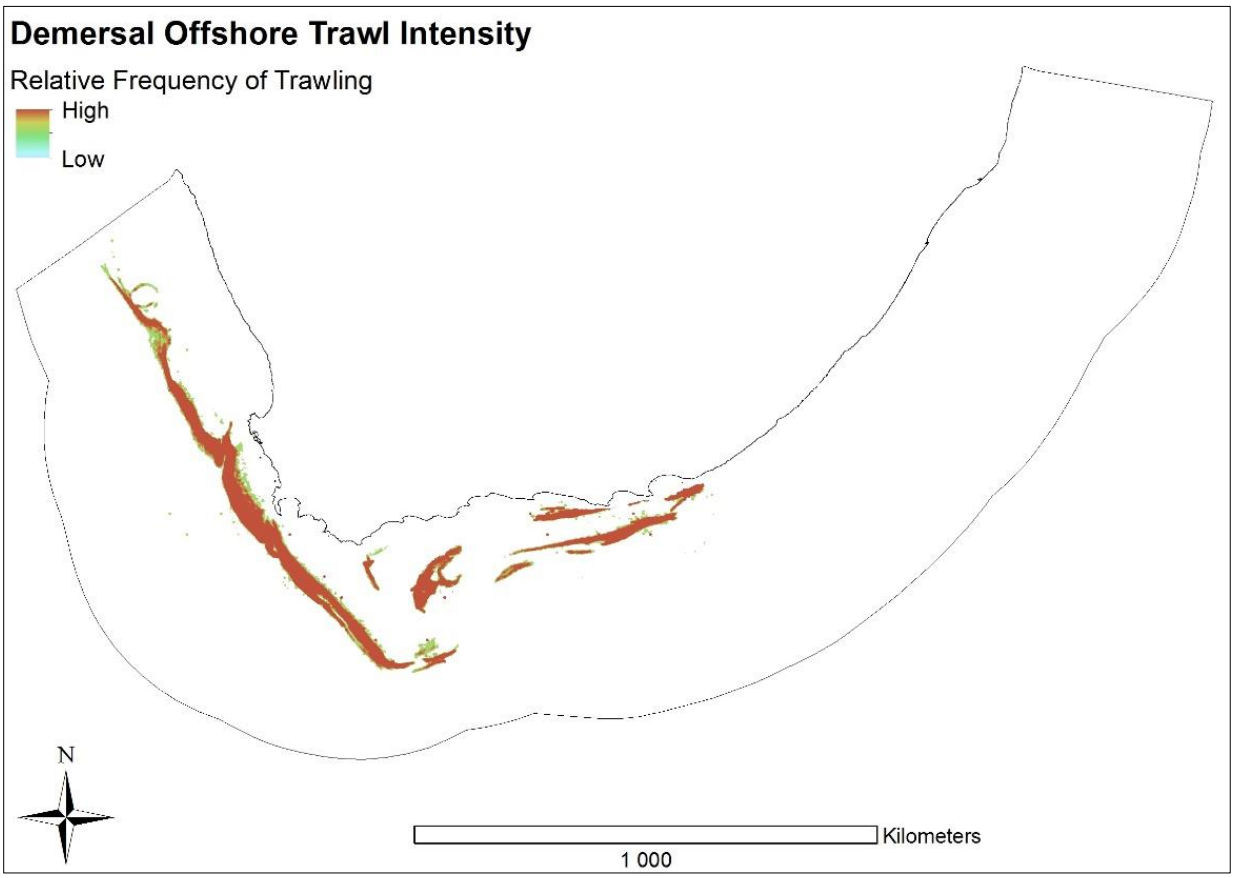


Figure 29. Scaled pressure values reflecting fishing effort using frequency of trawling for the offshore demersal trawl sector in South Africa for period 2000-2016.

As with the inshore sector, the frequency of trawling was used as the proxy for fishing effort (Figure 29). High values represent areas most often trawled, with low values reflecting areas that are sporadically trawled.

Biodiversity and fishery sustainability concerns associated with the offshore trawl sector have included:

- The impact of trawling on benthic communities (Shannon *et al.* 2006, Tillin *et al.* 2006, Atkinson 2010, Atkinson *et al.* 2011b, Puig *et al.* 2012, Clark *et al.* 2015, Rijnsdorp *et al.* 2016, Hiddink *et al.*

2019) and vulnerable marine ecosystems such as cold water corals (Sink and Samaai 2009, Sink *et al.* 2012b, 2013, Clark *et al.* 2015, Ragnarsson *et al.* 2016, Hinz 2017).
- Vulnerability of some bycatch species (Japp 2004, Walmsley *et al.* 2007b, Atkinson and Sink 2008, da Silva *et al.* 2015) and targeting of bycatch species (Walmsley *et al.* 2007b, 2007a).
- Discarding species or sizes of low commercial value (Walmsley *et al.* 2007b, 2007a).

Trawling impacts seafloor habitats and biodiversity (Clark *et al.* 2015). Its impacts are associated with reduced habitat complexity of the seafloor due to removal and/or disturbance of structure-forming fauna and sedimentary structures (Auster *et al.* 1996, Kaiser *et al.* 2000, Puig *et al.* 2012, Clark *et al.* 2015, Hinz 2017). Of particular concern are hard ground habitats, including deep reefs, submarine mounds, canyons and hard areas of shelf edge (Hinz 2017). Such substrates often support species that comprise complex three-dimensional habitats vulnerable to trawl damage, which may frequently be slow-growing (Kaiser *et al.* 2002, Althaus *et al.* 2009, Parker *et al.* 2009, Clark *et al.* 2015, Ragnarsson *et al.* 2016, Hiddink *et al.* 2019). In addition to its direct impacts, trawling activity can modify sediment fluxes and biogeochemical exchanges between sediments and the water column (Churchill 1998).

While trawl impacts on benthic habitats have been investigated internationally (Auster *et al.* 1996, Kaiser *et al.* 2000, 2002, 2003, Tillin *et al.* 2006, Clark and Rowden 2009, Clark *et al.* 2015, Hiddink *et al.* 2017, 2019) this has not yet been well studied in South Africa although some progress has been made in this regard (Atkinson 2010, Atkinson *et al.* 2011a, Sink *et al.* 2012b). Furthermore, a five year benthic trawl experiment is underway offshore of Child's Bank that may provide further information on trawl impacts (SADSTIA 2018) although the area under examination is lightly trawled and even limited trawling in the trawled lanes may further diminish contrast in this experiment.

The incidental trawl-associated mortality of seabirds (including threatened species) was a serious concern in the previous NBA (Sink *et al.* 2012a), but bird-scaring lines have greatly reduced this impact (Maree *et al.* 2014), reducing seabird mortalities to negligible levels when fully implemented and constructed as per regulations (Ross Wanless, Birdlife-SA, pers. comms.).

4.3.3 Crustacean Trawling

Pressure Description

As with the previously discussed trawl sectors, the crustacean trawl fishery uses **otter trawls** (see Box 17). The inshore fishery targets White Prawns *Fenneropenaeus indicus* (approximately 80% of the crustacean catch (DAFF 2016), Brown Prawns *Metapenaeus monoceros*, Tiger Prawns *Penaeus monodon* and Bamboo Prawns *Marsupenaeus japonicus,* on the shallow water mud banks (Fennessy and Groeneveld 1997, Forbes and Demetriades 2005, Everett *et al.* 2015b, DAFF 2016). The offshore crustacean trawl fishery targets the Knife or Pink Prawn *Haliporoides triarthus*, Langoustines *Metanephrops mozambicus*, Natal Deep-water Rock Lobster *Palinurus delagoae* and the East Coast Red Crab *Chaceon macphersoni* (Robey *et al.* 2013a, 2013b, DAFF 2016). Slipper lobsters *Ibacus novemdentatus* and *Scyllarides elizabethae* also constitute a component of the retained bycatch (Fennessy and Groeneveld 1997, Groeneveld *et al.* 2012). The shallow water target species have a juvenile phase dependent on estuaries while the offshore species are not estuarine dependent although in some cases their muddy habitats may rely on sediment supplied through rivers (Berry *et al.* (1975) in Robey *et al.* (2013a).

Pressure Distribution

South Africa's crustacean trawl fisheries are confined to the province of KwaZulu-Natal and include an offshore and inshore sector (Groeneveld and Melville-Smith 1995, DAFF 2016). The inshore crustacean trawl fishery has declined dramatically since 2000 with total catch for the inshore sector dropping from 107 tonnes in 2000 to a mere 0.3 tonnes in 2014 (DAFF 2016). The inshore fishery operates in shallow water (5-40 m, (DAFF 2016)), mostly in the 20-45 m depth range and is reported to be confined to areas within 0.5 to 7 nautical miles from shore (Fennessy 1999) (Figure 30). The Tugela Bank is the primary inshore trawl area, but some inshore trawling also takes place off Richards Bay and St Lucia. The deep-water crustacean trawl fishery operates on the edge of the continental shelf in water 100-600 m deep, from Port Edward to Cape Vidal, with highest effort offshore of Durban, (de Freitas 1989, Fennessy 1994a, 1994b, 1999, Fennessy and Groeneveld 1997, Forbes and Demetriades 2005, Atkinson and Sink 2008).

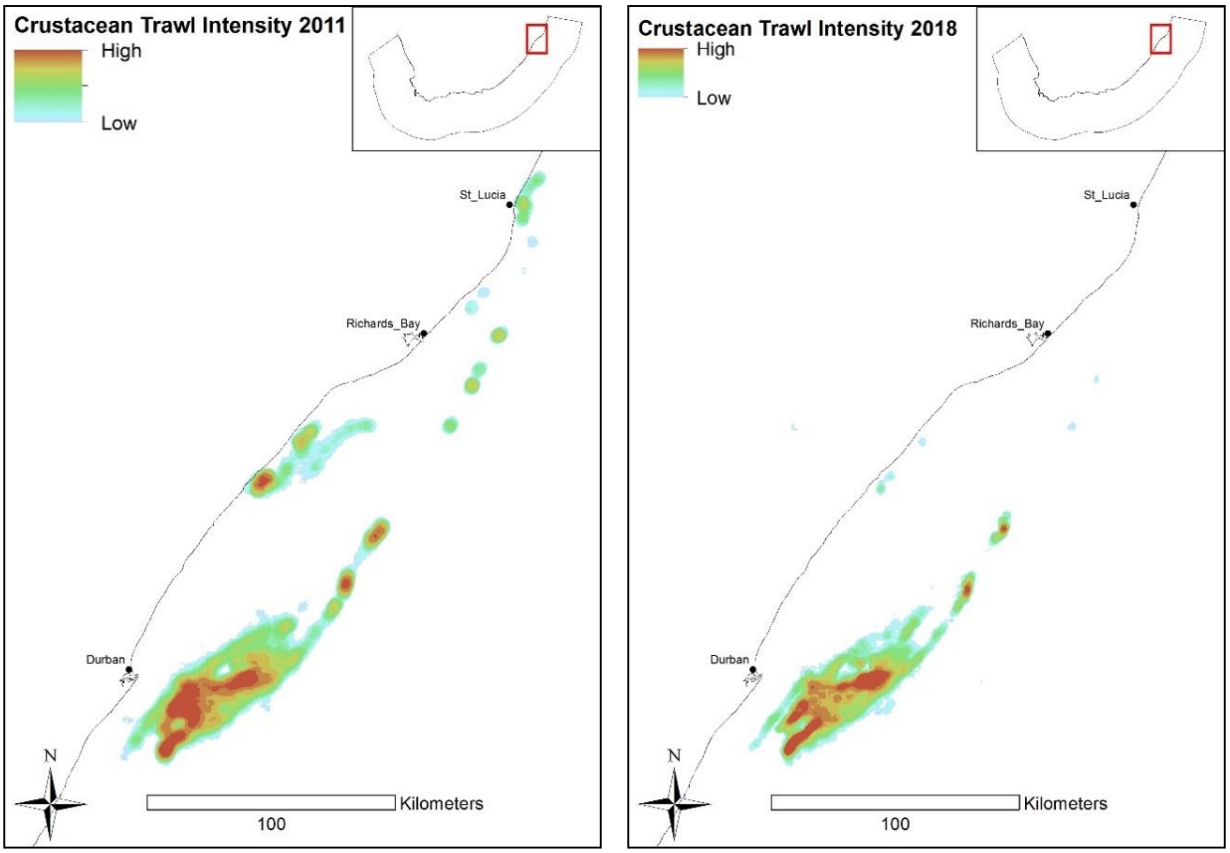


Figure 30. Maps of scaled intensity of crustacean trawling off the coast of KwaZulu-Natal, South Africa – Crustacean Trawl Intensity 2011 (left) represents the period 2000-2005; Crustacean Trawl Intensity 2018 (right) represents the period 2006-2017.

This assessment used the pre-industrial baseline of the year 1750 as the baseline for pristine, assuming that prior to 1750 very little to no biodiversity degradation had occurred. To account for the high impact of this fishery a trawl footprint was used in this assessment. The data for crustacean trawl intensity data used in the 2011 and the current 2018 datasets were combined to develop the crustacean trawl footprint, as it was noted that fishing intensity had shifted since the previous assessment (Figure 30), with declining inshore effort. No shallow water trawls have been recorded since 2013 (with a total of only 26 trawls recorded for the period 2010 – 2012), whilst the distribution of deep water trawls has contracted owing

to the increased cost of operations (Oceanographic Research Institute, unpublished data). The maximum annual average of hours of trawling recorded are 5700 hours for the period 2000-2005 used in 2011 (Sink *et al.* 2012a) and 916 hours for period 2006-2017.

Biodiversity and fishery sustainability concerns linked to the crustacean trawl fishery are detailed in text below but include:

- Potential seabed and associated biodiversity impacts on unconsolidated sandy and muddy shelf and shelf edge habitats inshore.
- The diverse and substantial bycatch particularly in the inshore sector (Fennessy 1994a, 1994b, Fennessy and Groeneveld 1997, Persad 2005, da Silva *et al.* 2015).
- Impacts on nursery habitats, juvenile fish and Hammerhead Sharks (Fennessy 1994a, 1994b, Fennessy and Groeneveld 1997, Dudley 2003).
- Concerns about impacts on sharks, rays and overexploited linefish and incidental mortality of turtles (Fennessy and Isaksen 2007, Bourjea *et al.* 2008, Harris *et al.* 2018).
- Concerns about the sustainability of some deep water resources due to inadequate stock status information and the recognised vulnerability of slow-growing, deep-water species (Groeneveld *et al.* 2012).

The **benthic impacts** of crustacean trawling have not been examined in South Africa to date. Elsewhere investigations of the effects of prawn trawl fisheries on benthic communities have shown that epifaunal abundance and biomass values decrease substantially as a result of trawl disturbance (Hansson *et al.* 2000, Lindegarth *et al.* 2000, Tanner 2003). Impacts of a lobster trawl fishery in the Irish Sea, United Kingdom were shown to have significant negative effects on benthic infauna and epifauna (Hinz *et al.* 2009). Variations in gear type, fishing intensity and habitat type greatly influence the extent of trawl impacts on benthic biota (Rijnsdorp *et al.* 2016). Eichert *et al.* (2018) overview the potential impacts of crustacean trawl fisheries including the effects on sediment biogeochemistry (particularly in muddy sediments (Sciberras *et al.* 2013), seafloor homogenisation, nutrient cycling impacts, and alterations in both infaunal and epifaunal communities.

Subtropical demersal communities are rich in species, and there is a high diversity of elasmobranchs, teleosts and invertebrates in **trawler bycatch** on the uThukela Bank (Fennessy 1994a, 1994b, 1995, Fennessy and Groeneveld 1997, Fennessy 1999, Persad 2005, Everett *et al.* 2015b). Prawn trawling is one of the global fishing sectors with the highest discarded catch, reported to account for as much as one third of the global discarded catch (Alverson *et al.* 1994). DAFF (2010) reported that this fishery has up to 75% bycatch and discard rates, and the problem persists in this fishery (DAFF 2016). The average amount of bycatch discarded has been reported as 400 metric tons per year for the inshore trawl sector (Fennessy 1994a) but diminishing effort within this sector has reduced the volume of bycatch. Analyses of the discards of the offshore fishery have not been formally published, but are thought to comprise about 70% of the total catch (Fennessy and Groeneveld 1997, Persad 2005). Fishes that are currently not marketable, such as Grenadiers (Rat-tails), dominate the discards, followed by crustaceans, asteroids and molluscs that have no commercial value (Persad 2005). Estimates of approximately 10 000 sharks and rays caught per year as bycatch in the shallow-water crustacean trawl fishery have been reported (Fennessy 1994a, 1994b).

Aside from the considerable bycatch, the impact of inshore prawn trawling on **nursery habitats** was previously raised as a concern (Atkinson and Sink 2008). The area offshore of St Lucia Estuary is a spawning area for multiple species and serves as a nursery area for several species of teleosts, elasmobranchs and invertebrates (Wallace 1975, Whitfield 1998, Hutchings *et al.* 2002). These species frequently feature in prawn trawl catches. Fennessy (1994a, 1994b) reported 26 elasmobranch species in shallow-water trawl bycatch with large discards of newborn Scalloped Hammerhead Sharks, *Sphyrna lewini,* by prawn trawlers on the uThukela Bank. Bycatch estimates for this species in this fishery ranged from an estimated 3288 sharks in 1989 to 1742 in 1992 (Dudley 2003) and it is unknown whether the uThukela Bank is the only nursery ground for *S. lewini* off the South African east coast. If this is the case, the impact of the prawn trawlers on this species may be substantial (Dudley 2003). Offshore, elasmobranchs and unique faunal assemblages on the slopes are also considered potentially vulnerable to slope fisheries (Stevens *et al.* 2000). Crustacean trawl fisheries also impact turtles with limited information regarding impacts in South African (but see (Fennessy and Isaksen 2007).

Stock assessments of targeted crustaceans are challenging (DAFF 2010, 2016) with catch rates likely influenced by seasonality, depth and recruitment patterns (Groeneveld and Melville-Smith 1995, Robey *et al.* 2013a, 2013b, DAFF 2016) and changes in fishing gear, effort saturation and targeting of different species to achieve the highest economic returns (Groeneveld and Melville-Smith 1995, Groeneveld *et al.* 2012, DAFF 2016). In the absence of stock assessments, the Total Allowable Effort for this fishery has been held as a status quo.

Acknowledging the high variability in annual inshore prawn catches (linked to droughts and estuarine mouth closures), **fishing pressure on inshore prawns** is considered optimal but **stocks** are considered to be depleted due to estuarine nursery recruitment challenges (DAFF 2016). Shallow-water prawn catches declined by about 90% between 2000 and 2008 due to the closure of the St Lucia Estuary mouth and associated recruitment failure (DAFF 2010). This situation has gotten worse with historically low catches of 0.3 tonnes in 2014 compared to 107 tonnes in 2000 (DAFF 2016).

The **stock status for deep-water prawn** is reported as optimal (DAFF 2016), although the need for improved data collection and research is recognised for this sector. Landings of deep-water prawns have increased in recent years and have been mostly stable over the past 18 years, whereas langoustine catches are reported as stable ranging between 51 and 82 tonnes (DAFF 2016). Red Crab catches declined by 45% between 2005 and 2008, with 30% decline between 2007 and 2008 (DAFF 2016). Groeneveld *et al.* (2013) detected a long-term decline in *Chaceon spp.* catches (using data from trawl and an experimental trap fishery) that is most likely attributable to fishing. (DAFF 2016) reported the lowest catches of Red Crab in 2014 (11 t) within the total available time series. The maximum catch (187 t) was in the first year (i.e. 1992) (DAFF 2016). Catches of deep-water rock lobster declined by approximately 30% between 1992/3 and 2000 and declined by a further 50% between this period and 2003 (DAFF 2010), at least partly a reflection of the deep water trap fishery for this species (Groeneveld *et al.* 2012). In 2016, a further dramatic decline in deep-water rock lobster was reported from 23 tonnes in 2011 to 5 tonnes in 2014 (DAFF 2016).

Although the NBA 2011 reported that relatively little is known about the **biology of deep-water crustaceans** and cited their slow-growth and low fecundity as potential concerns in terms of vulnerability

to overfishing in trawl fisheries (Berry 1969, Pollock 1989, Groeneveld and Cockcroft 1997, Pollock *et al.* 2000), updated information is now available. Recent studies (Groeneveld *et al.* 2012, Robey *et al.* 2013a, 2013b, Robey and Groeneveld 2014) on the biology of deep-water crustacean resources are building the knowledge base to improve resource assessments and fisheries management including spatial management. Concerns persist around the sustainability of some deep-water resources due to inadequate stock status information and the recognised vulnerability of slow-growing, deep-water species (Groeneveld *et al.* 2012, 2013, Everett *et al.* 2015b) but these are more relevant to the former experimental trap fishery.

The recent declaration of the **uThukela MPA** and the expanded **iSimangaliso MPA** will help mitigate most of the biodiversity concerns of this sector (See Chapter 8) eliminating inshore trawling from the uThukela Banks and off St Lucia, and further reducing the extent and impact of deep-water trawling. Further innovation in gear and bycatch reduction devices (See (Fennessy and Isaksen 2007) should continue to be developed to help reduce bycatch.

4.3.4 Midwater Trawling

Pressure Description

The South African **midwater-trawl** fishery targets Cape Horse Mackerel *Trachurus trachurus capensis* (or Maasbanker), a semi-pelagic species found all along the South African coast (Kerstan and Leslie 1994). Please refer to Box 17 for details on gear and fishing methods of this fishery.

This fishery was established in the mid-1960s and catches on the Agulhas Bank peaked in 1977 at 93 000 tonnes (Kerstan and Leslie 1994). After South Africa declared its Exclusive Economic Zone in 1977, catches stabilised at between 25 000 tonnes and 40 000 tonnes (DAFF 2014). When foreign fleets were finally phased out in 1992, the annual catches fell to below 10 000 t. While demersal trawls catches have remained low, the re-establishment of a midwater fishery in 1997 resulted in an increase in the annual catches of Cape Horse Mackerel. Norman *et al.* (2018) reported 6 vessels and 34 rights holders in this sector and a landed catch of 9674 tonnes in 2016. The midwater trawl sector is dominated by a single, large midwater trawler, a vessel named the Desert Diamond, which is a 120 m freezer-trawler and the largest South African registered commercial fishing vessel. The remaining participants are smaller hake trawlers that carry dual hake and horse mackerel rights that enable them to target Horse Mackerel (primarily on the west coast) with midwater trawl gear opportunistically, in addition to fishing for hake at other times using demersal trawl gear (Norman *et al.* 2018).

Pressure Distribution

Adult stocks of Horse Mackerel aggregate on the **Agulhas Bank**, near the continental shelf break (Sauer *et al.* 2003), where they are targeted in this fishery in the 10-500 m depth range. The midwater trawl fishery is therefore spatially restricted to the south coast, east of 20° E (Figure 31). This is a spatial management measure that was intended to constrain the fishery to catching only adult Horse Mackerel while protecting juvenile Horse Mackerel, which are found inshore predominantly on the west coast, as well as avoiding bycatch species of conservation concern (DAFF 2016). Since 2016 the Desert Diamond commercial fishing vessel has been carrying out experimental trawls west of 20° E to test the availability of Horse Mackerel, with 100% observer coverage and strict limitations on bycatch (Mqoqi 2016).

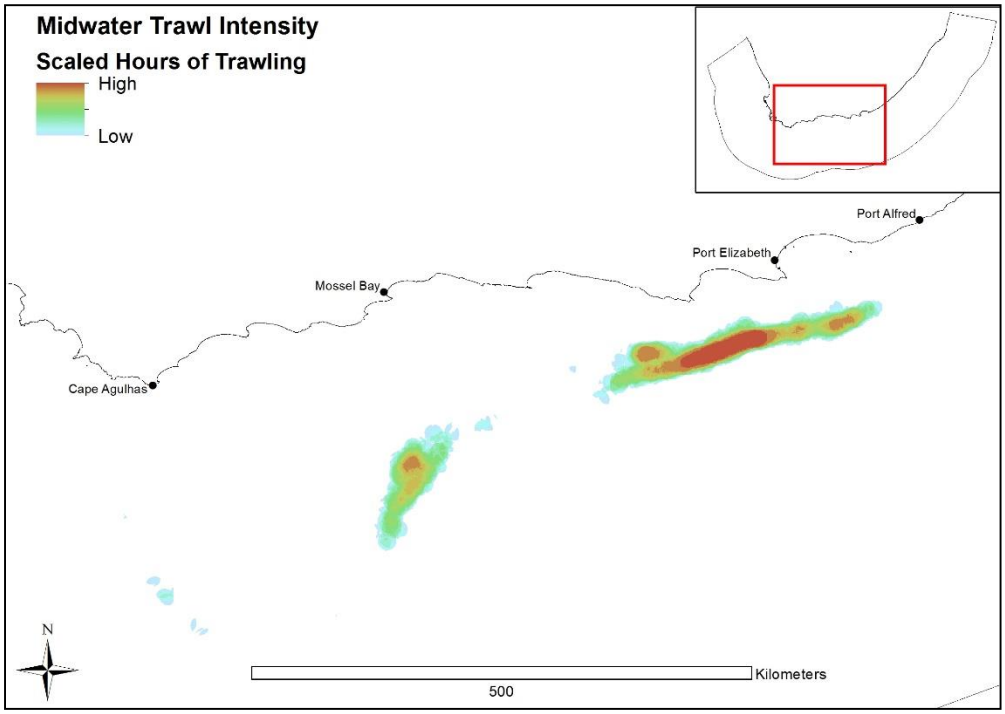


Figure 31. Map of midwater trawl intensity for period 2008 – 2016 displayed as scaled hours of trawling.

Current biodiversity and fishery sustainability concerns associated with this sector include:

- The current uncertain status of the Horse Mackerel resource with recent declines in catch rates (DAFF 2016).
- Bycatch of species of conservation concern, particularly certain sharks and Cape Fur Seals *Arctocephalus pusillus pusillus* with additional concerns regarding cetaceans and Sunfish (da Silva *et al.* 2015, Reed *et al.* 2017, Weston and Attwood 2017).

Uncertainty in stock concerns of this important forage fish are of increasing concern. Owing to the behaviour of the target species, specifically vertical migration patterns, the Horse Mackerel biomass has not been established with a high degree of confidence and it is therefore managed by a Precautionary Management Catch Limit (PMCL) (DAFF 2014, 2016). A portion of the PMCL is held as a bycatch reserve for the demersal trawl sector which also harvests adult Horse Mackerel as bycatch. Juvenile Horse Mackerel form bycatch in the small pelagic purse seine fishery on the west coast of South Africa, and so a further Precautionary Upper Catch Limit (PUCL) of Horse Mackerel is enforced in this fishery to control the bycatch of juvenile Horse Mackerel (DAFF 2016). A Total Allowable Catch (TAC) is issued to long-term rights holders annually.

A recent analysis of 10 years of at-sea observer data indicated a **bycatch** rate in this fishery of 6.9% by weight of the total catch, which is lower than in other South African fisheries and similar fisheries elsewhere (Reed *et al.* 2017). However, due to the large size of the individual hauls (average of 46.3 t), the average observer catch sampling rate of 1.56% is low (Reed *et al.* 2017). The analyses suggest that due to the combination of high catch volumes and low sampling rates, estimation errors for rare species are high and there is a substantial risk of incidental unmonitored bycatch of rare large fauna and aggregations of small fauna. Bycatch species with the highest average annual catches were Chub Mackerel

Scomber japonicus, Redeye Roundherring *Etrumeus whiteheadi*, Ribbonfish *Lepidopus caudatus* and Hake *Merluccius* spp. (Reed *et al.* 2017). Large fauna bycatch species include Cape Fur Seals *Arctocephalus pusillus*, sharks (14 species), Sunfish *Mola mola* and cetaceans (two species), most of which have a low survival rate but some of which are released alive (Reed *et al.* 2017).

Certain large fauna species caught as bycatch in the midwater trawl fishery are of **conservation concern**. These include several shark species - Dusky Shark *Carcharhinus obscurus*, Smooth Hammerhead Shark *Sphyrna zygaena*, Soupfin shark *Galeorhinus galeus*, Mako Shark *Isurus oxyrinchus*, Thresher Shark *Alopias vulpinus*, Bigeye Thresher Shark *Alopias superciliosus*, Porbeagle Shark *Lamna nasus* and Ragged-tooth Shark *Carcharias taurus* – which are globally assessed as threatened (Stevens *et al.* 2006, Walker *et al.* 2006, Amorim *et al.* 2009, Casper *et al.* 2009, Goldman *et al.* 2009, Musick *et al.* 2009, Pollard and Smith 2009, Rigby *et al.* 2019). Four species of shark caught – Smooth Hammerhead Shark, Thresher Shark, Bigeye Thresher Shark and Porbeagle Shark – are also included in CITES Appendix II, as are the Cape Fur Seal, Manta Ray *Manta birostris*, Devil Ray *Mobula* sp. and Bottlenose Dolphin *Tursiops truncatus* (CITES 2017). Furthermore, a continuation of the increasing trend in bycatch of Cape Fur Seals will lead to conservation concerns if the catches on local colonies become unsustainable (Reed *et al.* 2017). Midwater trawling is not considered to have significant impacts on benthic biodiversity provided the fishery adheres to the definition of midwater trawling by not making contact with the seafloor (Atkinson and Sink 2008).

4.3.5 Commercial Linefishing

Pressure Description

Linefishing is defined as the capture of fish with **hook and line**, and has a long history in South Africa dating as far back as the 1500s (DAFF 2016). Approximately 250 species have been reported in catches for this sector, although only 35 species make up the majority of catches. See (Mann 2013b) for the full list of species targeted in this sector. The commercial linefishery has the largest fleet but its catches make up only 6% of the total value of all commercial marine fisheries (DAFF 2016). Commercial fishing vessels range from 6 - 8 m ski-boats capable of surf-launching, to harbour-based freezer vessels (generally longer than 20 m) that can remain at sea for more than 2 weeks at a time (Mann 2013b). Marine recreational anglers in South Africa tend to use similar gear and target similar species to their commercial counterparts. Owing to the lack of catch and effort data for recreational boat-based fishing, the pressure data for the commercial linefishery is used as a proxy for recreational activities. Recreational boat-based fishing is discussed further in the next section.

Pressure Distribution

The South African commercial linefishery stretches from Port Nolloth on the west coast to Cape St Lucia on the east coast (Figure 32).

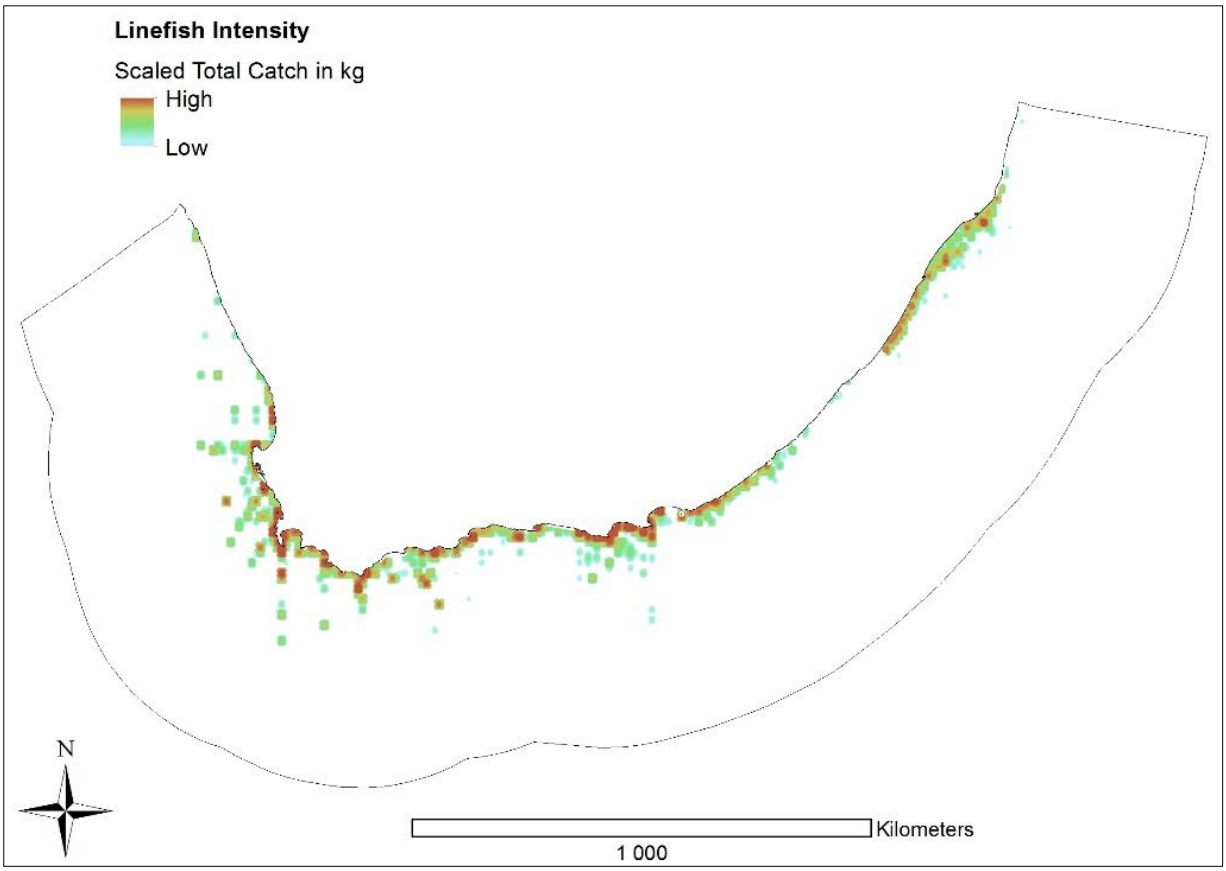


Figure 32. Map of intensity of commercial linefishing in South Africa for period 2000-2016, displayed as scaled total catch in kilograms. Note errors in this data set such as the record off Kosi Bay which is a reporting error.

Key limitations of this dataset include the lack of accurate capture of coordinates, as most boat-based activities are logged from the point of departure at the coast. There are also known areas of activity that are not covered in the dataset (e.g. Alphard Banks).

Biodiversity and fishery sustainability concerns for this pressure include:

- Poor stock status of many species including the collapsed status of Seventy-four, Red Steenbras, Dageraad, and Dusky Kob (Mann 2007, Winker *et al.* 2014, 2015, Comeros-Raynal *et al.* 2016, Boyd 2017, Parker *et al.* 2017b, Winker *et al.* 2017b, Kerwath *et al.* 2019).
- Lack of life history information for many target species (see (Mann 2013b)).
- Targeting of species especially vulnerable to harvesting (e.g. long-lived, highly resident species) (Attwood and Farquhar 1999, Penney *et al.* 1999, Griffiths 2000, Mann 2000, Götz *et al.* 2009b, 2009a, Mann 2013b, da Silva *et al.* 2015, DAFF 2016).
- Changes to ecosystem community structure and impacts on food webs (Toral-Granda *et al.* 1999, Götz *et al.* 2009b, 2009a, DAFF 2016).
- Removal of top predators such as sharks (Stevens *et al.* 2000, da Silva *et al.* 2015, Davidson *et al.* 2016c).
- Absence of bycatch information, particularly extent and mortality of discarded catch and extent of catches of undesirable species kept by crew as “fries”.

Biodiversity concerns for this sector are centred on the poor **stock status** of many linefish species, the lack of, or outdated stock assessments for several species (see Table 38) and the potential impact of reduced linefish populations on marine ecosystems (Attwood and Farquhar 1999, Penney *et al.* 1999, Toral-Granda *et al.* 1999, Griffiths 2000, Mann 2000, Götz *et al.* 2009b, 2009a, Blamey 2010, Mann 2013b, DAFF 2016). South Africa's commercial linefishery was characterised by rapid expansion and substantial effort increases through increased access and advances in fishing technologies leading to serial overfishing and a rising number of overexploited and collapsed species (Penney *et al.* 1999, Griffiths 2000, Mann 2000). Serial overfishing is when fishers continuously exploit different areas, shifting their focus of effort onto previously un-fished reefs as highly resident species are depleted from heavily fished sites (Penney *et al.* 1999, Booth and Hecht 2000). South Africa's linefishery was declared in a State of Emergency in 2000 as a result of the critical status of many linefish stocks.

Several factors are thought to have contributed to the demise of **linefish stocks**. These include increased commercial and recreational fishing effort, a recent upsurge in subsistence/small-scale commercial effort and poor compliance (Kramer *et al.* 2017). Furthermore, vulnerable life history traits (e.g. predictable locality, residency, longevity, late maturity, sex change, barotrauma and estuarine dependence for some species) make linefish species particularly susceptible to over-exploitation (Garratt 1985, Buxton 1993, Griffiths 2000, Mann 2000, 2013b, Comeros-Raynal *et al.* 2016). The traditional linefishery targets sharks when high-value teleosts are not available and is responsible for the highest catches of Smoothhound and Soupfin Shark (da Silva 2007, da Silva and Bürgener 2007, da Silva *et al.* 2015). Several other species, such as the Spiny Dogshark and several carcharinids such as Dusky Sharks and Bronze Whalers are also commonly caught (da Silva *et al.* 2015). Specialised studies on some fish species further confirm the poor status of linefish (Griffiths 2000, Griffiths and Wilke 2002, Griffiths and Lamberth 2002, Kerwath *et al.* 2007b, 2007a, Comeros-Raynal *et al.* 2016, Boyd 2017, Parker *et al.* 2017b, Kerwath *et al.* 2019).

In response to new management measures, including substantial commercial effort reductions, signs of recovery have been documented for several species since the State of Emergency (e.g. Geelbek, Slinger, Santer, Yellowtail, Hottentot and Carpenter) (DAFF 2016, Boyd 2017, Maggs *et al.* 2017a, Parker *et al.* 2017a) (see Chapter 9 The State of Indigenous Species). **Updated stock assessments and analysis of further trends are urgently needed**. Although some progress has been made in the development of a new framework for comprehensive stock assessment using state-of-the-art modelling techniques (Winker *et al.* 2012, 2013, 2015) (see Box 32), stocks of only four species have been recently assessed, namely Slinger *Chrysoblephus puniceus*, Carpenter *Argyrozona argyrozona*, Hottentot seabream *Pachymetopon blochi* and Silver kob *Argyrosomus inodorus* (DAFF 2016). Recovery of some species may be hampered by exploitation in other fisheries, as linefish also form an important component of the catch or the bycatch of other fisheries (Fennessy 1994a, Attwood *et al.* 2011, DAFF 2014, 2016, da Silva *et al.* 2015).

Linefishing impacts target and non-target fish species and there is evidence that fishing **alters reef ecosystems** through indirect effects on benthic assemblages (Pinnegar *et al.* 2000, Götz *et al.* 2009b, 2009a). Declines in reef fish may also have affected the link between the reef ecosystem and the pelagic food web (Attwood *et al.* 2000). Anchoring by linefishing boats, particularly on deep reefs may cause localised damage to stylasterine, stony and black corals, gorgonians and other slow-growing habitat-

forming reef biota. There are anecdotal reports of such taxa being retrieved on anchors (Atkinson and Sink 2008).

In terms of **management measures**, the commercial linefishery is limited in terms of the number of vessels and crew members that are allowed to participate, which is called the Total Allowable Effort (TAE). Commercial fishers are less regulated than their recreational counterparts in terms of the quantity of fish that they are allowed to catch so that they can make a living from fishing and provide a source of fresh fish to the public. To rebuild collapsed stocks and to achieve a sustainable level of utilisation, a Linefish Management Protocol (LMP) was developed in 1999 in order to base regulations in the linefishery on quantifiable reference points and this remains the basis of linefish management (Griffiths *et al.* 1999, DAFF 2016). Existing and new **MPAs** aim to help recovery of linefish with new MPAs including specific objectives to protect spawning aggregations and nursery areas (see Chapter 8). The effectiveness of the MPAs in resource recovery warrants increased research attention, including the effectiveness of South Africa's recently expanded MPA network (see Chapter 8).

4.3.6 Recreational Fishing (Boat- and Shore-Based)

Pressure Description

Recreational fisheries in South Africa include line fisheries, rock lobster fisheries and harvesting of intertidal resources such as mussels, redbait and oysters (Dye *et al.* 1994a, 1994b, Cockcroft and Mackenzie 1997, Griffiths and Branch 1997, Tomalin and Tomalin 1997, Wynberg and Branch 1997, Tomalin and Kyle 1998, Griffiths *et al.* 2004, Cooke and Cowx 2006, Lewin *et al.* 2006, Winker *et al.* 2014, Maggs *et al.* 2015, Parker *et al.* 2016, Kerwath *et al.* 2019, Steyn *et al.* 2019). Unfortunately, spatially referenced data were only available for linefishing and hence only recreational boat- and shore-based angling was included in this assessment.

Pressure Distribution

Recreational linefishing is a popular activity in South Africa and takes place across the coast (Figure 33). Between 1994 and 1997, the first nation-wide survey was conducted to evaluate participation in South Africa's recreational shore angling fishery, and its management (Brouwer *et al.* 1997, Mann *et al.* 2003). It was estimated that there were approximately 412 000 active participants at the time, with an estimated rate of increase of about 2% per annum (Mann *et al.* 1997, McGrath *et al.* 1997). A more recent study found that recreational fishing in South Africa includes participation from approximately 1.32 million fishers, of which approximately half are marine (Saayman *et al.* 2017) targeting mainly linefish and rock lobster. As previously mentioned in the section on Commercial Linefish, the data for commercial linefishing were used as a proxy for recreational boat-based fishing effort as experts advised that the locations and pattern of use are similar for the commercial and recreational sector.

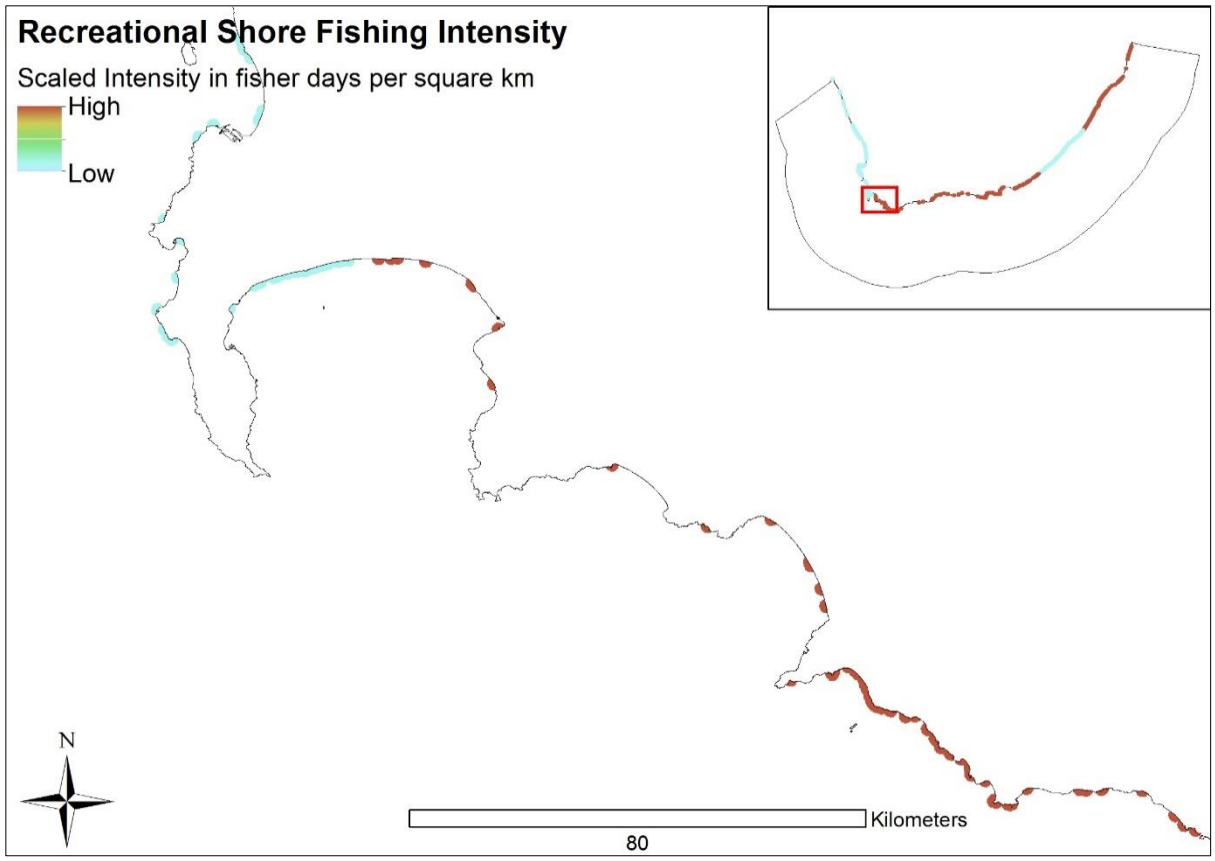


Figure 33: Map of estimates of recreational shore angling fishing effort. The insert shows the national distribution of pressure intensity.

A key **limitation of this dataset** is the exclusion of other recreational fishers. Previous literature indicate that, in general, recreational fishing for intertidal resources has less impact than those harvesting far greater volumes of resources for subsistence or commercial use (Dye *et al.* 1994a, 1994b, Lasiak and Field 1995, Tomalin and Kyle 1998, Sink 2001). However, the Abalone recreational fishery was closed in 2008 (DAFF 2010) due to unsustainable fishing largely caused by illegal fishing for this high value resource and the recreational abalone fishery has remained closed (see Box 35). Recreational fisheries in general receive less research attention than their commercial counterparts and their impacts are less well understood in South Africa (Brouwer *et al.* 1997, Griffiths and Lamberth 2002 and see Box 18). Recreational anglers also rarely consider themselves as a threat to fish resources as the cumulative impact of many thousands of anglers is seldom recognised (Coleman *et al.* 2004, Cooke *et al.* 2014, Arlinghaus *et al.* 2019). Recreational angling is however internationally recognised as a pressure on marine biodiversity at the genetic, species and ecosystem level (Lewin *et al.* 2006, Beckley *et al.* 2008, Arlinghaus and Cooke 2009, Maggs *et al.* 2015, Arlinghaus *et al.* 2019).

Biodiversity and fishery sustainability concerns associated with recreational fishing and harvesting in South Africa include:

- The poor stock and conservation status of many target species (Winker *et al.* 2014, Parker *et al.* 2016, Kerwath *et al.* 2019); additional information is provided in Chapter 9).

- Lack of fishing effort and catch reporting and data management for recreational fishing (DAFF 2016).
- Impacts associated with fishing including pollution, the impacts of bait collection (Wynberg 1991, Wynberg and Branch 1991, 1994, 1997, Watson *et al.* 2017) and ecosystem impacts (Celliers *et al.* 2004, Coleman *et al.* 2004, Götz *et al.* 2009b, 2009a, Goetze *et al.* 2011).
- Low levels of awareness, high levels of poaching and poor compliance (Kramer *et al.* 2017).
- Continuous technological advancements in gear significantly improves catch efficiency and increases access. A current emerging concern is drone fishing which is reported to be banned in some countries (Box 18). Drone fishing allows anglers to reach beyond areas reachable by casting.

The **impacts of recreational fishing** are recognised in global and local scientific literature. Internationally, there is evidence of the direct contribution of this sector to declines in fish stocks (Cooke and Cowx 2006, Arlinghaus and Cooke 2009) with research results from Canada (Post *et al.* 2011), Australia (McPhee *et al.* 2002) and America (Coleman *et al.* 2004). South Africa is not exempt from this trend and recreational fishing is seen as a contributing factor in the reduction of a number of important target species (Bennett and Attwood 1991, Attwood and Farquhar 1999, Cowley *et al.* 2002, Maggs *et al.* 2012, 2016). It has recently been shown that recreational angling in some instances may have a greater impact than commercial fishing on certain endemic species in South Africa, specifically highly resident reef-associated fish such as the Critically Endangered Dageraad, *Chrysoblephus cristiceps* (Winker *et al.* 2014). Recent research has indicated that recreational boat anglers caught up to five times more Dageraad than the commercial linefishery (Parker *et al.* 2016). Many of these endemic species have life history characteristics that make them vulnerable to overfishing, which means that recovery after heavy exploitation is often extremely slow (Mann 2013b, Comeros-Raynal *et al.* 2016, DAFF 2016). Even when catch and release angling is practiced, post release mortality can be extremely high, especially in deep reef species (Attwood *et al.* 2013, da Silva *et al.* 2015) that suffer from barotrauma (Kerwath *et al.* 2013a) such as Red Steenbras *Petrus rupestris* (Mann 2013b) and Dageraad (Parker *et al.* 2016).

Exploitation levels of some species is augmented by the fact that recreational angling often targets behaviours such as **spawning aggregations** (De Mitcheson and Colin 2012, Parker *et al.* 2016) and habitats that are critical for certain life stages of fish (Jackson *et al.* 2001). When fish are targeted during their spawning period, particularly when they are aggregated and more vulnerable to fishing effort, their reproductive success is reduced (Cooke and Cowx 2006). In South Africa the Seventy-four, *Polysteganus undulosus*, was heavily targeted during predictable spawning aggregations and depleted to such an extent that the stock collapsed (Mann 2007, 2013b). Dusky Kob (Box 43), Red Steenbras and Dageraad are also heavily targeted during their spawning periods (Mann 2013b) to a point where their stocks have collapsed (Griffiths and Lamberth 2002, Mann 2013b, Parker *et al.* 2016, Kerwath *et al.* 2019). Unlike commercial fishermen, recreational anglers are not constrained by the need to derive an income from their catch (Potts *et al.* 2009) and thus often tend to target larger or "trophy" fish (Shiffman *et al.* 2014) which also affects the **reproductive success** because larger fish produce orders of magnitude more eggs which are larger and produce more viable larvae (Berkeley *et al.* 2004, Birkeland and Dayton 2005). In South Africa, Carpenter *Argyrozona argyrozona* attained bigger sizes, bred at larger sizes and spawned for longer in protected areas. A 3 kg Carpenter was shown to produce five times more eggs per kg of body weight than a fish of 1 kg (Brouwer and Griffiths 2005a, 2005b).

The selective nature of recreational angling towards larger, trophy fish can have severe implications on **population structures** (Schroeder and Love 2002, Conover *et al.* 2005, Hutchings 2005, Cooke and Cowx 2006). In South Africa for example, there are a higher proportion of female Roman, *Chrysoblephus laticeps* (Götz *et al.* 2009b) and Dageraad (Buxton 1993), both protogynous hermaphrodites (change sex from female to male), in areas targeted by recreational anglers. The size at which Dageraad change from female to male was also much lower in exploited populations (Buxton 1993). Studies have shown that size-selective fishing can work as a selective, and possibly irreversible pressure and change age and size at maturity, longevity and possibly fecundity (Conover *et al.* 2005, Hutchings 2005). Distribution ranges have also been shown to decline from both recreational and commercial fishing pressures (Parker *et al.* 2016, Kerwath *et al.* 2019).

The removal of larger predatory fish species also has severe implications on **ecosystem processes and structure** (Blaber *et al.* 2000, Garcia *et al.* 2003) as it changes the trophic structure and the movement of energy through the ecosystem – known as trophic cascading (Garcia *et al.* 2003). Removing the large adults of a species by angling results in smaller prey species becoming dominant and often even out-competing the younger fish of the predatory species (Lewin *et al.* 2006). This also hinders the species' ability to recover from angling pressures (Lewin *et al.* 2006).

Marine recreational hook-and-line anglers in South Africa tend to use similar gear and target similar species to their commercial counterparts. To manage these two fishery sectors in a fair and transparent way, two different **management systems** are used. In contrast with the commercial sector that has limits on Total Allowable Effort but less regulation on total catch, the number of recreational anglers is not limited (i.e. it is an open-access fishery) but they are limited in terms of their daily catches through a bag limit. Recreational anglers are not allowed to sell their catch as they are fishing for enjoyment. This regulation is designed to avoid competition with the commercial sector although there is a long history of recreational anglers selling their catches, and compliance and high levels of poaching remain a concern in South Africa's recreational fisheries (Kramer *et al.* 2017). New technologies such as drone fishing have further complicated compliance in this sector (Box 18).

Box 18: Why do recreational fisheries need management?

By Colin Attwood, Bruce Mann and Warren Potts

The recreational fishery is an important economic activity in South Africa. By definition, this type of fishing is not pursued for financial gain, as the produce is not sold, at least not legally. The value lies in the recreational activity itself; for some it is the best form of relaxation, and for others a competitive sport. The expenditure by South Africans on fishing gear, boats and holiday accommodation (R8.9 billion spent per annum) leaves no doubt about its magnitude (Saayman *et al.* 2017). An estimated 625 000 South Africans engage in this activity (Saayman *et al.* 2017).

The impact on fish is even more profound. Three-hundred and twenty-five species of fish (Solano-Fernandez *et al.* 2012) and an unknown number of invertebrates are targeted by recreational fishers, from the shore, in estuaries and out at sea from all manner of boats. Although some of these species are also targeted by commercial and particularly the emerging small-scale commercial fishery sectors, the majority are not. It is the nearshore species which feature most heavily in recreational catches. Among them are many southern African endemics, most notably the seabreams.

Recreational fishing has not been prioritised in South Africa with little improvement in management during the last decade in the management of this fishery. Because there is no tangible product, and no taxable revenue based on landings, this fishery has likely been erroneously considered less important than commercial counterparts. Recreational catch and effort are not monitored nationally and no comprehensive database of recreational catches is available. The recreational fishery is not assessed in any of its forms. Although management efforts for this fishery used to be better in the province of KwaZulu-Natal, monitoring and compliance efforts have collapsed in this region and there is increasing illegal activity.

Over several decades, snapshot studies into the status of some recreationally-targeted species have revealed substantial declines and alarmingly high effort, e.g. Dusky Kob *Argyrosomus japonicus* (Griffiths 1997a), Galjoen *Dichistius capensis* (Attwood 2003) and Leervis *Lichia amia* (Maggs *et al.* 2015). Yet, with very few exceptions, no alterations to recreational catch regulations have been made since 2005, in contrast to commercial fisheries which have annual Total Allowable Effort (TAE) or Total Allowable Catch (TAC) adjustments. Several recreationally-targeted species have been listed as threatened by the IUCN, with limited management response from South Africa. This neglect has serious economic and ecological consequences.

Three characteristics of the recreational fishery make regular adjustments to catch limits necessary: (1) the number of participants grows in proportion to the population, (2) recreational fishers are self-subsidising (Kleiven *et al.* 2019) and (3) continuous technological advancements in gear significantly improves catch efficiency. The most recent advances include fish-finding electronics, computer-designed lures and drones, all of which have massively ratcheted-up the rate at which fish are caught, notwithstanding an increase in the practice of catch and release. Allowing the public unfettered access to gear and technology to exploit wild animals is clearly not a sustainable option and would unlikely be contemplated in terrestrial environments.

What can be done? The recreational fishery should be accorded a status equal to that of major commercial fisheries. Funding streams for recreational fishery management must be secured. Effort and catches can be effectively monitored. Stocks need regular assessments and regulations need annual review. A national monitoring and compliance strategy is urgently needed. These measures, if implemented can help restore and maintain these resources for all sectors and allow future South Africans to also enjoy the benefits from recreational fishing.

4.3.7 Demersal Longline Fishing

Pressure Description

Details on longline fishing gear and methods in South Africa are provided in Box 19. South Africa's demersal longline fishery started as an experimental fishery in 1983, targeting both species of Cape Hakes. This method was found to be very effective in targeting the more valuable Kingklip *Genypterus capensis* and led to overfishing and closure of the fishery in 1991. A hake directed experimental longline fishery was introduced in 1994 with commercial rights issued in 2001 (Fairweather *et al.* 2006b). South Africa's demersal longline fishery was reported to have 64 vessels in 2015 and 146 rights holders in 2016 (Norman *et al.* 2018). This section only discusses the impacts of hake-directed demersal longline fishing. The impacts of demersal shark fishing were not assessed, but are discussed in Box 20.

Pressure Distribution

The demersal longlining fishery operates along the west and south coast with effort concentrated along the shelf edge (Figure 34). Highest effort has been recorded in the vicinity of the Cape Valley off Cape Point, near Cape Canyon off Cape Columbine, offshore of Tsitsikamma and near Port Elizabeth.

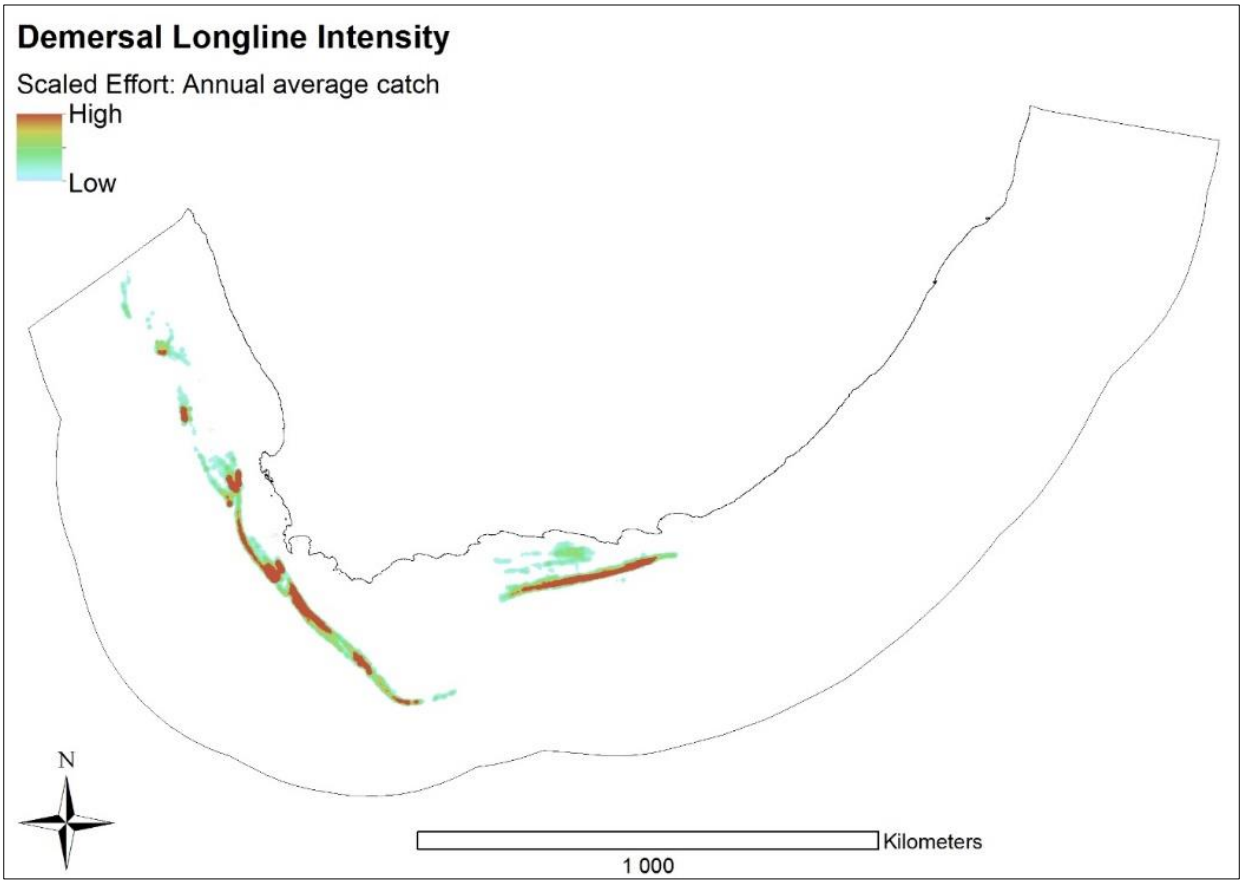


Figure 34. Map of scaled intensity of demersal hake longlining for period 2000 – 2017 presented as annual average catch in kilograms.

Biodiversity and fishery sustainability concerns related to this pressure include:

- Uncertainties in stock structure and status for Kingklip (DAFF 2016).
- Potential changes in community structure of vulnerable marine ecosystems (Mortensen *et al.* 2008, Sharp *et al.* 2009, Sampaio *et al.* 2012, Clark *et al.* 2015).
- Impacts to habitat-forming species such as deep-sea corals and sponges (Parker and Bowden 2010, Ewing and Kilpatrick 2014, Clark *et al.* 2015).
- Incidental mortality of vulnerable, non-target species such as seabirds, sharks and turtles (Anderson *et al.* 2011, Favaro and Côté 2015).

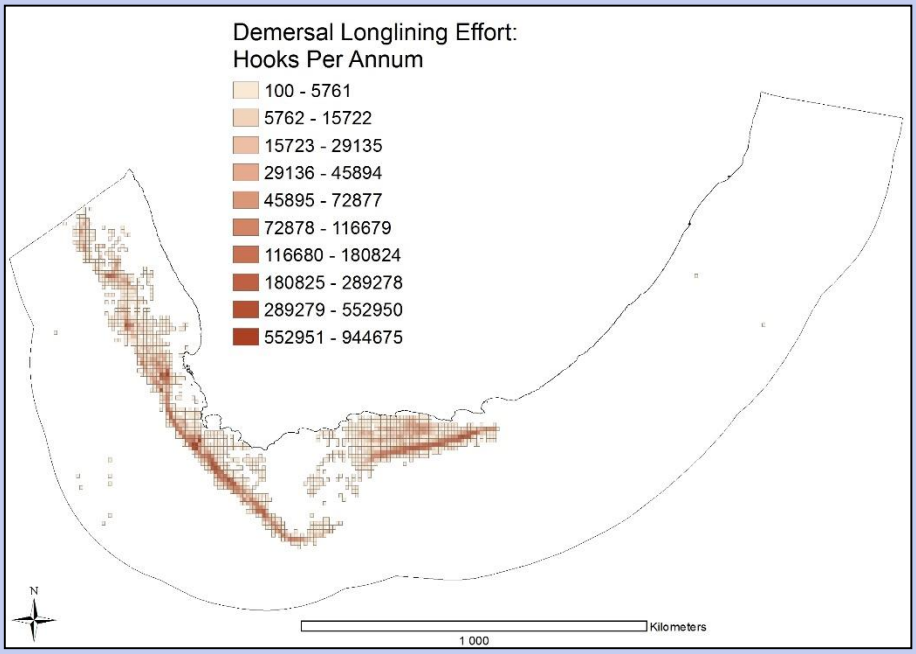
The stock status and fishing pressure for Kingklip are reported as optimal in the most recent DAFF status of South African marine fishery resources report (DAFF 2016). The questions regarding stock structure remain and anticipated advances in genetic research may help resolve these uncertainties.

Review of recent literature indicates that most demersal fishing activities are known to impact marine **benthic habitats**, and have shown to reduce diversity and abundance of associated invertebrates and fish species (Clark *et al.* 2015). While it has been shown that bottom longline sets have a far smaller impact area than trawl nets, various studies have observed that the damage caused by moving longlines can still be significant (Mortensen *et al.* 2008, Sharp *et al.* 2009, Sampaio *et al.* 2012, Clark *et al.* 2015). (Sharp *et al.* 2009) expressed additional concerns that lines may cause unobserved damage through the lateral movement of the mainline (or 'backbone') and chain due to currents or while hauling. A study by (Parker and Bowden 2010) identified thirteen broad taxonomic groups that are vulnerable to bottom longline fishing activities in the Ross Sea region including sponges, anemones and stylasterids. Sessile fauna, such as corals and sponges, have been shown to be susceptible to damage by longline weights or by the mainline cutting through them during fishing and/or hauling (Ewing and Kilpatrick 2014, Clark *et al.* 2015). Multiple deployments of lower impact fishing gears in the same area may also result in significant adverse impacts to benthic communities or reduce the capacity of these habitats to recover (Williams *et al.* 2011). When coming in contact with the seabed, longlines can cause plumes of sediments which may impact benthic communities. (Clark *et al.* 2015) suggested that if disturbed sediments settle on damaged cold water corals, it may delay their recovery.

Demersal longline fisheries frequently result in **incidental mortality of seabirds, turtles and sharks** (discussed further in Chapter 9). Longlining can be particularly detrimental to albatrosses and petrels that have gapes large enough to swallow hooks, and risk being drowned during setting (Anderson *et al.* 2011), and has also been identified as a major driver of declines in abundance of sharks and rays around the world (Favaro and Côté 2015). Some local and international studies have demonstrated how fisheries are able to significantly reduce accidental bycatch incidences through the implementation of appropriate best-practice mitigation devices and techniques (Brewer *et al.* 2006, Grantham *et al.* 2008, Favaro and Côté 2015, Sullivan *et al.* 2018). Seabird bycatch mitigation measures within South African longline fishing permit conditions have been in place in various iterations since the 1990s (Rollinson *et al.* 2016) and proved to be extremely successful in reducing seabird bycatch. A global meta-analysis, focussing on bycatch reduction devices in pelagic longline fisheries to reduce capture of sharks and rays, indicated limited effectiveness of bycatch reduction devices in reducing bycatch of these species (Favaro and Côté 2015). Bycatch reduction through improvements in fishing gear and behaviour remain an important global and local biodiversity priority.

Box 19: Longlining gear and fishing methods used in South Africa

In South Africa, demersal longlines are set on rocky substrate, adjacent to demersal trawling grounds (Badenhorst 1988). The demersal longline is composed of a mainline or groundline which forms the branching point of shorter lines called gangions or snoods, to which baited hooks are attached (Stevenson *et al.* 2004, Dietrich *et al.* 2007). Surface floats are attached to the ends of vertical droplines or anchor lines which connects to the mainline (Dietrich *et al.* 2007). The mainline lies on the seafloor or may be weighed down with anchors at regular intervals in the presence of strong currents which is the method employed in the South African fishery (Badenhorst 1988). The mainline is generally long, ranging anywhere from 1 to 40 km (Stevenson *et al.* 2004). The South African demersal longline fishery which targets deep sea hake employs the Spanish double-longline system whereby a top and bottom line is set between the anchor lines, and the number of hooks deployed can vary between 6000-7000 for smaller vessels and 9000-14000 hooks for longer vessels (Japp 1989) – see below the map of annual average hook numbers per 5 min grid cell. Lines are generally 30 km in length and are deployed around depths of 200-400 m (Fairweather *et al.* 2006b, Petersen *et al.* 2008a). Deployment of longlines takes place at night and are recovered by hauling during the day for approximately 8 (Petersen *et al.* 2008a).



Map of demersal longline fishing effort expressed as total number of hooks per annum per 5 x 5 minute gridcell.

Pelagic longline fishing uses gear similar to that found in the demersal sector; the main differences are that in the pelagic sector, longlines consist of a double-line system suspended at different depths covered in baited hooks and these do not touch the seafloor, as they have small buoys and float lines to suspend the gear below the surface (Watson and Kerstetter 2006).

4.3.8 Pelagic Longline Fishing

Pressure Description

The pelagic longline fishery targets large, highly mobile species including Bigeye Tuna *Thunnus obesus*, Yellowfin Tuna *Thunnus albacares*, Bluefin Tuna *Thunnus thynnus* and Swordfish *Xiphias gladius*. Albacore Tuna *Thunnus alalunga*, Blue Shark *Prionace glauca* and Shortfin Mako Shark *Isurus oxyrinchus* are the main bycatch species in this fishery (DAFF 2016).

The South African pelagic longline fishery dates back to the early 1960s, when the fishery targeted Albacore, Southern Bluefin Tuna *Thunnus maccoyii*, and Bigeye Tuna in relatively small quantities (Shannon *et al.* 1989, Petersen *et al.* 2007, da Silva *et al.* 2015). This fishery developed to target Swordfish and in response to interest from industry, the establishment of an experimental fishery to target mostly tuna occurred in 1997. At the inception of this experimental fishery (between 1997 and 1999) Swordfish were the most abundant species caught, comprising 70% of the landed catch (Kroese 1999). However, the catch composition changed due to local depletion of swordfish. As fleets moved into temperate and offshore waters, more temperate tuna were caught, such that swordfish comprised only 21% of the catch (Govender *et al.* 2002). In 2005 a formal commercial sector was established (DAFF 2016) with quota allocations for some internationally governed species (e.g. Albacore, Swordfish and Southern Bluefin Tuna). Management of these highly migratory species is the responsibility of Regional Fisheries Management Organisations (RFMOs). South Africa is a member of three tuna directed RFMOs namely the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Indian Ocean Tuna Commission (IOTC) and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT).

Pressure Distribution

Many of the pelagic longline vessels are reported to fish near the edge of, or on, the continental shelf (Petersen *et al.* 2009c). The fishery has a national distribution (Figure 35).

Biodiversity and fishery sustainability concerns associated with the large pelagic sector include:

- Concern about the stock and global conservation status of Southern Bluefin Tuna (Collette *et al.* 2011, DAFF 2016).
- Bycatch of pelagic sharks, particularly Blue and Shortfin Mako Sharks (da Silva and Bürgener 2007, Parker *et al.* 2017c, Jordaan *et al.* 2018).
- Incidental mortality of 15 seabird species, including 7 threatened species (Ryan *et al.* 2002, Petersen *et al.* 2009a, Rollinson *et al.* 2016, 2017).
- Interactions between longliners and Killer Whales (Govender *et al.* 2002, Williams *et al.* 2009)

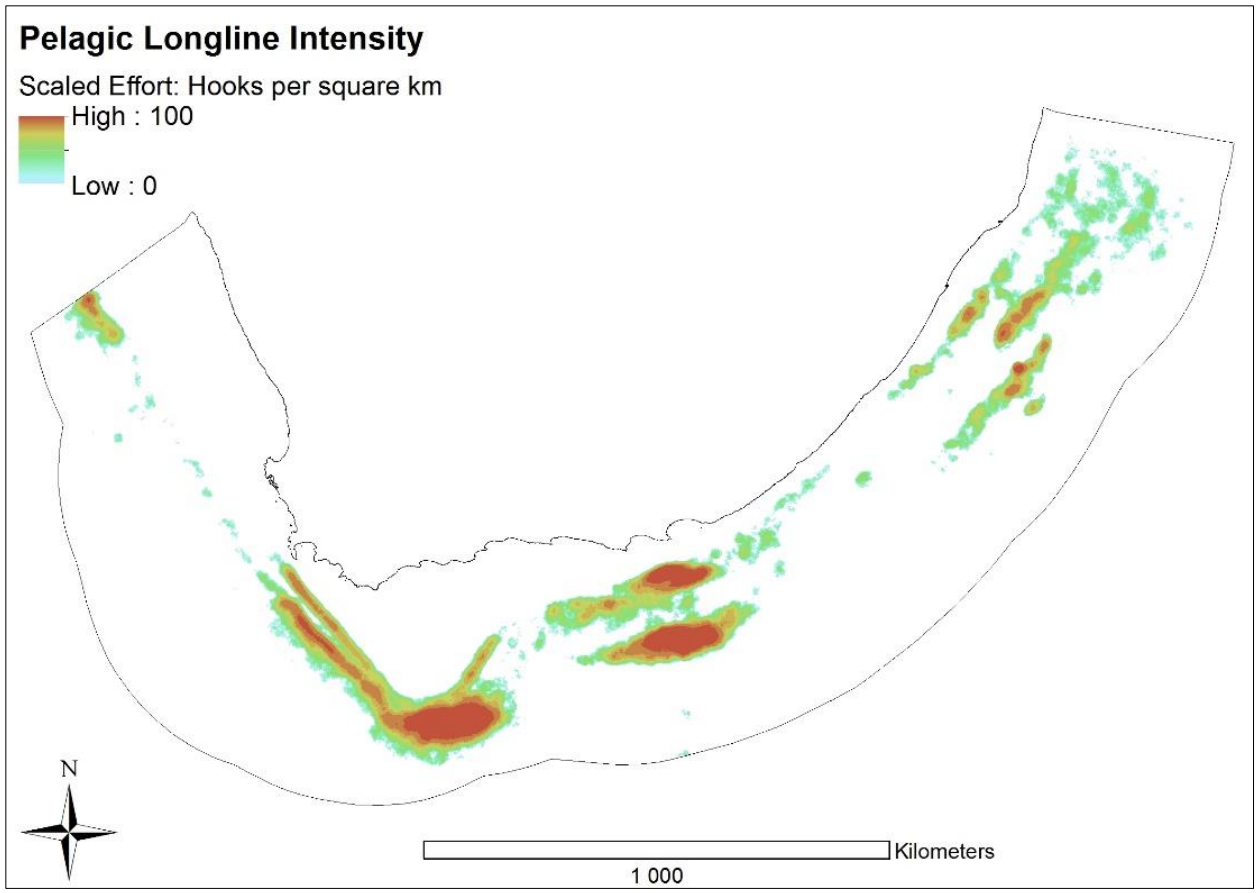


Figure 35. Map of scaled intensity of pelagic longline fishing for the period 2006-2016 using the annual average of the number of hooks per square kilometre.

Stock status is discussed in detail under the Tuna Pole section.

Of these biodiversity concerns, the **bycatch of sharks and seabirds** are most serious. Shark species most frequently caught by this sector include Blue and Shortfin Mako Sharks, and in recent years, catches of these two shark species have remained high (Parker *et al.* 2017c), despite these shark species both being listed on the global IUCN Red List of threatened species (Stevens 2009, Rigby *et al.* 2019). In addition to these two shark species, the fishery also catches a number of other shark species that are listed by the IUCN as threatened (Jordaan 2017). The stock status of many sharks is considered uncertain in South Africa due to a paucity of data (da Silva *et al.* 2015). See Chapter 9 for more on Data Deficiency among Chondrichthyans. The most frequently accidentally caught seabird in this fishery is the White-chinned Petrel *Procellaria aequinoctialis*, a species classified as Vulnerable for the South African region and globally. There is also concern about catch rates of Black-browed Albatrosses *Thalassarche melanophris* and Yellownosed Albatrosses *Thalassarche carteri* which have been assessed as Endangered for the South African region (Petersen *et al.* 2009a, Rollinson *et al.* 2017). The Critically Endangered Tristan Albatross *Diomedea dabbenena* has also been caught by this sector (Petersen *et al.* 2009a). See Chapter 9 for more detail on the threat status of seabirds.

The **high global catches of pelagic sharks and their vulnerable biology** have raised international concern for these species and RFMOs have called for a capping of fishing effort on sharks and protection of nursery grounds as precautionary management measures for these species (Tolotti *et al.* 2015, DAFF 2016). In 2011, the South African pelagic shark longline fishery was merged into the large pelagic longline fishery due to concerns about high pelagic shark catches and to reduce shark targeting (DAFF 2016). The current permit conditions prohibit the targeting of pelagic sharks and regulate catches of sharks using a Precautionary Upper Catch Limit (PUCL) of 2000 tonnes dressed weight. The 2017/2018 permit conditions also note that this PUCL will be reduced seasonally over a five-year period (DAFF 2017d). Furthermore, the 2017/2018 permit conditions include a ban on wire traces as these likely contributed to the high number of shark catches observed in recent years.

This fishery has a number of seabird **bycatch mitigation** measures included in the permit conditions, such as the use of bird-scaring lines (tori lines), line weighting and night setting (DAFF 2017d) and annual mortality estimates have decreased from approximately 5900 birds in 1998 to 1800 in 2005, to 278 in 2013 (Petersen *et al.* 2009a, Rollinson *et al.* 2017). Although seabird bycatch rates for the period 2006-2013 were lower than in 1998-2005, the rates still remain higher than the South African target of 0.05 birds killed per 1000 hooks (Rollinson *et al.* 2017). These mitigation measures have helped to reduced seabird bycatch in this fishery but there is a need for further reductions and compliance urgently needs to be improved (Petersen *et al.* 2009a, Rollinson *et al.* 2017).

Box 20: The impacts of the Demersal shark longline fishery on marine species
By Alison Kock

The demersal shark fishery operates from the Orange River mouth in the Northern Cape to the Kei River mouth in the Eastern Cape, but most catches take place between Cape Agulhas and East London (da Silva *et al.* 2015). The fishery uses bottom-set longline gear at depths of 50 – 100 m to target demersal (bottom-dwelling) sharks, such as Smoothhound (*Mustelus mustelus*), Soupfin (*Galeorhinus galeus*), Bronze Whaler (*Carcharhinus brachyurus*) and St Joseph Sharks (*Callorhinchus capensis*), and various rays and skates (da Silva *et al.* 2015). Shark meat and shark fins are retained and primarily exported to Australia and Asia, respectively (da Silva and Bürgener 2007). The fishery is managed on a total allowable effort basis with a maximum of six permits allocated in the sector.

Demersal shark longlining fishing effort has grown considerably since 2007 with a peak in catches of 408 tons reported in 2010 (da Silva *et al.* 2015). Since then catches have declined and preliminary stock assessments for the main target species have demonstrated that current Smoothhound Shark catches are unsustainable and Soupfin Shark are overfished (da Silva *et al.* 2018). Fisheries scientists have therefore motivated for a reduction in the total fishing effort across fishing sectors, which will require a co-ordinated management approach across all sectors (da Silva *et al.* 2018). Over the last two years there has been a growing concern from non-governmental organisations, local municipalities and members of the public around the sustainability of the fishery. Concerns are centred on the bycatch of vulnerable linefish and prohibited shark species, the proximity of fishing activities close to public beaches, the impact of the removal of these sharks on the ecosystem and irregular activities inside marine protected areas. An independent observer programme, coupled with a platform for communication between stakeholders would help address some of these concerns.

There have been a number of improvements in the fishery which are reflected in the permit conditions issued by DAFF. These include the prohibition of CITES Appendix II species, species on the Threatened or Protected Species list, the prohibition on catching of Sevengill Cow Shark (*Notorynchus cepedianus*), the prohibition of finning of sharks, and the provision of an identification guide to correctly identify sharks, rays and skates to species level as well as guidelines on how to safely release bycatch species to the fishery (da Silva *et al.* 2018). Fishing vessels are tracked by a vessel monitoring system, landings are monitored independently by fisheries control officers and skippers are required to complete logbook entries per longline set. Fishery independent scientific surveys have yielded important information on what is caught in the fishery (da Silva *et al.* 2018) and scientific information on the stock delineation for the target species has been improved (Bitalo *et al.* 2015) to better manage the fishery. Furthermore, research on heavy metal accumulation and toxicity in target species (Bosch *et al.* 2016a, 2016b) has prompted the implementation of a slot limit of 70 – 130 cm for these species (da Silva *et al.* 2018).

To ensure the sustainability of this fishery a number of priority actions are recommended. There is an urgent need for an observer programme and increased transparency and communication between stakeholders. Research has demonstrated that marine protected areas (MPAs) can benefit species like Smoothhound Sharks (da Silva *et al.* 2013), but more research on the spatio-temporal behaviour of target species in relation to MPAs is required to determine the extent of protection afforded to these species. Demersal sharks are important predators and prey for a range of species, it is therefore important that more research is conducted on the ecosystem impacts of this sector.

4.3.9 Tuna Pole Fishing

Pressure Description

This sector is also referred to as the Tuna Pole-Linefishery, as it uses pole fishing gear or rod- and-reel (DAFF 2016); the latter uses similar fishing gear to the commercial linefishery. In South Africa, rod and reel gear is used to target Yellowfin Tuna and pole gear used to target Albacore (Atkinson and Sink 2008, DAFF 2016). Pole fishing gear consists of a hooked line (usually a barbless hook with a feathered jig) attached to a rigid pole of 2-3 m. This method of fishing is very labour intensive with several fishermen fishing simultaneously off a platform at the rear of the vessel, catching one fish at a time (Gillett 2016).

Tuna boats use **bait and/or water-spraying** to aggregate fish (spray gives the illusion of activity from a shoal of small fish (FAO 2018b). Once the target species has aggregated, pole fishing is conducted by casting feathered jigs into the water and hauling them back a few seconds later. Once a tuna lands on the vessel's deck, it releases itself from the barbless hook and the line can be thrown again, leading to several tonnes of tuna being fished in a few hours (FAO 2018b). Smaller vessels make short trips of 5-7 days and have a specialised crew of 8-10 fishermen equipped with long poles and gaffs (long poles with hooks), while larger vessels with crew of 20 or more are capable of fishing further from port and operate along the entire west coast (Norman *et al.* 2018).

Tuna pole-line fishing started in the late 1970s and originally targeted Yellowfin Tuna, switching to Albacore due to fluctuations in the abundance of Yellowfin Tuna around the Cape (DAFF 2016). The tuna pole sector was previously included as part of the linefishing sector until 2000, and declared a separate fishery thereafter to be perceived as distinct from the linefishery owing to the stock collapse of several target linefish species and the associated announcement of the Linefish State of Emergency in 2000. The number of active vessels has fluctuated between 2005 to 2014, with the highest number of active vessels reported for 2007 (DAFF 2016); the annual average number of active vessels for the period 2005-2013 was 130 vessels but is expected to increase due to the long-awaited outcome of the fisheries rights appeals process. Norman *et al.* (2018) reported that the active number of vessels was 128 in 2015, with 170 rights holders logged in 2016.

Pressure Distribution

The South African tuna pole fishery largely operates off the **west coast** of South Africa, within the 200 nautical miles fishing zone, particularly between 29° and 32°S, targeting southern Atlantic tuna stocks (Figure 36). Less than 1% of the tuna pole catch is caught eastwards of the 20°E longitude line. Tuna fishermen focus their effort along the shelf edge with highest reported effort between Lamberts Bay and the southern tip of the Agulhas Bank and also in the vicinity of the submarine bank known as Childs Bank. Shannon *et al.* (1989) report that the Cape Valley and the Cape Canyon are important tuna fishing areas because of upwelling and the position of the oceanic thermal front close to the coast in these areas. The influence of these large submarine canyons in the southern Benguela warrants additional research attention to better understand their role in the broader marine ecosystem.

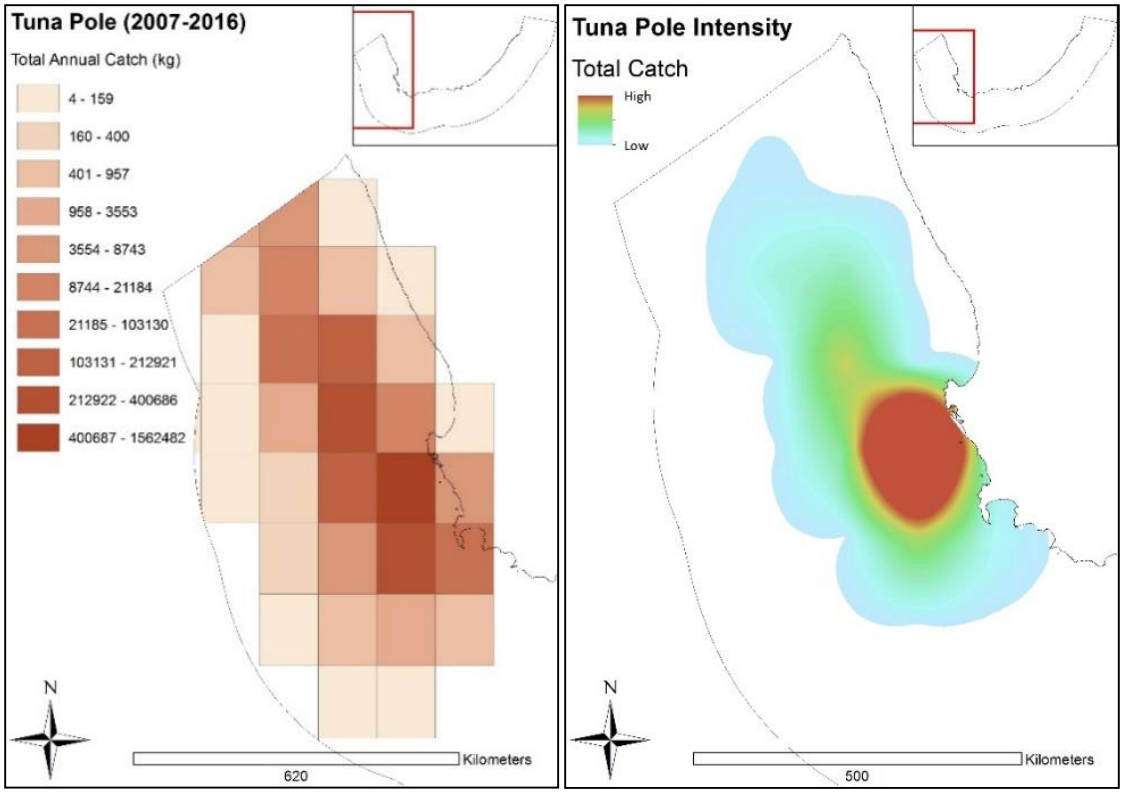


Figure 36: Maps of tuna pole intensity using annual average catch on a one degree grid (left), and the scaled tuna pole intensity used in the assessment (right).

The bulk of the fleet operates out of Cape Town and Hout Bay harbours and fishes within a 100 nm radius of those locations.

Biodiversity and fishery sustainability concerns associated with the large pelagic sector include:

- Stock concerns (ICCAT 2016, 2018, CCSBT 2017, IOTC 2018).

The tuna pole fishery is a highly targeted fishery with virtually **zero unintentional bycatch**. The targeted migratory tuna species are observed through international organizations (i.e. Regional Fisheries Management Organisations). Although the stock status of Albacore is considered optimally exploited in the latest edition of the Status of South African Marine Fishery Resources (DAFF 2016), there are concerns regarding the stock status of many affected species, including Albacore.

The **stock assessment** for Atlantic Ocean Yellowfin Tuna conducted by ICCAT (2016) indicated that the stock is considered to be overexploited however not experiencing overfishing, while the Indian Ocean Yellowfin Tuna stock is considered overexploited and subject to overfishing (IOTC 2018). There is uncertainty regarding the stock status of Albacore tuna in the Atlantic Ocean with a reported 66% probability of the stock being neither overexploited nor experiencing overfishing in this region (ICCAT 2016), while the Indian Ocean Albacore stock is not considered overexploited and not subject to overfishing (IOTC 2018). The Atlantic stock of Swordfish is considered overfished and subject to overfishing with current fishing mortality (F) very close to fishing mortality at maximum sustainable yield

(F_{MSY}) (ICCAT 2018). In the Indian Ocean the Swordfish stock is not considered overexploited and not subject to overfishing (IOTC 2018). The Bigeye Tuna stock in the Atlantic Ocean is considered overfished and experiencing overfishing (ICCAT 2016), while in the Indian Ocean the Bigeye Tuna stock is not considered overexploited and not subject to overfishing (IOTC 2018).

There is **uncertainty regarding the stock status** of Blue Sharks and Shortfin Mako in the Atlantic (ICCAT 2016, 2018). With regards to Blue Sharks and Shortfin Mako, it is recommended that catch levels should not be increased beyond those of recent years in the Atlantic a until uncertainty is resolved (ICCAT 2016, 2018, IOTC 2017). It has also been recommended that the fishing mortality of Shortfin Mako Sharks in the Atlantic Ocean not be increased until more reliable stock assessment results are available (ICCAT 2016). There is uncertainty in the stock status of Shortfin Mako in the Indian Ocean (IOTC 2018) while Blue Shark is considered not overfished and not subject to overfishing (IOTC 2018). Despite the absence of stock assessment information for Shortfin Mako in the Indian Ocean, a precautionary approach is recommended by implementing some management actions for this species. Improved compliance from parties regarding the reporting requirements on sharks to better inform scientific advice was also advocated (IOTC 2018). Southern Bluefin Tuna is globally assessed as Critically Endangered by the IUCN (Collette *et al.* 2011) and the stock remains at a low state, however there has been improvement since previous stock assessments and the stock is not considered overfished (CCSBT 2017).

4.3.10 Small Pelagic Fishery

Pressure Description

South Africa's small pelagic fishery catches the largest catch volume of all of the fishery sectors and constitutes the second largest catch value, second only to the hake trawl fishery (DAFF 2016). This fishery targets adult Sardine *Sardinops sagax*, juvenile Anchovy *Engraulis encrasicolus* and adult Redeye Round Herring *Etrumeus whiteheadi* using purse-seine nets. Purse-seine fishing consists of rapidly sinking a wall of netting around a group of fish, then closing the bottom edge with purse strings and finally hauling the catch aboard the vessel (Wardle 1986). Purse seine nets are deployed once a shoal of fish has been detected, and a smaller vessel is launched to deploy the net and encircle the shoal. The current fleet operating in this fishery consists of 101 vessels with landings ranging between approximately 200 000 and 600 000 tonnes between 2000 and 2016 (Norman *et al.* 2018). This fishery was established in the 1940s.

This fishery is managed using an Operational Management Procedure that aims to maximise overall sardine and anchovy catches while minimising the risk of resource collapse for South Africa's important forage fish resources (de Moor and Butterworth 2015). There is targeting of Sardines and Anchovy with challenges in balancing the catches of different species and juvenile bycatch. Juvenile Anchovy comprise the bulk of the Anchovy catch and shoal together with juvenile Sardine for much of the year. The Anchovy component of this fishery targets recruits (of approximately 6 months old) and processes them into fish meal and fish oil. The Sardine fishery targets adult fish, the catch being canned or frozen for human consumption and pet food. Juvenile Horse Mackerel *Trachurus capensis*, Sardine and Redeye are caught as bycatch during Anchovy-directed fishing operations (Hutchings *et al.* 2009a) and are turned into fishmeal and oil along with the Anchovy. Historically, this fishery has been characterised by resource fluctuations, changes in fishing patterns and dynamic ecosystem effects (Crawford *et al.* 1987, Hampton *et al.* 1999, Griffiths *et al.* 2004, Pecquerie *et al.* 2004, van der Lingen *et al.* 2006, Coetzee *et al.* 2008,

Hutchings *et al.* 2009b). Since 1995 a gradual increase in the proportion of Sardine biomass east of Cape Agulhas has been noted, and since 1999 the sardine biomass east of Cape Agulhas exceeded that to the west (Fairweather *et al.* 2006a, Coetzee *et al.* 2008). A higher-than-average exploitation of the Sardine stock west of Cape Agulhas may have contributed to this shift (Coetzee *et al.* 2008).

Pressure Distribution

The small pelagics sector operates relatively close to the coast from north of St Helena Bay to East London (Figure 37). The majority of the 63 current vessels in this fleet operate from St Helena Bay, Laaiplek, Saldanha Bay and Hout Bay, with fewer vessels operating on the south coast from the harbours of Gansbaai, Mossel Bay and Port Elizabeth (Norman *et al.* 2018). Ports of deployment correspond to the location of canning factories and fish meal plants along the coast. There is an established seasonal pattern that reflects the migration and inter-annual growth of the small pelagic resources exploited (DAFF 2016). The fishery operates throughout the year with a short break from mid-December to mid-January. The geographical distribution and intensity of the fishery is largely dependent on the seasonal fluctuation and distribution of the targeted species.

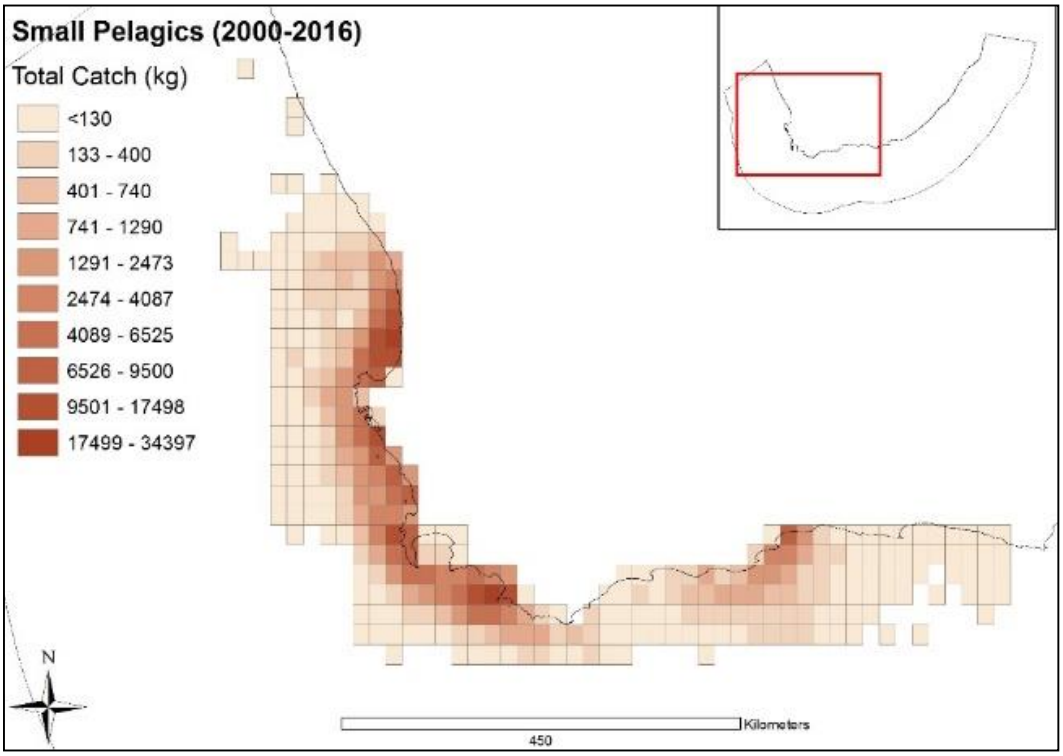


Figure 37. Map of intensity of small pelagic fishery reflecting total catch for period 2000-2016.

Total catch was used to assign intensity for this fishery (Figure 38).

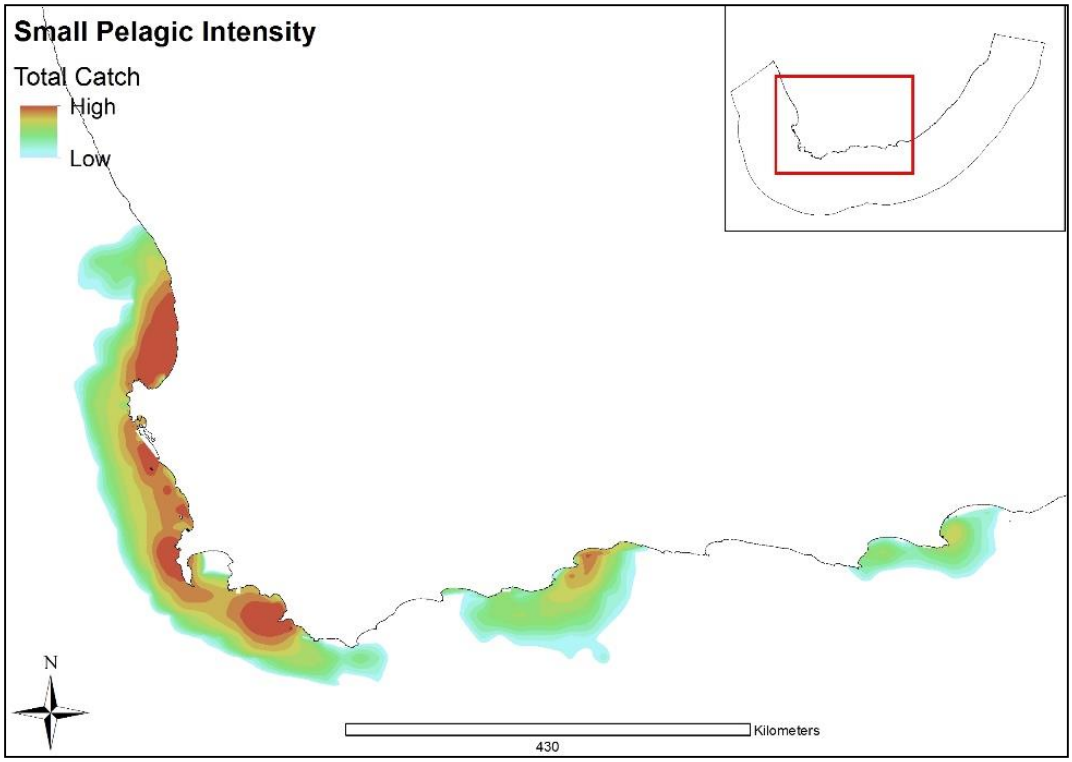


Figure 38. Map of scaled intensity for the small pelagic fishery which was used in the assessment.

Biodiversity and fisheries sustainability concerns associated with the small pelagic sector include:

- Uncertainty in stock structure (van der Lingen 2011, de Moor *et al.* 2015, van der Lingen *et al.* 2015, Weston *et al.* 2015).
- Bycatch of juvenile Sardine and Horse Mackerel during anchovy-directed fishing (Cury *et al.* 2000, Griffiths *et al.* 2004, Lynam *et al.* 2017).
- The potential role of fishing on the observed eastward shift of Sardine distribution (Fairweather *et al.* 2006a, Coetzee *et al.* 2008).
- Dumping of unwanted bycatch and undersized catch (Hutchings *et al.* 2009b, Hara 2013).
- Poor observer coverage (Hutchings *et al.* 2009a).
- The impact of fishing on the food availability for predators such as seabirds (Hamann *et al.* 2012, Pichegru *et al.* 2012, Gremillet *et al.* 2015, Robinson *et al.* 2015, Sherley *et al.* 2015, 2018).

Small pelagic fisheries are characterised by high levels of variability. Sardine stocks are reported as low, likely in response to unfavourable environmental conditions and some years of poor recruitment (DAFF 2016). Despite years of intensive research, some **uncertainty on sardine stocks** remains (van der Lingen 2011, de Moor *et al.* 2015, van der Lingen *et al.* 2015, Weston *et al.* 2015). Current research proposes that there are three semi-discrete sardine stocks: one each on the west coast, south coast and east coast (van der Lingen *et al.* 2015). The west and south coast 'stocks' are considered the most important for the small pelagic fishery. These stocks are not considered to be totally isolated from each other and there is thought to be movement of fish between them, with recruitment from the more productive 'west stock' to the 'south stock' thought to be particularly important for maintaining the productivity of the latter (Coetzee *et al.* 2008, de Moor *et al.* 2017).

The recent awareness of potentially different stocks and the relationships between them has important **implications for fisheries and biodiversity management** because it means that care must be taken not only to ensure that the population as a whole is not overexploited and reduced below thresholds at which future recruitment could be threatened, but also that the separate stocks are maintained above critical thresholds. In recent years this was achieved through an informal agreement between the former Department of Agriculture, Forestry and Fisheries and the fishing industry with consideration of the need to ensure a sufficiently large spawner-biomass in the western area that likely plays a key role in supplying the southern area. Formal spatial management measures have been introduced more recently and accounting for spatial structure and connectivity remains an important priority if the benefits from this fishery are to be maintained in the long term. Failure to take a spatial approach could have major negative impacts on the resource and the ecosystem given the current spatial mismatch between the distribution of the sardine resource and the location of the major landing and processing facilities. Potential adaptation by the industry is complicated by likely variability in the distribution of the two stocks between the west and the south coasts, which could make planning of, for example, future infrastructure development challenging.

As mentioned above, this fishery is managed by a joint Anchovy-Sardine **Operational Management Procedure**, which is an adaptive management system that is able to respond rapidly, without increasing risk, to major changes in resource abundance (de Moor *et al.* 2017). The OMP is used to recommend TAC and Total Allowable Bycatch (TAB) based on results from prior adult biomass surveys. A major recent focus of research has been a multi-disciplinary investigation into the population structure of sardine (van der Lingen 2011, de Moor *et al.* 2015, van der Lingen *et al.* 2015, Weston *et al.* 2015), after mounting evidence suggested that the eastward shift of sardine was brought about by differential growth in the western and southern sardine stocks (Coetzee *et al.* 2008). The two-stock scenario has been determined as more plausible than that of a single sardine stock, and the inclusion of spatial management measures, such as separate Sardine-directed TACs for the areas west and east of Cape Agulhas, is being investigated (Coetzee *et al.* 2008).

There is some concern about **dumping** in this fishery as observers have documented higher catch rates than those reported from vessels without observers (Hutchings *et al.* 2009a), with fishers admitting to practices of dumping and 'high grading' in an attempt to increase efficiency (Hara 2013). Low observer coverage (8%) is also of concern (Hutchings *et al.* 2009a).

Small pelagic fish are collectively referred to as "lower trophic level species" as they are near the bottom of the food chain and are important prey for many other fish species such as Hake, Snoek and seasonal (migratory) tunas, as well as some marine mammals and seabirds (DAFF 2016). As such small pelagic fish species play an important role in **marine food webs** particularly in the transfer of energy between upper and lower trophic levels and changes in their abundance can have substantial impacts on the ecosystem (Cury *et al.* 2000, Griffiths *et al.* 2004). Although small pelagic fishes are ranked at a lower to intermediate trophic level, because of their considerable population sizes, they can exert top-down control on zooplankton and bottom-up control of predatory fish and marine birds, suggesting that they form part of a wasp-waist system (Lynam *et al.* 2017).

Local food shortages are a key driver of **seabird declines** and the eastward shift in sardine distribution is considered to have contributed to the large reductions in numbers of Cape Gannets *Morus capensis*, Cape Cormorants *Phalacrocorax capensis* and African Penguins *Spheniscus demersus*, breeding on South Africa's west coast (Crawford 2007, Crawford *et al.* 2007, 2011). See Box 39 and Box 40 for more detail on the threat status of Cape Gannet and African Penguin. Recent attention has been given to determining whether competition with forage fisheries contributes to the ongoing declines (Hamann *et al.* 2012, Pichegru *et al.* 2012, Gremillet *et al.* 2015, Sherley *et al.* 2015, 2018). A programme of alternative, experimental fishing closures around sensitive penguin breeding-colony islands was initiated in 2008 (Pichegru *et al.* 2012, Sherley *et al.* 2015), and results demonstrated that fishing closures improved chick survival and condition (Pichegru *et al.* 2012, Sherley *et al.* 2015, 2018).

4.3.11 Netfishing: Gillnet and Beach-Seine Fishing

Pressure Description

Netfishing in South Africa is comprised of two sectors: beach seine and gillnet fishing. Beach seine fishing dates back to the mid-1600s and was initially mainly focussed on large linefish species. Lamberth *et al.* (1994) reported that in recent years the Mullet *Liza richardsonii* made up the majority of the proportion of catches in False Bay. There are currently about 28 rights holders (DAFF 2016). Gillnetting was introduced in the late 1800s (DAFF 2016). The main target species of both fisheries is harder and there are 162 reported rights holders (DAFF 2016). These activities have very different fishing methods, but have overlap in fishing area and target species. Beach seining is an active form of fishing whereby nets are deployed by row boat to encircle a shoal of fish and then dragged onto shore. Gillnetting is a passive form of fishing that involves the deployment of nets that are left to stand vertically in the water column so that fish are caught by becoming entangled in the nets. Seasonal beach seine fishing for Sardines on the east coast, and a single mixed-species beach seine fishery in Durban, are not considered here because of the sporadic/and or low level of effort.

Pressure Distribution

The netfishing sector has fishing areas on the west and south coasts (Figure 39).

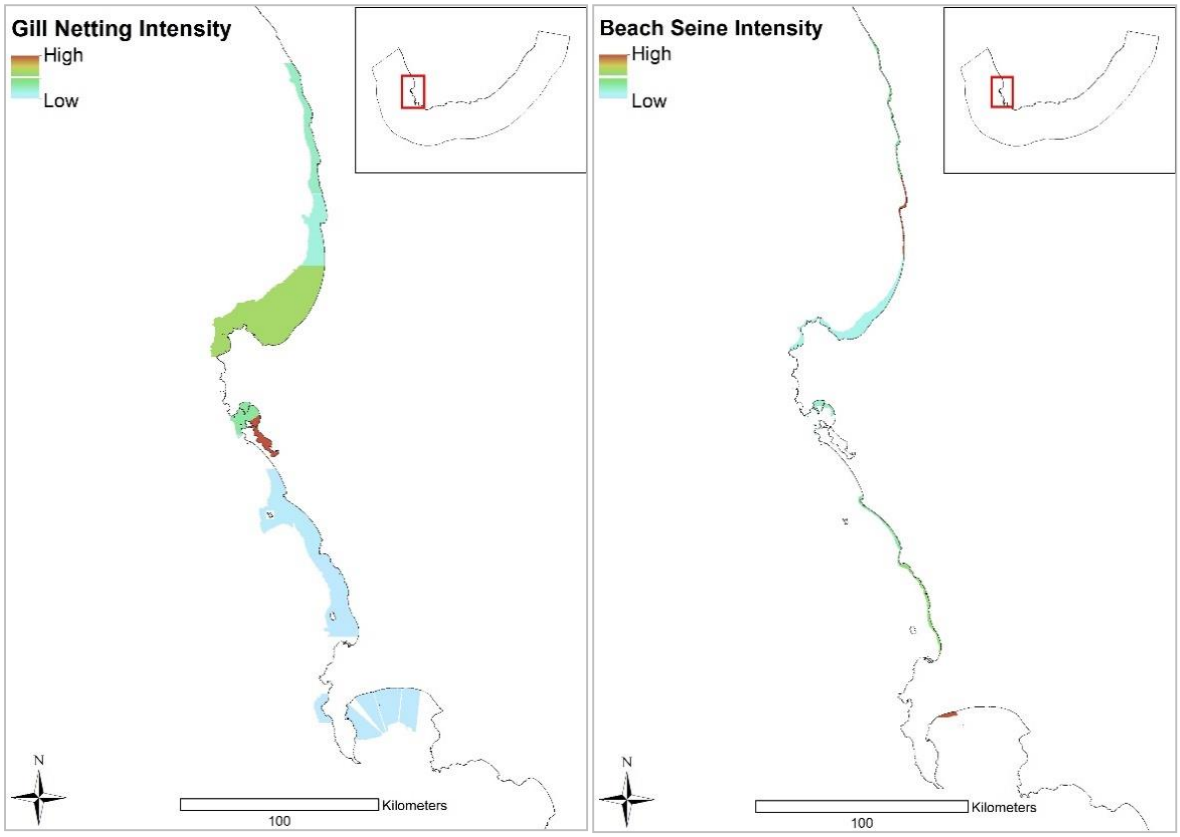


Figure 39. Map of gillnet (left) and beach seine (right) fishing effort illustrated using the average number of permits per square kilometre.

Total catch data for these sectors was not available at the time of the assessment owing to challenges in data management. The most important data source for these fisheries is the national linefish survey, but this has not been undertaken since 1995 (DAFF 2016), indicating the need for long term data collection and ongoing maintenance of datasets. The impacts of illegal activities were not included in this assessment, but further investigation into the intensity and distribution of illegal activities is required to allow for consideration in the next assessment. Although effort was mapped for Langebaan Lagoon (Figure 39, left), this area was not included in this assessment as it is assessed in the estuary component of the NBA (van Niekerk *et al.* 2019).

Biodiversity and fisheries sustainability concerns for the netfishing sector include:

- Heavy fishing pressure and the depleted stock status of Mullet (DAFF 2016).
- High rates of bycatch of sensitive linefish species and Heaviside Dolphins (Hutchings and Lamberth 2002).
- Targeting of juveniles by fishing in nursery areas (i.e. estuaries) (Hutchings and Lamberth 2002).
- Moderate impacts on invertebrate species and associated habitats.

The **stock status** of Mullet is considered overexploited and under heavy fishing pressure. Previous improvements in stocks of Mullet, the main target of both beach seine and gillnet fishers, have been eroded by increased illegal harvesting and adverse environmental conditions (DAFF 2016).

Prior to management intervention on the 1990s, the gillnet fishery had high **seabird bycatch mortality**, mainly due to the placement of nets across Penguin approaches near Dassen and Robben Island (DAFF 2016), while netfishing in generally has been associated with bycatch of linefish species (Hutchings and Lamberth 2002). Concern has been raised on the impacts of current illegal gillnetting with reports of bycatch of sensitive seabirds (DAFF 2016). The impact of illegal fishing was not included in this assessment, and should be considered in future assessments. However, the literature on the impacts, status and management of these fisheries is sparse with no recent peer-reviewed literature (i.e. post-2006) available.

Historically very few limits were imposed on beach seiners prior to 1983, when night fishing was banned and limits were introduced on fishing gear, fishing season and the species that beach seiners were allowed to catch (Bennett 1993b), but this was remedied with the introduction of management of both fisheries through a limit on the Total Allowable Effort (DAFF 2016). Concerns around frequent excessive gillnet catches of **Penguins** around Dassen and Robben Islands also prompted management intervention in the late 1990s as fishers were setting their nets across Penguin approaches as Mullets were feeding on the Penguin guano slicks. Gillnet exclusion zones now prohibit gillnets being set within 1–2 km of each island.

Literature on the Netfishing sectors is sparse and outdated, and more research is required to better understand impacts, levels of compliance, and ecosystem responses in this sector, alongside research to quantify the impacts of illegal activities.

4.3.12 West Coast Rock Lobster Harvesting

Pressure Description

The West Coast Rock Lobster (WCRL) fishery targets the temperate or cold water species *Jasus lalandii* and is South Africa's most valuable crustacean fishery. This is due to the high market value of the resource (more than R260 million per year) and job provision for more than 4200 people (DAFF 2016). The fishery dates back to at least 1875 when the first commercial processing plant was established (Griffiths *et al.* 2004). See Box 34 for information the current status of West Coast Rock Lobster. Two major fishing sectors harvest this resource; the offshore trap vessels operating in waters up to 100 m depth, and the inshore sector that utilises hoop nets to harvest WCRL in shallow water up to 1 nautical mile from the shore. Hoop Nets (also known as fyke, barrel or fiddler nets) are tubular shaped nets with a series of tapered hoops spaced along the length of the net to keep it open. The net is laid out and the bait is placed in the closed or tail end of the net, relying on lobsters to enter voluntarily and becoming trapped inside. Traps can be shaped as tubes or boxes that are set out and left to soak for a period of time, and also rely on lobsters being lured by bait and becoming trapped inside. The near-shore resource is also harvested by recreational fishers and the informal small-scale subsistence fishers (Cockcroft and Mackenzie 1997, DAFF 2016). The majority of the catch is apportioned to the offshore sector (80%) with a smaller portion (20%) being landed by the inshore sector (DAFF 2016). Recreational harvests range between 125 - 300 tonnes (DAFF 2014) with intended decline through the implementation of reductions in the length of fishing seasons.

Pressure Distribution

Due to differences in stock abundances and fishing pressures, WCRL are managed in five (5) super areas that consist of 14 different fishing areas within six zones (Figure 40). See (DAFF 2016) for definitions of super areas, zones and fishing areas.

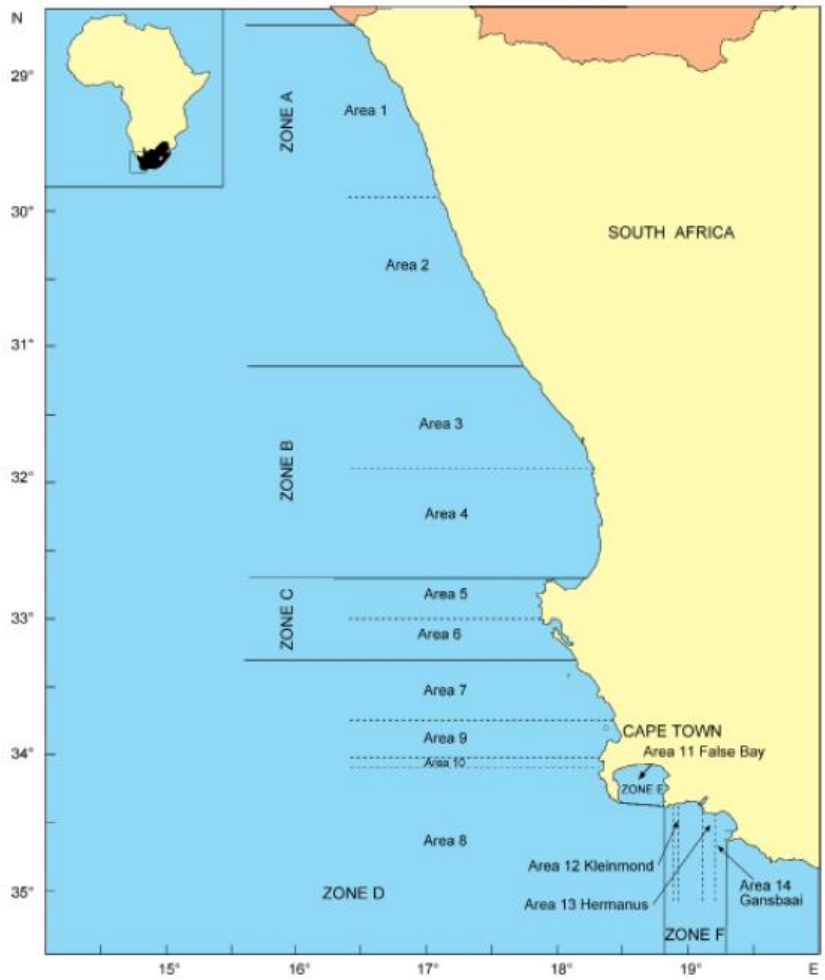


Figure 40. Map of fishing areas for West Coast Rock Lobster (taken from DAFF 2016).

The natural distribution range of this species ranges from Walvis Bay in Namibia to East London in South Africa with the local commercial fishery operating between the Orange River mouth in the north to Danger Point in the south. Data for catches were received per fishing area, thus limiting the ability to accurately assign effort to specific locations. To avoid overestimation of the affected area, effort was cut to the 100 m depth contour (Figure 41).

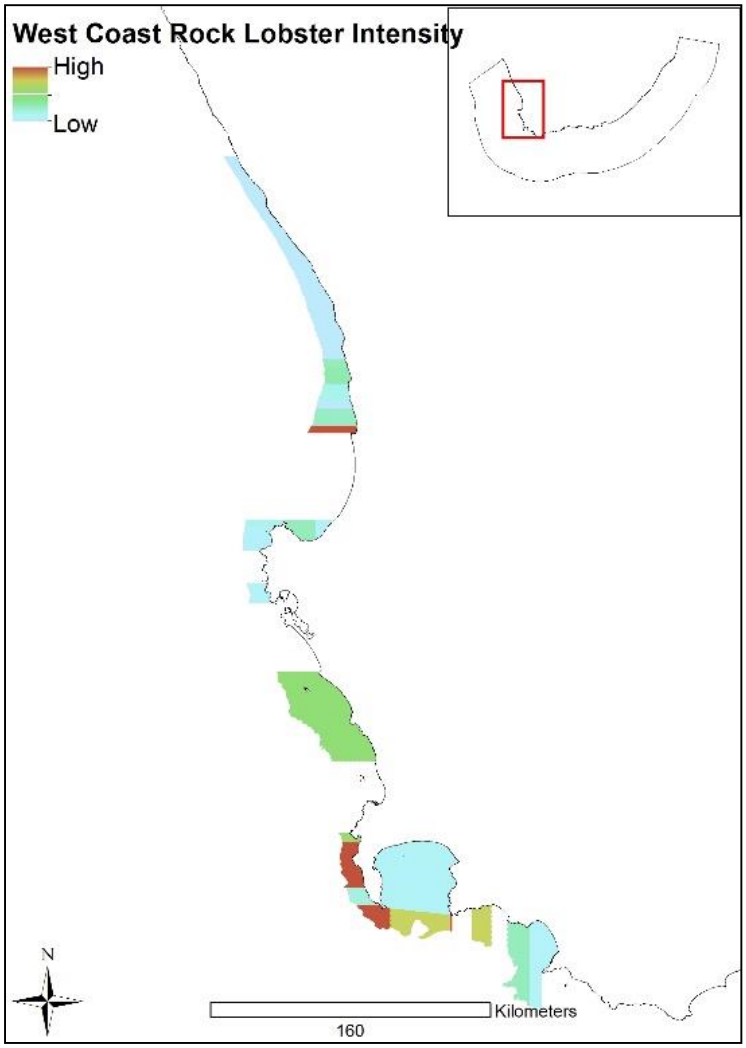


Figure 41: Map of West Coast Rock Lobster fishing effort using the annual average total catch per square kilometre.

Current biodiversity and resource sustainability concerns associated with this sector include:

- Stock status concerns and declining growth rates (Cockcroft and Payne 1999, Pollock *et al.* 2000, DAFF 2010, 2014, 2016).
- Compliance concerns associated with this high value resource and the impact of illegal fishing in preventing resource recovery (Brandão *et al.* 2016, DAFF 2016).
- Whale entanglement (Meÿer *et al.* 2011).
- Occasional trap loss, potential associated ghost fishing and possible localised damage to benthic invertebrates when traps are set on reefs (Atkinson and Sink 2008).

Commercial fishing for WCRL peaked in the 1950s yielding a catch of 18 000 t; in contrast the 2014/2015 Total Allowable Catch specified 1 688 tonnes (DAFF 2016). Ongoing **declines in catches** have been attributed to a complex combination of factors including overfishing, changes in fishing methods and efficiency, changes in management measures (size limits, fishing zones, quotas and protection of berried females), reduced growth rates and environmental change (Cockcroft and Payne 1999, Cockcroft *et al.*

2008, Blamey *et al.* 2015, DAFF 2016). In 1996, catches had declined to 1500 tonnes and an Operational Management Procedure was implemented to support resource rebuilding. The OMP incorporates an in-depth stock assessment for the resource which incorporates **illegal fishing** biomass estimates that are used to estimate the total catch. Current poaching estimates are based on policing effort and confiscation data (Brandão *et al.* 2016) and industry has raised concerns that these may be underestimates. The 2014 DAFF Status of the South African Marine Fishery Resources report indicated that the biomass of male lobsters above the 75mm size limit was at 2.6% and that if the recovery target (35%) was met, the resource biomass would increase to 4.8% of pristine by 2021. The resource is still heavily depleted and stocks were reported at being 2.5% of pristine levels. See Chapter 9 for more information about this species stock status. Reduced illegal harvesting is a key priority management measure for this fishery.

4.3.13 South Coast Rock Lobster Harvesting

Pressure Description

This longline trap fishery targets the endemic South Coast Rock Lobster (SCRL) *Palinurus gilchristi*. The commercial fishery commenced in 1974 after the discovery of concentrations of rock lobsters off Port Elizabeth (DAFF 2016). Vessels used to target SCRL are large steel-hulled ocean-going fishing boats (30–60 m long) specifically rigged for longline trap-fishing (Sauer *et al.* 2003). Each boat operates with 2 000–6 000 barrel-shaped plastic traps, that are tied to longlines in sets of 100–200 traps, with a line of traps being 2–3 nm long. As many as 12 lines are set daily (Pollock 1989).

Pressure Distribution

This fishery operates in predominantly rocky areas in the 90- 200 m depth range between Cape Point and East London (Pollock 1989, Groeneveld and Branch 2002). Highest effort was recorded off Mossel Bay, Port Elizabeth and East London (Figure 42).

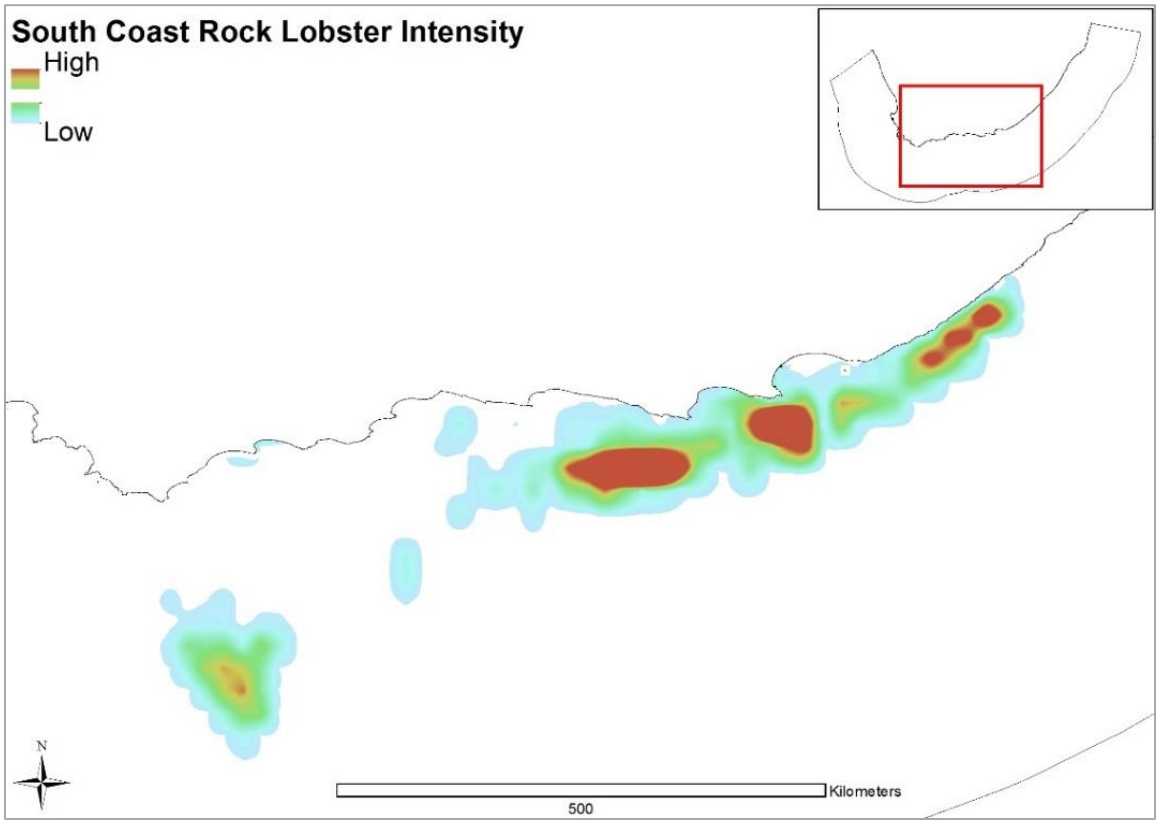


Figure 42. Map of fishing effort for South Coast Rock Lobster displayed as annual average total catch in kilograms per square kilometre.

Biodiversity and fishery sustainability concerns include:

- The vulnerability and potential stock status concerns of this slow-growing target species (Groeneveld 1997, 2003, Pollock *et al.* 2000, Groeneveld *et al.* 2012, DAFF 2016).
- Limited incidental bycatch of octopus, Kingklip and Slipper Lobsters (Japp 2004).
- Occasional trap loss and potential associated ghost fishing (Japp 2004).
- Localised damage to the seabed through anchor damage to benthic invertebrates (Japp 2004)
- Increasing reports of entanglement of marine mammals (Atkinson and Sink 2008) and recently turtles (K. Sink, SANBI, pers comm.)

The **stock status** of this endemic species is considered to be in an optimal to overexploited state (DAFF 2016). The exploitable biomass of SCRL is reported to be approximately 30% of pre-fished levels and spawner biomass is estimated to be approximately 29% (DAFF 2016). The SCRL resource has fluctuated since the inception of this fishery in 1974 with effort reductions and resource recovery measures implemented in the period between 1980 and 2001 (Pollock and Augustyn 1982, Pollock 1989, Atkinson and Sink 2008, DAFF 2010). DAFF (2010) reported that earlier declines in the SCRL resource had been arrested through these management interventions and the resource was optimally exploited. However, the 2016 Status of the South African Marine Fishery Resources report indicated that this species is under light to optimal fishing pressure to ensure recovery of this resource (DAFF 2016). Spatial and temporal information on the distribution of berried females is a research priority (DAFF 2016). Research on the

relationship between this resource and different benthic environmental factors is underway. There are few major ecosystem interactions that require attention in this fishery, although bycatch is a potential concern (DAFF 2016). There is concern regarding whale entanglement with evidence of occasional entanglement of leatherback turtles. This warrants monitoring, further research attention and innovation in trap fishing to reduce or avoid the use of ropes.

4.3.14 Squid Harvesting

Pressure Description

The Chokka Squid *Loligo reynaudii* has been targeted in South Africa for many years and the squid jig fishery makes a significant contribution to the economy of the South Eastern Cape coastal region. The South African linefishery for Squid developed along the south coast in the early 1980s where spawning aggregations between Plettenberg Bay and Port Elizabeth were targeted (Augustyn and Smale 1989). This fishery is somewhat seasonal (main season October-March) targeting adult Squid in spawning aggregations. In winter, Squid fishing takes place in deeper water where the use of lights is employed. *L. reynaudii* occurs from Namibian waters in the west to the Wild Coast region in the east, and spawns and lays its eggs on the seabed.

Pressure Distribution

As shown in Figure 43, most fishing takes place between Plettenberg Bay and Port Alfred (Roberts and Mullon 2010), between 20 m and 120 m depth range but effort is highest in water shallower than 40 m (DAFF 2016).

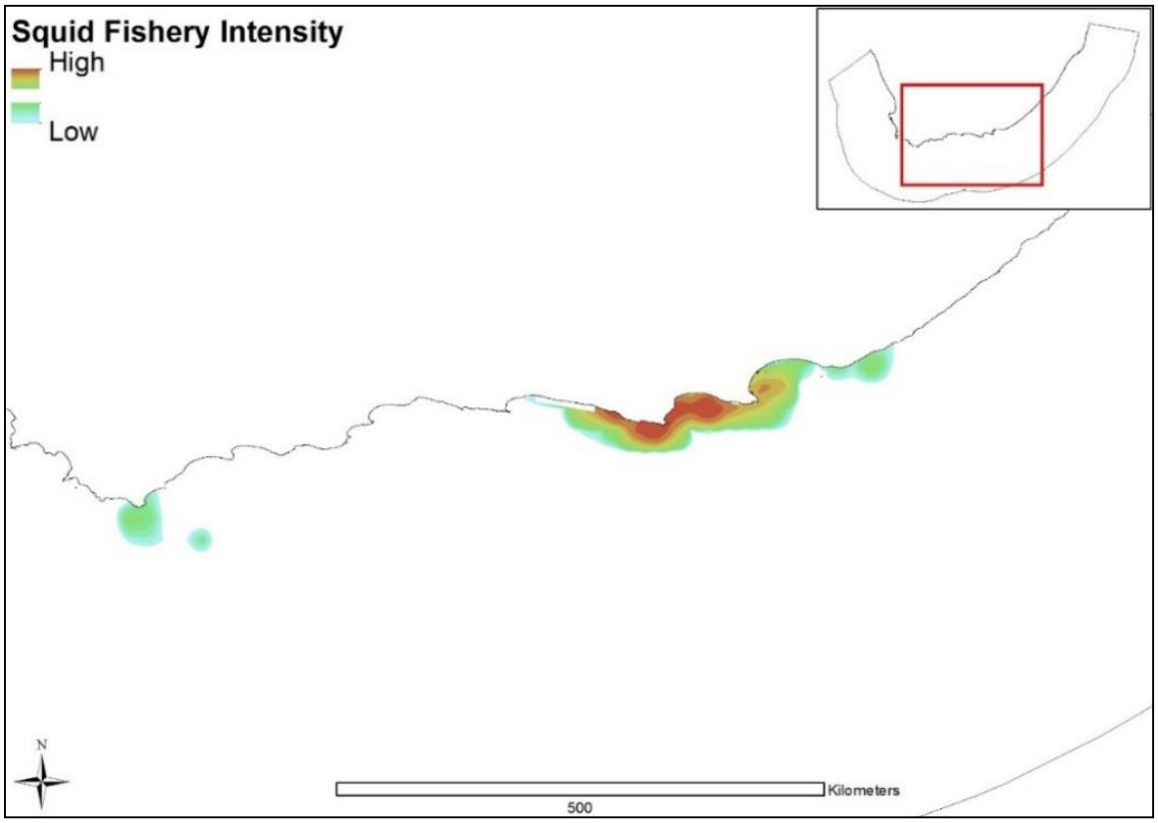


Figure 43. Map of squid fishing effort displayed as annual average catch in kilograms for the period 2000-2017.

Key biodiversity concerns include:

- The potential trophic impacts on predator populations (seals, linefish, cetaceans, sharks and seabirds (Atkinson and Sink 2008). C
- Plastic pollution from Squid boats (Petersen and Nel 2007).
- Localised damage to the seabed and squid beds may occur during deployment of fishing boat anchor chains and further research is underway to assess this (DAFF 2016).
- Potential effects from the use of bright lights at night (Solomon and Ahmed 2016).

The squid jig fishery has relatively little impact on other species and this targeted fishery is considered to have **low impacts on biodiversity** overall (Petersen and Nel 2007, Atkinson and Sink 2008, DAFF 2016). The Squid resource is considered to be optimally exploited (DAFF 2014). The latest stock status is estimated to be at approximately 30% of pre-fished levels (DAFF 2016).The NBA 2011 reported that there were uncertainties in the reliability of catch and effort data due to changes in reporting systems. These uncertainties have been resolved and a revised recruitment model implemented in 2013 shows that the resource is less productive than previously thought (DAFF 2016). Fishing effort has been adjusted in line with updated data on resource abundance (DAFF 2016). The potential impacts of lights on other species warrants further investigation.

4.3.15 Abalone Harvesting

Pressure Description

Abalone or Perlemoen (*Haliotis midae*) is a slow-growing mollusc and highly prized seafood delicacy both in South Africa and the Far East. Abalone are harvested by divers and pried from rocks using a blade. Abalone harvesting permits strictly forbid the use of scuba gear and no more than 3 bags are permitted on board an abalone boat (DAFF 2011). The **history** of this fishery follows and has been synthesised from the most recent status report on the state of marine resources (DAFF 2016).

The commercial (diver) fishery for abalone started in the late 1940s and was dominated by five large abalone processing plants. Initially, catches were unregulated, and reached a peak of close to 3 000 tonnes in 1965 but by 1970, catches had declined rapidly, although the fishery remained stable, with a total annual catch of around 600–700 t. The early 1990s saw the booming of the recreational fishery, and a significant increase in illegal fishing activities which contributed to the continuous declines in commercial catches experienced in the mid-1990s. Subsistence rights were introduced in 1998/1999, and were replaced by two-year medium-term rights. In 2003/2004, 10-year long-term rights were allocated, broadening participation in the fishery to some 300 right-holders. At this time, the previous management zones were replaced with Territorial Use Rights in Fisheries (TURFs). The fishery was closed in 2008 after rampant poaching and continued **resource declines** (DAFF 2016). In 2010, the commercial fishery was re-opened with a Total Allowable Catch of 150 t. This was conditional on poaching reductions that were not achieved. DAFF (2016) describes research and monitoring aspects for this sector noting the need to strengthen population surveys, improve the understanding of abalone aggregation dynamics and to improve estimates of illegal harvesting.

Pressure Distribution

Abalone are estimated to be distributed from the Brak River north of St Helena Bay to the Mbashe River just east of Port St Johns in shallow waters less than 20m depth, with highest abundance in waters less than 5 m depth (Khuzwayo 2014, DAFF 2016). The historic core range was between Cape Columbine on the west coast to Quoin Point near Gansbaai. Commercial fishing zones are shown in Figure 44, which are subdivided into fishing areas.

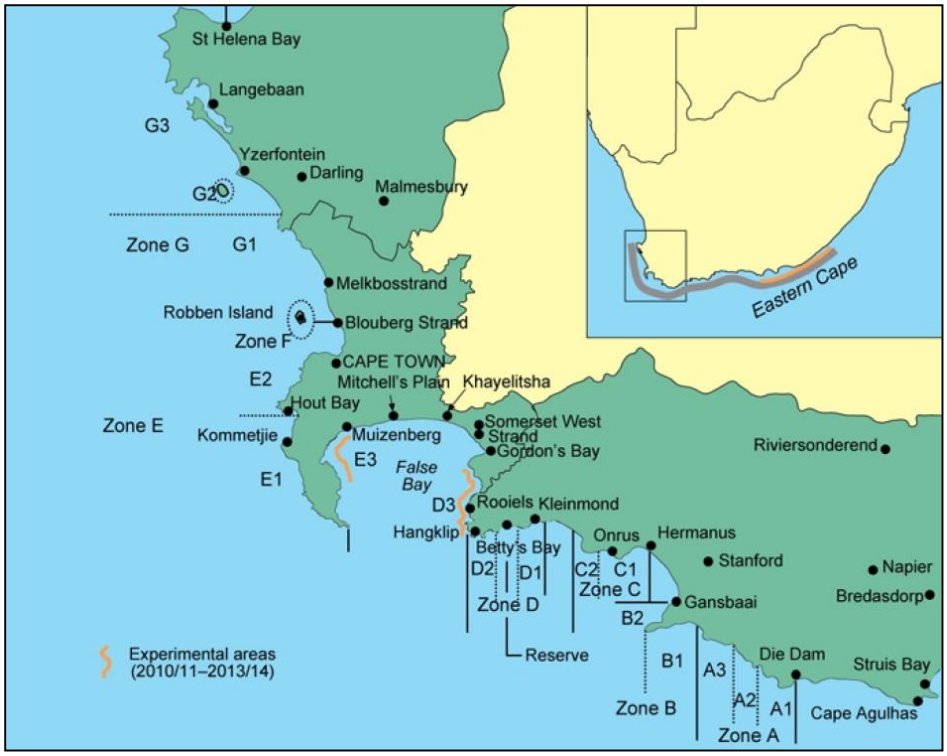


Figure 44. Map of commercial fishing zones and areas for abalone harvesting (taken from DAFF 2016).

The impacts of **legal harvesting and poaching** were considered in this assessment. Although actual catch data and estimated poaching data were received from DAFF, these data did not reflect the full coverage of Abalone distribution nor adequately represent poaching estimates outside of the legal fishing areas. Therefore, the full distribution of Abalone as reported in the literature was used as the distribution of fishing effort for both legal fishing and poaching. Intensity of legal harvesting and poaching were allocated using expert judgement supported by the literature across the Abalone distribution (Figure 45).

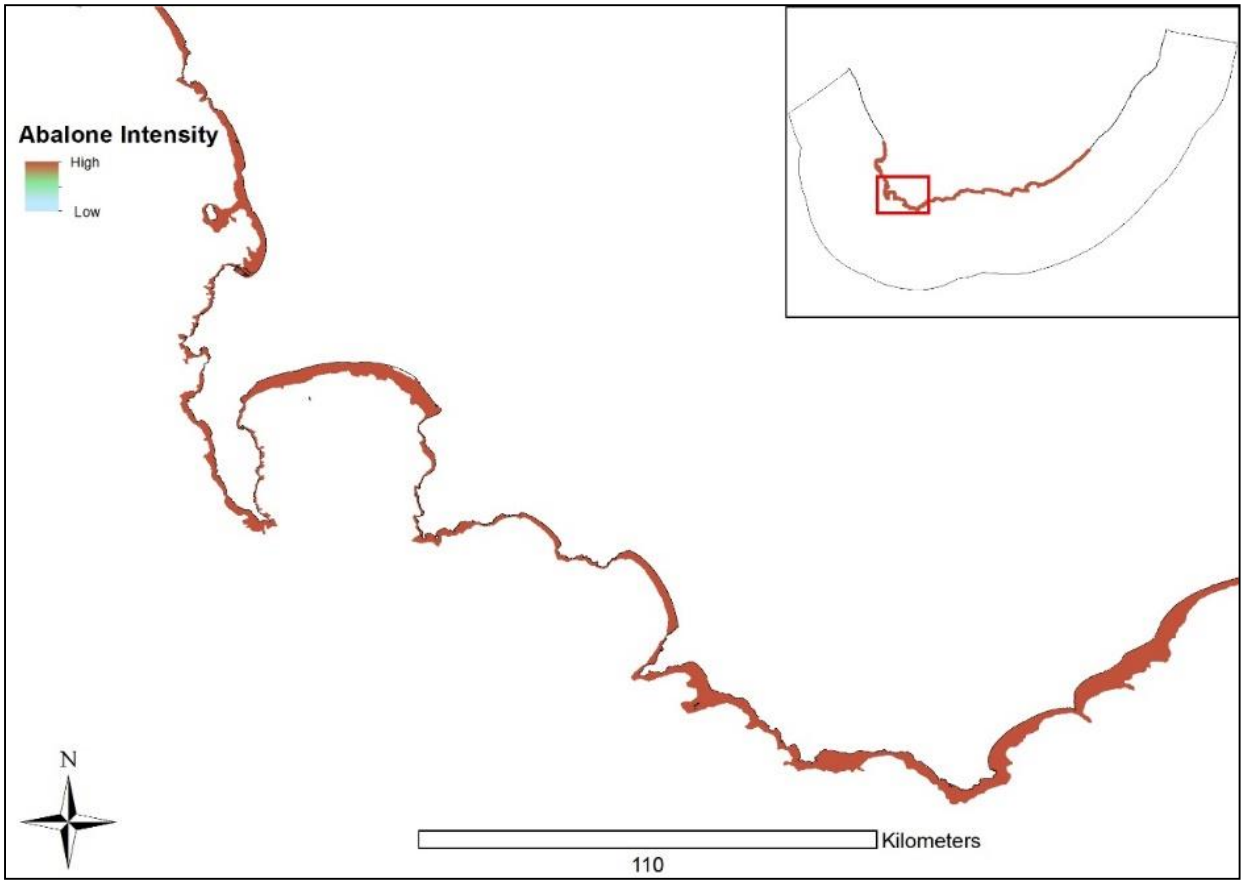


Figure 45. Map of abalone harvesting intensity across the range of abalone habitat. Intensity has been mapped uniformly to account for legal and illegal harvesting.

Biodiversity and resource sustainability concerns associated with this fishery include:

- Declining stock status of the species due to high levels of poaching and over-allocation of Total Allowable Catches for legal fishing (DAFF 2016).
- Changes in community structure and ecosystem functioning due to removal of Abalone.
- Declining protection of Abalone in MPAs due to poaching and ecological changes (DAFF 2016).

The **stock status** of the Abalone resource is collapsed (DAFF 2016). Declines in Abalone are predominantly a result of illegal harvesting coordinated largely through complex criminal syndicate (de Greef and Raemaekers 2014, Warchol and Harrington 2016). The impact of rampant **poaching** of this high value resource has seen a once lucrative fishery decline to provide diminishing benefits. At the turn of the century this fishery was estimated to earn R100 million but returns have significantly diminished (DAFF 2016) along with the stocks of this endemic species.

Ecological changes that have **disrupted abalone recruitment patterns** and are an additional concern that impact this resource (DAFF 2016). Small, post-settlement Abalone are known to feed on diatoms, microalgae, coralline algae and the bacteria found on encrusting coralline algae (Day and Branch 2002); juvenile Abalone shift to drift macroalgae (Barkai and Griffiths 1986). Abalone are therefore considered scavengers rather than grazers. Abalone have a commensal relationship with sea urchins, as the latter provide some protection of small Abalone from predators, whilst as adults they compete for food as sea

urchins also feed on drift algae (Jenkins 2004). Although not fully researched, a review by (Jenkins 2004) purports that Abalone may be more successful in competing for space than urchins in areas where food is not a limiting factor, allowing for space for kelp to attach and offering some control of sea urchins that are also known to feed on live kelp. This has implications for kelp ecosystems as urchins are known to create urchin barrens dominated by coralline algae where kelp forest was previously found, and removal of abalone combined with rock lobster may exacerbate the proliferation of urchins in light of climate change impacts (Tegner and Dayton 2000).

In terms of **management**, the commercial diver fishery for Abalone was largely unregulated until 1954 with the introduction of a minimum size limit (Dichmont *et al.* 2000) and the introduction of a Total Allowable Catch limit in 1970 (Madikiza 2013). The recreational sector also harvested Abalone for many years but this component was suspended in 2003/2004 (DAFF 2016) due to declining catch rates and increased levels of poaching threatening the legal commercial fishery. Management measures have done little to counter the high levels of poaching. The increasing pressure put on South African Abalone by both legal harvesting and poaching had led to the banning of Abalone harvesting and listing thereof on CITES in Appendix III. They were then removed from CITES because of administrative challenges (Raemaekers *et al.* 2011). The status of Abalone continues to decline in response to extremely high levels of poaching and over-allocation of Total Allowable Catches (DAFF 2016). Additional information on the history and management of this fishery is included in Chapter 9.

4.3.16 Oysters Harvesting

Pressure Description

The **commercial oyster fishery** dates back to the early 19th century and has mainly focussed on the Cape Oyster, *Striostrea margaritacea*, which has a distribution spanning from Cape Agulhas to Mozambique (DAFF 2016), while recreational and subsistence harvesting has mainly focused on harvesting of *Striostrea cucullata* (Haupt *et al.* 2010b); the latter is now known to comprise a **species complex** (Oceanographic Research Institute, unpubl. data). Fishing is carried out by hand as harvesters use a crowbar or steel blade to remove oysters from the rocks.

Prior to 1998, the *S. margaritacea* fishery included less than 8 rights holders who employed large numbers of people as pickers. In 2002, these rights were redistributed as medium-term rights to 34 rights holders who were allowed to have 3-10 pickers each with the **Total Allowable Effort** across the sector being 114 pickers. This redistribution also saw a move away from regional management of the two fishing areas (i.e. the south coast and the KZN Coast) towards management of the fishery at a national level with four commercial oyster-harvesting areas recognized. These are the southern Cape coast, Port Elizabeth, KZN North, and KZN South. The 2006 allocation process saw another redistribution of rights, with commercial rights distributed to 121 individuals with a large number of individuals who were formerly employed as pickers receiving rights. Rights holders were no longer allowed to employ pickers, but required to harvest oysters themselves. The current number of rights holders is 145 and has been distributed with 40 pickers on the east coast and 105 on the south coast since 2002 (DAFF 2016), with a maximum allowable catch of 190 oysters per day per rights holder.

Pressure Distribution

The fishing areas in the south coast span from Stillbaai to Plettenberg Bay, and from Port Shepstone to the Mhlali River on the east coast (Figure 46).

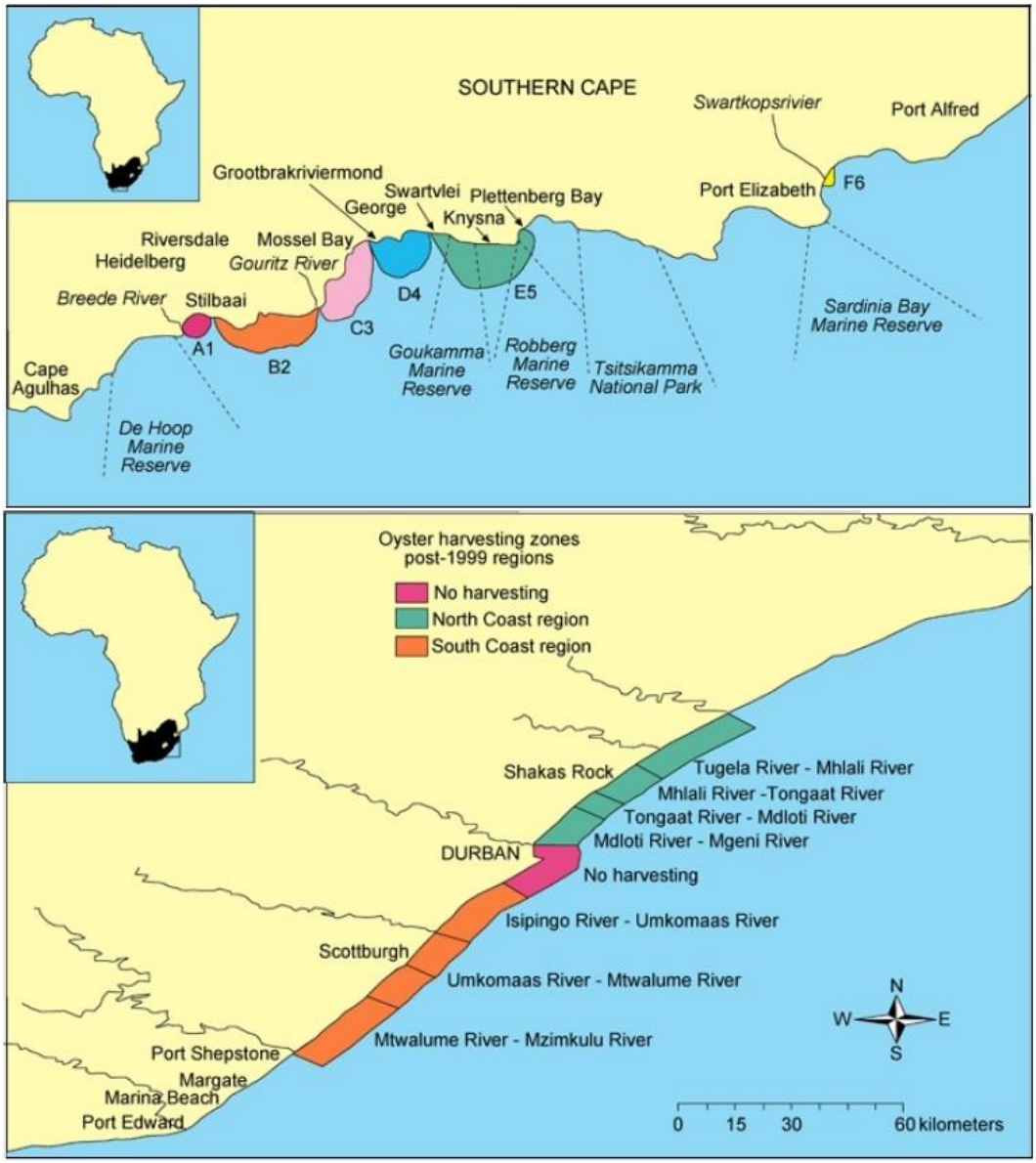


Figure 46. Fishing areas for oyster harvesting for the south coast (top) and east coast (bottom) – taken from DAFF (2016).

Data were not available per concession area as shown in Figure 22, but rather captured as per broad region i.e. south coast and east coast region. Higher catch was reported for the south coast than the east coast region (Figure 47).

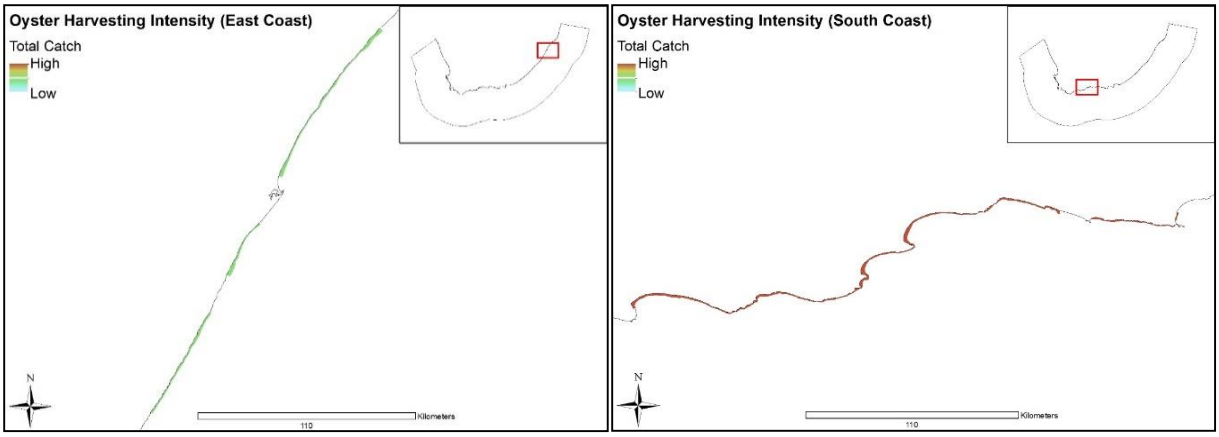


Figure 47. Map of the intensity of oyster harvesting using kilograms of oysters removed per fishing area.

Biodiversity concerns associated with this fishery are:

- Uncertainty in current stock status for Oysters (DAFF 2016).
- The potential habitat damage caused by harvesting methodology (De Bruyn 2006).
- Illegal harvesting of subtidal "mother-beds" (DAFF 2016).

The main concerns regarding the impacts of this fishery are related to the harvesting method and potential overexploitation of the resource. Harvesters are allowed to use a crowbar or steel blade to remove oysters from the rocks, which causes **localised physical damage**. Due to the relative low value of this industry, it has not been prioritised for research effort and management (DAFF 2016). There are therefore **uncertainties in stock assessments**. The fishery is managed by effort limitation with gear limitations and MPAs also contribute to resource sustainability. No scuba gear is allowed thus limiting the depth at which fishing can take place. Concerns about illegal harvesting of oysters particularly the deeper "mother-beds" that provide recruits to the shallower harvested areas need attention (DAFF 2016).

4.3.17 Kelp Harvesting

Pressure Description

Kelp harvesting is the process of removal of fresh kelp from live stocks and removal of kelp that has washed up in the surf from beaches, referred to as beach-cast kelp (DAFF 2016). The South African seaweed industry is based mainly on the harvesting of the kelp ***Ecklonia maxima*** for Abalone aquaculture as feed and for use in other kelp-based products, while the red seaweeds ***Gelidium*** and ***Gracilaria*** are used for agar. Intensive harvesting of ***Laminaria pallida*** as feed for Abalone culture and a source of alginate for the fisheries industry and medicine (Omoregie *et al.* 2010) is reported in Namibia. The harvesting of red seaweeds was not mapped and therefore the potential impact of this activity was not considered in this study.

Pressure Distribution

This species increases in dominance north of the west coast into Namibian waters. Fresh kelp is harvested along the coastline between Port Nolloth to Cape Agulhas (Figure 48), with high quantities being harvested mainly in the Western Cape driven by the demand for **feed** for local Abalone farms.

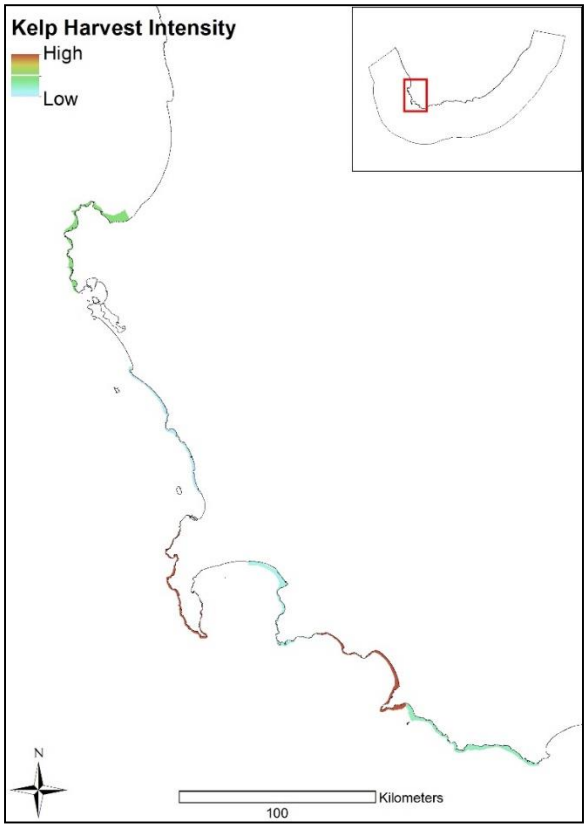


Figure 48. Map of kelp harvesting of *Ecklonia maxima* displayed as the kilograms per square kilometre for the period 2000-2017. Fresh kelp frond harvest has ranged between 3 to 6 tonnes per year with 0.4 to 1.8 tonnes of dry kelp harvested.

Biodiversity Concerns of kelp harvesting:

- Potential ecosystem impacts (Steyn *et al.* 2010, Davoult *et al.* 2011, Borras-Chavez *et al.* 2016).

There are currently **no stock status concerns** for kelps or other seaweeds with these resources considered underexploited (non-kelps) or optimal (kelps) and fishing pressure being light to optimal (DAFF 2016).

The primary biodiversity concern associated with this fishery is the **potential ecosystem impacts** of the removal of habitat forming kelp (Steyn *et al.* 2010, Davoult *et al.* 2011). Although fishing pressure remains light and resource stock status is reported as optimal (DAFF 2016), international literature has shown that negative impacts that may occur when harvesting intensity is high (Davoult *et al.* 2011) and unsustainable harvesting impacts resulting from repeated harvesting of the same area (Borras-Chavez *et al.* 2016). A study conducted at Danger Point (Levitt *et al.* 2002) on the effects of harvesting of *E. maxima* found that complete removal of whole organisms resulted in a 2-year recovery period with minimal impact on the understory biota, but also showed that optimal sustainable harvesting is possible if only the fronds of plants are collected, resulting in minimal disturbance to the kelp ecosystem. A few years later Anderson *et al.* (2007) showed that although *E. maxima* regenerate *ca* 2.5 years post-harvest, the effects of kelp harvesting significantly lowers epiphyte loads (which play a secondary productivity role) only recovery 4.5 years post-harvest.

Akin to other benthic foundational species such as hard corals, seagrasses ad massive sponges, kelps support elevated biodiversity through increasing habitat volume (Teagle *et al.* 2017). Kelp also provides an important food source to intertidal and subtidal consumers (Bustamante and Branch 1996a, 1996b), with both filter feeders and grazers on the west coast dependent on the kelp-derived organic matter. Lorentsen *et al.* (2010) described kelp harvesting as the removal of feeding and nursery grounds of coastal fish, influencing local **food webs** and the availability of food to different trophic levels e.g. predators.

Beach-cast kelps also underpin the food chain of adjacent sandy beaches (Branch and Branch 2018). Harvesting of **beach-cast kelp impacts** beach ecosystems because this wrack is an important food source for sandy beach macrofauna (Dugan *et al.* 2003) and interstitial fauna, including microbes (Koop and Griffiths 1982, Kirkman and Kendrick 1997). In addition, kelp wrack plays a key role in climate regulation with wrack piles on sandy beaches having higher CO_2 efflux rates than rain forests (Coupland *et al.* 2007). Beach-cast kelp harvesting or beach grooming removes this valuable wrack as well as the wrack-associated organisms, particularly amphipods, with knock-on implications for foraging seabirds (Dugan *et al.* 2003). In addition, it reduces native plant abundance and diversity (Dugan and Hubbard 2010). The impacts on beach fauna can be detrimental to the beach ecosystem because these animals play an important ecological role in terms of kelp breakdown (Lastra *et al.* 2008) and nutrient remineralization, which is subsequently important for driving phytoplankton communities (Koop and Griffiths 1982, McLachlan *et al.* 1985).

Kelp harvesters are supplied with a kelp harvesting manual which sets out **best practices** to ensure sustainability, and current harvesting levels of kelps are considered sustainable (DAFF 2016). Kelp forest ecosystem services are estimated to be valued around R5.8 billion, but unsustainable resource use (e.g. Abalone and West Coast Rock Lobster harvesting) coupled with other drivers could lead to a decrease in this monetary derived value (Blamey and Bolton 2018) . It is important to ensure that resource use continues to be sustainable and that continued good practices are applied.

4.3.18 Subsistence Fishing

Pressure Description

Subsistence fishing in South Africa has been considered to include various fishing methods targeting more than 30 species (Griffiths and Branch 1997) from a range of habitats (Branch *et al.* 2002, Clark *et al.* 2002). In 2002, the subsistence sector was estimated to include 29 000 participants of which the majority (75%) were found on the east coast in KwaZulu-Natal and the former Transkei (Clark *et al.* 2002). The dominant activity on the east coast is the harvesting of intertidal and subtidal invertebrates including mussels, oysters, redbait and limpets, crabs and octopus as well as fishes (Hockey and Bosman 1986, Siegfried 1988, Kyle *et al.* 1997, Clark *et al.* 2002). On the west coast, boat-based harvesting of near-shore subtidal species such as fishes and lobsters is the dominant activity (Clark *et al.* 2002). High value resources such as rock lobsters, oysters and Abalone are also caught by this sector although these resources are usually sold, leading Clark *et al.* (2002) to classify this as small-scale commercial fishing. South Africa's cabinet adopted a **Small-Scale Fisheries Policy** in June 2012, but implementation has not been fully realised leading to challenges in the ability to map and assess this pressure separately.

Pressure Distribution

Subsistence harvesting takes place across the entire South African coastline. The lack of long-term monitoring of effort and catch for this sector has limited the ability of this assessment to accurately account for its biodiversity impacts and footprint. The data used to assess this pressure was therefore not updated from the previous assessment (NBA 2011) and has been mapped as the number of harvesters per kilometre of coastline (Figure 49).

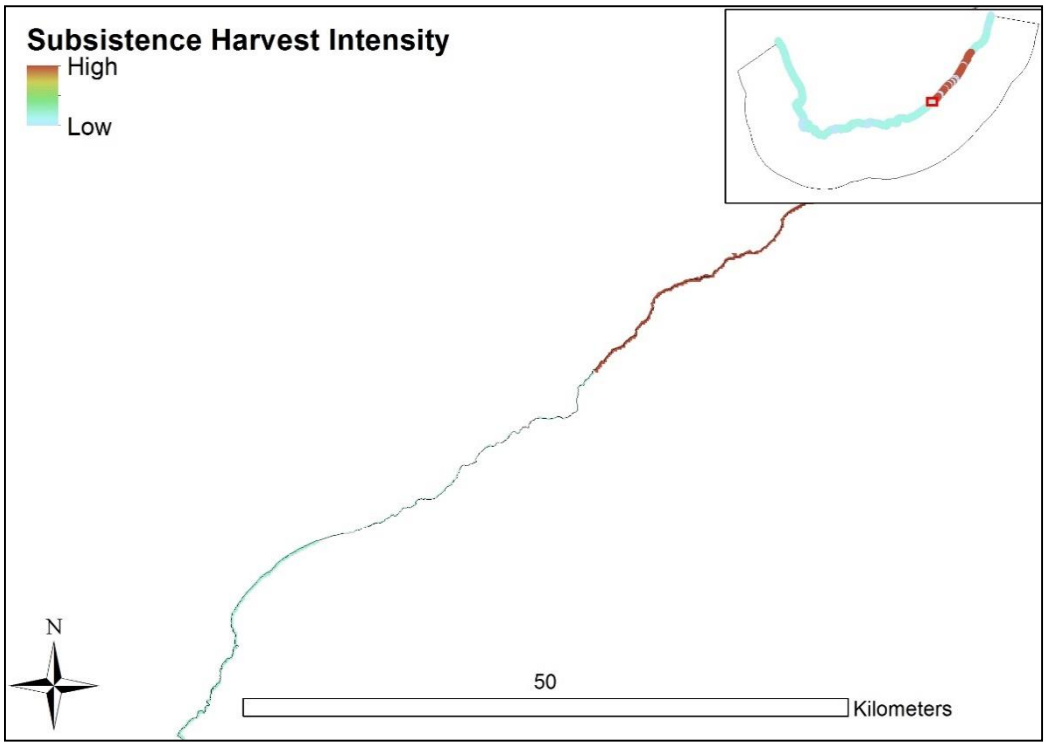


Figure 49. Map of estimated subsistence fishing effort for South Africa based on expert opinion and literature. (The insert represents the footprint of subsistence harvesting across the country.)

Biodiversity concerns linked to subsistence harvesting include:

- Overexploitation of intertidal resources (Hockey and Bosman 1986, Hockey *et al.* 1988, Lasiak 1991, Tomalin and Kyle 1998, Branch and Odendaal 2003).
- Changes in abundance and sex ratios of limpets (Branch and Odendaal 2003, Lasiak 2006).
- Transformation of intertidal habitats due to clearing of mussel beds with wide-bladed implements (Siegfried *et al.* 1985, Hockey and Bosman 1986, Siegfried 1988, Lasiak and Dye 1989, Lasiak and Field 1995, Sink 2001).
- Reduced recruitment of key resources due to changes in stock and community structure (Harris *et al.* 1998).
- Lack of long-term monitoring to accurately reflect the effort and catch of this sector.

Mussel harvesting has led to **stock concerns** in many areas along the east and south coast (Lasiak and Dye 1989, Tomalin and Kyle 1998) while limpet harvesting has decimated populations of *Cymbula oculus* in the former Transkei area (Branch and Odendaal 2003). By comparing harvested areas to those in MPAs,

Branch and Odendaal (2003) showed that harvesting dramatically reduced the abundance and size of limpets and skewed sex ratios with much lower recruitment success outside of MPAs. Changes in community structure are also of concern as the loss of mussel habitat to articulated coralline algae (Sink 2001) may lead to changes in recruitment success (mussels preferentially settle onto mussels) and changes in food and energy flow in coastal habitats (Harris *et al.* 1998, Sink 2001). The greater impact of subsistence versus recreational mussel harvesting is related to both the larger quantities required by subsistence harvesters and the tools and methods involved (Sink 2001).

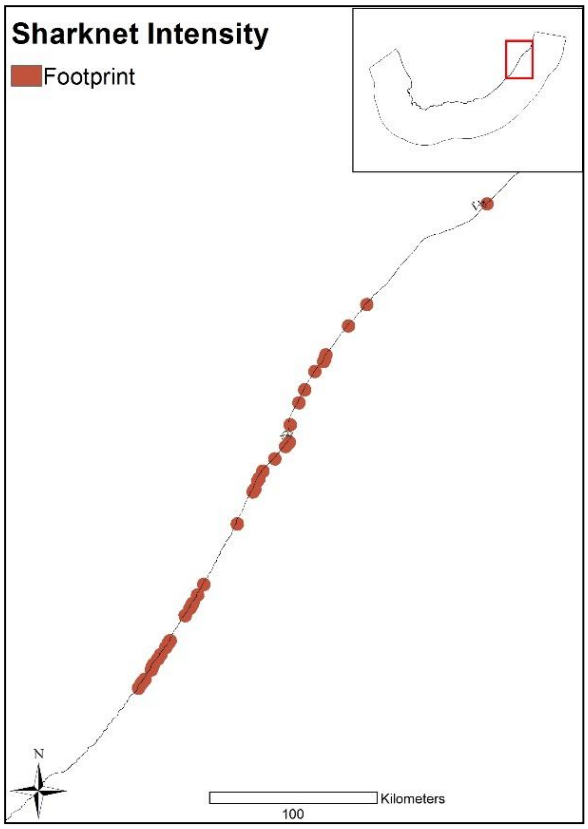
Co-management initiatives have helped reduce harvesting impacts in northern KwaZulu-Natal (Harris *et al.* 2003). However, another example of co-management from Coffee Bay elucidates the complex societal problems that sometimes need to be considered before appropriate biodiversity management can be achieved (Calvo-Ugarteburu *et al.* 2017). Future assessments should map the small-scale fisheries sector at a fine scale in accordance with the new structures implemented in the roll-out of Small-Scale Fisheries Policy framework. In addition, true subsistence fishing should also be considered in assessments and spatial management.

4.3.19 Shark Control

Pressure Description

Shark nets have been set off the beaches of KwaZulu-Natal since 1952 to protect bathers from the risk of shark attack. Further details of the history of the shark control program are published by Davies (1964), van der Elst (1979), Dudley (1997), Dudley and Simpfendorfer (2006), Dudley and Cliff (2010a) and Cliff and Dudley (2011). The shark control program had a peak of **gill net installations** in 1989 with a total of 45 km of nets at that time (Dudley and Simpfendorfer 2006). Nets have been replaced with baited **drum lines** in some areas.

Pressure Distribution



The shark control program extends from Richards Bay to Port Edward (Figure 50). The actual length of nets for each site was not available. Historical and current nets were considered in this assessment.

The scaled pressure values may underestimate the impact of the shark control program but reflect areas where localised shark depletion may have occurred. The nomadic and migratory nature of many sharks is difficult to account for in such a spatial assessment and the impacts of the shark control program may be far more widespread.

Figure 50. Map of deployed shark control nets in Kwa-Zulu Natal for the period 1952-2017. Some nets have been removed and/or replaced by drumlines.

Biodiversity concerns associated with the shark control program include:

- The overexploited status of several elasmobranch species (da Silva *et al.* 2015, DAFF 2016).
- Potential ecosystem effects linked to the removal of sharks (Myers *et al.* 2007, Hussey *et al.* 2011).
- Bycatch of harmless elasmobranchs, marine mammals and turtles (Brazier *et al.* 2012, Atkins *et al.* 2013, Dicken *et al.* 2018). Also see Box 44 for more on species caught in the KZN shark nets.

A large variety of elasmobranch species are captured by the Natal Sharks Board in large-mesh gillnets set along some of KwaZulu-Natal's popular bathing beaches. The **impacts on sharks** have been examined (Dudley and Cliff 1993, Dudley and Simpfendorfer 2006 and references therein)). Dudley and Simpfendorfer (2006) assessed the population status of 14 commonly caught species using catch rate and size trends, with more recent updates for Smooth Hammerhead Shark (Dicken *et al.* 2018). The nets are deemed to have potentially high impacts on two species; the Dusky Shark *Carcharhinus obscurus* and the Raggedtooth Shark *Carcharias taurus*, linked to the low intrinsic rates of population increase for these species. However, neither of these species showed indication of decline between 1987 and 2003 although careful monitoring is recommended for these species as these species were nationally assessed as Data Deficient using the IUCN Categories and Criteria (see Chapter 9). Moderate impacts were estimated for Zambezi Sharks *Carcharhinus leucas* and the Scalloped Hammerhead *Sphyryna lewini* and low impacts were assessed for other shark species (Dudley and Simpfendorfer 2006). Sharks are characterized by slow growth rates, late maturity, low reproductive output and longevity. These lifestyle characteristics make

sharks vulnerable to overexploitation which is considered the most significant threat to sharks. Shark control programs add to the already severe pressure on elasmobranchs from other fisheries, particularly longlining and trawl fisheries. The removal of large numbers of top predators by this inshore fishery may also have resulted in ecosystem impacts (van der Elst 1979, Stevens *et al.* 2000). Van der Elst (1979) showed an increase in the CPUE of small sharks in the 1970s and predicted a 40-fold increase in Dusky Sharks by the early 1980s, but this prediction was countered by Dudley and Cliff (1993) who found no evidence of increased Dusky Shark numbers. Ecosystem effects from shark control programs are difficult to quantify and remain poorly understood (Dudley and Simpfendorfer 2006, Dudley and Cliff 2010a).

Incidental **bycatch** of rays, large teleosts, turtles and dolphins and other marine mammals are also associated with shark control programs (Paterson 1979, Cockcroft 1990, Paterson 1990, Dudley and Cliff 2010a). In South Africa, about 60 dolphins (4 species) are caught a year in the shark nets but there is specific concern about the impact of the shark nets on the Indo-Pacific Humpback Dolphin *Sousa chinensis*, population estimates of which are below 200 in KwaZulu-Natal (Cockcroft 1990), and there is growing concern for Indian Ocean Humpback Dolphins (*Sousa plumbea)* with 203 individuals caught in shark nets from 1980-2009 (Atkins *et al.* 2013) (see Box 37 for more detail on *S. plumbea*). Although fewer numbers of Loggerhead Turtles are caught in the shark nets since originally report in Dudley and Cliff (2010), effort should be made to further reduce this species as bycatch owing to their threatened IUCN status (Brazier *et al.* 2012). See Chapter 9 for more on the threat status of sea turtles. Increasing problems with the entanglement of Baleen Whales is a concern in all shark control programs (Dudley and Cliff 2010a). Drumlines have been shown to be similarly effective at control of dangerous sharks when compared to shark nets but have lower bycatch (Dudley and Cliff 2010a). Netting has been reduced in recent times with 28 km of nets reported in 2003 and 23 km nets in 2011 (Cliff and Dudley 2011). In some areas, nets have been replaced with drumlines, a more selective shark fishing device (see (Cliff and Dudley 2011).). Nets are also removed during the annual sardine run to reduce mortalities on sharks and other species.

The recent installation of **exclusion nets** in False Bay, Cape Town, in the most sheltered area of Fish Hoek are a different type of bather protection device with far less impact on marine life (Figure 51). These nets have a mesh size of 45 x 45 mm and effectively create a barrier to exclude marine megafauna from the area; a top rope connects a series of buoys, which hold the net at the surface, while two leaded ropes weight it to the sea floor (Waries *et al.* 2014). The nets were installed in March 2013 as an experiment to assess their effectiveness and feasibility, as they are deployed daily in the summer months (i.e. November to March) and on weekends and public holidays in October. These nets have proved highly effective with almost no impact on the biodiversity in this region. This installation is therefore not considered in the pressure map for this pressure.



Figure 51. Shark exclusion zone in Fish Hoek (photo: Shark Spotters). This is distinct from the bather protection program in KwaZulu-Natal which uses gillnets and drumlines to reduce the population of dangerous sharks.

4.3.20 Sea-Based Aquaculture

Pressure Description

Marine aquaculture operations along the South African coast take the form of ***in-situ*** **marine operations** (i.e. those using long-lines, rafts, racks or cages suspended directly in the sea) and **land-based operations** that abstract sea water, pass it through the culture facility, and then return it to the marine environment. The impacts of land-based operations are considered under the section on Wastewater Discharge, and only the impacts of sea-based operations are considered here. However, land based aquaculture can have impacts on wild marine stocks through genetic contamination caused by farmed fish escaping and interbreeding with wild stocks (Arechavala-Lopez *et al.* 2013) and through introduction of diseases and parasites. These farms are not mapped in this section but it must be recognised that many of the risks to biodiversity also pertain to land based aquaculture.

In South Africa there are currently 20 **species** that are cultured in operations that have connections to the sea. These include two algae (*Gracilaria verricosa*, *Ulva lactuca*); one oyster (*Magallana gigas* (Formerly *Crassostrea gigas**); two mussels (*Choromytilus meridionalis*, *Mytilus galloprovincialis**); one scallop (*Pecten sulcicostatus*), one Abalone (*Haliotis midae*), one ascidian (*Pyura stolonifera*), one prawn (*Litopenaeus vannamei**) and three fishes (*Argyrosomus japonicus*, *Atractoscion aequidens*, *Seriola lalandi*). Four of these cultured species (indicated by * above) are alien to South African waters. Of these *M. galloprovincialis* and *M. gigas* (formerly *C. gigas*) are recognised as invasive alien species (Mead *et al.* 2011a, 2011b). While *L. vannamei* is currently restricted to culture facilities in South Africa, it has escaped and established populations in other regions (Senanan *et al.* 2007).

Pressure Distribution

Currently, **sea-based aquaculture** is only found in Algoa and Saldanha Bay (Figure 52). The footprint of the current aquaculture operations was used to determine the affected area. Currently, South Africa has

nine operational shellfish farms that grow two species of non-native oyster and mussel, *Magallana gigas* (formerly *Crassostrea gigas*) and *Mytilus galloprovincialis* (invasive) respectively.

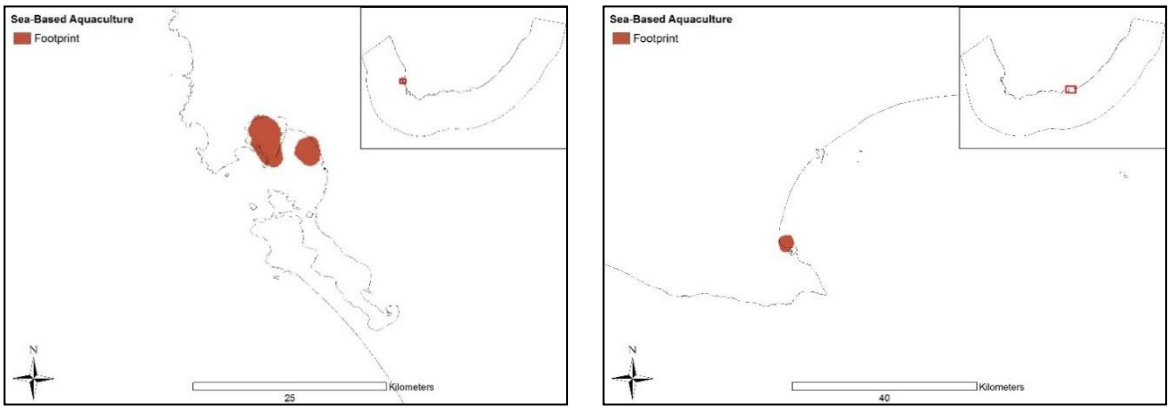


Figure 52. Map of the footprint of sea-based aquaculture operations for Saldanha Bay (left) and Algoa Bay (right).

The **main biodiversity concerns** associated with aquaculture include:

- Introduction of alien and potentially invasive species to the natural environment (McKindsey *et al.* 2007, Rocha *et al.* 2009b, Haupt *et al.* 2010c, Muehlbauer *et al.* 2014, Bolton *et al.* 2016a, Davidson *et al.* 2016c, Díaz López 2017).
- Transfer of disease and pathogens to local populations and potential for emergence of superbugs due to the use of antibiotics (Ogawa *et al.* 1995, Burreson and Stokes 2000a, Bondad-Reantaso *et al.* 2005, Peeler *et al.* 2011, Joshi *et al.* 2012, Arechavala-Lopez *et al.* 2013, Cabello *et al.* 2016)
- Genetic fluxes between farmed and wild populations (Cognetti *et al.* 2006, Grigorakis and Rigos 2011, Arechavala-Lopez *et al.* 2013, Mirimin *et al.* 2016).
- Impacts on apex predators (Cabello *et al.* 2016, Díaz López 2017).
- Ecosystem impacts from infrastructure, pollution, and modification of nutrient cycles (Buschmann *et al.* 1996, Wilding and Nickell 2007, Fitridge *et al.* 2012a, Wiber *et al.* 2012, Gozlan 2017a).

The environmental impacts of marine aquaculture have long been recognised to depend on the species, culture method, stocking density, feed type, husbandry practices and environmental conditions (Wu 1995). The **known impacts** of mariculture include localised impacts related to fish farms and the impacts from effluent which include pollution, eutrophication, introduction of invasive species, pathogens, and disease transfer to wild stocks (Buschmann *et al.* 1996, Holmer *et al.* 2008a, Sanchez-Jerez *et al.* 2008, FAO 2009b). As such, aquaculture can impact on ecosystem services (Gozlan 2017a). Furthermore the high stocking densities in aquaculture could potentially result in the evolution of native pathogens (especially viral and bacterial agents) to which wild fish do not have resistance.

While little research has been undertaken on the impacts of marine and freshwater aquaculture in the South African context, recent local work has highlighted the risks associated with the introduction of **alien species** (Haupt *et al.* 2010b, Mead *et al.* 2011a, Bolton *et al.* 2016a), pathogens and diseases (Bondad-Reantaso *et al.* 2005) and eutrophication (Lemley *et al.* 2019). For example, the Sea Vase Ascidian *Ciona robusta*, a common non-indigenous fouling species in aquaculture settings, can fundamentally change the composition of sessile communities by depressing local species diversity and altering community assembly

processes (Fitridge *et al.* 2012a). Internationally, the Code of Practice of the International Council for the Exploration of the Sea (ICES) is commonly applied in an effort to prevent introductions associated with aquaculture. Principles of the code include the periodic inspection (including microscopic examination) of material prior to importation and the disinfection and quarantine of imported organisms in the receiving country (ICES 2005). Although South Africa is affiliated to ICES, it is not a member of the organisation and the Code of Practice has not been strictly applied in this country. Additionally, inter-regional translocation of imported aquaculture species within South Africa is not controlled. As such, aquaculture target species and any associated fauna are often moved to multiple locations along the South African coast (Haupt 2009).

In terms of **pollution**, effluent discharge from aquaculture facilities can lead to biodeposition, a process that modifies the nutrient dynamics in the surrounding ecosystem, leading to an altered benthic community structure (Fitridge *et al.* 2012a). Aquaculture activities **affect water quality** including nutrient levels, turbidity, organic matter and foreign chemicals and can reduce oxygen concentrations, conductivity and alter pH (Buschmann *et al.* 1996, Wilding and Nickell 2007, Fitridge *et al.* 2012b, Gozlan 2017b). Organic waste accumulates in the vicinity of aquaculture farms due to non-ingested feed, non-digested feed components and excretions (Grigorakis and Rigos 2011). Furthermore, dissolved nutrients in the water column stimulate phytoplankton growth (Dalsgaard and Krause-Jensen 2006) leading to areas with low dissolved oxygen and poor water quality, potentially causing the death of associated species (Granada *et al.* 2016). Also, nearby sediments are affected by organic efflux. Nutrient enriched sediments, depending on site characteristics (Holmer and Barry 2005, Munari *et al.* 2010) can cause increasing anoxic microbial activities and finally lead to highly **anoxic zones** and a spatial change and biodiversity decrease in benthic communities (Karakassis 2000, Ferreira *et al.* 2011). Changing benthos conditions can be severe, especially if it leads to a decline in the density of species with important functions in the marine environment, for example the continued change in the morphology of the Mediterranean Tapeweed *Posidonia oceanica* due to its close proximity to a fish farm (Delgado *et al.* 1999, Holmer *et al.* 2008b). Overall, integrated multitrophic farms are reported to reduce the influence of organic matter efflux on the marine environment (Granada *et al.* 2016), although there are studies that question the effectiveness of the currently applied concepts in fish-bivalve systems (Navarrete-Mier *et al.* 2010, Cranford *et al.* 2013, Brager *et al.* 2016).

Aquaculture activities can affect the **quality of sediments** beneath culture installations and the chemical composition of the water column, which include increased nutrient levels, turbidity, organic matter, and reduced oxygen concentrations, conductivity, pH and foreign chemicals (Buschmann *et al.* 1996, Wilding and Nickell 2007, Fitridge *et al.* 2012a, Wiber *et al.* 2012, Gozlan 2017a).

Recent research has reported some of the negative socio-economic impacts of aquaculture given the potential leaking into the surrounding environment of the **chemicals** that are used that could potentially cause mortality of commercial species (Basaran *et al.* 2010, Burridge *et al.* 2010, Grigorakis and Rigos 2011, Wiber *et al.* 2012, Farmaki *et al.* 2014, Squadrone *et al.* 2016). Persistent organic pollutants can be found in high concentrations in sediments close to aquaculture farms, originating primarily from fish feed and antifouling agents (Wang *et al.* 2014). The consequences of the accumulation of these pollutants are broad and severe, as they can cause cancer, birth defects, learning disabilities, immunological,

behavioural, neurological and reproductive dysfunctions in wildlife species and humans (Pauwels *et al.* 2000, Sweetman *et al.* 2005).

A substantial risk is the introduction of **parasites**, potentially beyond the geographic range of parasites and pathogens, resulting in the emergence of disease (Ogawa *et al.* 1995, Burreson and Stokes 2000b, Bondad-Reantaso *et al.* 2005, Peeler *et al.* 2011, Joshi *et al.* 2012). A number of aquaculture farms produce introduced species due to their resilience to complex environments, their body sizes compared to native species and as a way to boost the economic aspect of fisheries trade. With the import of introduced species (spat or live species) there is potential for further transfer of hitchhiking parasites and introduced species into the wild. In Europe, this mode of transport for marine introduced species is attributed among others to aquaculture (McKindsey *et al.* 2007, Rocha *et al.* 2009b, Haupt *et al.* 2010c, Muehlbauer *et al.* 2014, Bolton *et al.* 2016a, Davidson *et al.* 2016b, Díaz López 2017). Excess food from farms may attract aggregations of wild fish increasing the risk for the transfer of pathogens to wild fish (Sanchez-Jerez *et al.* 2008, Arechavala-Lopez *et al.* 2013). Aquaculture facilities may use antimicrobials to prevent and treat bacterial infections. These antimicrobials have the potential to pass into the surrounding environment through effluent and affect wild populations and can cause, among other impacts, the stimulation of bacterial mutation. This has further potential to affect the human population through the consumption of infected aquatic species (Cabello *et al.* 2016). The risk for the **transfer of pathogens** to wild fish is one of the greatest concerns regarding mariculture (Sanchez-Jerez *et al.* 2008, Arechavala-Lopez *et al.* 2013).

Parasites such as gill and skin flukes have been identified as major factors limiting aquaculture production elsewhere (Mansell *et al.* 2005, Dezfuli *et al.* 2007, Yamamoto *et al.* 2011, Shirakashi and Hirano 2015) and this is relevant in South Africa. Indigenous species currently under consideration for aquaculture include Silver and Dusky Kob (*Argyrosomus inodorus* and *A. japonicus*). The parasites and diseases infecting these (and other finfish) species in South African waters are not well studied, although both kob species are known to be infected by sea lice of the same genus (*Caligus*) that caused serious problems amongst salmonids, as well as other copepod, trematode, Acanthocephalan (parasitic worm) monogean (specifically the gill fluke *Diplectanum oliverii),* dinoflagellates (*Amyloodinium ocellatum*) and myxozoan species (Grobler *et al.* 2002, Christison and Vaughan 2009, Joubert *et al.* 2009). Sciaenids farmed elsewhere, including Dusky Kob in Australia and the meagre *A. regius* in the Mediterranean have proved to be very susceptible to monogean gill parasites that caused disease and mortality (Hayward *et al.* 2007, Merella *et al.* 2009). Kobs are migratory and these taxa and others may be at an increased risk of contracting diseases and or parasites from effluent or escapes. These can spread through wild populations. Potential further negative effects on wild kob stocks are particularly concerning as all these species are important in the commercial, small-scale and recreational line fisheries (Winker *et al.* 2015, 2017b). The national stock of Silver Kob and east coast stock of Dusky Kob are considered collapsed (Winker *et al.* 2015, 2017b). Dusky kob has recently been assessed using IUCN criteria and are considered Critically Endangered in South Africa due to population decline, low and declining effective population size, genetic and estuarine degradation (see Box 43 for more detail the status of Dusky Kob). Although treatment of cultured stock to control disease and parasite outbreaks is possible (unlike wild stocks), chemical treatment is not without further environmental impacts, whilst build-up of antibiotic and chemical resistance is an increasing problem (Cabello *et al.* 2016).

In addition to disease transfer between wild and farmed individuals, there are concerns about **genetic contamination** (Mirimin *et al.* 2016). The escape of cultured fish can pose a threat to local wild fish populations One of the main hazards of aquaculture to the surrounding ecosystem are genetic fluxes between farmed organisms and wild animals (Cognetti *et al.* 2006). This can happen if farmed individuals escape into the surrounding waters (Grigorakis 2010, Grigorakis and Rigos 2011). The escape of genetically modified culture fish, and subsequent mixing with wild populations, can result in the transfer of non-native genotypes among differentiated wild populations resulting in changes in the natural genetic architecture. Furthermore, the deliberate or unintentional selection for performance traits may result in aquaculture fish outcompeting native fish (Holmer *et al.* 2008b).

The use of wild collected seeds in aquaculture facilities ("ranching") has potential deleterious effects as this can encourage collection of fry which has further impacts on the wild production of the species (Joshi *et al.* 2012; Naylor *et al.* 2000). Collection of **broodstock** of threatened species should be carefully considered and not be permitted within protected areas designed to protect such large breeding individuals.

Aquaculture facilities have several potential direct **hazards to top predators** including the risk of entanglement, habitat exclusion as a result of physical structures, aversive acoustic devices, habitat degradation from effluent (Cabello *et al.* 2016), alteration of natural behaviour patterns and intentional reactive killing of predators. These threats can have significant consequences in cases where top predator populations are limited or endangered (Díaz López 2017).

4.3.21 Coastal Development

Pressure Description

Coastal development is one of the most significant pressures on coastal ecosystem types, as recognised by local and international studies (see Annexure 3). This pressure includes the **habitat loss** or transformation from construction of buildings, harbours and other hard structures (equivalent to the land cover class, 'built-up'), particularly that which is inappropriately located within the littoral active zone and replaces beach or dune habitat, and accelerates erosion of sandy shores (Daniel 2001, Miles *et al.* 2001, Harris 2008). Further, a variety of coastal armouring, including seawalls, is constructed to protect urban areas from flooding or erosion; each structure causing different disturbances (review by Nordstrom (2014) and Firth *et al.* (2016)). This generally operates as a negative feedback: houses and other amenities are developed too close to the shore and, because of their high economic value, it often leads to their defence by **seawalls**. In turn, this raises the vulnerability of the infrastructure at the edges of the wall, where scouring is high, and ultimately leads to a gradual hardening of the coast (Morton *et al.* 1998, Harris *et al.* 2010). There is evidence that where increasing proportions of the shoreline are armoured, cumulative and threshold impacts occur (Dethier *et al.* 2016).

Pressure distribution

Coastal development was mapped using data from the NBA 2011 (Sink *et al.* 2012a) and updated using the composite land cover used in the NBA 2018 Terrestrial Technical Report (Skowno *et al.* 2019b). A 1 km radius from the coastline was used to identify areas that were more than 10% developed and included into a coastal development footprint (Figure 53).

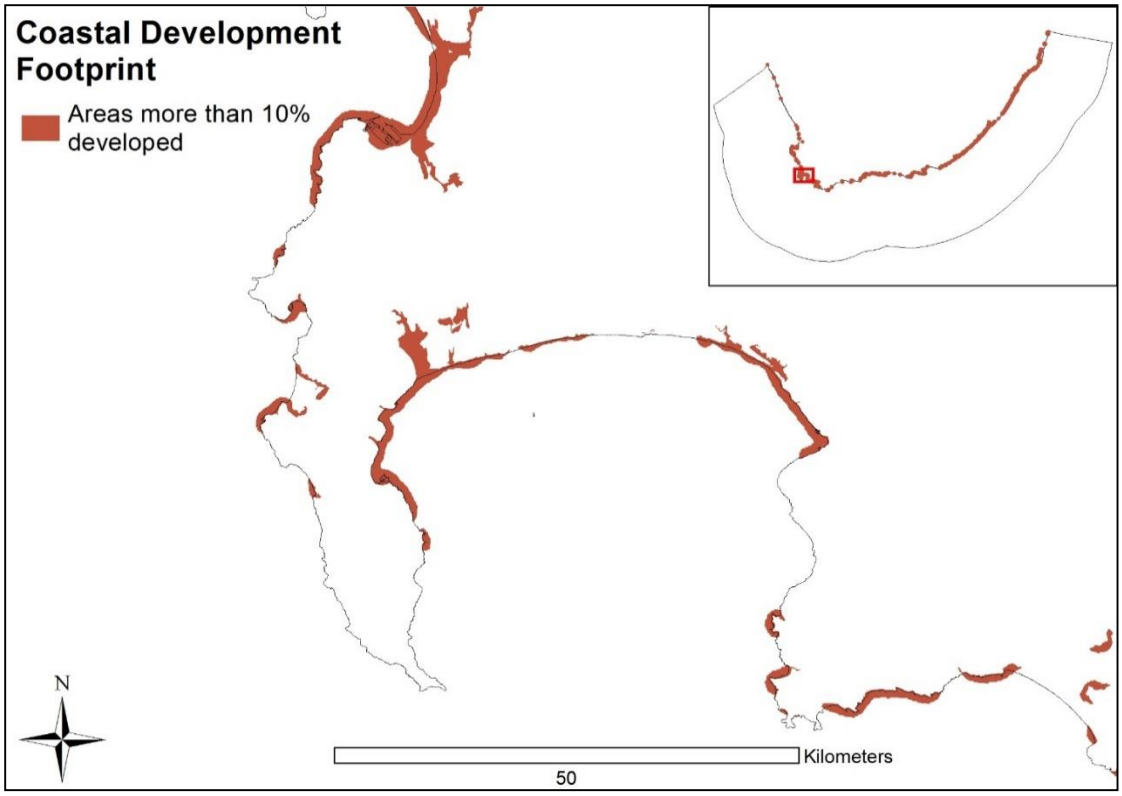


Figure 53. Map of intensity of coastal development for South Africa.

Coastal development also has serious impacts on adjacent terrestrial ecosystems, but these are detailed in the NBA 2018 Coast report (Harris *et al.* 2019a); this section focusses more on the impacts to marine biodiversity.

The main **concerns for marine biodiversity** associated with coastal development include:

- Interrupted connectivity between beaches and dunes and associated breakdown of cross-realm ecological processes (e.g. nutrient and sediment exchanges) that are important for sandy beach ecosystems, particularly during storm events when beaches need to rely on sand stored in the dunes to maintain their form and function (Morton 1988, McLachlan 1990).
- Reduction in beach species abundance and diversity, with implications for prey-availability for higher trophic levels, such as seabirds (Dugan *et al.* 2008, Lucrezi *et al.* 2010).
- Loss of habitat for high shore and supralittoral species, including those that come to the intertidal to feed, sometimes leading to extirpations of species (Lucrezi *et al.* 2010, Hubbard *et al.* 2014) .
- Reducing the natural capacity for beaches to adapt to rising sea levels, and instead of realigning the position of the shore further inland, the beach is gradually inundated and lost to coastal squeeze (the phenomenon of being trapped between coastal development and sea-level rise) (Dugan *et al.* 2008, Fish *et al.* 2008, Defeo *et al.* 2009, Pontee 2013).

The primary mechanism by which coastal development impacts the coast is to **cut off the sand supply from the dunes** to the shore. Interruption of the littoral active zone (geologically functional unit comprising the dunes, beach and surf zone) by building too close to the shoreline thus affects the

resilience of the coast to high wave-energy events and natural hazards by depriving the beaches of the sand stored up in the dunes (Harris *et al.* 2011c, El Mrini *et al.* 2012, Mead *et al.* 2013). Coastal development also **disrupts key linkages between dunes and the beach** (e.g. nutrient exchanges, and movement paths of high-shore biota) (McLachlan 1990). It can also lead to degradation and loss of physical habitat, associated loss of biodiversity and important coastal ecosystem services, interruption of important physical and biological processes, and compromised ecosystem resilience (Dugan *et al.* 2011). The biological impacts are mainly driven by the level of alteration of the abiotic conditions and the associated cascading biological effects they trigger (Perkins *et al.* 2015).

Development can alter sandy beach macrofaunal community structure by **reducing species diversity and abundance**, with additional direct (such as impacts on nesting and/or roosting) and indirect (such as reduced prey) implications for endemic and threatened seabirds (Dugan *et al.* 2008, Hubbard *et al.* 2014). It also affects beach and beach community resilience to storms (Harris *et al.* 2011b). Further, the change of substrate from soft to hard has proven to allow invasive species to spread along the coast (Airoldi *et al.* 2015, Firth *et al.* 2016). The flora of beaches are also affected by coastal development (Hernández-Cordero *et al.* 2017). In Jeffreys Bay, dune vegetation altered with increasing infrastructure development, with reduced dune width, species richness and plant height along with changes in community composition recorded in areas of higher development (Lucrezi *et al.* 2014). Adjacent habitats can also be affected by coastal modifications (Dugan *et al.* 2011). For example, the resulting alteration of sand movements towards subtidal horizontal reefs can lead to a **change of community composition** (Porter *et al.* 2017b) and by restructuring and shading shallow-water habitats, associated fish assemblages may alter feeding, reproduction and migration activities (Munsch *et al.* 2017). Consequently, the loss of coastal habitat and biodiversity due to coastal development may suppress the provision of important coastal ecosystem services (Mendoza-González *et al.* 2012, Firth *et al.* 2016, Gittman *et al.* 2016). In addition, coastal development has been identified as a key driver for other multiple threats to sandy shores because the level of development was significantly correlated with the sum of all pressures to beaches (Harris *et al.* 2015).

The most significant implication of coastal development is **coastal squeeze**, which is the product of development and sea-level rise. Inappropriately located coastal development prevents the natural landward migration of sandy beaches in response to sea-level rise, sensu Bruun's rule (Bruun 1962). Consequently, beaches are trapped in a coastal squeeze where they are narrowed and eventually lost as sea levels rise (Dugan *et al.* 2011, Jones 2012, Schlacher *et al.* 2014). Since intertidal ecosystems have distinct zones associated with tidal gradients, even partial coastal squeeze can lead to the loss of specific zones (starting with the supratidal) and associated species with knock-on implications for foodwebs and top predators such as birds (Dugan *et al.* 2008, Hubbard *et al.* 2014). Of particular concern is the associated loss of vital habitat for species, such as reduced or locally lost nesting habitat for endemic and/or threatened seabirds and turtles (e.g. Fish *et al.* (2008), Brittain and Craft (2012), and Clausen and Clausen (2014)). Coastal squeeze is thus considered the greatest threat to sandy beaches because it decreases their resilience (Berry *et al.* 2014) and adaptive capacity to climate change, which in turn threatens the ecosystem in its entirety (Harris *et al.* 2010). Coastal squeeze has also been shown to be a threat to rocky shores (Jackson and McIlvenny 2011), but there have been no studies in South Africa that have investigated this to date. For more detail on coastal squeeze, refer to Harris *et al.* (2019a).

The NBA 2011 reported that 17% of South Africa's 3113 km long coastline (Harris *et al.* 2011b) had development located within 100 m of the shoreline. Broadly speaking, it is the areas associated with ports and harbours that are most intensively developed (Harris 2012) and have medium to high priority development located precariously close to the shoreline. The coastal cities and urban areas surrounding these ports, all similarly too close to the shore, are thus particularly vulnerable to the effects of sea-level rise and extreme coastal storms (see Harris (2008)). Given the high priority of these buildings, there will be strong pressure to defend many of them with hard engineering (Dugan *et al.* 2011, Hallegatte *et al.* 2013, Gittman *et al.* 2015). This means that the local beaches are especially vulnerable to coastal squeeze, where the ecosystem will be gradually lost between sea walls and rising sea levels (Pilkey and Cooper 2014), unless there are management interventions to mitigate the effects, such as beach nourishment. Impacts up to 100 m inland (cumulative inland erosion of 40 – 100 m) were shown to occur in erosion hotspots following the March 2007 storm in KwaZulu-Natal (Smith *et al.* 2010). Thus, in combination with climate change predictions of increased intensity and frequency of extreme storms (IPCC 2012), there is a strong possibility that localised damages of this nature could occur more frequently in the near future. Key areas at risk of coastal squeeze in South Africa include the central and southern coasts of KZN, several beaches along the Wild Coast and south coast (nodes like Port Elizabeth and Cape St. Francis), and many areas around the city of Cape Town (Musekiwa *et al.* 2015). In theory, the east coast of South Africa is more vulnerable than the other coastal parts of South Africa as sea-level rise is occurring fastest on eastern shores (Mather *et al.* 2009, Musekiwa *et al.* 2015), and a lot of the inappropriately located coastal development is in KwaZulu-Natal and the south-eastern Eastern Cape (Harris 2012, Harris *et al.* 2015).

4.3.22 Coastal Disturbance

Pressure Description

Coastal disturbance includes various forms of non-extractive human activities on sandy, mixed and rocky shores (see the NBA Coast Report (Harris *et al.* 2019a) which also details impacts to dunes as well), such as trampling, off-road vehicle (ORV) driving, in-water recreation (such as swimming and surfing), and boating (including launching, power boating and jet skiing). Sink *et al.* (2012a) reported that virtually the entire South African shoreline is accessible, and thus potentially vulnerable to human disturbance in some form. This is confirmed by Harris *et al.* (2015), who noted the popularity of recreational activities on South African shores and showed that this is the most widespread (albeit generally low impact) pressure on beaches, nationally.

Pressure Distribution

The data for this pressure are from the NBA 2011, which included the popular areas (recreational beaches) and those that are easily accessible (formal access points). A 1 km buffer was set around the latter because research shows that people tend to aggregate around access points and life-saving facilities when visiting beaches (De Ruyck *et al.* 1997, Schlacher and Thompson 2012), and thus this is the area where disturbance impacts are likely to be most concentrated. Almost half (43%) of South Africa's coastline is exposed to impacts from disturbance. The south coast (between Cape Agulhas and Algoa Bay) and north-west coast are least accessed, primarily because of the long stretches of cliff and rock in the south (e.g. Tsitsikamma) and closed-access diamond mining areas in the northwest. However, there are still some very popular spots along the south coast, including Mossel Bay, Sedgefield, Knysna, Plettenberg Bay, Cape St Francis,

Jeffrey's Bay, Maitlands, and Port Elizabeth that have high coastal disturbance, particularly in the holiday seasons (Figure 54). The beaches in KZN and in Cape Town are also particularly popular for recreational activities.

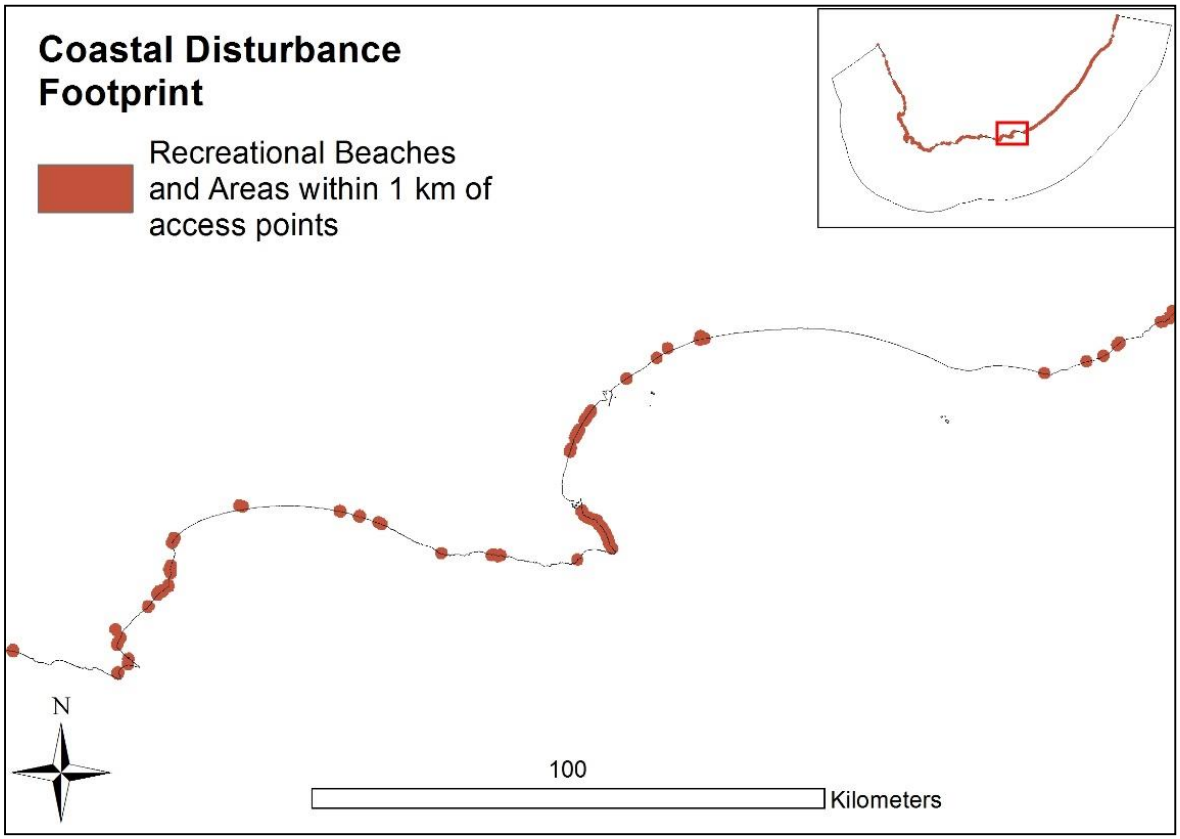


Figure 54. Map of coastal disturbance footprint for South Africa. These areas includes recreational beaches and areas within 1 km of access points.

The **main concerns for marine and coastal biodiversity** associated with coastal disturbance include:

- Trampling and crushing sandy beach and rocky shore biota, with implications for prey availability for higher trophic levels, e.g. shorebirds (Moffett *et al.* 1998, Schlacher *et al.* 2008, 2016, Schlacher and Thompson 2012, Mendez *et al.* 2018).
- Disturbance of natural animal behaviours (e.g. foraging and resting) with increased energy expenditure on vigilance and perceived threat avoidance (e.g. birds flushing and fish swimming away), especially if chased (e.g. by dogs), that may have cumulative effects on individual energy budgets and ultimately population productivity through reduced chick survival (Leseberg *et al.* 2000, Schlacher *et al.* 2013).
- Destabilisation of dunes, accelerating and enhancing erosion (Hesp 2002, Santoro *et al.* 2012).

The most destructive form of coastal disturbance is **off-road vehicle (ORV) driving**. Trampling is a second form of disturbance that has the potential to have unappreciated impacts to coastal ecosystems. Trampling impacts on rocky shores include crushing and dislodging biota (Bally and Griffiths 1989, Sarmento *et al.* 2013, Mendez *et al.* 2017, 2018) with shifts towards opportunistic species in community

assemblages of rocky shore algae (Deepananda and Macusi 2012). There are also impacts to sandy beach macrofauna through crushing (Moffett *et al.* 1998, Brown and McLachlan 2002, Schierding *et al.* 2011, Noriega *et al.* 2012, Schlacher and Thompson 2012, Reyes-Martínez *et al.* 2015), with the impacted species depending on the beach morphodynamic state (Vieira *et al.* 2012). Deep-burrowing species, e.g. Ghost Crabs (scientific name), may be more resilient to trampling effects, even if trampling closes burrow entrances in the short term (Lucrezi *et al.* 2009), although it is not clear what the long-term effects are; trampling impacts to Ghost Crabs identified as an area that needs more research (Schlacher *et al.* 2016). There are also disturbance effects to coastal birds when breeding (Leseberg *et al.* 2000, Brown and McLachlan 2002, Crawford *et al.* 2013b) or foraging (Thomas *et al.* 2001, Ryan 2013) where more energy is spent in vigilance and flushing away from approaching people (and dogs), resulting in an influence on avian habitat selection (Meager *et al.* 2012). Trampling effects to beach fauna thus include the loss of biodiversity, spatial shifts of species, declining numbers of individuals and shifts in community structures (Schlacher and Thompson 2012, Crawford *et al.* 2013b, Ryan 2013, Pereira *et al.* 2014) Other key impacts to beaches, although of less direct relevance to the marine realm, is loss of dune vegetation (Santoro *et al.* 2012) that, in turn, destabilises the dunes, which can lead to blowouts (see (Bate and Ferguson 1996, Hesp 2002), and the NBA 2018 Coast Report (Harris *et al.* 2019a)). Trampling is also known to impact intertidal seagrass beds (Mead *et al.* 2013, Travaille *et al.* 2015).

Recreational boat use has direct and indirect influences (e.g. anchoring or mooring, noise, waves, pollution, hits by propellers, etc.) on seagrass meadows (Demers *et al.* 2013, Vázquez-Luis *et al.* 2015), marine invertebrates (Hendriks *et al.* 2013), fish species (Whitfield and Becker 2014, Simpson *et al.* 2016) and marine mammals (Rako *et al.* 2013), while bathers cause disturbance to surf zone fish and elasmobranchs (Brown and McLachlan 2002, Pereira *et al.* 2014). These aspects of coastal disturbance were not considered in this assessment. Future assessments may expand activities considered under this pressure.

ORV driving has been mitigated by the beach-driving ban. Since this ban in 2002, there has been a significant increase in the abundance, number of breeding pairs, and/or breeding productivity in several coastal bird species (Williams *et al.* 2004). This rapid recovery following the beach-driving ban indicates what impact the ORVs have on coastal birds and provides key ecological evidence to support the ban. Beach driving is now strictly regulated, and is allowed under very strict and limited conditions (e.g. management) in discrete locations.

4.3.23 Mining

Pressure Description

Marine and coastal diamond mining has a long history in South Africa. Following international developments, marine mining has also **diversified and expanded** with increasing interest in heavy minerals and phosphates (Biccard *et al.* 2018). Heavy minerals of interest include the titanium bearing minerals (such as ilmenite, zircon and rutile). South Africa is reported as the second-largest producer of coastal heavy mineral sands in the world after Australia, contributing up to 30% of global production, and is Africa's largest producer (Browning *et al.* 2017). Recent **reviews** of marine and coastal mining methods are provided by (Biccard *et al.* 2018) and (Kenan and Mitha 2018). These include beach mining, diver based mining of diamonds and offshore mining by drill ship, crawler and hopper (see below). Creation of seawalls

and seabed excavation and tailings disposal were identified as being of greatest concern for diamond mining operations (Biccard *et al.* 2018). These activities pose a significant threat in the absence of effective mitigation due to the frequently unavoidable loss of benthic marine biota as a result of destruction from mining tools and smothering of the benthos from the disposal of tailing.

Pressure Distribution

The extent and intensity of mining was mapped by building on the NBA 2011 dataset for points and polygons, and including the NBA 2018 land cover data for mining used in the NBA 2018 Terrestrial Report (Skowno *et al.* 2019b). The area of mining was buffered by 500m to account for areas within this distance of a mined area (Figure 55).

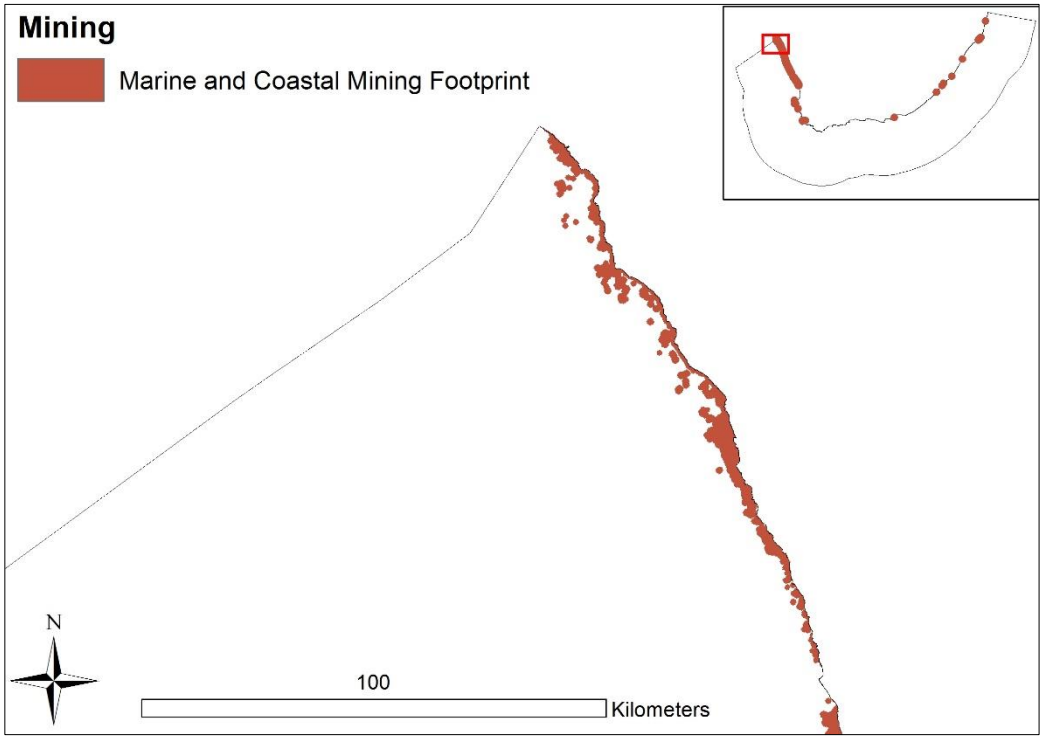


Figure 55. Map of intensity of mining in South Africa.

Coastal and marine mining has the following **known and potential biodiversity impacts**:

- Habitat destruction and negative impacts on the key components of marine ecosystems including the actual seabed, benthic biota and zooplankton (Biccard *et al.* 2018).
- Habitat alteration including changes in beach morphodynamic state and hence ecosystem type (Pulfrich and Branch 2014). Increased risks of beach erosion and destabilisation of dunes is also of concern (Biccard *et al.* 2018).
- Ecosystem degradation from trampling, kelp cutting, crushing of biodiversity (mainly onshore), sand removal, excavation and anchorage (McLachlan *et al.* 1994, McLachlan 1996, Parkins and Branch 1996, Clark *et al.* 1998, Pulfrich 2004, 2007a, Karenyi 2009, Harris *et al.* 2011a).
- Burial and smothering of organisms (Parkins and Branch 1995, 1996, 1997, Pulfrich 1998, Penney *et al.* 2008, Biccard *et al.* 2018).

- Raised turbidity with impacts on many marine species, particularly apex predators (Biccard *et al.* 2018).
- Potential disruption of photosynthetic processes through creation of fine sediment plumes and associated changes in community structure (Parkins and Branch 1995, 1996, 1997, Pulfrich 1998, Penney *et al.* 2008).
- Pollution in the forms of tailings disposal, waste disposal, noise from activities and machinery, re-suspension or introduction of heavy metals (Essink 1999, Attwood *et al.* 2000, Pulfrich *et al.* 2007). This includes reduction in water quality and the release of toxic substances that could impact entire marine foodwebs (Biccard *et al.* 2018).
- Significant biogeochemical and microbial impacts (Biccard *et al.* 2018).
- Potential introduction and proliferation of alien and invasive species (Pulfrich *et al.* 2007, Sink *et al.* 2010, Biccard *et al.* 2018).
- Elevation of organic loads (Essink 1999) with organic enrichment potentially leading to oxygen depletion and die-offs (Biccard *et al.* 2018)
- Displacement of benthic and pelagic species due to changes in feeding behaviour and species distribution in birds, mammals and fish (Biccard *et al.* 2018).
- Discharge of brine is recognized as a high risk impact as, with limited mixing in the surf zone, marine organisms can be directly affected. Changes in salinity may impact marine species through direct toxicity and initiate changes in physiological functioning and by indirect toxicity by modifying species distributions (Biccard *et al.* 2018). Limited mitigation is considered possible.
- Abstraction of freshwater for coastal dune mining affects run-off to coastal habitats

These impacts can also impact on other sectors including **fisheries and aquaculture** (Biccard *et al.* 2018) with particular biodiversity concerns on potential impacts on breeding, spawning, feeding and aggregation areas (Biccard *et al.* 2018). Fishing grounds can be considered as ecosystem support areas (Harris and Sink 2019) and the biodiversity benefits from sustainable fisheries should be safeguarded from activities that put such key ecosystem services at risk.

Diamond mining on beaches, in the surfzone, mid-water (40-80 m) and in deep water (110-150 m) have different types of documented impacts due to the differing methods used (Penney *et al.* 2008, Karenyi 2009, Biccard *et al.* 2018). In northern KwaZulu-Natal, mining of the coastal dunes for titanium and other heavy metals threatens dune and beach ecosystems and the services these important coastal ecosystems provide (see NBA 2018 Coast report (Harris *et al.* 2019a)). The dunes are a component of the coastal littoral active zone and mining impacts affect beaches through disruption of the sediment budget. The success of rehabilitation efforts on dune ecosystems are debated but long-term impacts on estuaries, wetlands and water supply are recognised (DEAT 2006).

Beach mining reduces species richness, can alter beach habitat type or morphodynamic state (Pulfrich and Branch 2014), and is considered the greatest extractive threat to sandy beach ecosystems along South Africa's west coast (McLachlan *et al.* 1994, McLachlan 1996, Clark *et al.* 1998, Pulfrich 2004, Harris *et al.* 2011a). Recovery times for beach macrofauna vary between 20 and 50 months depending on the type and extent of beach mining (Nel and Pulfrich 2002, Nel *et al.* 2003, Pulfrich *et al.* 2007, Penney *et al.* 2008).

Rocky and mixed shores are also impacted by diamond mining with documented changes in species richness and community structure particularly for more sheltered shores (Parkins and Branch 1995, Pulfrich *et al.* 2003b). Mining-induced sand inundation of rocky shores adjacent to pocket beach mining areas has significant impacts including an increase in dominance of the alien invasive mussel *Mytilus galloprovincialis*, and a loss of various limpet species (Pulfrich *et al.* 2007). Impacts on surf zone biota related to increased sedimentation from mining have been recorded (Clark *et al.* 1998) with potential food web implications. Reduced filter-feeder cover has been linked to mining impacts on reefs but no short- or long-term effects on West Coast Rock Lobster population structure or abundance were detected in impacted areas (Parkins and Branch 1995, 1996, 1997, Pulfrich *et al.* 2003b). Where large scale beach mining operations such as those conducted in Namibia are maintained for decades, coastal impacts are more severe and habitat recovery rates are estimated to be longer than 20 years because shoreline habitats may be altered by seawalls (Clark and Nel 2002, Biccard *et al.* 2018).

Diver-based mining takes place by suction pump in gullies and the gravels are processed on board small vessels, with the tailings (the materials left over after the process of separating the valuable fraction from the uneconomic fraction during mining) discharged directly overboard (Penney *et al.* 2008). The rate at which diver-based mining occurs is estimated to be between 300 and 1000 m^2/yr. The data received from concession holders practicing this type of mining were not measured in area but in total number of dives; therefore this type of mining has not been accurately mapped (Penney *et al.* 2008). Impacts include localised habitat damage, smothering and associated changes in community structure (Parkins and Branch 1995, 1996, 1997, Pulfrich 2007a) although recovery times are reported to be short (less than 2 years) (Pulfrich *et al.* 2003b, 2003a). The cutting of kelp to facilitate diver access also impacts benthic communities but kelp forests are reported to recover within two years (Parkins and Branch 1996, Pulfrich 2007a). However, repeated kelp cutting is considered more detrimental and could lead to the loss of kelp forest habitat (Pulfrich 2007a). Although diver-based mining has been implicated in reduction of rock lobster numbers and habitat degradation, research results reflect no long-term impacts on rock lobster populations, recruitment or their primary reef habitat (Barkai and Bergh 1992, Parkins and Branch 1995, 1996, 1997, Pulfrich 1998, 2007a, 2007b).

Offshore mining involves prospecting with a megadrill or decadrill and large-scale bulk mining with a crawler or decadrill (Penney *et al.* 2008). Offshore mining impacts benthic communities, which can take up to 5 years to recolonise (Savage 1996, van der Merwe 1996, Pulfrich and Penney 1999, Winckler 1999, Savage *et al.* 2001, Steffani and Pulfrich 2004). There has been concern over the re-suspension of heavy metals through mining activities (Attwood *et al.* 2000) however heavy metal concentrations in the tailings have been evaluated and are considered below the guideline levels (Penney and Pulfrich 2004, Biccard *et al.* 2018). Biccard *et al.* (2018) note risks of increased trace metal concentrations above established safety thresholds that can result in negative impacts on marine organisms, especially filter feeders, such as mussels, which tend to accumulate trace metals in their tissues. High concentrations of trace metals can also render these species unsuitable for human consumption. Metals occurring in sediments are generally inert (non-threatening) when buried in the sediment but can become toxic when they are converted to the more soluble form of metal sulphides. Metal sulphides are known to form as a result of natural re-suspension of the sediment and from anthropogenic disturbance events such as dredging activities (Biccard *et al.* 2018).

The only actively mined offshore area in South Africa's EEZ is that of the former ML3/2003 lease, operations led by De Beers Consolidated Mines, wherein less than 1% of the area is considered to have potentially viable diamond reserves, while less than 1% is considered economically viable for mining (Penney and Pulfrich 2004). This implies that it is highly unlikely that more than 1% of a mining concession area will ever be mined, and the overall impact from discharged sediment is considered minimal (Roos 2005). There is however, concern that should diamond concentrations occur in a particular unique habitat, the biodiversity of that habitat would largely be lost with the impacts incurred by mining activities (Attwood *et al.* 2000). Our understanding of **offshore diamond mining impacts** is constrained by our limited understanding of the natural drivers of biodiversity pattern and the observed high levels of natural variability in west coast offshore ecosystems (Steffani and Pulfrich 2007).

Other potentially important marine and coastal mining-related environmental impacts that have been overlooked in the past include those linked to the **export of minerals from ports** around South Africa (Biccard *et al.* 2018). For example, trace metals, transported by storm water, can enter marine ecosystems and affect organisms by smothering or through physical damage, thereby reducing the survival fitness of affected organisms. Impacts of this nature can also affect human health as accumulation of trace metals in bivalve tissue (or tissues from other harvested species) can harm humans when eaten. Coastal and marine exploration and mining activities can **potentially negatively impact fisheries** by reducing catch and or catch-per-unit-effort (CPUE) thereby increasing costs and decreasing profit with potential associated knock-on socio-economic impacts for communities and other businesses involved in the fishing industries are an additional concern (Biccard *et al.* 2018).

Although **phosphate mining** has not been initiated in South Africa, there are additional concerns and impacts from this new type of mining that warrant thorough investigation. For example, soluble phosphate release may increase algal blooms with associated impacts on shellfish (Biccard *et al.* 2018). The most efficient method for extracting phosphates entails bulk sediment removal using a Trailing Suction Hopper-Dredge and such bulk removal of marine sediments on a large scale could destroy entire benthic ecosystems. Habitat-forming taxa (such as corals and sponges) could be lost creating an undesirable low-resource habitat for other organisms. Phosphatic rock deposits offshore of the south coast are likely to require explosives or other destructive technology to break up hard grounds of mineral interests (Morant 2013). Impacts in such hard ground ecosystems could be worse than in unconsolidated ecosystem types. These effects are considered a significant threat as proposed phosphate prospecting licenses in South Africa overlap with critically endangered ecosystems as well as important commercial fishing grounds and effective mitigation strategies have yet to be identified. **Offshore heavy mineral prospects** off the east coast, including in the newly-declared uThukela MPA, are of similar concern.

4.3.24 Petroleum activities

Pressure Description

The impacts of petroleum activities span the impacts of **seismic surveys**, the direct impact of **infrastructure installation and drilling** and **indirect effects** such as light pollution. Cordes *et al.* (2016) provide a global review of petroleum impacts with a focus on offshore ecosystems and Biccard *et al.* (2018) provide a local review. However, there are few South African studies that have examined such impacts apart from Sink *et al.* (2010) who undertook a dedicated collaborative research project with

PetroSA to examine the impacts of petroleum activities on part of the Agulhas Bank. The direct and indirect impacts of wellheads are reported below with an additional synthesis of the potential impacts of seismic surveys also provided although this pressure was not accounted for in the analyses of ecosystem degradation in 2011 or 2018. There has been no analysis of the spatial impact of seismic surveys and it is difficult to feature the effect of this pressure in threat assessment. However, many experts raised concerns about the potential impacts of the increasing oil and gas activities through efforts of Operation Phakisa. Changes in the environmental regulations on mining related activities have also raised concerns as some activities, including seismic surveys, no longer require an EIA (Petroleum Agency SA, pers. comm.).

Pressure Distribution

Data were received from the Petroleum Agency SA, a parastatal under the Department of Mineral Resources, which is responsible for the licencing and permitting of oil and gas activities in South Africa. The data included information on planned, proposed, abandoned, completed, recovered and suspended wells, and impacts were not considered for planned or proposed wells. The highest density of wellheads was found on the Agulhas Bank (Figure 56).

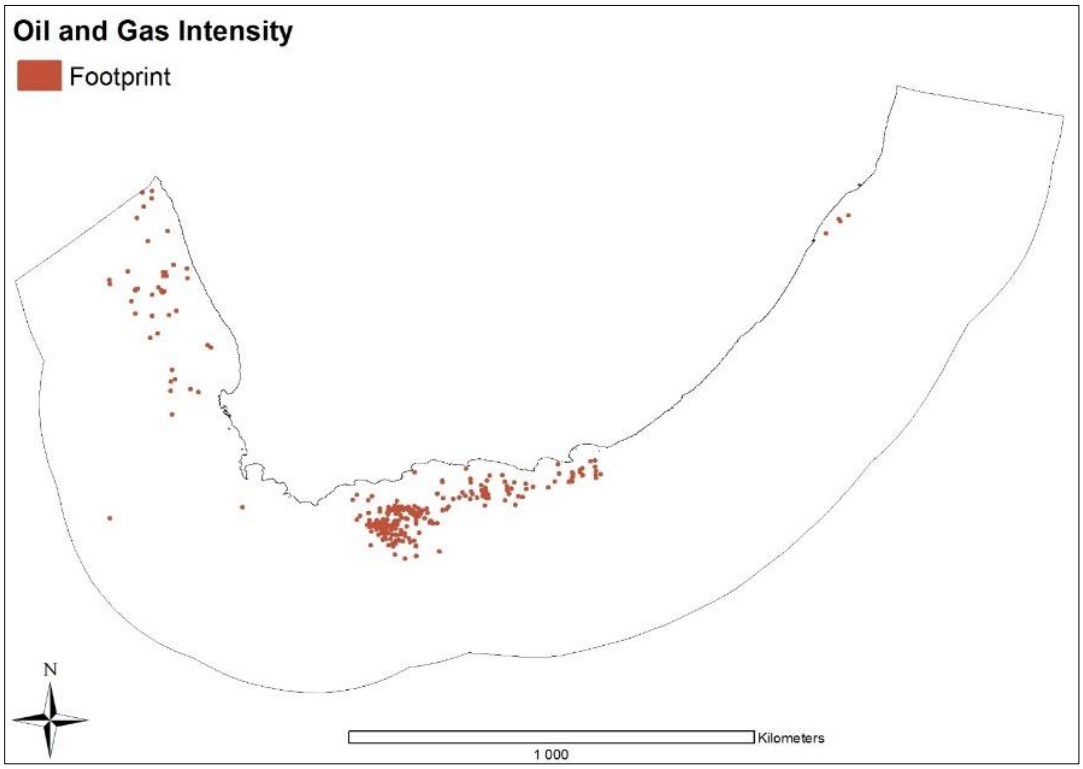


Figure 56. Map of all drilled wells in South Africa.

Biodiversity concerns for this activity include:

- Physical impacts to ecosystems and species from infrastructure installation (Biccard *et al.* 2018).
- Pollution from chemicals in water-based and oil-based drilling muds (Sink *et al.* 2010).
- Introduction and proliferation of alien and potentially invasive species (Sink *et al.* 2010).

- Disruption of feeding and communication, and potential physical damage, caused by noise pollution (Hawkins and Popper 2014, New *et al.* 2014).
- Impacts to ecosystems and species due to oil spillage

Direct impacts of infrastructure installation include sediment re-suspension and burial by seafloor anchors and pipelines (typically restricted to a radius of ~100 m from the installation) and the impact of discharges during drilling. Discharges of water-based and low-toxicity oil-based drilling muds and produced water can span to an area of more than 2 km from the source with ecological impacts at the population and community levels most commonly found within 300 m of the source. (Cordes *et al.* 2016) reported that these impacts may persist in the deep sea for many years and likely for greater time periods in the case of slow growing fragile species and their associated ecosystems, such as cold-water coral reefs, authigenic carbonates and cold seeps. The South African study in the Oribi-Oryx field and at the FA Platform assessed the potential pollution impacts on the Agulhas Bank (Sink *et al.* 2010). Benthic infaunal assemblages sampled closest to the wellhead were significantly different to those sampled more than 250 m away, suggesting some degree of impact within a 250 m radius of the sampled wellhead. These changes were most likely a result of physical disturbance rather than petrochemical effects as sediment properties measured (particle size, organic carbon, trace metals and hydrocarbons) showed no significant differences among any sites in this study.

An additional serious concern was the potential role of this industry in the introduction, hosting and spread of **alien species** (Page *et al.* 2006, Coutts *et al.* 2007, Wanless *et al.* 2009, Sheehy and Vik 2010) (Sink *et al.* 2010) documented at least 5 introduced species, the expansion of two cryptogenic species into deep water and the presence of at least 3 unidentified potentially introduced species through initial limited sampling of petroleum infrastructure on the Agulhas Bank. The risk of introducing or spreading nonindigenous species should be carefully considered in environmental management and decommissioning for this sector, as alien and invasive species can have serious biodiversity and economic impacts. Other operational activities such as lighting, helicopter operations and flaring could also impact on marine life (Blood and Corbett 2006).

Oil and gas production activities have focused on the Agulhas Bank with the development of the Oribi, Oryx and Sable oil fields, although a production license for the west coast was issued for the Ibhubesi Gas Project; this is yet to be developed. Focus has recently shifted to the large Total exploration lease area that spans from the Agulhas Bank to deeper offshore areas where a substantial gas resource has been discovered in deep water. More than 300 **offshore wells** have been drilled in South Africa with most wells having been drilled in less than 250 m water depth on the Agulhas Bank (Figure 56). Limited drilling exploration (4 wells) has occurred on the east coast, while seismic survey of this region has increased in recent time. The east coast has been the subject of increasing exploration activity and interest with discoveries in Mozambique contributing to the increasing interests in KwaZulu-Natal. Globally, petroleum activities are expanding into deeper water and South Africa is no exception. Exploration rights have been awarded across the South African marine seascape since 2013 (Figure 57).

a)



b)

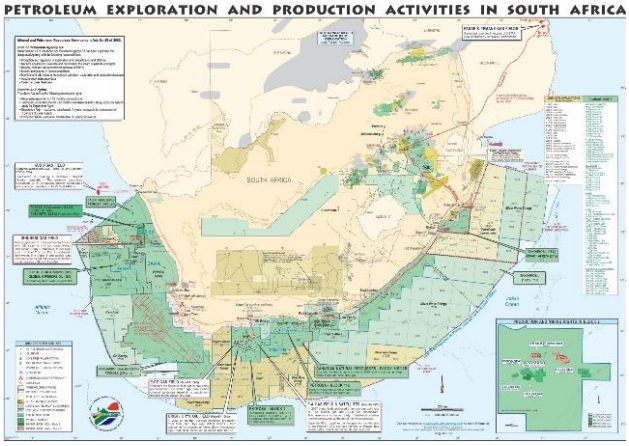


Figure 57. Map of petroleum exploration and production activities illustrating major expansion of approved oil and gas leases into deep water a) 2006 and b) 2013. The white areas in image (a) are not leased whereas in image b more than 90% of the ocean territory around South Africa is under exploration or production lease or technical co-operation permit. Maps downloaded from Petroleum Agency South Africa website.

The possibility of an **oil spill** is perceived as the greatest threat posed by this industry to marine biodiversity in South Africa (Attwood *et al.* 2000). Oil spills associated with offshore production platforms can be classified into three groups: small accidental oil spills arising during routine operations, large spills arising after incidents such as the grounding of an oil tanker or collisions with other vessels, and offshore production accidents such as 'blowouts' of wells and pipeline ruptures. A blowout or "loss of well control" can occur if a drilling rig encounters a pocket of subsea oil under excessive geological pressure, or due to technical failures. Under such conditions an extensive oil spill is likely to develop which is generally considered the greatest possible environmental threat in exploratory drilling. The probability of this occurring is generally considered to be low, although the environmental consequences of oil spills are severe. The oil spill event resulting from the blowout at the Deepwater Horizon rig in the Gulf of Mexico in April 2010 and the concomitant impacts on various marine and coastal environmental parameters serve to illustrate the extensive impacts of effects such an event could cause (Kerr *et al.* 2010).

4.3.25 Invasive Species

Alien and invasive species are discussed in great detail in the Chapter 5, and therefore this section will only summarise the main biodiversity concerns and mapping of invasive species extent. Alien and invasive species are considered serious threats to biodiversity.

The **biodiversity concerns** include:

- Changes in ecosystem function and structure
- Competition with local species resulting in decreases abundance of local biodiversity
- Human health and biodiversity implications for the introduction of pathogens

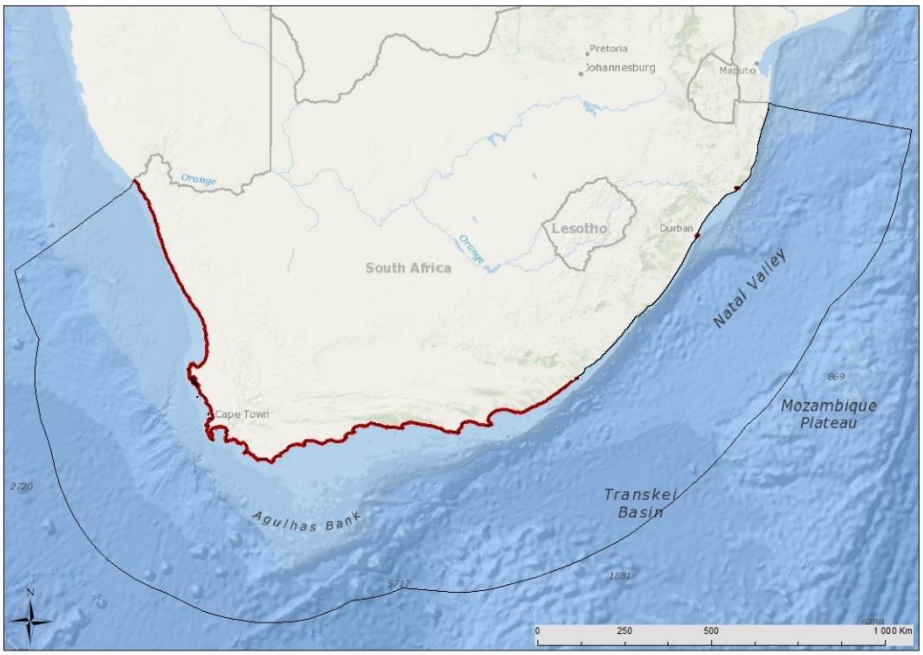


Figure 58: Map of the distribution of marine and coastal invasive species in South Africa.

The data used to assess the impact of invasive species relied on that used in the NBA 2011 (Figure 58).

Although the alien species reflected in Figure 58 are concentrated on the west and south coasts, there are also problems on the east coast where invasions are concentrated in harbours and estuaries. It should be noted that aquatic alien and invasive species found in freshwater and estuaries are assessed in the relevant realm technical reports (van Deventer *et al.* 2019, van Niekerk *et al.* 2019), whilst alien and invasive species found on dunes are assessed in the terrestrial technical report (Skowno *et al.* 2019b).

4.3.26 Port and Harbour Activities

Pressure Description

This section deals solely with the impact of activities taking place within ports and harbours. Impacts from infrastructure are dealt with in the section on Coastal development. The ports and harbours included in this assessment are listed in Table 10. **Ports and harbours** are hubs of activity and have a historical role in the development of ancient and current economies by facilitating regional and foreign trade (de Graauw 2017). Dwarakish and Salim (2015) describe ports as primary components of the transport sector acting as hubs of activity related to import and export of goods, providing jobs and access to foreign markets and products, and landing areas for local small-scale and industrial fisheries.

The two state-owned entities involved in port and harbour management are Transnet National Ports Authority (TNPA) and the South African Maritime Safety Authority (SAMSA). The TNPA controls and manages the country's major ports and is the dominant provider of port services whilst SAMSA is responsible for ensuring safety of life and property at sea, and to prevent and combat pollution from ships in the marine environment. South Africa has **eight commercial ports** which receive over 90% of international trade (SAMSA 2002). Durban, Cape Town, Port Elizabeth and East London operate as multi-

purpose ports, Saldanha and Richards Bay as predominantly bulk ports, and Mossel Bay as a fishing port which also supplies the offshore oil & gas industry. The port of Ngqura (which includes Coega) handles both unitised cargo and break-bulk cargo, with plans for it to handle bulk cargo in future (Trade and Industrial Policy Strategies 2014).

Table 10. Ports and harbours of South Africa included in the NBA 2018 marine assessment.

Name	Town	Province	Type
East London Harbour	East London	Eastern Cape	Harbour
Port Alfred Marina	Port Alfred	Eastern Cape	Marina
Port Elizabeth Harbour	Port Elizabeth	Eastern Cape	Port
Port of Ngqura	Port Elizabeth	Eastern Cape	Port
Port of Durban	Durban	KwaZulu-Natal	Port
Richards Bay Harbour	Richards Bay	KwaZulu-Natal	Port
Port Nolloth	Port Nolloth	Northern Cape	Harbour
Gans Bay Harbour	Gans Bay	Western Cape	Harbour
Gordon's Bay Harbour	Gordon's Bay	Western Cape	Harbour
Hermanus Harbour	Hermanus	Western Cape	Harbour
Hout Bay Harbour	Hout Bay	Western Cape	Harbour
Kalk Bay Harbour	Kalk Bay	Western Cape	Harbour
Knysna Harbour	Knysna	Western Cape	Harbour
Lamberts Bay Harbour	Lamberts Bay	Western Cape	Harbour
Mossel Bay Harbour	Mossel Bay	Western Cape	Harbour
Port of Cape Town	Cape Town	Western Cape	Port
Robben Island Harbour	Robben Island	Western Cape	Harbour
Saldanha Bay Harbour	Saldanha Bay	Western Cape	Harbour
Simon's Town Harbour	Simon's Town	Western Cape	Military base
Struis Bay Harbour	Struis Bay near Cape Agulhas	Western Cape	Harbour

Pressure Distribution

Ports and harbours are not evenly distributed along the coast. The province with the most harbours is the Western Cape with more than half of the total 20 ports and harbours (Table 10), whilst the Northern Cape is reported to have only one. It should be noted that jetties and slipways were not included in this assessment. Ports have geographically defined limits, whilst harbours are usually defined as points. Therefore it was necessary to buffer the harbours to accurately account for the affected area (Figure 59).

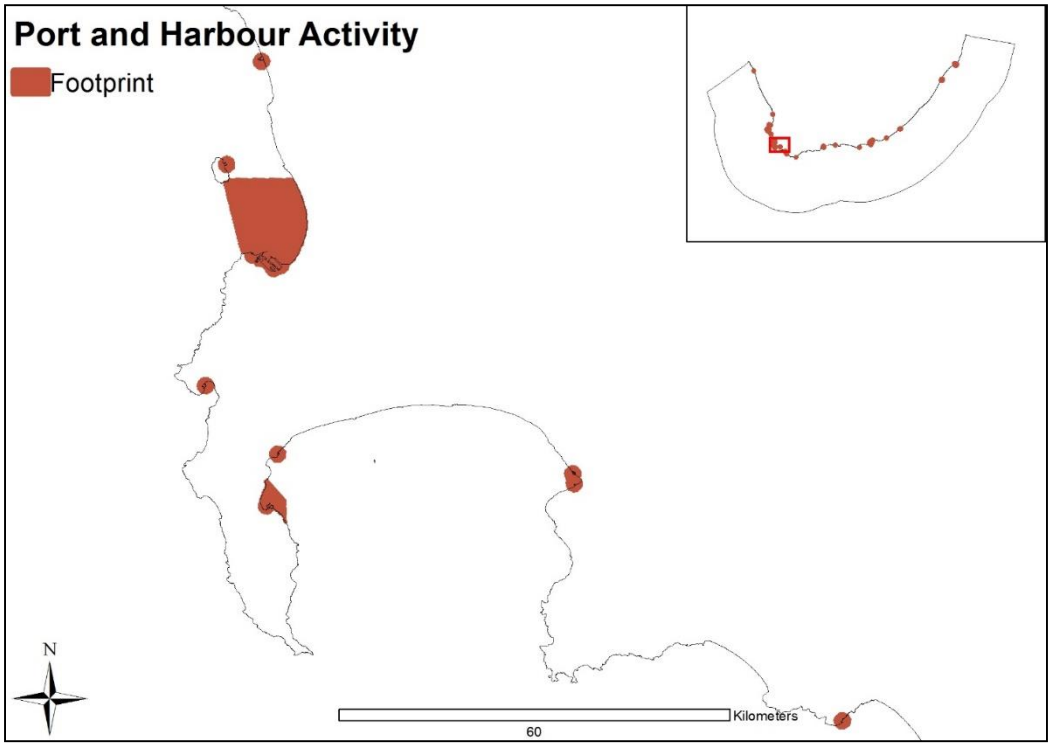


Figure 59. Map of footprint of ports and harbours activity.

This map does not include the Koeberg harbour and the smaller marinas found in estuaries. There is no literature known to this assessment on the activities taking place at the Koeberg harbour in relation to those found at typical harbours.

The **key biodiversity concerns** associated with ports and harbours include

- Habitat modification (Harris *et al.* 2015)
- Pollution (See Table 11)
- Alien and invasive species (see details in Chapter 5)
- Broader cumulative environmental impacts provide by concentration of industrial activity and increased access (see the NBA 2018 Coast Report, (Harris *et al.* 2019a))

Marine services such as pilotage, towing and tug assistance, fuelling and watering, garbage collecting and ballast waste disposal, port captain's services, lights and navigational aids, Vehicle Tracking System (VMS) services, mooring, anchorage, berth and berthing services constitute an integral part of the activities of a ports system. Shipping emissions in ports account for 18 million tonnes of carbon dioxide emissions, 0.4 million tonnes of nitrogen oxides, 0.2 million of sulphur oxide and 0.03 million tonnes of particulate matter 10 micrometres or less in 2011 globally, with approximately 85% of emissions coming from containerships and tankers (Merk 2014). All ship activities are responsible for air pollutant emissions, particularly ship movement in port, ship activities in hotelling phase (lighting, heating, refrigeration, ventilation, etc.), tanker loading and unloading (Trozzi and Vaccaro 2000).

Environmental impacts on the marine environment from port activities have been synthesised from Trozzi and Vaccaro (2000), United Nations (1992), Sjödin and Fridell (2007), and Fivaz (2008) in Table 11.

Table 11. Impacts of activities associated with ports and harbours

Impact	Sources of pressure
Water Pollution	• oil of bilge and motor fuel leakage from ships and gasoline and diesel oil • leakage from pleasure crafts • accidental leakage of oil and chemical substances in loading and unloading of products • pollution from slop (residual of chemical products contained in the tanks and of the product used in the washing operations) • leaching of antifouling paints • operations on terminals and fuel deposits (accidental discharge of oil in the sea, loss from deposit tankers and pipeline) • dry docks operations (accidental discharge of oil and other chemicals in the sea) • ships demolition (accidental discharge of oil and other chemicals in the sea) • storm water runoff from port parking lots (organic compounds, fine particulate, heavy metals, etc.) • water thermal pollution • water stagnation and eutrophication and anoxia risks due to weak water turnover • Dredging and excavation of port areas with resuspension of materials and pollutants.
Sediment Pollution	• operations on terminals and fuel deposits (accidental discharge of oil in the soil, loss from deposit tankers and pipeline) • spill from the bulk handling device (oil, rubber etc.) and dust spread during the handling (transports between quay and storage area) • oil and other spillage from the vehicles dissolve the surface and may cause a homogeneous tarmac to dissolve heat and high loads cause settlements of the surface • spill of chemicals from demolition of ships
Ship waste	• oil terminals and fuel deposits (oily and toxic sludges) • dry docks operations (oily and toxic sludges) • ships demolition (particularly in India, Bangladesh, Pakistan and in the future probably, China, Vietnam and Philippines) connected with the nearly complete absence of facilities for handling waste residues from the demolition process (including heavy metals, PCB, HFC's, asbestos as well as hydrocarbons) • maintenance and retrofits of older vessels, also in developed countries.
Ecological impacts	• Alteration of currents and circulation patterns from infrastructure • Effects on sensitive near-shore ecosystems • Introduction of alien species • Alteration of habitat (via anchoring, dredging and dredge dumping)

In addition to individual impacts, ports and harbours experience significant cumulative environmental impacts as evidenced by the pressure and condition layers developed for the NBA 2011 and NBA 2018 (see Chapter7). The NBA 2018 Coast Report (Harris *et al.* 2019a) further emphasises the intensity of cumulative effects caused by the increased access provided by ports and harbours. It is for these reasons that the sighting of ports and harbours warrant careful consideration and effective spatial planning.

4.3.27 Shipping

Pressure Description

South Africa is a maritime nation with several major ports (see Table 10 in the previous section on Port and Harbour Activities). In global terms, the concentration of maritime traffic passing South Africa is not considered to be as high as in areas like the Panama Canal, Suez Canal or Strait of Hormuz (Gründlingh *et al.* 2006) but nonetheless, ship traffic is considerable. In 1999, approximately 1000 bulk carriers, 1000 cargo vessels, 400 tankers, 1000 container vessels and several smaller vessels were estimated to pass around Cape Point each year (State of Environment Report 1999 – www.environment.gov.za/soer/nsoer/index.htm). The International Maritime Organization estimates that approximately 120 million tonnes of oil and substantial volumes of bunker fuel pass through South African waters every year (IMO 2005) which indicates that South Africa has one of the highest concentration of oil tankers and cargo ships in the world (Figure 60).

Pressure Distribution

Ship traffic around mainland South Africa was extracted from global data compiled by Walbridge (2013) and Halpern *et al.* (2015).

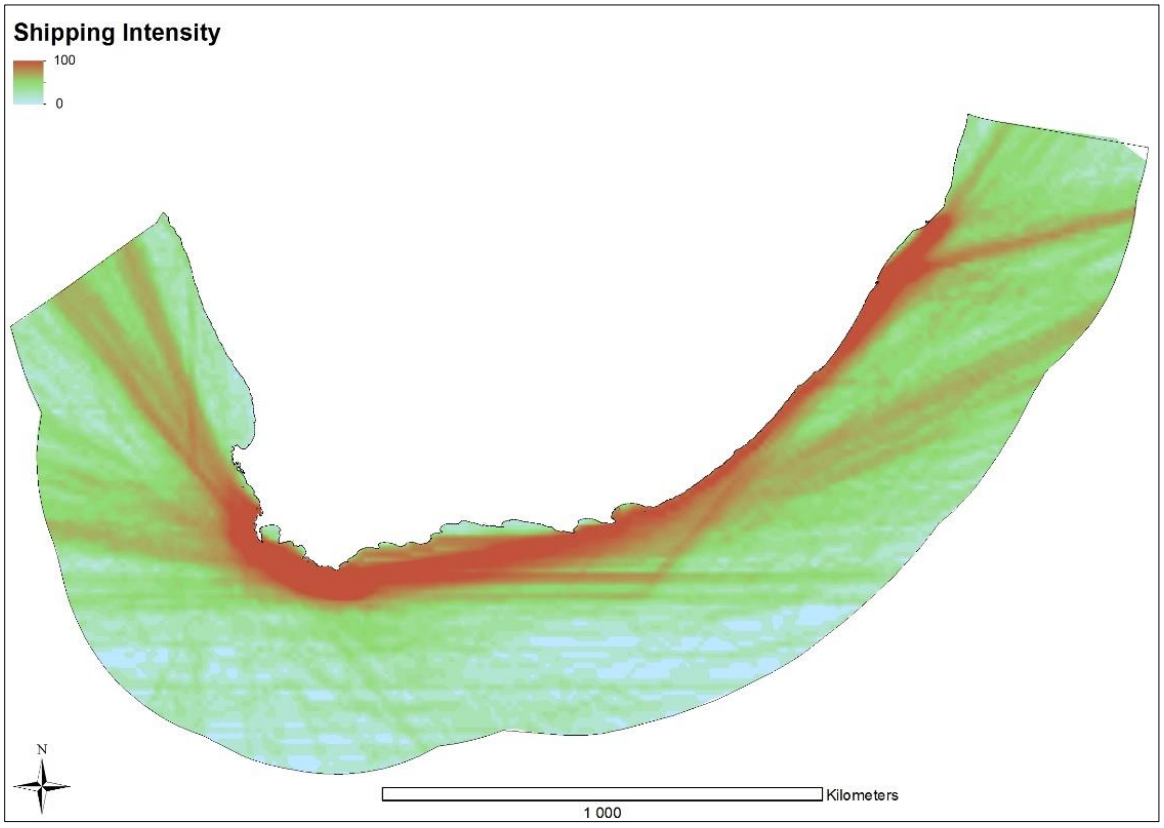


Figure 60. Map of shipping intensity for South Africa using data sourced from Walbridge (2013) and Halpern *et al.* (2015).

The **main biodiversity impacts** associated with shipping are:

- Impacts from oil spills as a result of shipping accidents (SAHO 2009).

- Introduction of invasive alien species through ballast water discharge and hull fouling (see Chapter 5)
- Pollution impacts from dumping of waste materials, leaching of toxic compounds from anti-fouling paint, and accidental oil leakages (Holdway 2002, IMO 2005).
- Ship strikes i.e. collisions between vessels and large marine animals such as whales and basking sharks (Atkinson and Sink 2008, Pirotta *et al.* 2019).

South Africa's oceanographic conditions can be hazardous as reflected by the estimated 2300 vessels lost at sea within South African territorial waters since the 16th century (SAHO 2009). Operational and **accidental oil discharges** do occur with an estimated 3.25 events per month (IMO 2005). Between 1983 and 2000 a total of 37 shipping accidents occurred mostly between Saldanha Bay and Cape Point resulting in oil being leaked into the sea or coast, the greatest of which amounted to 175 000 tonnes (IMO 2005). The most recent major oil spills along the South African coast were those of the Apollo Sea in 1994 and the Treasure in 2000. Both of these had **significant impacts on seabirds** and in particular the endangered, endemic African Penguin *Spheniscus demersus* (Underhill *et al.* 1999, Crawford *et al.* 2000).

Oil is a highly hazardous marine pollutant that is harmful to marine life. Contamination can kill seabirds and marine larvae and increases susceptibility to disease from suppressed immune function, reduced growth, and delayed sexual maturity in fish (Holdway 2002). Chronic **toxicity of crude oil** is greatly detrimental to a wide variety of marine organisms because the oil constituents adhere to and infiltrate their systems. A great number of effects of chronic oil exposure have been documented including behavioural impacts, suppressed growth, induced or inhibited enzyme processes and other molecular effects, physiological responses, reproductive effects, reduced immunity to disease and parasites, histopathological lesions and other cellular effects, tainted flesh and chronic mortality. Impacts on reptiles, birds and mammals include the effects of physical cleaning of oil (for a full list of references see Holdway 2002). Seabirds in particular are most affected since they lose their water repellent properties which cause their wings to become waterlogged, rendering them flightless (Clark 1984).

Oil spilt in the marine environment tends to spread quickly over the water surface as a slick, while volatile components rapidly evaporate removing some toxic components. The nature of the fuel is an important factor in determining the proportion that will evaporate. The lighter the oil, the greater the power of evaporation to remove it from the sea surface. Remaining fuel may be oxidised by sunlight, bound to suspended sediments, dissolved into the sea water or be degraded by organisms in the water column (Kingston 2002). When a spill occurs in a coastal setting, the intertidal zone may become smothered by oil. Spills of light oils, such as diesel, tend to have less negative impact on the marine environment as much of the spill tends to evaporate. **Ecological effects of oil pollution** can be toxic (i.e. poisonous to biota) or physical (i.e. the physical smothering of organisms. These effects act at various levels, for example at the level of individual organisms (resulting in physiological responses such as depressed respiration, (García-de La Parra *et al.* 2006)) or at the community level (resulting in decreased diversity and changes in community composition, (Serrano *et al.* 2006)). Recovery of the intertidal zone following petroleum pollution is determined mainly by the wave exposure level at the affected site and the degree to which the shore is cleaned. The fastest recovery times have been recorded for exposed shores which have been thoroughly cleaned, while sheltered sites and uncleaned sites recover the slowest (Kingston 2002).

The **discharge of ballast water** from ships entering South African waters brings with it the risk of introducing invasive marine species (see Chapter 5). More than 22 million tonnes of ballast water are discharged in South African ports and harbours annually (Atkinson and Sink 2008) from sources all around the world. A ballast water risk assessment for the Port of Saldanha in 2004 (Awad *et al.* 2004) showed high risks for South African marine ecosystems associated with international sources of ballast water. Activities to mitigate the risk associated with ballast water have been conducted at all 8 major ports in the country, including baseline biological surveys in 7 ports to establish potential invasive alien species presence. South Africa has been playing an active role at the International Maritime Organization (IMO) Marine Environment Protection Committee as concerns developing international guidelines and regulations. The IMO Ballast Water Convention was adopted by member states in 2004 and ratified in South Africa in 2008. The Department of Transport is currently in the process of developing regulations for its domestic implementation. The Transnet National Port Authority (TNPA) also has developed some ballast water and biofouling regulations within its port plans, supported by the National Ports Act. The former Department of Environmental Affairs has been developing regulations under the Biodiversity Act for the control and management of invasive alien species. It is ultimately imperative that the regulations regarding unintentional marine species introductions (e.g. through ballast water) be coordinated with the regimes being developed under the Department of Transport and TNPA. A Ballast water task force was assembled from 2000 to 2006, but has not recently been active. Re-activation by these primary stakeholders is needed to ensure the appropriate communication in this regard.

Many large marine species, especially whales and dolphins, may be vulnerable to collisions with vessels (see Pirotta *et al.* (2019) for an updated review on the impacts of global shipping on large marine species). Most reports of **ship strikes** involve large whales but collisions also occur with smaller species. Collisions involving large vessel especially, often either go unnoticed or unreported, particularly for the smaller cetacean species. As such quantification of the threat posed by ship strikes is very difficult and has not been done for South African waters. The problem is being addressed at an international level by the International Whaling Commission through its Scientific and Conservation Committees (http://iwcoffice.org/sci_com/shipstrikes.htm).

Air pollution from shipping activities have also been addressed at the international level **with IMO regulations** in place since 2005 to cut sulphur oxide emissions by 2020. In 2016, the IMO took a decision to reduce the maximum sulphur content in the exhaust gas to air from 3.5% to 0.5% from 2020, although there is concern that the technologies employed to meet this target will increase emissions and/or releases of other chemicals and materials (Lindstad *et al.* 2017). Although no legislation has been enacted within South Africa, SAMSA has communicated its intention to adhere to the 2020 deadline through notices to mariners and provide fuel that meets the requirements under IMO regulations.

4.3.28 Wastewater Discharge

South Africa's first National Spatial Biodiversity Assessment (Lombard *et al.* 2004) highlighted marine pollution as the second greatest pressure on marine biodiversity and called for a complete investigation into the impacts of pollution from sewerage and storm water, highlighting the increasing pressure on coastal municipalities and the need for improved monitoring and regulation of waste management (Lombard *et al.* 2004). The NBA 2011 (Sink *et al.* 2012a) mapped discharge sites for municipal and

industrial wastewater but noted that a lack of flow volumes for several discharge points limited the ability to accurately map the impact of this pressure in the marine environment. Access to information on current discharge volumes and effluent composition of wastewater discharges to the marine environment continues to be a challenge.

Wastewater is made up of industrial and municipal effluent, brine discharge from desalination plants, effluent from aquaculture facilities, power station cooling water and runoff. In this assessment, the analysis of the impacts of wastewater were confined to those emanating from outfalls and excludes inputs from stormwater and runoff into inland river and coastal systems. For more information on pollution effects in the inland freshwater systems such as rivers and wetlands, please refer to van Deventer *et al.* (2019).

Pressure Distribution

Over 100 pipeline outfalls were mapped for the South African coast (Table 12).

Table 12. Wastewater discharge types and locations for South Africa within the coastal area. (* indicates that the active status of some outfalls were unclear at the time of the assessment.)

Outfall Type	Effluent Type	Northern Cape	Western Cape	Eastern Cape	KwaZulu-Natal	Total
Nearshore	Aquaculture Effluent		1			1
	Domestic Effluent		1			1
	Industrial Effluent		1			1
Estuary	Brine			1		1
	Domestic Effluent		3	1	14	18
	Fish Processing Effluent		1			1
	Industrial Effluent			1	6	7
	Mixed Effluent		5		2	7
Surf-zone	Aquaculture Effluent	3*	23	3		29
	Domestic Effluent		7	2	3	12
	Fish Processing Effluent		15			15
	Food Processing Effluent		1			1
	Industrial Effluent		3		1	4
	Mixed Effluent		1	4		5
Offshore	Domestic Effluent		3		1	4
	Industrial Effluent		4		6	10
	Mixed Effluent				2	2
	Grand Total	**3**	**69**	**12**	**35**	**119**

As previously stated, data on actual flow volumes is not available owing to challenges in monitoring outfalls. However, based on the authorised maximum volume data per outfall, estimates for annual volumes can be determined (Table 13).

Table 13. Estimated annual discharge of wastewater into the marine realm. No data were available for some aquaculture and desalination facilities and this table may therefore underestimate the annual wastewater flows.

Sector	Estimated Annual Discharge in cubic metres
Aquaculture	189346670
Cooling Water	2920027450
Fish Processing	17448820
Food Processing	2900000
Hydrostatic Testing	5487045
Industry (includes chemical, organic and pulp)	182295580
Wastewater Treatment	428172975
Water Purification Plant	10220000
Total	**3755898540**

Data were collated from the former DEA: Oceans and Coasts and DAFF: Fisheries and combined with data used in the previous NBA (2011) assessment (Figure 61). There was uncertainty on the status of some of the outfalls related to desalination and aquaculture. Authorised discharge amounts were also not available for all outfalls.

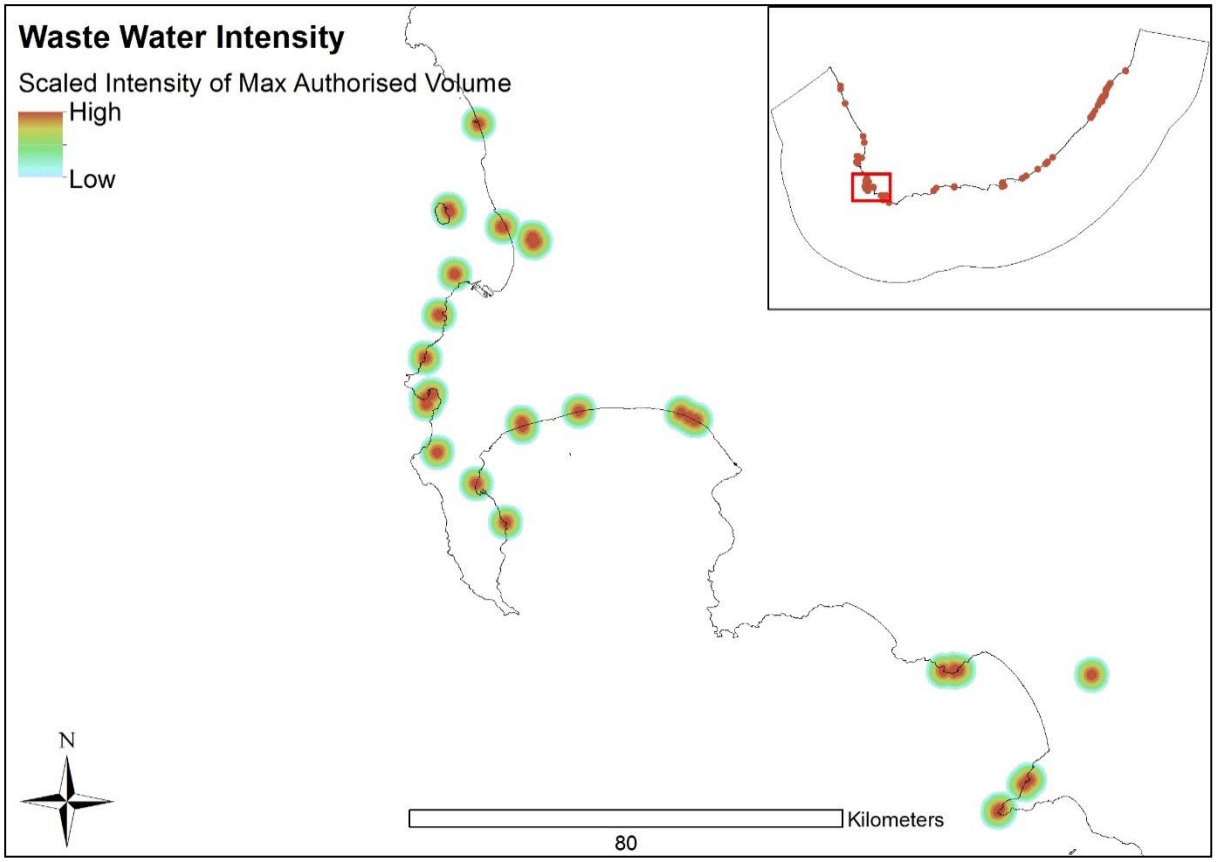


Figure 61. Map of the intensity of wastewater discharge for South Africa. The insert shows the national distribution of wastewater outfalls.

The **biodiversity concerns** related to wastewater discharge are:

- Increased impacts in less dynamic areas such as estuaries and bays due to the high level of retention in these areas (see Section 3.2 Drivers of marine biodiversity pattern).
- Bioaccumulation of heavy metals, organic pollutants and pharmaceuticals (Lim *et al.* 2013, Wang *et al.* 2013, Zhang *et al.* 2013, Sparks and Mullins 2016, Petrik *et al.* 2017).
- Eutrophication resulting in increased instances of red tide events and anoxic sediment (Brown and McLachlan 2002, Akpor and Muchie 2011).
- Proliferation of diseases and potential risks to human health (Akpor and Muchie 2011, VAGO 2018, WHO 2018).

Wastewater to the marine environment is either discharging to the nearshore (just above or onto the beach), the surf zone (along the beach or within the breaker zone), directly into estuaries, or offshore (beyond the surf zone in water depths greater than 2 m). These **wastewater discharges** comprise mainly municipal wastewater (domestic sewage, sometimes also including trade effluent), effluent from fish processing operations, wastewater from chemical works, refineries and other industries, backwash and cooling water.

Since approximately 1985 the design of **offshore marine outfalls** discharging wastewater to sea in South Africa has followed the receiving water quality objectives approach. Effluent quantities and composition must be within limits to meet site-specific Environmental Quality Objectives, as recommended in the South African Water Quality Guidelines for Coastal Marine Waters (DWAF 1995). Generally, long-term environmental monitoring programmes at these offshore marine outfalls have not indicated any widespread detrimental impact on the marine environment (RSA-DEAT 2008, Weerts *et al.* 2009). The former DEA have gazetted for comment the Coastal Waters Discharge Permit Regulations (RSA 2019) to regulate discharge into coastal and estuarine habitats that retains the receiving waters objective approach.

The inclusion of pollution inputs from **runoff and stormwater** is a priority for the next assessment. In addition a better understanding of pollution of groundwater is needed. Porter *et al.* (2018) found organochlorine pesticide accumulation in corals off Maputaland and attributed this to coastal groundwater inputs. Further research is required to understand the effects of these and other pollutants on marine and coastal biodiversity – see Box 21 for concerns regarding emerging pollution issues.

Box 21: Pollution in South African coastal waters: an important but poorly understood challenge

By Brent Newman

Pollution in South Africa's coastal waters takes many forms. The most visible is plastic litter on shorelines, particularly after heavy rainfall. Birds, whales and turtles are known to mistake large plastic items as food, the ingestion of which frequently results in their death. Recent research has focused on the risk posed by microplastics, the breakdown product of larger plastic items or fibres released from items such as clothing. Microplastics are found along the entire South African coastline (de Villiers 2018; Nel *et al.* 2017). They are present in the stomachs of South African fish (Naidoo *et al.* 2014) and undoubtedly also in shellfish such as mussels. It is now apparent that some of the smallest animals in coastal systems are ingesting microplastics (Desforges *et al.* 2015; Sun *et al.* 2018), although the impact on these animals is not always clear or consistent. There are increasing concerns that plastic is entering the human diet through the consumption of shellfish that have ingested microplastics, but here too the health implications are not entirely clear (Smith *et al.* 2018).



Severe plastic pollution in Durban Bay and near a river mouth in Durban.

Chemical and microbiological pollution in coastal waters is less visible, and the impacts often less evident unless it results in a fish kill, for example. The impact of some contaminants in South Africa's coastal waters is well understood. Excess nutrient concentrations in estuaries as a result of wastewater discharge are, for example, known to overstimulate the growth of macro- and microalgae (Adams *et al.* 2019), resulting in low dissolved oxygen concentrations at night when they consume rather than produce oxygen. This may lead to fish kills. The sediment in estuaries and harbours in many South African coastal cities is often (severely) contaminated by various chemicals (CSIR 2015; Newman *et al.* 2015), including highly persistent chemicals such as polychlorinated biphenyls, whose production was banned decades ago because of toxicity concerns. These and other chemicals pose a toxic risk to aquatic fauna and flora (Vogt *et al.* 2018). Endocrine disruption as a result of contaminant exposure has been shown in some South African coastal waters, including the development of male sex organs in female gastropods that results in their sterility (Marshall & Rajkumar 2003; Truter *et al.* 2015; van Gessellen *et al.* 2018). Wastewater discharge into the sea through outfalls impairs water and sediment quality, and may result in a shift in the benthic invertebrate community near the discharge point to more pollution tolerant forms (CSIR 2017). Some contaminants accumulate in the tissue of fish and shellfish. These may pass through the food chain from prey to predator, becoming more concentrated the further they move through the food chain. In this way they may reach high concentrations in top predators, such as tuna, swordfish and sharks, leading to reproductive complications. Contaminants taken up by fish and shellfish in some South African coastal systems pose a risk to the health of humans (Newman *et al.* 2015). A major challenge in chemical contaminant research is that there are thousands of chemicals in daily use, yet scientists usually are only able to measure a small number of these. The impacts of many contaminants are, consequently, unclear and undocumented. These include so-called emerging contaminants, such as personal care products and pharmaceuticals.

Regardless of its form, pollution in coastal systems almost always has its source on land. Solutions to the challenge posed by pollution in South Africa's coastal systems must, perforce, focus on minimising land-based sources. Acknowledgment that there is a pollution continuum from land to freshwater to coastal systems is critical in this context – the amount of plastic litter on the shoreline near river mouths in most coastal cities after heavy rain exemplifies this connection. The generally poor understanding of the ecological and human health and economic impacts of pollution in South Africa's coastal systems calls for national scale research if the nation's coastal resources and the goods and services they provide are to be protected and managed sustainably.



High nutrient concentrations over stimulate the growth of microalgae in estuaries. At night, when the microalgae cease to produce but rather consume oxygen, their oxygen demand can be so high it removes most of the oxygen from the water column, resulting in fish kills.

4.3.29 Ammunitions Dumping

Pressure Description

Dumping of ammunitions at sea is a form of marine pollution where obsolete ammunition such as artillery shells from used ammunition, expired or unusable ammunitions, and obsolete ammunitions are disposed of in the marine environment. The **dumping of disused ammunition at sea** was practiced in South Africa from the 1970s and ceased in 1995 (Godeschalk and Ferreira 1998), owing to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (referred to as the London Convention) which introduced stricter limitations on dumping at sea. The protocol came into effect in 2006, although South Africa has complied with this protocol since 1995. Heinonen (2016) reported that chemical weapons produced in South Africa during the 1970's and 80's were dumped at sea in 1993, however there are no spatial records for chemical weapons disposal at sea in South Africa (Wilkinson 2017). This section therefore focuses on conventional munitions that cause damage through kinetic (e.g. bullets and guns) or explosive energy (e.g. bombs and missiles).

Pressure Distribution

Data were received from the Navy Hydrographic Office in the form of point and polygon data. Unfortunately, data on the amount and type of ammunitions dumped was not available and it was therefore assumed that equal amounts of ammunition were dumped at each site, and spread out across each area (Figure 62).

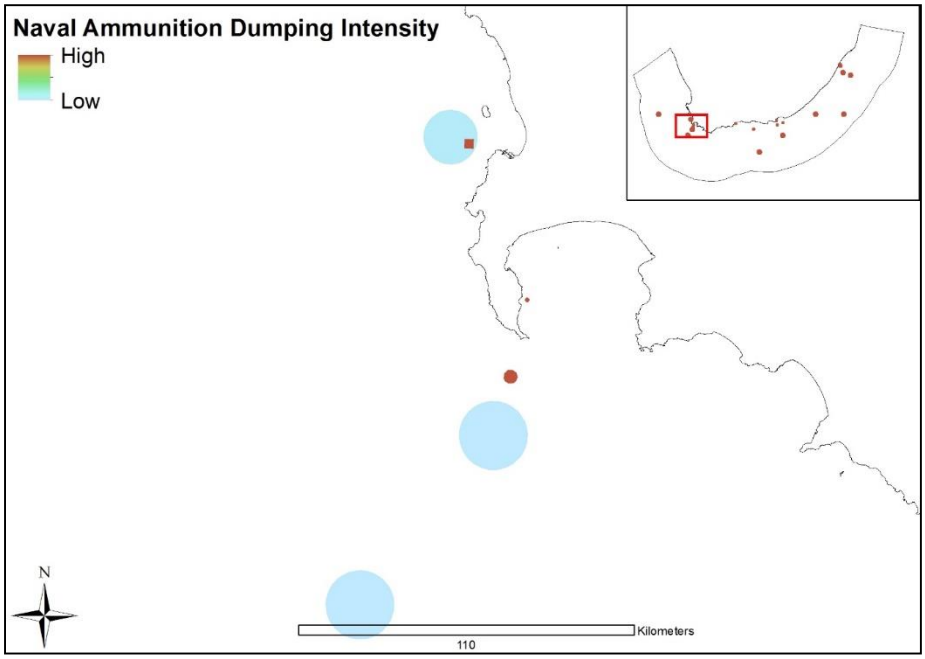


Figure 62. Map of ammunition dumping intensity at dumping sites of South Africa. Insert shows the national distribution of all areas of munition dump sites.

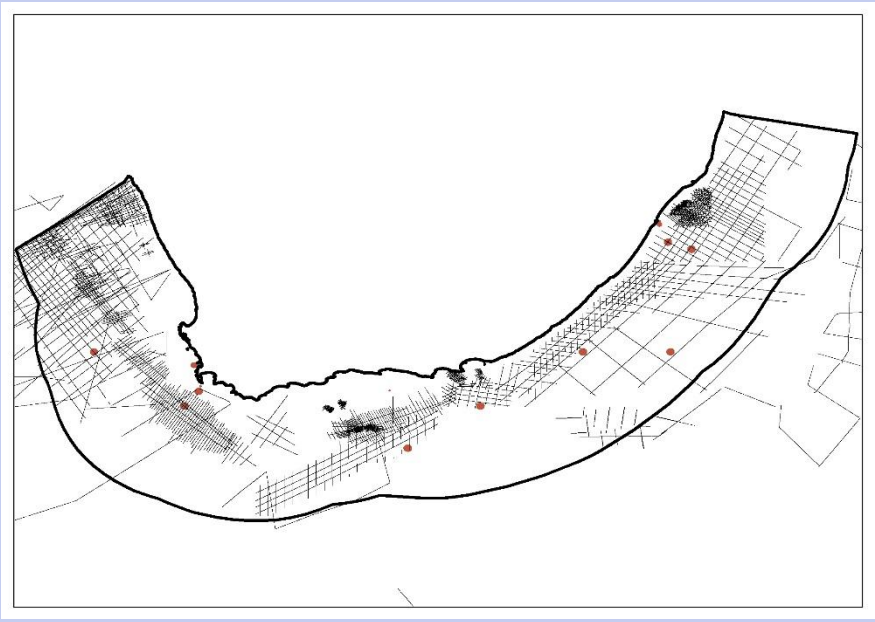
The **main biodiversity concerns** surrounding munitions dumped at sea are:

- Changes to the physical environment and potential damage or smothering of natural ecosystems due to presence of foreign structures and/or damage to habitat forming species (Beck *et al.* 2018).
- The potential for these munitions to detonate and cause more serious localised destruction to underwater ecosystems due to deterioration and/or disturbance.
- The potential for the contents of munitions (especially heavy metals such as lead and mercury) via corrosion to pollute the surrounding environment resulting in toxicity to biodiversity (Granbom 1994, George *et al.* 2015, Beck *et al.* 2018).

Corrosion rates are higher in high energy environments, such as near-shore shallow coastal regions or where deep water currents are strongest and mixing is high (Granbom 1994), and it was found that ammunitions exposed to seawater for long periods of time undergo extensive corrosion (MEDEA 1997). This long term exposure may even increase their sensitivity to detonation due to deterioration of stabilising compounds or the production of volatile secondary compounds (Pfeiffer 2012) – see Box 22 for a local example.

Box 22: Potential hazards of historical ammunitions dumping

Ammunitions dumped at sea also pose a threat to other sectors such as fishing and mining. Disturbance of those sites where there has been extensive corrosion, or where there has been a proliferation of volatile secondary compounds and/or deterioration of stabilising compounds could lead to a potential disaster at sea. The Navy Hydrographic Office has published the location of dumping sites in "The Notice To Mariners" series but as the map below shows there has been interaction between oil and gas exploration (using seismic surveys) and known ammunitions dump sites. The lack of information on the type, tonnage and condition of the dumped ammunition requires that future exploration and planned infrastructure (e.g. underwater cables, renewable energy infrastructure, etc.) be cognisant of these sites and avoid unnecessary disturbance.



Map of overlap of post-1995 seismic survey lines with ammunition dump sites. Seismic data were provided by the Petroleum Agency SA.

South Africa's munition dumping sites are at least 40 years old and it can therefore be assumed that there has been some corrosion of munitions, but it is unclear if there has been any associated leakage of munition compounds to the marine environment. No records of studies on leakage and/or toxicity levels on South African ammunition dump sites were found during this assessment. According to (George *et al.* 2015), the rate of corrosion is dampened by exposure to anoxic conditions and/or burial within the sediment.

A study conducted on a reef system in Puerto Rico found that reefs with the highest concentrations of bombs and bomb fragments had the lowest **health indices** (i.e. lower coral species diversity and fewer colonies), and that sessile species had higher loads of toxic compounds than mobile species (Porter *et al.* 2011a). This study also found that toxin loads in the surrounding sediment showed an exponential decline with increasing distance from the source. Pollution impacts where corrosion has led to leaking of munition components may therefore be localised with very little impact on the surrounding biodiversity, but does impose a heavy toxicity load on species and sediment within the site of dumped ammunitions. Visual surveys along the North American coastline produced video footage showing numerous 55-gallon (~200

litres) drums in and on the muddy seafloor (MBARI 2013). Many of these rusting barrels were covered with anemones, sponges, crabs, and other animals (MBARI 2013), suggesting that biodiversity can persist in the presence of dumped ammunitions.

4.3.30 Dumping of Dredge Material

Pressure Description

Dredging is the removal of accumulated sediment from a body of water such as lakes, estuaries, coastal and marine waters, and water ways and canals; this section will deal solely with dredge material collected from harbours that are dumped at sea. The removal of sediment within waterways ensures that ships do not run aground and are a key service performed by the Ports Authority as part of harbour management and maintenance.

Pressure Distribution

Data for dumping of dredged material was only available for areas off Durban and Richards Bay harbours (Figure 63) and sourced from the Navy Hydrographic Office. Unfortunately no data were available on the rates or amounts of dumping.



Figure 63. Map of the dredge dumping sites for Durban Harbour (left) and Richards Bay Harbour (right) dredged material.

Environmental impacts from dredge disposal include:

- Decreased primary production and decreased predator success due to increased turbidity, which may also increase the bioavailability of contaminants (Essink 1999).
- Increased bioavailability of pollutants which could result in decreased health of sensitive species (Smith *et al.* 1995).
- Longer term impacts from disposal including alteration of bathymetry which in turn could result in changes in currents and waves, as well as alter natural sediment deposition and erosion cycles (Vander Pluym *et al.* 2017).

(Smith and Rule 2001) found that four key factors could determine the level of impact experienced by the receiving ecosystem type:

(i) Similarity of sedimentary characteristics between the dredged material and the receiving site would result in low levels of impact;
(ii) dredged material that is free from contaminants will result in lower pollution at dump site as well as lower rates of resuspension of contaminants at source;
(iii) where the disposal method systematically distributes a number of shallow layers of sediment over the disposal site, motile macrofauna may have a greater opportunity to migrate upwards between dumping events and thus avoid being smothered, and
(iv) ecosystems in a high energy environment, where the resident biota are likely to be adapted to dynamic sedimentary conditions, would be more resilient to additional suspended particles.

Therefore, the type of disposal methodology applied, as well as the quality of the sediment being deposited, may amplify or mitigate these environmental impacts. This information could be used to refine the impact intensity of this pressure more accurately, and improvements in ecosystem mapping could be used to improve management of this activity so as to minimise impacts to the receiving environment. Offshore dredging (to supply sediment to sediment-starved beaches) could be included in future assessments.

4.3.31 Freshwater Flow Reduction

Pressure Description

Freshwater inputs into the marine and coastal environments are made via rivers, estuaries and groundwater flow. Reductions in freshwater inputs are associated with abstraction for use upstream through damming, direct abstraction from rivers and groundwater, the closure of estuaries and decreases in annual rainfall. The NBA 2018 Assessment found that by freshwater flow reduction threatens 64% of river ecosystem types (van Deventer *et al.* 2019)and 20% of estuaries are severely impacted by reduced flow (van Niekerk *et al.* 2019). In this assessment freshwater flow reduction was estimated as changes in mean annual runoff (MAR) from rivers. Freshwater flow reduction has consequences for marine biodiversity and resources as described below.

As described in Chapter 3 (Ecosystem Classification and Mapping), **river-influenced ecosystem types** have been included in the marine ecosystem classification. River-influenced marine systems are receiving increasing research attention in both global and local literature due to the recognition of the role of freshwater in marine ecosystems. Rivers are the highways that connect the marine environment to the terrestrial environment and are essential in transporting freshwater, nutrients and sediment from the terrestrial environment to the marine environment. Many fish and other marine fauna complete part of or entire life-history stages in rivers or estuaries (Able 2005, Vasconcelos *et al.* 2011, De Lecea *et al.* 2013b, Blanco *et al.* 2019). A river plume is described as the area of water juxtaposed to the terminal end of a river that is inundated with suspended sediment. Satellite imagery and aerial photography are used to delineate and quantify the area of a plume. Plumes have a direct impact on the salinity, pH, light penetration (Mallin *et al.* 2005), sedimentation (Obura and McClanahan 1997, Golbuu *et al.* 2008, 2011, Polónia *et al.* 2015), nutrients (Rabalais *et al.* 2004, Gao and Wang 2008) and primary production (Vargas and Martínez 2009) of the adjacent environment.

Pressure Distribution

The total freshwater flow to the marine environment has been reduced by more than 12 billion m^3/year translating to a 33% reduction in MAR. Reductions in the largest catchments in South Africa (those that contribute 1% or more of total MAR in the region) are provided in Table 14.

Table 14. Estimated change in freshwater flow for the major river systems in South Africa.

River	Reference Mean Annual Runoff (million m3/year)	% of South African runoff	% Change
Orange (Gariep)	10833.01	29.4%	62%
Tugela/Thukela	3753.6	10.2%	27%
Mzimvubu	2665.58	7.2%	4%
Breë	1785	4.8%	42%
Mzimkulu	1452.49	3.9%	19%
Mkomazi	1077.74	2.9%	14%
Olifants	1070.1	2.9%	33%
Great Kei	954.93	2.6%	32%
Groot Berg	916	2.5%	43%
Mfolozi	885	2.4%	0%
Mbashe	801.82	2.2%	-2%
Mgeni	671.3	1.8%	69%
Mhlathuze	645	1.7%	0%
Gourits	628.78	1.7%	29%
Great Fish	513.29	1.4%	10%
St Lucia	417.89	1.1%	0%
Mtata	392.2	1.1%	19%
Gamtoos	388.84	1.1%	32%
Mvoti	374.66	1.0%	40%

The greatest reduction is on the west coast (-7 478 million m^3/year) but there are significant reductions along both the south (-1 721 million m^3/year) and east coasts (-2 808 million m^3/year). The larger river systems that have experienced the greatest flow reduction are expected to have driven the most change in marine ecosystems (Figure 64).

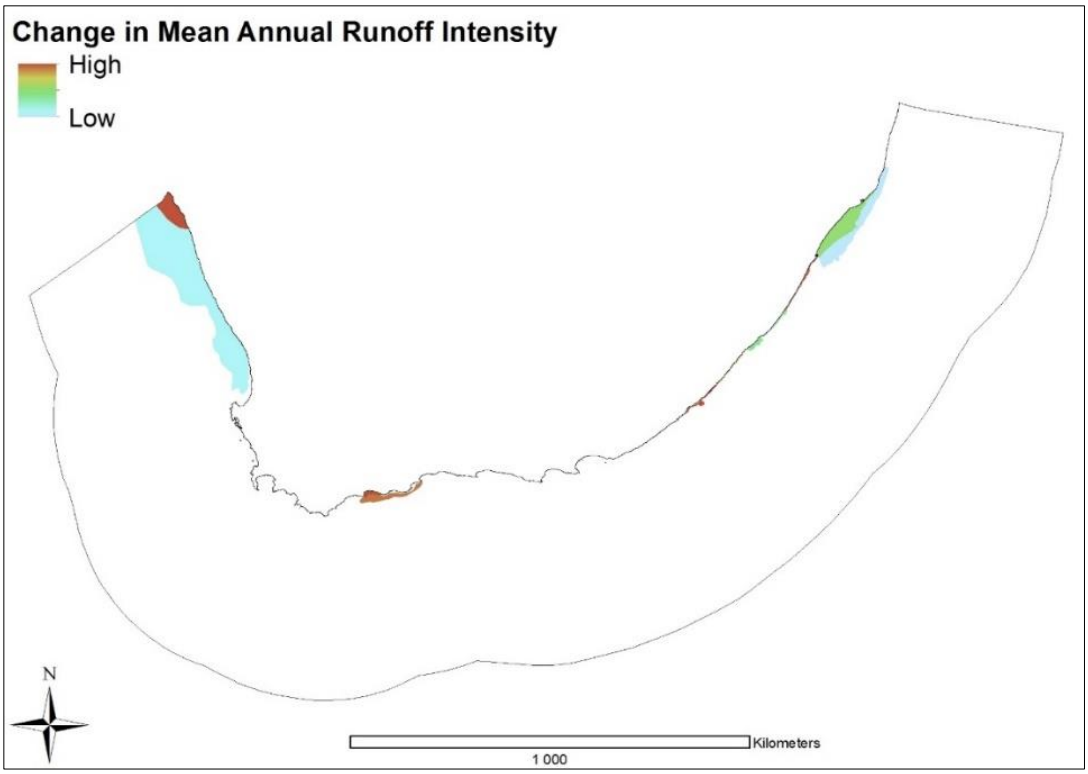


Figure 64. Map of intensity of changes in mean annual runoff for river-influenced ecosystem types. Values for changes in mean annual runoff were sourced from the NBA 2018: Estuarine Assessment (van Niekerk *et al.* 2019).

Biodiversity Concerns due to freshwater flow reduction include:

- Physical habitat changes, beach loss and loss of mud habitat (van Ballegooyen *et al.* 2007, Harris *et al.* 2010).
- Impacts on ecological processes including nursery functions, environmental cues, productivity, nutrient provision and food web processes (Demetriades *et al.* 2000, van Ballegooyen *et al.* 2007, Lamberth *et al.* 2009, Porter *et al.* 2014, Scharler *et al.* 2016).
- Potential reductions in fisheries catches and associated economic impacts (Lamberth *et al.* 2009, Turpie and Lamberth 2010).

Riverine nutrient input drives primary production in the adjacent shelf environment. Grippo *et al.* (2010) noted that settled microalgal detritus was potentially an essential source of organic carbon which may be utilised by benthic consumers in the inner shelf of the north-central Gulf of Mexico. For example, the Amazon River plume has been shown to have a seasonal influence on the benthic environment (Moura *et al.* 2016) and the plume effect has a direct influence on the rhodolith composition and structure off the Amazon River (Vale *et al.* 2018). A number of studies have been undertaken in KwaZulu-Natal to study the effects of riverine inputs on the nearshore and offshore environment, bearing in mind that the region has a particularly narrow shelf. Studies by de Lecea *et al.* (2016) concluded that organic matter from the uThukela River is an important component **supporting the demersal food webs**, and that the estuary was the main biological driver of Natal Bight's benthic environment. Similarly, freshwater flow reduction

through the development of freshwater infrastructure (dams, weirs etc.) negates the productivity of this whole shelf-wide ecosystem adjacent to the river mouth (de Lecea *et al.* 2016, Scharler *et al.* 2016). In another study, terrigenous sediments originating from the Thukela estuary were found to be important in forming and maintaining soft sediment habitats which are essential to some demersal fish communities and the linefishery in the region (Lamberth *et al.* 2008, Fennessy 2016).

The reduction of river flow leads to a **reduced sediment supply** to the coast with implications for shore ecosystems including beaches, fluvial fans and muddy ecosystem types. Reduced sediment input can change beach morphodynamic state, altering the beach biodiversity, accelerating beach erosion and can even lead to the loss of beach habitat (Harris *et al.* 2010). In the subtidal environment, riverine inputs provide important sediment inputs for the maintenance of unconsolidated sediment habitats such as mud banks (Bosman *et al.* 2007). Reduced river inputs reduce the spatial extent of such habitats (van Ballegooyen *et al.* 2007), which may have implications for fisheries (Lamberth *et al.* 2009, Scharler *et al.* 2016). Many of these habitats are also important for ecological processes. For example the endemic and threatened White Steenbras *Lithognathus lithognathus* spawns on submarine fluvial fans, a localised habitat of limited extent, associated with mixed mud and sand banks deposited by rivers in the southeast Cape coast (Bennett 1993b); on the east coast, the Squaretail Kob *Argyrosomus thorpei* uses mud banks as a nursery (Fennessy 1994a). Changes in salinity and water temperature linked to flow alteration also impact thermohaline fronts which affects plankton feeding communities and the fish, birds and mammals that feed on the concentrated food associated with these habitats (van Ballegooyen *et al.* 2007).

Important processes that can be compromised through altered freshwater flow include **nursery functions, environmental cues, productivity and food web processes**. Increased frequency of estuary mouth closures and associated conditions due to reduced freshwater flow can also disrupt lifecycles and connectivity and deprive fish and invertebrates of the important nursery function of estuaries (Whitfield 1998). On the south coast, freshwater seepage from dune aquifers constitutes an important source of nitrogen for surf-zone phytoplankton (particularly accumulation-forming diatoms), and researchers caution against the use of groundwater from such aquifers without considering the ecological needs of marine and coastal ecosystems (Campbell and Bate 1991). Sediment delivery is also an important ecological process associated with freshwater input. Sediment provides turbidity and a refuge for fish which is a key component of estuarine, coastal and offshore nursery areas (Whitfield 1998, Lamberth *et al.* 2009). Reduced turbidity can alter predation pressure and the catchability of fisheries resources (van Ballegooyen *et al.* 2007). Altered freshwater flow leads to changes in important environmental cues such as those relevant for spawning, recruitment and migration (Louw 2003 in van Ballegooyen *et al.* 2007, Lamberth *et al.* 2009). Changes in spawning intensity have been correlated with altered freshwater flow (Demetriades *et al.* 2000, Quiñones and Montes 2001).

Catchment-derived nutrients are an important component of marine and coastal foodwebs stimulating phytoplankton production. The impacts of **reduced nutrient supplies** will travel through marine and coastal ecosystems via foodwebs (van Ballegooyen *et al.* 2007) Reduced detritus may also impact on marine and coastal foodwebs as river-associated detritus and associated epiphytes are believed to be an important food source for microorganisms, filter feeders, detritivorous fish and invertebrates (Berry *et al.* 1979, Schleyer 1981, Berry and Schleyer 1983, Whitfield 1998, Porter 2009, Porter *et al.* 2014). In KwaZulu-

Natal, an isotope study showed that suspended riverine particulate organic matter (terrestrial, aquatic plant material and plankton) plays an important role in supporting inshore filter-feeder communities i.e. intertidal and subtidal assemblages dominated by the sea-squirt known as Redbait *Pyura stolonifera*, Brown Mussels *Perna perna*, and oysters *Striostrea margaritacea* and *Saccostrea cucullata* (Porter *et al.* 2014). Porter (2009) found that between 8 and 33% of filter-feeder diets consisted of material introduced to the sea by rivers and concluded that rivers play an important trophic role in promoting filter-feeder biomass in the Natal ecoregion.

Changes in freshwater flow and associated variations in turbidity, nutrients and sediment supply can impact fisheries resources, alter catch composition and decrease the economic returns of fisheries (Lamberth and Turpie 2003, Lamberth *et al.* 2009, Turpie and Lamberth 2010). **Fisheries resources** in South Africa that have or may have been compromised by reduced freshwater input include linefish (Lamberth *et al.* 2009), prawns (Demetriades *et al.* 2000), soles and kobs and filter feeding invertebrates such as Brown Mussels *Perna* and Redbait *Pyura stolonifera* in the intertidal and shallow subtidal (Porter *et al.* 2014). Lamberth *et al.* (2009) identified significant relationships between flow and the catches of 14 linefish species (more than 90% of the total catch) on the uThukela Banks in KwaZulu-Natal. Most fish responded negatively with reduced catches correlating with reduced flow (after a lag phase) with Slinger *Chrysoblephus puniceus* and Squaretail Kob *Argyrosomus thorpei* showing a strong relationship to flow alteration. Turpie and Lamberth (2010) estimated a potential decline of 20% total catch and 7% in value for the uThukela Bank linefishery under the most serious flow decline scenario. Recently, ecosystem modelling research highlighted the importance of maintaining the estuarine to offshore ecosystem connectivity for the Thukela Bank foodweb and its associated fisheries (Scharler *et al.* 2016).

The ecological needs of the marine and coastal environment should be considered in the allocation of freshwater resources to ensure healthy functioning marine ecosystems that support productive and sustainable fisheries (see Chapter 11: Priority Actions).

4.4 Cumulative Pressures

Cumulative pressures from all pressure layers used in the NBA 2011 and NBA 2018 assessments are shown in Figure 65. These maps illustrate the intense pressure along the coastline, on the shelf and on shelf edge, close to major economic centres and ports. These maps reflect summed pressures without considering impacts. They do not take into account the distributions of ecosystem type and the differential impacts of pressures on different ecosystem types. This and the expected impacts of pressures are addressed in Chapter 7.

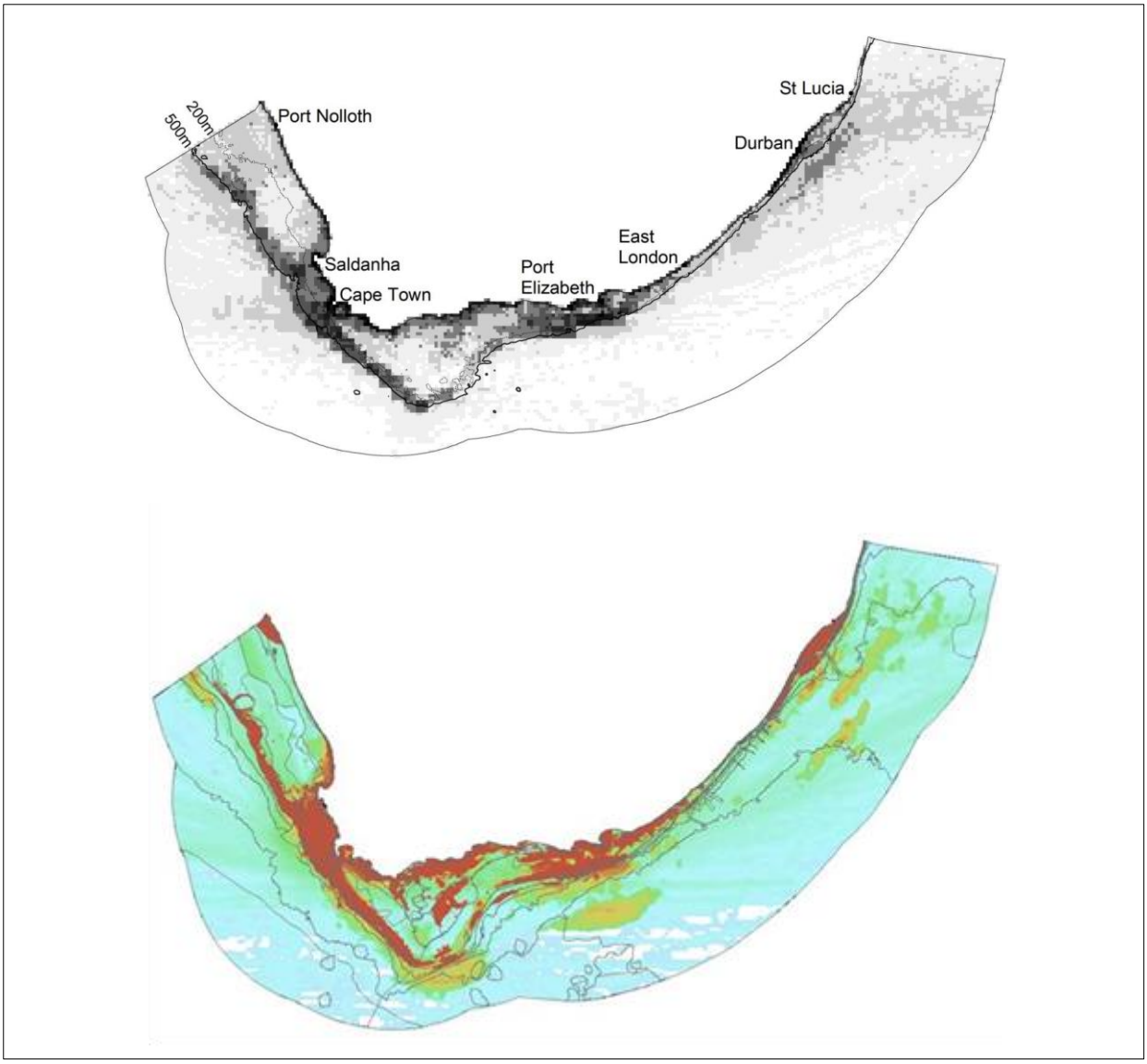


Figure 65. Map of cumulative pressure used in the NBA 2011 (top) and NBA 2018 (bottom). Note the coarser grid used in the NBA 2011 assessment.

The 2018 cumulative pressure map indicates that the highest cumulative pressure occurs in Saldanha Bay with all other bays also facing high cumulative pressures (Figure 65). Additional high pressure areas include the area offshore of the Orange River, the shelf edge on the west and south coast, large portions of the Cape inner and middle shelf, the Agulhas Bank and the KwaZulu-Natal Bight (Figure 65). For details of the application of pressure mapping in the assessment of ecosystem threat status refer to Chapter 7. The following two chapters cover the threats of climate change and invasive species which exacerbate and interact with pressures on marine biodiversity. Appendix 2 provides a short summary for the rationale and processing methods used for each of the pressure impact layers.

4.5 Limitations of the pressure datasets and maps

Although the finer scale mapping of a diverse range of pressures on marine ecosystems represents an advance in the NBA 2018 compared to previous assessments, there are some limitations to these datasets and maps. **Pressures that were not included** in this assessment include the demersal shark fishery, the emerging small-scale commercial fishery, recreational invertebrate harvesting and experimental fisheries such as those for octopus and whelks (DAFF 2016). The experimental hoop-net fishery for Whelks *Bullia laevissima* and Three-Spotted Swimming Crab *Ovalipes trimaculatus* was established in 1989 and takes place on sandy seabed areas in the subtidal between False Bay and Cape Town harbour (DAFF 2016). In addition the anchorage areas within port limits should be mapped and included in future assessments. As in 2011, oil pollution from documented historical or recent oil spills has not been mapped. Finally, non-extractive recreational activities such as scuba diving were not considered in this assessment.

In future assessments, the demersal shark fishery must be included and experimental fisheries should also be considered for inclusion. Some pressure maps require improvement. The linefish data used in this assessment exclude data from many localities where fishing (including with high effort) is known to occur (such as the Alphard Bank). The map of recreational fishing effort is incomplete and based on outdated information. A **standardised national survey of recreational fishing effort remains a key research priority**. There was insufficient information to map the emerging small-scale commercial fishery and this will require mapping once the implementation of the small-scale policy is complete.

There is a need to strengthen knowledge of local impacts of marine mining, demersal trawling, mariculture and pollution. The latter includes the impacts of **persistent organochlorides** (see Porter *et al.* 2018), **pollution from pharmaceuticals** from municipal wastewater discharge, and **light pollution**. Data to map the impacts of recreational fishing including emerging new fishing practices such as **drone fishing** is a high priority.

Globally, there is an increasing recognition of the complexity of **interacting pressures** on marine ecosystems. Hodgson *et al.* (2019) expose the challenges in understanding how multiple anthropogenic pressures translate into ecological consequences. The inherent variability within ecosystems and the complexity in species and ecosystem responses to multiple pressures requires additional international and local effort. These authors recommend risk-based approaches that better account for uncertainty in our understanding. While this chapter feeds into a risk based approach in terms of ecosystem assessment (Chapter 7), there is a need to improve our understanding of the uncertainties involved and better incorporate such uncertainty into assessments.

5. INVASIVE SPECIES

Chapter Citation: Miza SA, Robinson TB, Peters K, Majiedt PA, Jackson L, Hampton SL, Sink KJ. 2019. Chapter 5: Alien and Invasive Species. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



Marine invasive species are increasing despite limited survey effort

Chapter Summary

Alien and invasive species are those that have migrated via human-induced activities to areas outside of their natural range. This chapter summarises the literature, to report on marine alien and invasive species in South Africa. In 2011, the NBA reported that the known number of marine alien species had expanded from 17 in 1992 to 84, only 8 of which were considered as invasive. Based on recent research, the number of marine alien species has been amended to 96 including 55 that are considered to be invasive. Rocky shores are the most invaded broad ecosystem group with most invasions in the Southern Benguela ecoregion. Crustaceans and molluscs are the taxonomic groups most often recorded as invasive. Attempts to eradicate the European Shore Crab *Carcinus maenas* in South Africa failed but this species has not expanded its footprint in the last decade. The main points of introduction and refugia for marine alien and invasive species are ports, harbours and marinas; which is where most introduced species have been recorded (62). The role of petroleum infrastructure in the introduction and spread of marine alien species is being increasingly recognised. The main vectors of accidental introductions remain ship fouling and ballast water. Recreational boating has also been identified as a significant contributor to the intra-regional spread of invasive species, and the expanding aquarium trade is an emerging vector of introduction. Gaps in taxonomic knowledge, capacity and opportunities for systematic surveys limit the ability to detect and understand marine introductions and invasions in South Africa. Although the local ecological and socio-economic impacts of marine alien and invasive species are poorly understood, further afield, impacts of marine alien species on biodiversity and industries are well established. The impacts of marine invasive species on other ocean economies and ecosystems signal the risks to South Africa's ocean economy, biodiversity and coastal communities. Ambitious plans to increase port and harbour development, maritime transport, oil and gas activities, aquaculture and coastal tourism in the interests of growing the ocean economy in South Africa, are therefore of serious concern - these developments have the potential to increase the introduction and spread of alien species unless adequate biosecurity measures are implemented. A risk assessment protocol for transfer and introduction is needed to identify pathways that constitute the highest risk of introductions. Monitoring, early detection and rapid response protocols, that include clear roles and responsibilities and sufficient resources, are needed to ensure appropriate invasive species management for the marine realm. The highest priority action is to secure resources and develop capacity to enable rapid management action to prevent potential invasive species from becoming established when detected through monitoring programmes.

5.1 Overview of Marine Alien and Invasive Species in South Africa

The establishment of introduced animals, plants and microorganisms in locations outside their native range is one of the most serious threats to the natural ecology of biological systems worldwide (Wilcove *et al.* 1998, Mack *et al.* 2000). In some cases, successful introduction and establishment of non-indigenous species can result in biological invasions which can adversely affect native biodiversity, industry and human health. **Marine alien species** are **defined** as species whose presence in a region is attributable to human actions that enabled them to overcome fundamental biogeographical barriers, and **invasive species** are alien species that have self-replacing populations over several generations that have spread from their point of introduction (Robinson *et al.* 2016). Introduced marine species have transformed marine habitats around the world; many compete with and displace native species (Robinson and Griffiths 2002, Branch and Steffani 2004, Anderson 2005, Steffani and Branch 2005, Branch *et al.* 2008, 2010), change community structure and food webs (Laird and Griffiths 2008), and alter fundamental processes such as nutrient cycling and sedimentation (Molnar *et al.* 2008).

In South Africa, research focussed on marine alien and invasive species has increased as evidenced by the **expanding list of alien species** for South Africa (Table 15). The number of marine alien species recorded in South Africa increased from 15 introduced and two invasive species in the early 1990s (Griffiths *et al.* 1992), to 85 reported introduced and 39 cryptogenic[4] species in marine and estuarine environments in 2011 (Mead *et al.* 2011c). In 2016, a total of 89 alien species, of which 53 are considered invasive, were reported for South Africa (Robinson *et al.* 2016). An additional five alien species - the intertidal isopod *Ligia exotica* (Greenan *et al.* 2018), the Chilean Stone Crab *Homalaspis plana* (Peters and Robinson 2018), the South American Sunstar *Heliaster helianthus* (Peters and Robinson 2018), the Maritime Earwig *Anisolabis maritima* (Griffiths 2018), and the barnacle *Perforatus perforatus* (C.L. Griffiths pers comm) - as well as two invasive species - the amphipod *Caprella mutica* (Peters and Robinson 2017) and the Porcelain Crab *Porcellana africana* (Griffiths *et al.* 2018) have been recorded since 2016. The updated list of **96 marine alien species** recorded in South Africa is shown in Table 15. The 96 marine alien species occurring in South Africa represent 14 phyla (Figure 66) with the majority being Crustaceans (33%), Cnidarians (16%) and Molluscs (14%) (Figure 67).

[4] Cryptogenic referring to species that cannot be reliably demonstrated as being introduced or native (Carlton 1996)

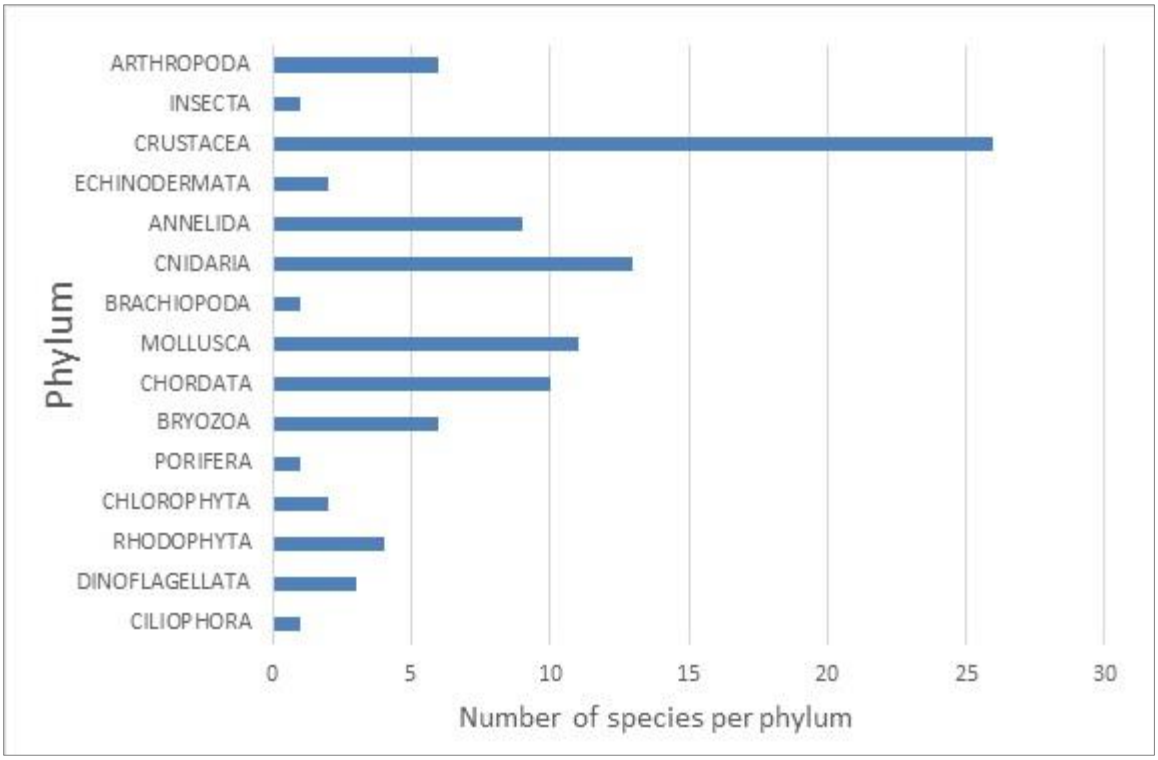


Figure 66: The number of recorded marine alien and invasive species per phylum in South Africa.

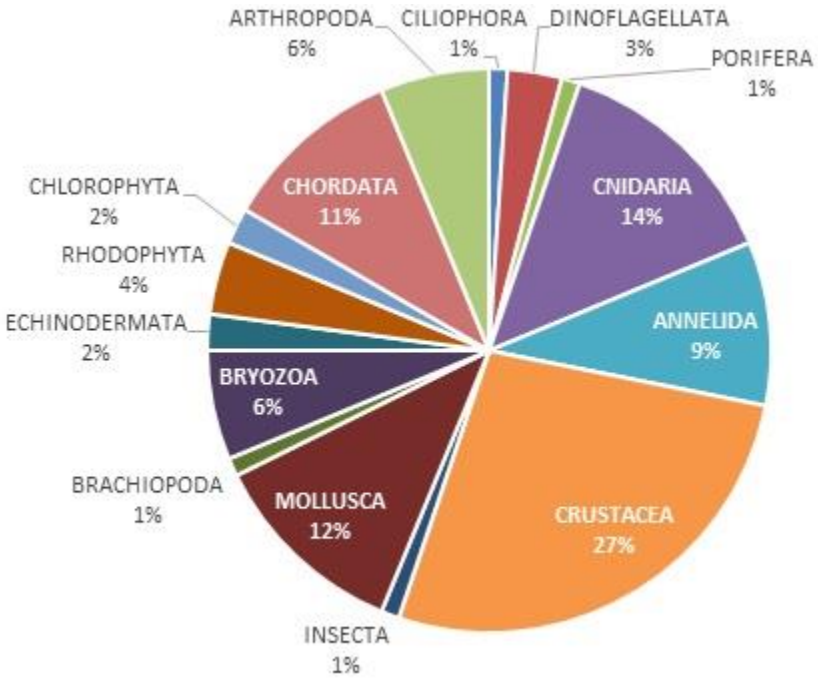


Figure 67: Pie chart showing the proportion of recorded marine alien and invasive species per phylum in South Africa

Currently, most marine alien species have been recorded from artificial habitats such as aquaculture facilities, ports, harbours and oil and gas infrastructure, while some are also known from natural habitats such as rocky shores and beaches. **Ports and harbours** support the highest number of marine alien species and as such are the most invaded habitats (Robinson, unpublished data). This is attributed to the fact that harbours are the points of entry for the shipping and recreational boating industry, and as a result they act as recipients of alien species. Additionally, these areas are sheltered from the wave-exposed nature of the South African coastline (Peters *et al.* 2014, 2017, Peters and Robinson 2017) and offer a refuge for alien biota. Unfortunately, few studies have systematically addressed the **impact** of marine alien species in South Africa, with only a small proportion of marine alien species having been assessed (Alexander *et al.* 2016). Furthermore, marine alien species are spread among local harbours by the intra-regional movement of small vessels (Peters *et al.* 2017). Although most marine alien species have been reported from harbours, it is important to note that more surveys need to be conducted in other habitats and ecosystem types as ecosystem types beyond the shore are currently under-surveyed for alien species.

Table 15: The list of 96 marine alien and invasive species recorded along the coastline of South Africa. Adapted from (Chavanich 2006, Gallagher et al. 2015, Robinson *et al.* 2016, Peters and Robinson 2017, 2018, Picker and Griffiths 2017, Greenan *et al.* 2018, Griffiths 2018, Griffiths *et al.* 2018).

Phylum	Class	Taxon	Status	Common name	Natural Range
ANNELIDA	Polychaeta	*Dodecaceria fewkesi*	Alien	Black Coral Worm	Pacific Northern America
ANNELIDA	Polychaeta	*Janua pagenstecheri*	Alien		Europe
ANNELIDA	Polychaeta	*Polydora websteri*	Alien	Oyster Mudworm	
ANNELIDA	Polychaeta	*Simplaria pseudomilitaris*	Alien		Europe
ANNELIDA	Polychaeta	*Alitta succinea*	Invasive	Pile Worm or Clam Worm	Atlantic coast
ANNELIDA	Polychaeta	*Boccardia proboscidea*	Invasive	Shell Worm	Northern Pacific
ANNELIDA	Polychaeta	*Ficopomatus enigmaticus*	Invasive	Estuarine Tubeworm	Undetermined
ANNELIDA	Polychaeta	*Neodexiospira brasiliensis*	Invasive	Estuarine Tubeworm	West Indies, Brazil
ANNELIDA	Polychaeta	*Polydora hoplura*	Invasive	Mud Worm	Europe, Mediterranean
ARTHROPODA	Hexanauplia	*Perforatus*	Alien	Acorn Barnacle	
ARTHROPODA	Insecta	*Anisolabis maritima*	Alien	Maritime Earwig	Asia
ARTHROPODA	Malacostraca	*Homalaspis plana*	Alien	Chilean Stone Crab	Chile
ARTHROPODA	Malacostraca	*Ligia (Megaligia) exotica*	Alien	Sea Roach or Wharf Roach	
ARTHROPODA	Malacostraca	*Caprella mutica*	Invasive	Japanese Skeleton Shrimp	north-east Asia
ARTHROPODA	Malacostraca	*Porcellana africana*	Invasive	Porcelain Crab	NW Africa between Western Sahara and Senegal
BRACHIOPODA	Lingulata	*Discinisca tenuis*	Invasive	Disc Lamp Shell	Namibian Coast
BRYOZOA	Gymnolaemata	*Bugula neritina*	Invasive	Purple Dentate Moss Animal	
BRYOZOA	Gymnolaemata	*Bugulina flabellata*	Invasive		
BRYOZOA	Gymnolaemata	*Conopeum seurati*	Invasive		Europe
BRYOZOA	Gymnolaemata	*Cryptosula pallasiana*	Invasive		Europe
BRYOZOA	Gymnolaemata	*Virididentula dentata*	Invasive	Blue Dentate Moss Animal	Indo-Pacific
BRYOZOA	Gymnolaemata	*Watersipora subtorquata*	Invasive	Red-rust Bryozoan	Caribbean
CHLOROPHYTA	Ulvophyceae	*Cladophora prolifera*	Invasive		
CHLOROPHYTA	Ulvophyceae	*Codium fragile*	Invasive	Green Sea Fingers	Korea
CHORDATA	Actinopterygii	*Cyprinus carpio*	Invasive	Common Carp	Eastern Europe, Asia
CHORDATA	Ascidiacea	*Ascidia sydneiensis*	Invasive	Crevice Ascidian	Asia
CHORDATA	Ascidiacea	*Ascidiella aspersa*	Invasive	Dirty Sea Squirt	North Sea
CHORDATA	Ascidiacea	*Botryllus schlosseri*	Invasive	Star Sea Squirt	Northeastern Atlantic
CHORDATA	Ascidiacea	*Ciona robusta*	Invasive	Solitary Tunicate	Undetermined
CHORDATA	Ascidiacea	*Clavelina lepadiformis*	Invasive	Light-bulb Sea Squirt	Europe
CHORDATA	Ascidiacea	*Cnemidocarpa humilis*	Invasive	Leathery Sea Squirt	
CHORDATA	Ascidiacea	*Diplosoma listerianum*	Invasive	Jelly Crust Tunicate	Europe
CHORDATA	Ascidiacea	*Microcosmus squamiger*	Invasive	Blunt-spined Microcosmus	Australia
CHORDATA	Ascidiacea	*Styela plicata*	Invasive	Pleated Sea Squirt	West Pacific
CILIOPHORA	Heterotrichea	*Mirofolliculina limnoriae*	Alien		
CNIDARIA	Anthozoa	*Metridium senile*	Alien	Plumose Anemone	North Atlantic
CNIDARIA	Anthozoa	*Sagartia ornata*	Alien	Brooding Anemone	Europe, Mediterranean
CNIDARIA	Hydrozoa	*Ectopleura crocea*	Alien	Pink-mouthed Hydroid	North Atlantic coast of North America
CNIDARIA	Hydrozoa	*Ectopleura larynx*	Alien	Ringed Tubularia	North Atlantic
CNIDARIA	Hydrozoa	*Gonothyraea loveni*	Alien		North Atlantic
CNIDARIA	Hydrozoa	*Laomedea calceolifera*	Alien		North Atlantic
CNIDARIA	Hydrozoa	*Obelia bidentata*	Alien	Doubled-toothed Hydroid	
CNIDARIA	Hydrozoa	*Obelia dichotoma*	Alien	Sea Plume	
CNIDARIA	Hydrozoa	*Obelia geniculata*	Alien	Zigzag Hydroid	Europe, Mediterranean
CNIDARIA	Hydrozoa	*Pachycordyle navis*	Alien	Brackish Hydroid	Europe, Mediterranean
CNIDARIA	Hydrozoa	*Coryne eximia*	Invasive		North Atlantic, Pacific

Phylum	Class	Taxon	Status	Common name	Natural Range
CNIDARIA	Hydrozoa	*Odessia maeotica*	Invasive		Black sea region
CNIDARIA	Hydrozoa	*Pennaria disticha*	Invasive	Sea Fern Hydroid	
CRUSTACEA	Amphipoda	*Apocorophium acutum*	Alien	Tube-building Amphipod	Northern Atlantic
CRUSTACEA	Amphipoda	*Ericthonius difformis*	Alien		
CRUSTACEA	Amphipoda	*Jassa marmorata*	Alien		Northern Atlantic
CRUSTACEA	Amphipoda	*Monocorophium acherusicum*	Alien	Stout-antenna Amphipod	Northern Atlantic
CRUSTACEA	Cirripedia	*Austrominius modestus*	Alien	Australian Barnacle	Australasia
CRUSTACEA	Copepoda	*Acartia (Odontacartia) spinicauda*	Alien		South East Asia
CRUSTACEA	Decapoda	*Xantho incisus*	Alien	Black Fingered Crab	Europe, Mediterranean
CRUSTACEA	Isopoda	*Limnoria quadripunctata*	Alien	Quadripunctate Gribble	
CRUSTACEA	Isopoda	*Limnoria tripunctata*	Alien	Gribble	
CRUSTACEA	Isopoda	*Paracerceis sculpta*	Alien	Sponge Isopod	North-east Pacific
CRUSTACEA	Isopoda	*Sphaeroma serratum*	Alien	Sea Slater	Europe
CRUSTACEA	Isopoda	*Sphaeroma walkeri*	Alien	Pill Isopod	Northern Indian Ocean
CRUSTACEA	Pycnogonida	*Ammothella appendiculata*	Alien		Pacific
CRUSTACEA	Amphipoda	*Cerapus tubularis*	Invasive		
CRUSTACEA	Amphipoda	*Chelura terebrans*	Invasive	Wood-boring Amphipod	Northern Atlantic
CRUSTACEA	Amphipoda	*Ericthonius brasiliensis*	Invasive		Northern Atlantic
CRUSTACEA	Amphipoda	*Ischyrocerus anguipes*	Invasive		Northern Atlantic
CRUSTACEA	Amphipoda	*Jassa morinoi*	Invasive		
CRUSTACEA	Amphipoda	*Jassa slatteryi*	Invasive		Pacific Northern America
CRUSTACEA	Amphipoda	*Orchestia gammarellus*	Invasive	Beach Hopper	Europe, Mediterranean
CRUSTACEA	Amphipoda	*Platorchestia platensis*	Invasive	Beach Flea	
CRUSTACEA	Cirripedia	*Amphibalanus venustus*	Invasive		Tropical Northern Atlantic
CRUSTACEA	Cirripedia	*Balanus glandula*	Invasive	Pacific Barnacle	Northern American Pacific
CRUSTACEA	Decapoda	*Carcinus maenas*	Invasive	European Shore Crab	Europe, Mediterranean
CRUSTACEA	Decapoda	*Pinnixa occidentalis*	Invasive	Pea Crab	Pacific Northern America
CRUSTACEA	Isopoda	*Dynamene bidentata*	Invasive	Horned Isopod	Europe
DINOFLAGELLATA	Dinophyceae	*Alexandrium minutum*	Alien		
DINOFLAGELLATA	Dinophyceae	*Alexandrium tamarense-complex*	Alien		
DINOFLAGELLATA	Dinophyceae	*Dinophysis acuminata*	Alien		
ECHINODERMATA	Asteroidea	*Heliaster helianthus*	Alien	South American Multiradiate Sunstar	Chile
ECHINODERMATA	Ophiuroidea	*Ophiactis savignyi*	Alien	Savigny's Brittle Star	North Indian and Pacific oceans
INSECTA	Coleoptera	*Cafius xantholoma*	Invasive		Europe
MOLLUSCA	Bivalvia	*Lyrodus pedicellatus*	Alien	Blacktip Shipworm	
MOLLUSCA	Bivalvia	*Perna viridis*	Alien	Asian Green Mussel	South East Asia
MOLLUSCA	Gastropoda	*Catriona columbiana*	Alien	British Columbia Aeolid	North Pacific
MOLLUSCA	Bivalvia	*Crassostrea gigas*	Invasive	Japanese Oyster	Japan, Northwestern Pacific
MOLLUSCA	Bivalvia	*Mytilus galloprovincialis*	Invasive	Mediterranean Mussel	Mediterranean, Northeastern Atlantic
MOLLUSCA	Bivalvia	*Semimytilus algosus*	Invasive	Bisexual Mussel	Pacific South America
MOLLUSCA	Bivalvia	*Teredo navalis*	Invasive	Ship Worm	Europe, Mediterranean
MOLLUSCA	Gastropoda	*Littorina saxatilis*	Invasive	Lagoon Snail	Europe, Mediterranean, Western Atlantic
MOLLUSCA	Gastropoda	*Tarebia granifera*	Invasive	Quilted Melania	South East Asia
MOLLUSCA	Gastropoda	*Thais blanfordi*	Invasive	Blandford's Whelk	Tropical Indo-Pacific
MOLLUSCA	Gastropoda	*Thais tissoti*	Invasive	Tissot's Rock Shell	Tropical Indo-Pacific
PORIFERA	Demospongiae	*Suberites ficus*	Invasive	Sulphur Sponge	Northeastern Atlantic and Mediterranean
RHODOPHYTA	Florideophyceae	*Schimmelmannia elegans*	Alien		Atlantic island of Tristan da Cunha and Venezuela
RHODOPHYTA	Florideophyceae	*Antithamnionella spirographidis*	Invasive		
RHODOPHYTA	Florideophyceae	*Asparagopsis armata*	Invasive	Red Harpoon	Southern Australia and New Zealand
RHODOPHYTA	Florideophyceae	*Asparagopsis taxiformis*	Invasive		

5.2 Pathways and Vectors

In biological invasions, introduction pathways are described as the processes by which alien species are introduced to geographical locations outside of their natural range (Richardson *et al.* 2010). A vector is the physical means or agent by which a species is transported, this includes the spread of diseases, parasites or pathogens, e.g. introduction of diseases from non-native individuals to native populations (Carlton 2001). However, in this section the terms pathway and vector will be used interchangeably to mean the ways in which alien species are spread both internationally and regionally. The most prominent pathways for alien species introduction in South Africa are shipping via biofouling and ballast water, and marine aquaculture of non-native species (Mead *et al.* 2011d).

5.2.1 Shipping

Shipping plays a major role in world trade, carrying approximately 90% of internationally traded goods, and therefore is one of the primary sources of introduced marine species globally (Lord *et al.* 2015, Lacoursière-Roussel *et al.* 2016, Faulkner *et al.* 2017). In Canadian ports, for example, the diversity of alien fouling species was attributed to shipping activity - implying that this vector is important in translocation of alien species (Lacoursière-Roussel *et al.* 2016). Furthermore, the genetic diversity of alien species recorded in these ports was also found to be linked to the high shipping traffic (Lacoursière-Roussel *et al.* 2016), demonstrating the important role that shipping plays in marine invasions. Ballast water and biofouling are by far the major vectors for the transfer and spread of alien species via shipping (Carlton 1985, Ruiz *et al.* 2000a, Bax *et al.* 2002, Griffiths *et al.* 2009, Ruiz *et al.* 2011, Peters *et al.* 2014). See Box 24 for examples of transport of mining infrastructure contributing to the transport of alien species.



A fouling assemblage within a ship as seen at the Cape Town dry dock. Photo by De Beers.

5.2.2 Biofouling

Biofouling is the accumulation of organisms on surfaces and structures immersed in or exposed to the aquatic environment and as such plays a key part in the transfer and spread of marine alien species (Minchin *et al.* 2006, Hewitt *et al.* 2009). Harbours are known foci of marine alien fouling species (López-Legentil *et al.* 2015, Peters *et al.* 2017) and due to the presence of numerous **pathways and vectors** associated with harbours, alien fouling species can be transferred among them. International and local vessels are often fouled with marine alien species and the movement of these vessels facilitates transfer of species in biofouling assemblages from one port/harbour/marina (Minchin *et al.* 2006) to another (Minchin *et al.* 2006). Biofouling threatens marine aquaculture production, as fouling growth on farmed species and infrastructure results in increased maintenance costs and reduced product value (Campbell and Kelly 2002, Minchin 2007). Previously, a lot of focus has been placed on fouling of large, international vessels due to their role in primary marine introductions (Davidson *et al.* 2009, Lacoursière-Roussel *et al.* 2016). Smaller recreational vessels such as fishing boats, yachts and tour boats have been overlooked. However, recreational boating is being increasingly recognised

as an important pathway for the intra-regional transfer of marine alien species (Davidson *et al.* 2010, Clarke Murray *et al.* 2011, Brine *et al.* 2013). Yachts have been highlighted as having high potential for the regional spread of marine alien species (Murray *et al.* 2013, Zabin 2014, Davidson *et al.* 2016a) as they have long layover times in harbours or marinas, are slow-moving and tend to travel amongst marinas (Peters *et al.* 2017).

In South Africa, a total of 20 alien fouling species was recorded on **yachts** from four marinas; Port Owen, Saldanha Bay, Royal Cape and False Bay Yacht Clubs, in the Western Cape (Peters *et al.* 2019). Niche areas, such as the rudder, keel, propeller shaft and water inlets were often fouled with alien species, even on yachts that appeared to be free of fouling from the surface. It is therefore important to consider both the hulls and niche areas when monitoring alien species on yachts. Another indication pointing towards the potential role of yachts in intra-regional transfer included the detection of a new alien species to South Africa, found only on yachts. The **Japanese Skeleton Shrimp** *Caprella mutica*, was detected on several yachts in False Bay Yacht Club and Saldanha Bay Yacht Club, but was not detected on adjacent harbour infrastructure (Peters and Robinson 2017). Since then, *C. mutica* was detected on yachts in Royal Cape Yacht Club, situated between the two already invaded marinas (Robinson *et al.* unpublished data). The detection of *C. mutica* on yachts across multiple marinas and their absence on adjacent harbour infrastructure, highlights the potential for yachts to spread alien fouling species within South Africa. These findings hold important implications as recreational vessels are able to travel freely among marinas, which are often adjacent to larger ports or housed within ports, and are also able to travel to pristine locations within marine protected areas (Campbell and Hewitt 2013), posing a high risk of introduction to these protected habitats.

5.2.3 Ballast Water

Ballast water is water that is stored in the ballast tank or cargo hold of a ship in order to stabilise the ship's movement during voyage when it is not carrying cargo. This water is usually taken onboard a ship from one geographical area and discharged in another, introducing new species to regions they do not naturally occur in (Pierce *et al.* 1997, Ruiz *et al.* 2000b, David and Perkovič 2004, Albert *et al.* 2013). Ballast water is regarded as the **major vector** for marine alien species (Anil *et al.* 2003, Awad *et al.* 2003, Salgado-Barragán and Toledano-Granados 2006, Loebmann *et al.* 2009, Miller *et al.* 2011, Werschkun *et al.* 2014, Cohen and Dobbs 2015). In South Africa, several species are thought to have been introduced through ballast water (Mead *et al.* 2011d). The International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO 2004), which entered into force in September 2017, offers the first international tool for managing this global vector. The efficacy there of will, however, depend on its implementation, a process which is facing a variety of technical and administrative challenges.

5.2.4 Marine Aquaculture

In South Africa, a number of aquaculture facilities farm introduced species that are preferable to native species because of their higher economic value (Bax *et al.* 2003), their resilience in long journeys outside of water (e.g. oysters), and their ability to adapt to complex environments (Haupt *et al.* 2010a). Imported, introduced species' **spat or live species** have the potential to bring hitchhiking parasites and other introduced species (McKindsey *et al.* 2007, Rocha *et al.* 2009a, Haupt *et al.* 2010a, Muehlbauer *et al.* 2014, Bolton *et al.* 2016b, Davidson *et al.* 2016a). In a recent study, (Bolton *et al.* 2016a) describe the introduction of two invasive ***Grateloupia*** **macroalgae species** through imported oysters farmed in Saldanha Bay, the economic impacts of which are not yet quantified. Currently,

South Africa has nine operational shellfish farms that grow non-native oysters and mussels, *Magallana gigas* (formerly *Crassostrea gigas*) and *Mytilus galloprovincialis* (invasive) respectively (Figure 68).

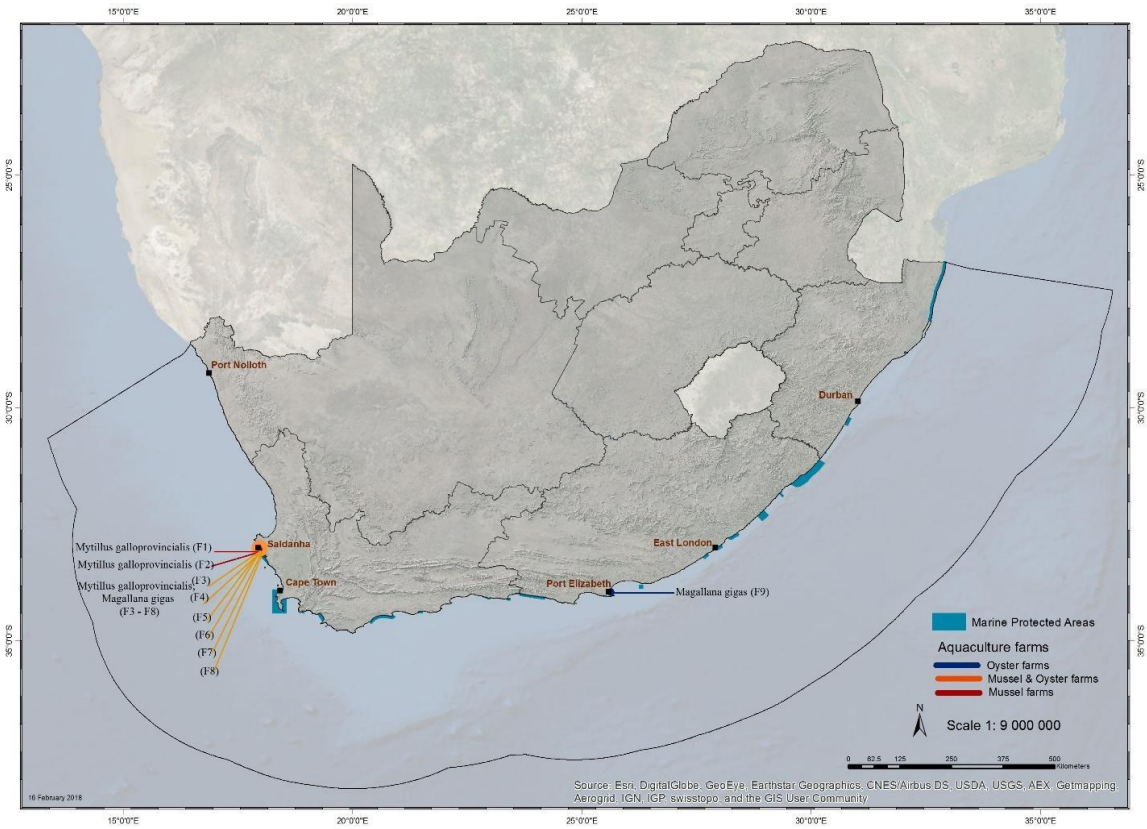


Figure 68: Map showing the location of shellfish aquaculture facilities that farm marine alien and invasive species within South Africa.

An emerging pathway that is receiving research attention for the first time in South Africa is the **aquarium trade** (Box 23). Further research and monitoring of pathways and vectors for marine and coastal alien and invasive species is required to inform monitoring and management programs.

Box 23. Aquarium trade as a vector of species introductions

By Sinothando Shibe

The trade of live marine animals for home and public aquaria has grown into a major global industry. Millions of marine fishes and invertebrates are removed from coral reefs and associated habitats each year to supply this sector (Rhyne *et al.* 2012, 2017). The aquarium trade, which involves hobbyists, pet shops, the ornamental species industry, aquarists and public aquariums, includes the buying and selling of aquatic organisms regionally and internationally; an estimated 30 million tropical reef fishes are supplied by 76 countries annually in a worldwide trade (Bruckner 2005, Rhyne *et al.* 2012, 2017). This trade has a long history of transporting and introducing marine and freshwater species into non-native areas thus being recognized as an important pathway for alien and invasive species (Cohen *et al.* 2007) but has received minimal research (Semmens *et al.* 2004) and management attention and as a result there are few control measures in place (Rhyne *et al.* 2012, 2017). In the United States alone, more than 11 million people keep marine animals as a hobby (hobbyists) while worldwide, the aquarium and ornamental species industry is worth $25 billion per year with most of the species being readily available over the internet (Padilla and Williams 2004). In the Pacific Northwest, it is reported that pet shops alone import thousands of fish monthly of which 58% are considered to have negative impacts on the natural environment (Strecker *et al.* 2011). **A third of the aquatic species that are listed on the IUCN Invasive Species Specialist Group list of the 100 worst invasive species were introduced via ornamental or aquarium releases** (Padilla and Williams 2004). In addition, as a result of the ornamental and aquarium trade, 150 species of microbes, invertebrates and vertebrates have been reported to invade natural ecosystems (Padilla and Williams 2004). These species are introduced into the environment through the release of untreated water and unwanted animals (Strecker *et al.* 2011), incidental escapes from tanks and breeding farms during adverse weather conditions such as storms, and sometimes intentional release during religious practices (Padilla and Williams 2004). Some studies have shown that most pet shop owners who distribute aquatic animals are not familiar with the concept of alien and invasive species (Martin and Coetzee 2011), and may unknowingly import and sell potentially invasive species. This highlights one of the challenges in preventing introductions of invasive species through the aquarium trade (Padilla and Williams 2004) because the industry is highly unregulated (Cohen *et al.* 2007, Hoveka *et al.* 2016). Hoveka *et al.* (2016) found that a proportion of the aquarium plants sold in Johannesburg are listed as prohibited alien and invasive species, while in the United States every aquatic plant that is considered harmful is readily available over the internet (Padilla and Williams 2004). Some of the effects that released ornamental or aquarium species have include displacing native species, carrying pathogens, clogging waterways and some are a direct health hazard to humans (Padilla and Williams 2004).

5.3 Impacts

Biological invasions are one of the direct drivers of biodiversity loss and a major pressure on the functioning of ecosystems. Alien species have the potential to displace native species, cause the loss of native genotypes, modify habitats, change community structure, affect food web properties and ecosystem processes, impede the provision of ecosystem services, impact human health and cause substantial economic losses (Katsanevakis *et al.* 2014).

5.3.1 Ecological impacts



The invasive Pacific barnacle, Balanus glandula, has had widespread ecological impacts ©Charles Griffiths.

The ecological impacts of an alien species can be complex and occur as a result of changes to local biodiversity and/or alteration of ecological processes. While the initial impacts could be minor and near-invisible, as the alien population increases through time, the impacts are likely to increase (Bax *et al.* 2002) and can range in severity from minimal to massive (Blackburn *et al.* 2014). The magnitude of the impact ranges from weakened individual fitness of a single native species, to an entire population decline and/or extinction, changes in community structure, and effects on entire ecosystem function (Katsanevakis *et al.* 2016). Few studies have systematically addressed the impact of marine alien species in South Africa, with only a limited number of marine alien species having been assessed (Alexander *et al.* 2016). Species that display substantial impacts include the Mediterranean Mussel ***Mytilus galloprovincialis***, the Chilean Mussel ***Semimytilus algosus*** and the Pacific Barnacle ***Balanus glandula***. All three of these species have become abundant and widespread along the coastline, occurring in both artificial and in wave-exposed rocky shore habitats along the west coast, ultimately altering intertidal community structure and causing changes in habitat complexity (Branch *et al.* 2010, Sadchatheeswaran *et al.* 2015, 2018).

The Mediterranean Mussel ***M. galloprovincialis***, originates from the north-eastern Atlantic and occupies the intertidal rocky shores on the west coast of South Africa. On the south coast, *M. galloprovincialis* establishes mixed beds with the indigenous Brown Mussel *Perna perna* (Bownes and McQuaid 2006). *M. galloprovincialis* forms dense, multi-layered beds that monopolise space on intertidal rocks. This species displaces indigenous mussels such as the Ribbed Mussel, *Aulacomaya atra* (Branch and Steffani 2004, Branch *et al.* 2008) and limpets such as the Granular Limpet *Scutellastra granularis* (Griffiths *et al.* 1992, Hockey and van Erkom Schurink 1992), although smaller limpet species flourish within the beds (Hanekom and Nel 2002). On exposed shores, *M. galloprovincialis* displaces the native limpet *Scutellastra argenvillei* but this effect is moderated on semi-exposed shores (Steffani and Branch 2003).

The Pacific Barnacle sector (Box 18).was recorded over more than 400 km of coastline between Elands Bay and Misty Cliffs near Cape Point (Laird and Griffiths 2008). However, it has recently been reported to have extended its range by 150 km and has spread beyond what was thought to be the Cape Point boundary to Dalebrook (50 km) in the south, and from Elands Bay to Lamberts Bay in the north (100 km) (Robinson *et al.* 2015). *B. glandula* has reportedly displaced populations of the indigenous and formerly abundant *Cthalamus dentatus* species which is now rare on South African west coast shores (Laird and Griffiths 2008). This species has also been associated with changes in community structure on invaded shores (Sadchatheeswaran *et al.* 2015, 2018).

The Sea Vase Ascidian ***Ciona robusta***, formerly known as *Ciona intestinalis* (Brunetti *et al.* 2015), is the only ascidian species for which impact has been assessed locally. This species occurs in harbours and aquaculture facilities along the entire coast where it is a prominent fouling organism (Mead *et al.*

2011d). Whilst no ecological impact was detected on local fouling communities (Robinson *et al.* 2017), international studies have reported impacts, especially in aquaculture farms (Carver *et al.* 2003). As such, it is expected that the impact of *C. robusta* in the South African context is likely to be abundance-related (Robinson *et al.* 2017), as substantially high densities of *C. robusta* have been reported to negatively impact species richness of sessile communities (Blum *et al.* 2007).

The mussel ***S. algosus,*** native to Chile, has shown negative impacts on indigenous mussels on the South African west coast. This is seen in the absence of the native mussels *Alacomya ater* and *Choromytilus meridionalis* from the intertidal rock and wave-exposed sites on the west coast as it occupies the lower shore (de Greef *et al.* 2013). Additionally, *S. algosus* has reduced the available space for the native limpet *S. granularis* on the shore and because the shell size of *S. algosus* is too small the limpets are unable to attach epifaunally as is the case with *M. galloprovincialis* (de Greef *et al.* 2013, Sadchatheeswaran *et al.* 2015, 2018).

5.3.2 Economic Impacts

Economic impacts of marine alien and invasive species are mostly attributed to **biofouling** and are mainly felt by the shipping industry, but can affect aquaculture facilities and other sectors that require water inlet and outlet pipes. Biofouling can either occur on infrastructure (e.g. in Koeberg Power Station in Cape Town, water cooling system pipes get blocked by the Mediterranean mussel, *M. galloprovincialis*) (T. Robinson, Stellenbosch University, pers. obs.) or on other species (Haupt *et al.* 2012). Fouling of other species is particularly problematic when they are the target of mariculture operations (Wallentinus and Nyberg 2007, Katsanevakis *et al.* 2014, Desher 2018). Under these conditions, biofouling increases the cost of maintenance of facilities and can lead to loss of economic opportunity as cultured individuals that are covered in biofouling species do not achieve the same selling price as unaffected individuals. Additionally, biofouling species can compete for food with target species and thus impede growth and reduce survivorship of cultured species (Watson *et al.* 2009). On a ship's hull, biofouling increases the hydrodynamic drag and lowers the vessel's ability to move easily, thus leading to increased fuel consumption and subsequently increases the shipping industry's costs through increased manpower, fuel, material and dry docking time (Chambers *et al.* 2006).

Box 24. The oil and gas industry as a vector of species introductions

By Sinothando Shibe

Oil and gas infrastructure includes floating oil platforms which are submersible drilling rig, semi-submersible drilling rigs, jack-up drilling rigs, floating production storage offloading systems, and drill barges (Yeo *et al.* 2009). Worldwide, the estimated number of offshore infrastructure units is 7000 (Page *et al.* 2006) of which about 900 are floating oil platforms in service, including 6 submersible drilling rigs, 186 semi-submersible drilling rigs, 451 jack-up drilling rigs, 163 floating production storage offloading systems, and 94 drill barges (Yeo *et al.* 2009).



Oil Platforms form a substrate for the attachment of species and are a vector of species introductions

With the expansion of marine oil and gas exploration there is a potential risk posed by the translocation of alien and invasive species across bio-geographical boundaries through oil and gas infrastructure (Yeo *et al.* 2009, Sink *et al.* 2010, Wanless *et al.* 2010). These structures are amongst the largest artificial structures in the marine environment (Page *et al.* 2006) and they can play a role in the introduction and range expansion of alien and invasive species. Additionally, they can act as corridors that link previously unconnected areas therefore acting as pathways for the spread of alien and invasive species (Sheehy and Vik 2010). These species could colonise infrastructure as early as the construction stage, staying on while the infrastructure is being towed to its deployment position. Oil and gas infrastructure can be colonised throughout its lifespan (Foster and Willan 1979) and because it is stationary, provides alien and invasive species with enough time to establish and potentially spread (Yeo *et al.* 2009).

In Singapore, a semi-submersible oil platform surveyed in a dry dock was found to harbour 25 species of decapods of which 13 were identified as alien and were new records to Singaporean waters - two of the 13 alien species had been reported as invasive in other parts of the world (Yeo *et al.* 2009). In South Africa, two introduced ascidians, two introduced and invasive anemones and the Mediterranean Mussel *Mytilus galloprovincialis* were recorded on oil platforms together with other unidentified species which are suspected introduced species (Sink *et al.* 2010). The colonization of oil and gas platforms by alien and invasive species has implications for platform decommissioning. The removal and relocation of oil and gas platforms could potentially aid in the transportation and dispersal of alien species (Page *et al.* 2006, Yeo *et al.* 2009, Sink *et al.* 2010), as evidenced by the transport of 62 alien taxa on an oil rig into a sensitive island environment at Tristan da Cunha after it had been left stranded due to towing difficulties *en route* to Brazil (Wanless *et al.* 2010).

5.4 Genetic work on marine alien species

Molecular techniques have proved useful in clarifying the identity of species thought to either be cryptic or cosmopolitan. For example, a molecular study in South Africa that aimed to verify the invasive status of six bryozoan species (*Watersipora subtorquata*, *Bugula neritina*, *Bugulina flabellata*, *Virididentula dentata*, *Conopeum seurati* and *Cryptosula pallasiana*) found that only three of these species (i.e. *B. neritina*, *B. flabellata* and *W. subtorquata*) were alien (Taft 2015). For *V. dentata* and *C. pallasiana* it is thought that they were described using historical descriptions, while there were uncertainties regarding *C. seurati*. Micklem *et al.* (2016) found that the green shelled mussel that was previously misidentified as the native *Perna perna* was actually the Asian Green Mussel*, Perna viridis.* This mussel was found to only occur in Durban harbour but due to the impacts seen in other parts of the world where this species has been introduced, it is feared that it will spread to the open coast and compete with the native *P. perna* (Micklem *et al.* 2016). In North and South America and some eastern Asian countries, *P. viridis* is thought to have been introduced to parts where it did not naturally occur

via aquaculture, ship fouling and ballast water, and is posing an ecological threat to native species (Micklem *et al.* 2016).

Additionally, there has been growing interest in the use of **environmental DNA** (eDNA) (Dougherty *et al.* 2016, Clusa *et al.* 2017, Mauvisseau *et al.* 2018) to detect the presence of invasive species in aquatic environments (Ficetola *et al.* 2008, Balasingham *et al.* 2018). eDNA surveys are considered an increasingly important tool for assessing biodiversity and, in particular, invasive species monitoring as they provide high levels of resolution and sensitivity (Holman *et al.* 2018), although this is only possible for species that are already pre-identified from existing sequences. For example, an international study used eDNA to perform a comprehensive study of the microbiology associated with ballast water and its potential to introduce pathogens and other threats to human health using water samples from major ports, including South African ports (Gerhard and Gunsch 2019). From their results, they were able to detect bacteria contained in the ballast water at both phylum and class levels.

5.5 Management of Marine Alien and Invasive Species in South Africa

The NBA 2011 recommended the prevention of introductions of alien species through strengthening of the Alien and Invasive Species Regulations and ensuring that all the relevant alien marine species are listed. Currently, 21 invasive invertebrates, four algal species and 12 other prohibited alien and invasive species have been **listed**. South Africa, as a signatory to the Law of the Sea Convention, is required to take steps to prevent and reduce the intentional or accidental introduction of alien species which could cause harmful changes to the marine environment. The Aichi Target 9, as stipulated in the Convention on Biological Diversity, aims for "invasive alien species and pathways to be identified and prioritised, priority species to be controlled or eradicated and measures to be in place to manage pathways to prevent their introduction and establishment" by 2020.

Management measures can be applied at various points in the process of invasion, starting from prevention, early detection and rapid response to eradication, containment and long-term control (see Box 25 for the outcomes of the first management attempts of marine alien species). Prevention is recognised as the most cost-effective and environmentally desirable option and should be given priority in any Invasive Alien Species management strategy. **Prevention** requires a focus on the management of the pathways of introduction of alien species. In the case of marine species, key pathways include shipping, boating, canals, floating marine debris, equipment (e.g. diving and fishing gear), fisheries and aquaculture, the aquarium industry and the import of specimens for research purposes. Preventive measures depend on whether the alien species are being deliberately introduced (e.g. for aquaculture purposes) or whether they are accidentally introduced (e.g. as "hitchhikers" in ship ballast water or on ship hulls).

The **South African Status Report on Biological Invasions** (Van Wilgen and Wilson 2017) states that both ballast water and hull fouling are moderate in terms of pathway prominence, although it is likely that they – together with aquaculture - are the major pathways for marine alien species. With respect to ballast water, South Africa is a Party to the International Convention for the Control and Management of Ships' Ballast Water and Sediments (commonly known as the Ballast Water Management Convention) (IMO 2004) whose purpose is to regulate and control the discharge of ballast water and sediments into the marine ecosystem. The **Ballast Water Management Convention** came into force in September 2017 and South Africa is in the process of finalising legislation which will bring its provisions into force domestically.

The objectives of the proposed legislation include:

- Minimise or prevent harmful impacts by invasive species on the biological diversity within South African waters;
- Minimise or prevent harmful impacts by invasive species on the environment, human health, property or resources of South Africa;
- Provide for cooperative governance in both the management of alien and invasive species introduced by ship's ballast water and the conservation of biological diversity; and
- Meet South Africa's obligations in terms of the Convention.

The **Ballast Water Bill** sets out how ballast water is to be discharged, but specifies that these requirements are not applicable in emergency situations or when ballast water is discharged as a result of a collision. All ships are expected to have a ballast water management plan and to keep an up-to-date ballast water record book. Vessels constructed after 2009 are required to be designed so that accumulation of sediment is prevented and removal of sediment is facilitated (Department of Transport 2003). At present, there is no international agreement on biofouling although the Marine Environment Protection Committee of the IMO adopted Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (2011). Recently, South Africa has initiated the issuing of permits for in-water hull cleaning as a means to curb the introduction and establishment of marine alien species via hull-fouling for large vessels (Arnoldi 2019).

Intentional introductions are currently managed through a permitting system with a number of Acts and regulations being pertinent to the introduction of marine alien species. These include the Biodiversity Act and the associated **Alien and Invasive Species (AIS) regulations**, as well as the Marine Living Resources Act (MLRA) and its regulations. The AIS Regulations regulate the importation of alien species in general, while the MLRA contains provisions for the issuing of permits for aquaculture. The MLRA regulations require that: "if imported species are being considered, the measures to be taken to avoid introduction of exotic commensals, parasites and pathogens, and measures to be taken to avoid establishment of introduced species in the wild, shall be stated." However, Cochrane *et al.* (2015) note that the MLRA fails to include any provisions to control the introduction of alien species or assess their impact on the ecosystem where they could have been legally or illegally introduced. These authors recommend that such shortfalls are addressed through amendments to the MLRA and other relevant policies and legislation; however, import permits under NEMBA are approved subject to risk assessments and/or whether the species concerned is listed in terms of the regulations. See Box 26 for a brief explanation of the risk assessment framework used in South Africa.

Early detection measures include border inspections and monitoring of key points of entry of marine alien species including ports and harbours, and aquaculture facilities farming alien species. Although border controls are in place, environmental monitoring is limited. Moreover, although discussions have been held around a **reporting and rapid response system** for marine bioinvasions, no formal system has been put in place and no long-term management plans are in place for marine species.

5.6 Recommendations

The increasing number of marine alien species creates an urgent need for the **routine monitoring** of key points of entry of these species and their vectors, e.g. ports and harbours, and shipping respectively. This will enable the **early detection** of marine alien species, and up-to-date knowledge on their status in our waters. An in-depth study should be undertaken to assess the pathways for marine aliens and identify priorities for regulation. Current information suggests that biofouling

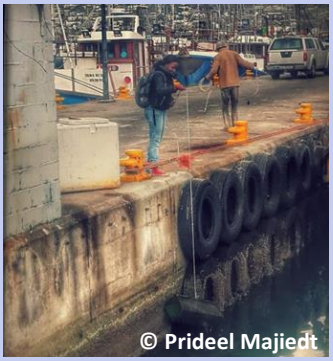
should be regarded as a priority. Impacts of marine alien species are not well understood, and as a result it is important to strengthen research efforts in order to improve this knowledge and prioritise action where negative socio-economic or ecological impacts are likely.

Box 25. Outcomes of the first management efforts for marine alien species in South Africa

The first attempts at management of marine alien and invasive species in South Africa were undertaken between 2013 and 2016. Of the four marine plants, and sixteen marine invertebrates listed in the alien and invasive species regulations published in 2014 (RSA 2014), only two were identified for management intervention. These were the **Chilean Black Urchin** (*Tetrapygus niger*) and the **Mediterranean Green Crab** (*Carcinus maenas).*

T. niger is believed to have been unintentionally introduced to Alexander Bay on the West Coast of South Africa with oyster spat imported for aquaculture and was first found in oyster dams in 2007 (Haupt *et al.* 2010). The major concern regarding this species was its potential to create urchin barrens along the South African coastline should it escape (Mabin *et al.* 2015). A resurvey of the aquaculture farm undertaken in 2014 found that those dams where *T. niger* was recorded were no longer in operation, having either dried up completely or had become hypersaline, thus no longer supporting any live specimens of the urchin. Surveys of the adjacent intertidal habitat found no evidence for the presence of the alien urchin, indicating that this species in no longer present in South Africa. It is therefore recommended that this species be delisted from the regulations (Mabin *et al.* 2015).


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The management efforts for *C. meanus*, which involved a two year investigation into the potential for effective eradication of this species from Hout Bay harbour (Mabin 2017), were less favourable. Mabin *et al.* (2017) found that due to inability to eradicate the crab from Hout Bay harbour combined with the high cost of the management intervention, the feasibility of effective eradication of *C. meanus* from South African waters was unlikely. When considered with the environmental factors limiting the spread of *C. meanus* and the lack of reported local biodiversity impacts of the species, it was found that further effort to control or eradicate this species would not be an effective or efficient use of resources. However, monitoring and rapid response should be implemented to ensure that if these components show change, effective management intervention can be applied.

A protocol for reporting new sightings and a rapid response plan are required for the management of marine alien species that have been recorded in the country. There is a protocol in place for importing alien species but it is imperative that there are pre-border inspections at identified harbours and ports and a protocol to deal with accidental introductions. The use of **citizen science** in strengthening the identification of sightings of marine alien species is recommended as this platform has been used successfully in alien plant population sightings.

The marine species and the categories under which they are listed in the Alien and Invasive Species regulations need to be reviewed. Coordination amongst the various authorities responsible for multiple aspects of marine alien and invasive species management, from pathways such as shipping and aquaculture to monitoring and eradication, needs to be improved. Appropriate **resources** need to be secured to enable the implementation of the regulations, along with national and regional monitoring programs to facilitate early detection of introduced and potentially invasive species.

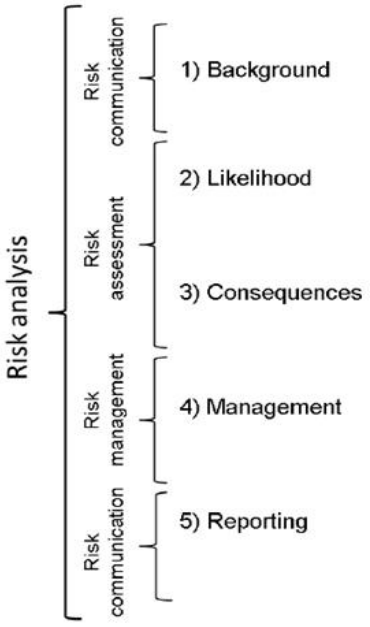
Established marine invasive species are expensive and difficult to manage or **eradicate** (Box 25), and therefore preventing introductions is more effective and cost-effective than controlling them. To do this, all significant vectors of introduction need to be identified and protocols put in place to minimise

introductions, detect those that do occur and respond timeously with quarantine, eradication and control measures (Bax *et al.* 2002). A recent survey of 19 of South Africa's coastal marine protected areas (**MPAs**) found that 17 of the MPAs host well-known invasive species. It is recommended that MPA management authorities conduct routine surveys to check for the presence of alien species (Robinson *et al.* in press, Brooker 2016).

South Africa's developing ocean economy includes ambitious plans to increase port and harbour development, maritime transport, oil and gas activities, aquaculture and coastal tourism. This may lead to increasing vessel and oil rig traffic, increased connectivity between ports, harbours and petroleum leases and more aquaculture facilities. This could increase introductions unless additional **effective biosecurity measures** are implemented. Strategic monitoring is needed but the highest priority action is to secure resources and develop capacity to enable rapid management action to prevent potential invasive species from becoming established when detected through monitoring programmes.

Box 26. Risk analysis vs. risk assessment

Alien and invasive species have been recorded globally and most of them have had negative impacts in their newly introduced regions (Cohen *et al.* 1995, Katsanevakis *et al.* 2014, 2016). Chapter Five of the NEMBA Alien and Invasive Species Regulations (AIS) specify the prevention, management and eradication of alien and invasive species in South Africa. Chapter Six of NEMBA specifies the required information for the completion of a risk assessment undertaken for import permit purposes. A risk assessment as stipulated in the NEMBA does not cater for species that are already in the country. Therefore, in order to accommodate the assessment of alien and invasive species already in the country and to assign them to their relevant categories for management, a risk analysis framework was developed which enables the listing of alien and invasive species in the NEMBA AIS regulations based on scientific evidence (Kumschick *et al.* 2018). This risk analysis framework includes hazard identification (the environmental and socio-economic impacts posed by the introduced species), risk assessment (the likelihood of the introduced species to cause negative impacts and its consequences), risk management (options to reduce the risk caused by the introduced species) and risk communication (the accessibility of the information) (Kumschick *et al.* 2018).



	Description	Why?	Parameters
1) Background	Provides details of what the analysis is on, and who did the analysis	To "set the stage" and ensure transparency and repeatability	BAC1 – BAC14
2) Likelihood	To collate evidence on aspects which could facilitate entry, establishment, and spread	To assess the potential for establishment and invasion	LIK1 – LIK6
3) Consequences	All evidence of possible impacts needs to be collated and scored for environmental impacts and socio-economic impacts	To enable estimation of current and potential severity of impacts	IMP1 – IMP5
4) Management	Available management options are assessed which could mitigate invasiveness and impacts, and benefits	To get insight into options for regulation and management	MAN1 – MAN3
5) Reporting	Summarise results of risk assessment and management and provide recommendation for management and regulation	To communicate results clearly and ensure objective interpretation of assessment	

A schematic of the risk analysis framework (taken from Kumschick *et al.* 2018).

6. MARINE CLIMATE CHANGE

Chapter Citation: Kelly C, Foden W, Midgley G, Porter S, Lamberth S, van der Lingen C, Atkinson LJ, Robinson J. 2019. Chapter 6: Climate Change. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



Climate change worsens pressure impacts, decreasing resilience of people and biodiversity

Chapter summary

Literature and reports were reviewed to summarise information on climate change in South Africa's marine environment and its associated impacts on marine biodiversity. South Africa has experienced significant oceanographic changes over the past few decades. Parts of the Agulhas Current have warmed more rapidly than 90% of the world's oceans, while upwelling on the west and south coasts has increased due to intensified winds, leading to inshore cooling. These shifts are accompanied by increases in sea level, changes in ocean currents (which affect regional climate, energy transfer, and species dispersal), wave height, ocean acidification, low oxygen events and increasingly frequent storms. Such changes are already having marked impacts across a wide variety of South Africa's marine taxa including sponges, kelp, fish, seabirds, molluscs, corals, crustaceans and foraminifera. Resulting shifts in species distribution, abundance, physiology and behaviour are causing changes in community composition, hybridisation, and spread of alien species. Climate stress is altering species' physiology and body condition and significantly increasing the number of harmful algal blooms (HABs), particularly off the south coast. South Africa's national economy is considered moderately vulnerable to the impacts of climate change on fisheries. Coastal fisheries most at risk in the short to medium term include those for small pelagics, linefish, netfish and West Coast Rock Lobster. Marine tourism may also be impacted. The complexity and variability of South Africa's marine systems, aggravated by anthropogenic stressors (including historical overexploitation of some marine resources), make future impacts difficult to predict. However, there is high certainty that impacts on biodiversity, ecosystem function, food security and valuable economic industries will continue to intensify. Sustainable, adaptive, ecosystem-based management is crucial to strengthening resilience and helping South African marine life adjust to future impacts. South Africa needs to maintain (in some areas, institute) and increase research and consistent uninterrupted monitoring to track and understand climate change impacts on marine systems, including their interactions with the impacts of other pressures. Also, it is essential to assess the effectiveness of adaptive measures for both human communities and natural systems. South Africa's unique position and rich history of marine research, combined with the variety, speed and scale of predicted changes, offers a rare opportunity to facilitate global learning of the development and application of adaptation pathways.

6.1 Introduction

Covering 71% of the planet, the world's oceans provide food, protect coasts, regulate climate, cycle nutrients, stimulate industry, sustain health and wellbeing, and produce half of the world's oxygen (Field *et al.* 1998, McLeod and Leslie 2009, Hoegh-Guldberg and Bruno 2010). They are also the largest source of **heat storage** in the climate system and contain approximately 50 times more inorganic carbon than the atmosphere (Bindoff *et al.* 2007). The oceans have **absorbed roughly half of all anthropogenic emissions** since the Industrial Revolution (Sabine *et al.* 2004, Mikaloff Fletcher *et al.* 2006). While this has helped slow the global rate of climate change, it has also triggered profound impacts on marine systems worldwide (Rhein *et al.* 2013). Yet, our understanding of the severity and extent of these impacts has lagged behind that of terrestrial systems (Rosenzweig *et al.* 2008, Hoegh-Guldberg and Bruno 2010).

Southern Africa's marine environment is one of the most diverse, complex and variable anywhere in the world and supports remarkable biodiversity (see Chapter 1). Oceanographically, the marine environment is shaped by two main drivers, the warm, fast-flowing Agulhas Current along the east and south coasts, and the cold upwelling Benguela system on the west coast. These current systems

both drive, and are influenced by, **regional climate patterns**, with far-reaching impacts on South African biodiversity.

Over the past few decades, South Africa has experienced significant **oceanographic changes** and has been identified as one of 24 global marine hotspots, with parts of the Agulhas Retroflection warming faster than 90% of the world's ocean (Hobday and Pecl 2014, Popova *et al.* 2016). Conversely, intensified upwelling in the southern Benguela has cooled sea temperatures along the west and south coasts (Rouault *et al.* 2010). Changes in sea surface temperature (SST) have been accompanied by a rise in sea level, changes in current strength, intensified winds and wave height, more frequent storms and harmful algal blooms (Davis-Reddy and Vincent 2017, Augustyn *et al.* 2018). Freshwater discharge in some regions has been altered both directly by changes in rainfall, and indirectly by dams (Lamberth *et al.* 2009). Key environmental changes already detected in deep ocean ecosystems (>200 m) elsewhere include increasing temperatures, ocean acidification, reduced oxygen levels and changes in particulate organic carbon (POC), which translates into food supply (Levin and Le Bris 2015, Barange *et al.* 2018). These changes impose strong pressures on biodiversity, and can magnify the impacts of other anthropogenic threats, such as overexploitation. Human responses to climate change play an important role in the biodiversity outlook, introducing both threats and potential opportunities for biodiversity conservation.

Unmitigated, climate change impacts will continue to escalate in the marine realm. In this chapter **observed and predicted impacts** of these changes are reported and their implications for biodiversity are discussed. Strategic responses to these mounting pressures can help protect South Africa's marine species, ecosystems and the services they provide, from the worst impacts of climate change. Examples of the country's responses to date and recommendations for further action are discussed.

6.2 How is South Africa's marine climate changing?

6.2.1 Ocean temperature

Broad trends in observed SST between 1961 and 2008 reveal **warming** at all latitudes along the entire African coastline (Figure 69). A global analysis of SST trends over the past 50 years identified the Agulhas Current, particularly the retroflection eastwards back into the South Indian Ocean, as one of the fastest warming marine regions on earth (Hobday and Pecl 2014, Popova *et al.* 2016). Since the 1980s, the Agulhas Current has warmed by up to 0.7 °C per decade, despite a substantial increase in heat fluxes that should have cooled the region (Rouault *et al.* 2009). This has, likely in conjunction with strengthening Indian Ocean westerly winds, increased the leakage of warm, high-salinity water into the Atlantic Ocean (Loveday *et al.* 2015). The **Agulhas leakage** serves as a thermocline link between the Indian Ocean and Atlantic Ocean, and these interactions in South African waters play a key role in influencing global climate (Beal *et al.* 2011).

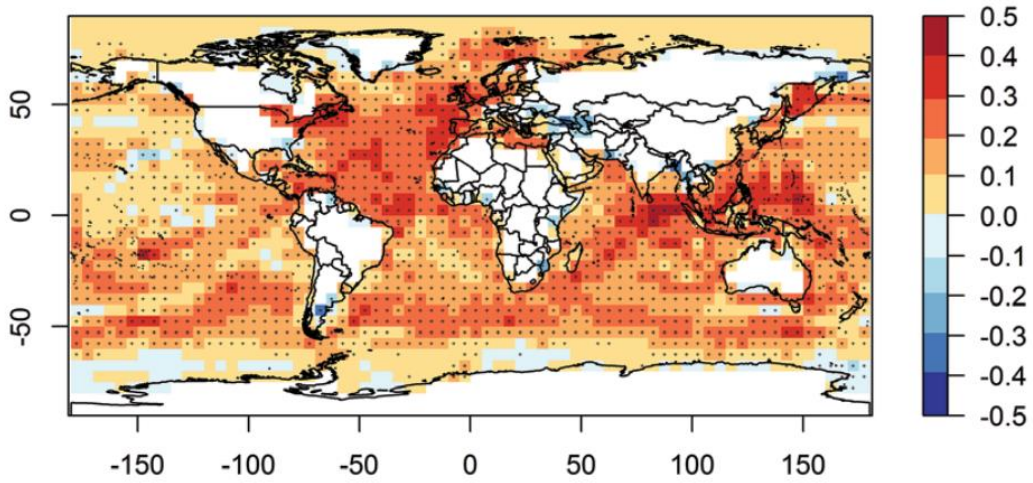


Figure 69. Observed broad-scale trends in sea-surface temperature for the period 1961-2014 based on the HadSST 3.1.1.0 climate data set. Crosses indicate grid boxes where the trend is statistically significant (Mann-Kendall test) (Davis-Reddy and Vincent 2017)

Alongside these warming trends, **intensified southeasterly and easterly winds** have also increased upwelling along portions of South Africa's coast, resulting in **cooler sea temperatures** during certain times of the year (Rouault *et al.* 2010, Blamey *et al.* 2015, Augustyn *et al.* 2018) (Figure 70). Since 1982, temperatures in the southern Benguela have decreased by up to 0.5 °C per decade between January and August, with continuous cooling from Cape Agulhas to the Namibian border (Rouault *et al.* 2010). Changes of a lesser magnitude are evident along the south coast (from Cape Agulhas to Cape St. Francis) and around Port Elizabeth from May to August (Rouault *et al.* 2010, Blamey *et al.* 2015). Moreover, in Maputaland in the Delagoa region of northern KwaZulu-Natal, temperatures (hourly, monthly average and monthly maxima) have displayed a gradual declining trend during the past 20 years (1994-2014), although this may be due to a relatively strong El Niño Southern Oscillation (ENSO) event that occurred during the beginning of the temperature time series (Porter and Schleyer 2017).

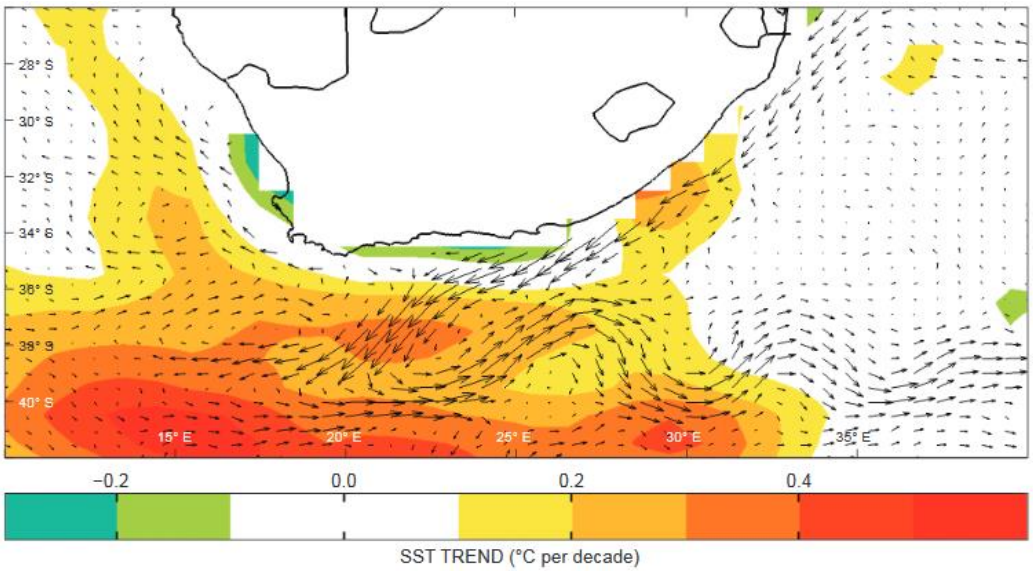


Figure 70. Linear trend of 1° × 1° resolution Reynolds Sea Surface Temperature, 1985–2009 in the waters around South Africa. Mean AVISO absolute geostrophic velocity vectors derived from the mean dynamic topography (Rio *et al.* 2005) are superimposed illustrating current strength and direction. (Rouault *et al.* 2010)

Extreme ocean temperature events (marine heat waves and marine cold spells) occur on average at least once per year at South African coastal sites (Schlegel *et al.* 2017). While changing global temperatures are one driver of such events, many may also be attributed to aseasonal shifts in wind and currents. The lack of long term monitoring complicates the identification of decadal trends, however based on available data, marine heat waves appear to be generally increasing in annual occurrence as marine cold spells grow more infrequent in offshore areas (Schlegel *et al.* 2017). In cooler upwelling areas along the west and south coast inshore waters, occurrence trends are more mixed. For example, shifts in wind regime, distribution and intensity of upwelling cells has seen Still Bay on the south coast experiencing an apparent increase in cold upwelling events, herding fish into the nearshore (pers. obs. S. Lamberth, Department of Environment, Forestry and Fisheries) whereas Tsitsikamma has seen a decline in cold water events (Hanekom *et al.* 1989, Lamont *et al.* 2018). While the west, south, and east coasts experience approximately the same number of extreme events, their duration and intensity differs. The east coast is the most thermally stable, while the south coast experiences the most intense events, placing those ecosystems most at risk from excessive heat waves (Schlegel *et al.* 2017).

6.2.2 Ocean currents

The Agulhas Current is the strongest western boundary current in the Southern Hemisphere, transporting warm water polewards and influencing the climate on the east coast of South Africa (Walker 1990, Jury *et al.* 1993, Rouault *et al.* 2002). The response of the **Agulhas Current** to anthropogenic climate change could markedly impact regional marine ecosystems and climate, whereby warming and extreme weather events could be significantly intensified or reduced (Beal and Elipot 2016). Mesoscale meanders in the Agulhas Current facilitate cross-shelf exchanges (Bryden *et al.* 2005); (Jackson *et al.* 2012, Krug *et al.* 2014, Malan *et al.* 2018) and the transportation of nutrients onto the shelf, especially in the region of the Agulhas Bank, where several commercially important fish species spawn (Hutchings *et al.* 2002, Roberts 2005, Roberts *et al.* 2010). Much of the mesoscale variability in the Agulhas Current can be attributed to source region eddies, which form in the Mozambique Channel and south of Madagascar and dissipate as they propagate towards the Agulhas Current (Braby *et al.* 2016). A study by (Backeberg *et al.* 2012) shows that the mesoscale variability of the Agulhas Current system intensified from 1993 to 2009. This resulted in accelerated eddy propagation from the source regions of the Agulhas Current and the retroflection region, where Agulhas Rings that transport heat and salt into the South Atlantic Ocean are spawned (Backeberg *et al.* 2012).

Model research suggests an increase and poleward shift in the westerly winds and an increase in wind stress curl over the Indian Ocean (Rouault *et al.* 2009, Wu *et al.* 2012, Yang *et al.* 2016). Consequently, these studies suggest an intensification and a poleward shift of the Agulhas Current. More recent studies, however, show that the Agulhas Current has not strengthened in more than 20 years, despite these wind trends (Beal and Elipot 2016, Elipot and Beal 2018). The increased **eddy activity** described by Backeberg *et al.* (2012) has instead resulted in a broader rather than a stronger current, consistent with trends observed in other major ocean currents (Cetina-Heredia *et al.* 2014, Yan and Sun 2015, Beal and Elipot 2016, Elipot and Beal 2018). An increase in eddy kinetic energy in the region could result in an increase of cross-frontal transfer of nutrients between shelf waters and the open ocean ocean (Beal and Elipot 2016). The effects of the broadening of the Agulhas current on warming trends in the region are still to be investigated (Beal and Elipot 2016).

The **Benguela Current** is the eastern limb of the South Atlantic subtropical gyre (Peterson and Stramma 1991) and lies offshore of the cold, nutrient-rich and highly productive Benguela upwelling regime, one of the world's four major eastern boundary upwelling systems. The latter is driven by the prevailing southeasterly winds associated with the South Atlantic Anticyclone and the thermal barrier set up by the coastline of the subcontinent. It has been hypothesized (Bakun 1990) that increased greenhouse gases would intensify upwelling-favourable wind stresses in all of the eastern boundary upwelling systems. (Sydeman *et al.* 2014) tested this hypothesis by conducting a meta-analysis of literature on upwelling-favourable winds in each of these systems over the last six decades. Their analysis suggested that the upwelling-favourable winds in the Benguela system have intensified over the past few decades, particularly so at higher latitudes, thereby confirming Bakun's hypothesis. Lamont *et al.* (2015) investigated long term changes in the Benguela upwelling system in more detail, making use of modelled reanalysis data over the past 36 years. They noted an overall intensification in upwelling on the Agulhas Bank and a tendency toward increased upwelling in the southern Benguela and while there was no significant trend in the northern Benguela, a notable decrease occurred between 2009 and 2015. These results are consistent with the findings of (Sydeman *et al.* 2014) and (Rykaczewski *et al.* 2015) and are related to the poleward shift of the South Atlantic Anticyclone (Hutchings *et al.* 2009a, Jarre *et al.* 2015b, Lamont *et al.* 2018).

Strong inter-decadal variability was noted in all regions by (Lamont *et al.* 2018) and is likely related to fluctuations in the large-scale climate models that oscillate with similar periodicities: **El Niño Southern Oscillation** (ENSO) and the **Southern Annular Mode** (SAM). During austral summer months El Niño events have been shown to cause a northward shift of the South Atlantic Anticyclone therefore reducing upwelling-favourable wind stresses, resulting in warmer than average sea surface temperatures in the southern Benguela (Rouault *et al.* 2010, Dufois and Rouault 2012). This pattern is reversed when the South Atlantic Anticyclone shifts southwards. During La Niña events, the opposite is shown to occur. However, obvious trends in the frequency and intensity of ENSO in recent decades are lacking (Blamey *et al.* 2015). The leading mode of atmospheric variability south of 20°S is the SAM, which has been shown to play a major role in atmospheric circulation in the southeastern Atlantic (Reason *et al.* 2002, Reason and Rouault 2005). As such, it is likely to influence the Benguela system, however given the extreme variability in the region, detecting its effect is challenging (Reason *et al.* 2006).

6.2.3 Sea-level rise

Global sea level has risen 3.3 ± 0.4 mm/year over the last decade (Rahmstorf *et al.* 2007), and the IPCC AR5 report (Stocker *et al.* 2013) concludes that anthropogenic global warming and sea-level rise will continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations are stabilised or reduced (Figure 71) (Davis-Reddy and Vincent 2017). Given differences in barometric-pressure change and vertical movements of the Earth's crust around South Africa's coast, the west, south, and east coasts of southern Africa have experienced different relative rates of sea-level rise: +1.87 mm/year for the West Coast (1959 to 2006; intermittent data), +1.48 mm/year for the South Coast (1957 to 2006; intermittent data), and +2.74 mm/year for the East Coast (1967 to 2006; intermittent data) (Mather *et al.* 2009, Davis-Reddy and Vincent 2017). In combination with increased intensity of sea storms, accompanied by increases in wave heights, sea level rise will result in increased storm surges (IPCC 2012, Stocker *et al.* 2013). However, the storm events and associated surge events are region-specific and at this stage region-specific projections are made with a relatively low confidence level (Stocker *et al.* 2013). Yet, even if the intensity of sea storms

remains unchanged, higher sea levels will mean that smaller storms are likely to have an increased impact on the coastline (Theron 2011). This is compounded by statistically significant increases in measured average and extreme (90th percentile) wind speeds and significant wave heights since 1985, both globally and in some places around South Africa, most notably around the southwestern Cape (Young and Ribal 2019).

Sea-level rise itself is a threat to coastal ecosystems only where the shoreline is constrained, and it cannot naturally realign. When the littoral active zone (coupled dune-beach-surf systems, called the 'seashore' in the NBA 2018) is intact and unconstrained, beaches and dunes erode and realign further inland in response to rising sea levels, as per Bruun's rule (Bruun 1962, Harris 2008). However, when hard infrastructure is built inappropriately close to the shore (e.g., buildings, promenades and seawalls on or replacing the foredunes), this natural realignment cannot take place. Beaches become trapped in a 'coastal squeeze' between rising sea levels and hard infrastructure, and slowly become inundated and lost. The implications include **loss of beach biodiversity** (Dugan *et al.* 2008), loss of turtle nesting grounds (Fish *et al.* 2008), and loss of access to beaches for tourism – even if only initially during high tide when the waves run all the way across the shore and into the seawalls (L. Harris, Nelson Mandela University, pers. comm.). It can also bring risk of infrastructure failure and very costly damages to coastal municipalities, particularly when superimposed with high wave-energy events and storms, such as happened in March 2007 in KwaZulu-Natal (Smith *et al.* 2007). These risks and threats can be mitigated and largely avoided through sensible land-use planning, and building infrastructure behind scientifically determined setback lines, which in turn contributes to keeping the ecological infrastructure for coastal protection (in this case, the dunes) intact (Harris *et al.* 2019a).

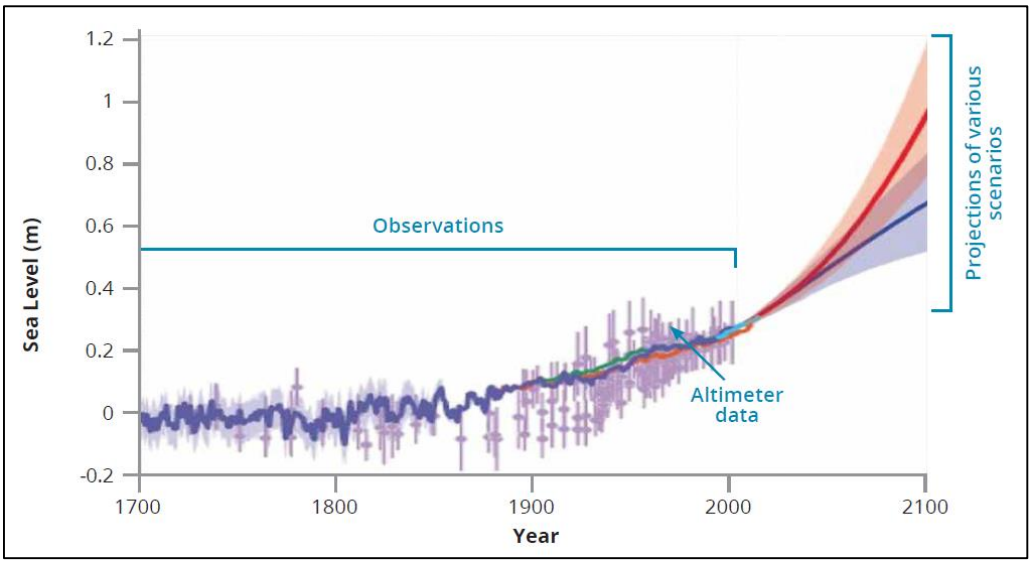


Figure 71. Observed and projected global sea level rise, adapted from IPCC AR5 (Stocker *et al.* 2013). Observations include paleo sea-level data (purple), tide gauge data (blue, red and green) and altimeter data (light blue). The projections are of the absolute mean sea-level rise over the 21st century relative to 1986–2005 formulated on process-based models. Error ranges are indicated by the shaded areas and the corresponding mean value as a solid horizontal line (Stocker *et al.* 2013).

6.2.4 Ocean acidification

Oceanic uptake of anthropogenic CO_2 has altered the **seawater chemistry** of the world's oceans, making them more acidic and reducing the saturation state for carbonate minerals (Zeebe *et al.* 2008). Marine calcifying species use these minerals (such as calcite and aragonite) to build coral reefs, produce shells and grow skeletons (Zeebe *et al.* 2008). Calcium and aragonite are also widely used by marine fauna to grow gravity sensory organs (statoliths and otoliths) (Fabry *et al.* 2008). In addition to the physiological impacts, ocean acidification can also alter species' competetive interactions, resulting in ecosystem shifts (Kroeker *et al.* 2013). For example, mat-forming algae show enhanced productivty in projected near-future CO_2 conditions, which is likely to reduce the resilience of kelp forests (Connell *et al.* 2013). In coral reef ecosystems, decreased pH favours a shift towards fleshy algal dominated communities as aragonitic accretion becomes more energetically expensive for hard corals (Diaz-Pulido *et al.* 2011). Furthermore, the growth of crustose corraline algae can be comprimised by **ocean acidification**, which can in turn affect the settlement of corals (Doropoulos *et al.* 2012, Connell *et al.* 2013). Ocean acidification has also been shown to comprimise the reef framework by accelerating reef bioerosion (Wisshak *et al.* 2012).

Globally, surface oceans have an average pH of 8.2 units, but measurements can vary based on local, regional, and seasonal factors (Royal Society 2005). On average, the **pH of surface seawater has decreased by 0.**1 units worldwide – representing a 30% increase in the concentration of hydrogen ions (Royal Society 2005). If emissions continue unabated, average pH is predicted to fall by 0.5 units by 2100, a level of acidity the oceans have not experienced in hundreds of millenia (Royal Society 2005).

Due to upwelling activity, the Benguela system has a naturally low pH currently ranging from 7.60 to 8.25 (Gregor 2012). Global biogeochemical climate models and data analysis predict that the **Benguela** will experience corrosive and irreversible consequences of ocean acidification within the 21st century (Caldeira and Wickett 2003, Fabry *et al.* 2008, Davis-Reddy and Vincent 2017, Augustyn *et al.* 2018). Benguela system pH levels were predicted to decrease to between 7.5 and 7.8 by the year 2100 (Caldeira and Wickett 2003, Davis-Reddy and Vincent 2017), however *in situ* measurements show that coastal pH is already even lower in some areas (DEA 2016a). Due to changes in the **Agulhas Current** and local upwelling, the east coast will not escape these effects either (Davis-Reddy and Vincent 2017). On Two-mile Reef, Sodwana Bay on the east coast, pH ranges between 8.14 and 8.31 in summer months, and between 8.04 and 8.23 in winter months (Hayman 2015). Total alkalinity ranges between 2310.64 and 2332.09 µmol/kg, and 2224.46 and 2320.81 µmol/kg in the summer and winter months respectively (Hayman 2015). Aragonite saturation state (Ω_{Ar}) ranges from 3.32 and 4.21 in summer, and 2.43 and 3.51 in winter. Calcite saturation state (Ω_{Ca}) ranged from 5.00 and 6.39 in summer, and 3.71 and 5.35 in winter (Hayman 2015). These above carbonate parameters, associated with ocean acidity levels, are synergistic with temperature and will have a direct impact on the region's **corals and other calcifying organisms.**

Long term in situ measurements of ocean pH in South Africa are insufficient to identify historical trends with certainty, however there are signs that biota living in coastal waters are already under strain from effects related to ocean acidification (DEA 2016a). South Africa's first large-scale assessment was carried out in April 2015 to establish a crucial **baseline** for long-term monitoring (DEA 2016a). This analysis revealed higher pH (about 7.9) along the east coast, intermediate levels along the south coast, and very low pH (below 7.4) along the west coast (DEA 2016a). The effects are most

severe along the inshore region of the west coast, where the water is 200% more acidic than surface water in the open ocean (DEA 2016a). These results are troubling for coastal ecosystems, as any seawater below 7.7 is undersaturated with respect to aragonite and has been shown to impact some species of Abalone (*Haliotis*), sea urchins (*Psammechinus, Strongylocentrotus*), pteropods (*Clio spp.*), clams (*Mercenaria spp.*), oysters (*Pinctada spp.*), and dogfish (*Scyliorhinus spp.*) (Fabry *et al.* 2008, DEA 2016a). This will also have significant implications for mariculture, which is currently being promoted in the area (Scholes *et al.* 2015). Elsewhere, acidification has also been shown to impact fish, especially the soniferous (sound producing) Sciaenidae (e.g. Dusky Kob), in which changes in otolith structure have led to switches from hearing-based to visual foraging (van der Sluijs *et al.* 2011).

6.2.5 Summary of changes

A summary of the climate change related pressures on South Africa's marine systems is provided for each coast (Table 16), and overall (Figure 72).

Table 16. Relative anticipated changes in the southern African marine environment by 2050. Modified from (Potts *et al.* 2015)

	SST	Upwelling	Current Strength	Rainfall	pH	Sea Level
Tropical and subtropical west coast	↑			↓	↓	↑
Warm-temperate west coast	↑			↑	↓	↑
Cool-temperate west coast	↓	↑		↓	↓	↑
Warm-temperate south coast	↓	↑	↑		↓	↑
Subtropical and tropical east coast	↑		↑	↑	↓	↑

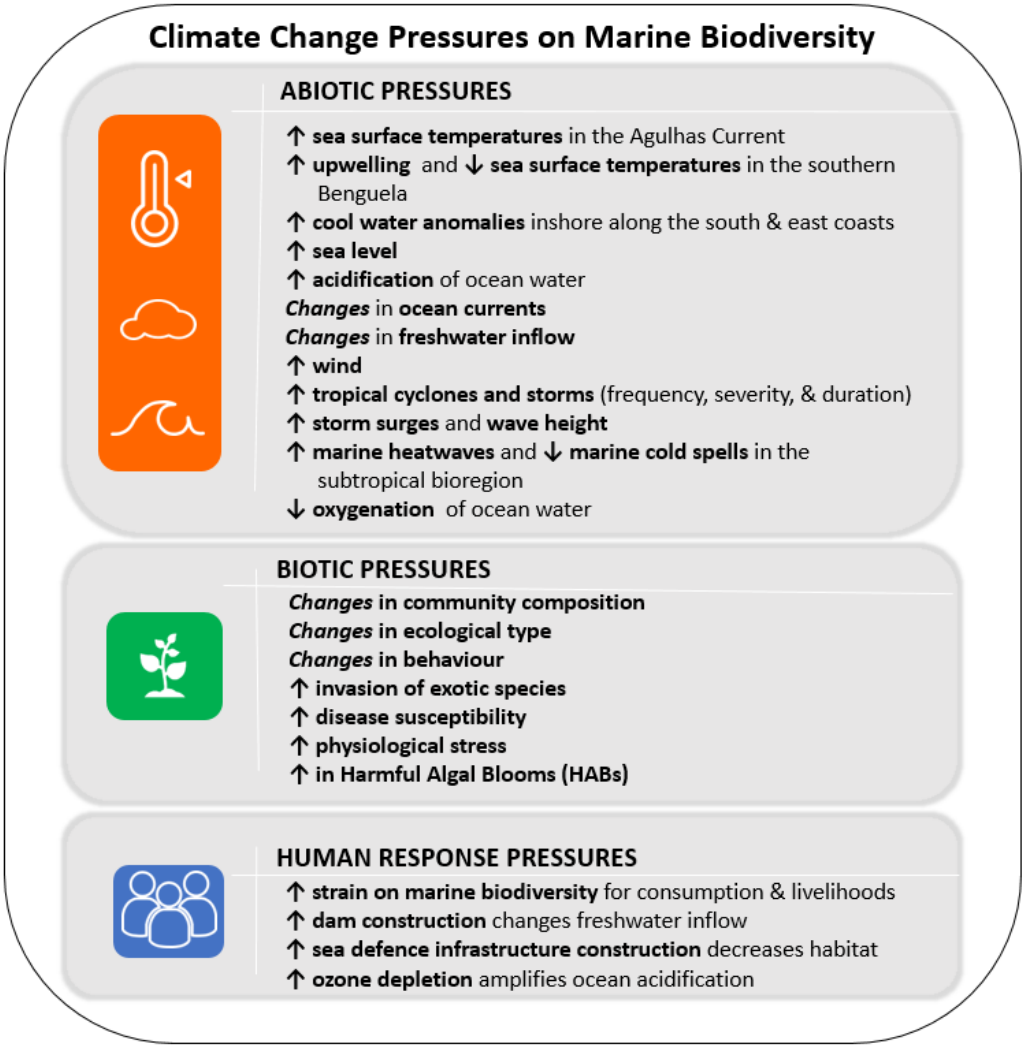


Figure 72. A summary of observed and anticipated climate change pressures on South Africa's marine biodiversity. These include those from abiotic climate changes and resulting changes in physical processes, biotic systems, as well as in human behaviour in response to climate change

6.3 How is climate change impacting South Africa's marine biodiversity?

6.3.1 Observed impacts so far

Globally, climate change impacts have been detected across 81% of core marine ecological processes, with effects documented at levels from **genes to species, communities, ecosystems and their services** (Scheffers *et al.* 2016). South Africa has experienced impacts at each of these organisational levels. Table 16 provides examples of these impacts, with the addition of those covering climate change impacts on invasive species. Findings are summarised below.

Temperature-driven shifts in **spatial distribution** have been experienced across multiple taxa. Many impacted species are considered pioneers and may trigger ecological successions (Whitfield *et al.* 2016). Several species including kelp (Bolton *et al.* 2012), West Coast Rock Lobster (Cockcroft *et al.* 2008), Anchovy (Roy *et al.* 2007) and Sardine (Coetzee *et al.* 2008) have shown recent eastward changes in their distributions, with Anchovy distribution being significantly correlated with decreased coastal temperatures east of Cape Agulhas (Augustyn *et al.* 2018). Widening of the tropical belt

already appears to be influencing species' **abundance and diversity** in KwaZulu-Natal, likely increasing the competitive ability of sub-tropical fish relative to temperate species (Lloyd 2012, James *et al.* 2013). Such shifts have also led to changes in distribution of predators, for example seabirds, which track shifts in distribution and abundance of prey species with varying effects on bird populations (Crawford *et al.* 2008b, Crawford 2009). The ability of **predators** to respond to new prey distributions is likely influenced by their life-history traits, such as fidelity to mates or breeding sites (Crawford 2009). Temperature changes also facilitate invasive harmful algal bloom (HAB) forming organisms (Whitfield *et al.* 2016). When range shifts result in overlap between previously disjunct congeneric species, **hybridisation** may occur (Mirimin *et al.* 2014, Potts *et al.* 2014, 2018). While hybridisation in fish is usually associated with an increase in disease resistance and physiological tolerance, it can also reduce fitness when under environmental stress (DEA 2013a). Many of these shifts have been compounded by other drivers [e.g. loss of habitat in an animal's original range (Whitfield *et al.* 2016, Augustyn *et al.* 2018) making it difficult to determine exactly how much of the change was expressly due to temperature.

Fish stocks in the southern Benguela have declined and while long histories of exploitation are a key driver, environmental changes have also played a role (Blamey *et al.* 2015). For example, the demise of the West Coast Sole resource is linked to **reduction in freshwater flow** from the Orange River, loss of sediment replenishment, loss of juvenile habitat and refuge, loss of crypsis and increased predation (Van Niekerk *et al.* 2013).

Copepods constitute an important component of zooplankton and are excellent indicators of environmental changes. Despite considerable interannual variability, a long-term decline in some **copepod** species abundance is evident along the south coast (DEA 2016a). Rising sea temperatures have also enabled the range expansion and increased abundance of non-indigenous ascidians, algae and HAB forming organisms along South Africa's coast (Rius *et al.* 2014, Whitfield *et al.* 2016).

Driven by anomalously warm ocean temperatures, **coral bleaching** is perhaps one of the best-known impacts of climate change. Peak temperatures on South African reefs have attained thresholds for coral bleaching, however in Maputaland, where coral communities flourish, cold-water upwelling facilitated by submarine canyons appears to be moderating some of the effects of the regional rise in water temperature (Schleyer *et al.* 2008). In addition, the relatively high-latitude position and depth of the reefs have afforded them protection from extreme bleaching events (Porter *et al.* 2016). The highest levels of coral bleaching in South Africa were recorded in 2000, when up to 12% of the total living cover bleached (Celliers and Schleyer 2002). The third and most recent global coral bleaching event left the reefs largely unscathed, with an average of 9.4% of the coral cover bleaching in 2016 with only negligible mortality (<0.5%) (Porter *et al.* 2016)**.** Although long-term monitoring of changes in coral community composition have detected a steady decline in the cover and number of soft coral colonies, and an increase in the cover and number of hard coral colonies (Porter and Schleyer 2017), this has not been linked with certainty to climate change. The decline is unlikely to be due to bleaching, as no bleaching has been recorded within the monitoring transects, but may rather be linked to ocean acidification-related changes or pollutants (Porter *et al.* 2016, Porter and Schleyer 2017).

Table 17. Impacts of climate change on South African biodiversity, including both those that have been observed and those that are predicted

	Observed Impacts	Predicted Impacts
Genetic impacts	• **Dusky Kob (*Argyrosomus coronus*):** southward shift from Angola to Saldanha Bay in South Africa, interbreeding with species *A. inodorus* & creating a hybrid (Potts *et al.* 2014).	
Species impacts	• **Major kelp-bed (*Ecklonia maxima)* has moved 73 km eastward along the south coast** since 2006, having remained static for the previous 70 years (Bolton *et al.* 2012). • **Cape Anchovy (*Engraulis encrasicolus*):** Abrupt eastward shift in spawner distribution on the Agulhas Bank in 1996 (Roy *et al.* 2007); positive correlation between Anchovy recruitment and upwelling (van der Sleen *et al.* 2018). • **Seabird species:** anticlockwise changes in the distributions of multiple seabird species (Crawford *et al.* 2008b). • **African Penguins (*Spheniscus demersus*)** on Dassen Island bred approximately one month earlier during 2004-2008 compared to 1995-2001, a change attributed to warmer temperatures which led to a reduction in per capita growth rates (Durant *et al.* 2010, Moloney *et al.* 2013). • **Pelagic and demersal fish stocks in decline in the southern Benguela:** key species impacts and changing distributions since 1980's-1990's from overfishing and climate change pressures (Moloney *et al.* 2013, Blamey *et al.* 2015). • ***Anchovy (Engraulis encrasicolus)* and *Sardine (Sardinops sagax):*** Spawning habitat change in southern Benguela by climate & other drivers (Moloney *et al.* 2013, Mhlongo *et al.* 2015). • **Sardine (*Sardinops sagax*):** Dinoflagellate bloom in southern Benguela may have prevented sardine from feeding, while Anchovy and Round Herring appeared unaffected (van der Lingen *et al.* 2016). • **Brown Mussel (*Perna perna*):** range contraction at its southern range limit on the west coast (Mead 2011). • **Cape Gannets (*Morus capensis*):** Climate-mediated displacement of sardine & anchovy stocks triggered dietary shift and population increase at Bird Island, Algoa Bay (Green *et al.* 2015). • **Swift Terns (*Thalasseus bergii*)**: Increase in breeding pairs after 2005 followed southern displacement of sardine and anchovy (Crawford 2009). • **Bank Cormorants (*Phalacrocorax neglectus*):** Reduced numbers in northern Western Cape and increases in the south consistent with distributional shift in rock lobster (Crawford *et al.* 2010) • **Coral (*Porites lutea*):** High-latitude conditions, reef depth and upwelling in Sodwana Bay moderate local ocean temperatures, mitigating bleaching events	• **Shelled pelagic snails (pteropods) of the Southern Ocean's surface waters:** likely to be impacted by ocean acidification within the next 50 years, shifting north to less acidic waters or dying off under most probable scenarios (Bernad 2011). • **Sardine (*Sardinops sagax*):** reduction in productivity due to increased HABs (van der Lingen *et al.* 2016), and possible cessation of the sardine run due to unfavourable oceanographic conditions (Portwig 2016, Augustyn *et al.* 2018) • **Chokka Squid (*Loligo reynaudii*):** rising temperatures, increased storms, and changes in freshwater runoff, turbidity, and sediment replenishment will reduce embryonic developmental time, growth, recruitment and may result in a spatial/temporal shift in spawning ground (Augustyn *et al.* 2018). • **Rock Lobster (*Jasus lalandii*):** Impacts of increased upwelling along the west coast likely to increase walkouts, reduce growth rates and delay embryonic development (Augustyn *et al.* 2018). • **Dusky Kob (*Argyrosomus japonicus*):** Ocean acidification likely to cause metabolic depression and mortality in larvae, as indicated by experimental studies (James and Potts 2017) and changes in structural sensory perception and behaviour (van der Sluijs *et al.* 2011). • **Abalone (*Haliotis midae*):** Preliminary data indicate acidic water will corrode abalone shells and reduce growth during both short and long term exposure (Auerswald 2017) • **Puffadder Shyshark (*Haploblepharus edwardsii):*** Acidic seawater will corrode denticles and teeth, which will reduce ability to feed (Auerswald 2017) • **Cape Hakes (*Merluccius* spp.):** Atlantis modelling framework predicts 10-20% reduction in biomass of Cape Hake by 2050 under predicted warming scenarios for southern Benguela (Ortega-Cisneros *et al.* 2018). • **Cape Anchovy (*Engraulis encrasicolus):*** Ecological niche & global circulation models predict substantial distributional shift and 40-50% reduction off southern Africa (Raybaud *et al.* 2017). • ***Amphistegina* spp.:** Species distribution model predicts substantial southward shift for amphisteginid foraminifera, which will likely trigger changes in ecosystem functioning (Langer *et al.* 2013). • **Staghorn Coral (*Acropora austera*):** Survival rates of coral embryos were lowest at warmest (28°C) experimental temperatures and highest at coolest (24°C) temperatures (Masse 2014). Thus global warming is predicted to compromise local coral recruitment.

	Observed Impacts	Predicted Impacts
	and restraining the influence of regional temperature rise (Hayman and Uken 2015). • **Coral communities (Sodwana Bay):** Coral bleaching was recorded for the first time in 1998 (Jordan and Samways 2001) (Schleyer and Celliers 2000) and peaked in 2000 when up to 12% of the total living cover bleached (Celliers and Schleyer, 2002). Subsequent bleaching events have not impacted more than 9.4% of the coral cover (Porter 2017); see (Porter *et al.* 2016) for historical review. • **The hard corals *Montipora* spp., *Favia* spp. & *Pocillopora* spp.:** displayed highest incidences of bleaching in 2016 during the 3rd global coral bleaching event (Schleyer *et al.* 2008, Porter *et al.* 2016, Porter and Schleyer 2017) • **Coral communities:** To date, bleaching related coral mortality has been negligible (<0.5%) (Porter *et al.* 2016) • **Coral communities (Sodwana Bay):** Increase in cover and number of hard coral colonies with steady decline in cover and number of soft corals, resulting in a 5% loss of overall coral reef cover, but the cause of this remains uncertain (Schleyer *et al.* 2008, Porter and Schleyer 2017)**.** • **Sponge (*Suberites kelleri*):** Bleached during the 2000 bleaching event (Celliers & Schleyer, 2002). • **Rock Lobster (*Jasus lalandii*) biogeographical and regime-shift:** Changed community composition east of Cape Hangklip from early 1990s (Blamey and Branch 2012)**.** • **South coast fish communities:** Over 20 range extensions of tropical/subtropical marine fish species into the warm / cool temperate transition zone along the south coast including False Bay (Lamberth *et al.* 2011). • **Sub-tropical reef fish communities:** decreased relative abundance of temperate species and increase of tropical species off the coast of KwaZulu-Natal consistent with ocean warming and widening of the tropical belt (Lloyd 2012). • **Copepods (south coast):** Decline in total copepod biomass on the Agulhas Bank (particularly the large *Calanus agulhensis),* due to fishing pressure and environmental variability. (DEA 2016a). • **Copepods (west coast):** Copepod abundance increased on the west coast from 1950-2000, followed by a slight decline, however copepod species composition has changed over the past 60 years resulting in a long-term reduction in mean copepod size [Verheye 2017 in: Hampton *et al.* (in prep)].	• **Brain Coral (*Platygyra daedalea*):** Based on experimental studies across three treatments (26°C, 28°C, and 30°C), embryonic survival rates and zooxanthellae acquisition will decrease with rising temperatures while bleaching and mortality will increase. Thus further warming will likely compromise local coral recruitment (Masse 2014). • **Loss of *Acropora austera*** (a particularly thermally sensitive species) due to bleaching may have a significant ecological impact on reef fish communities due to its nursery function (Floros and Schleyer 2017, Schleyer *et al.* 2018). • **Tropical cyclones:** The frequency, intensity, and possibly their southward migration is predicted to increase with climate change (Webster *et al.* 2005), which would result in an increase in structural damage to coral communities, especially branched acroporids. • **Coral reefs:** temperate areas south of their current distribution are unlikely refugia for tropical corals due to the densely populated coastline with high river effluent (Porter *et al.* 2017b) and susceptibility to acidification (Whitfield *et al.* 2016), as well as insufficient photosynthetically available radiation, especially in winter months (Muir *et al.* 2015). • **Sole:** distribution and abundance will likely be strongly influenced by alterations in river flow (Whitfield *et al.* 2016). • **Juvenile Anchovy (*Engraulis encrasicolus)*:** spatial and temporal changes in fluvial plumes will affect distribution and biomass (Whitfield *et al.* 2016). • **Foraminifera:** Change in the distribution and abundance (Langer *et al.* 2013); Whitfield *et al.* 2016). • **Stromatolites:** Increased storms, altered freshwater inflow will impact stromatolite survival (Perissinotto *et al.* 2014). • **Altered freshwater inflow to marine environment** will influence recruitment and survival of marine linefish species (Lamberth *et al.* 2009). • **Continued poleward range expansions of tropical species** resulting in increased species richness on subtropical reefs (Lloyd 2012, Moloney *et al.* 2013).

	Observed Impacts	Predicted Impacts
Ecosystem impacts	• **Upwelling:** Stronger southeasterly winds have intensified coastal upwelling with increased intra-annual variability (Rouault *et al.* 2010) • **Ocean temperature (Agulhas):** Sea surface temperature has warmed significantly, up to 0.55°C per decade, since the 1980's (Rouault *et al.* 2009), but cool water anomolies have been recorded inshore (Rouault *et al.* 2010). • **Ocean temperature (Benguela):** Angolan and North Namibian coastline has warmed 0.2-0.5°C per decade, the central Benguela has not changed while the south Benguela has cooled (April-August) by 0.3-0.5°C per decade (Blamey *et al.* 2015). • **Harmful algal blooms (HAB):** Increased incidence of HABs in the southern Benguela (Pitcher and Weeks 2006); (Pitcher *et al.* 2008). • **Low oxygen events as a result of algal blooms**: increase in rock lobster walkout events during the 1990s (Cockcroft 2001). • **Sea level:** has risen by +1.87 mm per year (1959-2006) along the West Coast, +1.48 mm per year (1957-2006) along the southern coast, and +2.74 mm per year (1967-2006) along the East Coast (Mather *et al.* 2009). • **Altered freshwater inflow** has resulted in changes in sediment volume and type reaching the marine environment thereby altering soft-bottom habitats (van der Lingen *et al.* 2016).	• **SA marine hotspots:** Grouped with locations of strongest intensification/shift of dominant surface currents by 2099 (Popova *et al.* 2016) • **Rising sea levels:** likely to result in the loss of intertidal areas, important nursery grounds for coastal fish species (Potts *et al.* 2015). • **Benguela Current system:** Intensified upwelling could impact primary productivity, reduce food density for fish larvae, raise ocean acidity and increase the frequency of hypoxic events (Bakun *et al.* 2015). • **Agulhas Current system:** changes in current temperature and speed could affect advection of eggs and larvae of subtidal fishes (Potts and Götz 2011).
Ecosystem Services	**Changes in catch distributions:** the centre of gravity (CoG – a spatial average) of directed Sardine (Fairweather *et al.* 2006; Augustyn *et al.* 2018) and west coast round herring (DAFF, 2014) catches have shown significant southward and eastward shifts; west coast rock lobster catches have declined off the west coast and increased east of Cape Hangklip (Cockcroft *et al.* 2008).	• **Vulnerability Workshop conducted under the Climate Change Adaptation and Mitigation Plan (CCAMP)** ranked the commercial linefish small-scale and netfish fisheries as the most vulnerable to climate change, followed by small pelagic fish (Augustyn *et al.* 2018). • **Predicted sites of coastal squeeze** in KZN based on shoreline realignment using Bruun's rule, in response to different sea-level rise scenarios (Harris 2008).
Invasive species	• **Non-indigenous ascidians** are expanding their ranges and increasing in abundance along the South African coastline, concurrent with changes in seawater temperature (Rius *et al.* 2014)	

6.3.2 Predictions of future impacts

Given the escalating trajectory of climate change, impacts on marine biodiversity will almost certainly increase in extent, severity and frequency. Documented **predictions** include negative impacts on species' physiologies, particularly during vulnerable embryonic and early development stages, thereby reducing growth and successful recruitment (Whitfield *et al.* 2016). Temperature changes and current alterations will prompt spatial and temporal shifts in spawning and distribution of some species**.** Continued poleward shifts of tropical species in response to warming of the Agulhas current is expected to gain momentum, but the east-west orientation of South Africa's coastline may limit southward distribution of temperate species. Endemics are subject to a temperature 'squeeze' from both the east and the west, likely resulting in increased competition (Whitfield *et al.* 2016). Southward expansion of corals may be limited by coastal development and river effluent (Whitfield *et al.* 2016). Conversely, there is also an apparent anomalous northwards movement of predominantly cool-temperate fish on the west coast and certain inshore species on the east coast (Van Niekerk *et al.* 2008, Currie *et al.* 2019). Range expansions are likely to occur in a pulsed manner because potential for colonisation is greater at the edges of a species' range (Whitfield *et al.* 2016). Predicted climate change impacts on Southern Africa's coastal fishes, including migratory, resident, estuary dependent and catadromous species are outlined by (Potts *et al.* 2015) are represented in Figure 73.

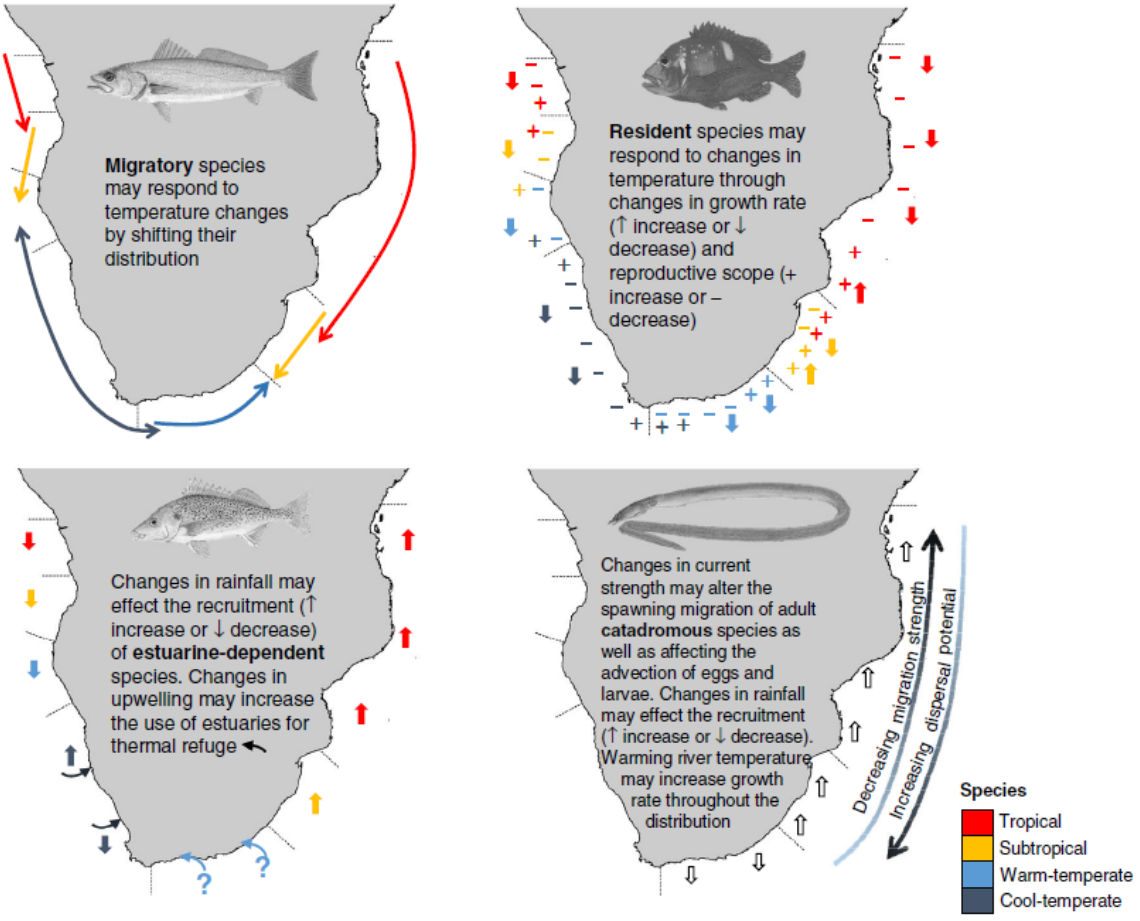


Figure 73. Predicted climate driven impacts for southern African coastal migratory, resident, estuary dependent and catadromous fishes (Potts *et al.* 2015).

Declines in some **wild capture stocks**, such as Sardine, are anticipated, and overexploited species will be more vulnerable to climate change than unexploited or optimally managed species (DEA 2013a). Of the small pelagic fishery species, sardines are considered most likely to respond negatively to climate change because of the deleterious impacts that HABs appear to have on their productivity (van der Lingen *et al.* 2016), while Anchovy are most likely to exhibit a positive response because increased upwelling during their summer spawning season appears to increase their recruitment (van der Sleen *et al.* 2018). Sardines undertaking the sardine run to KwaZulu-Natal move into waters close to their upper thermal tolerance limit (approximately 21°C) and continued warming will make it even less hospitable (Augustyn *et al.* 2018). Compounded by potential changes in break-away eddies that facilitate the sardine's movement north, this could lead to the cessation of the sardine run (Portwig 2016, Augustyn *et al.* 2018). Alternatively, persistent cool water anomalies occurring southwards could shift the core of the tourism activity following small pelagic fish, cetaceans and birds, southwards to the Wild Coast region.

It is widely anticipated that climate change impacts on **marine mammals** will primarily be mediated by changes in prey distribution and abundance (Simmonds and Isaac 2007). While there is scarce evidence, as yet, of direct responses to climate change by marine mammals in South African waters, shifts in distribution, social behaviour, mortality events, and changes in reproductive success have been documented in other regions (Simmonds and Isaac 2007). There is a similar lack of documented responses for **sharks** in South African waters. However, rising temperatures and ocean acidification have been shown elsewhere to impact embryonic duration, odour tracking, hunting behaviour, metabolic efficiency and growth rates in experimental environments (Pistevos *et al.* 2015). Globally, some species of shark are predicted to shift their distribution as a result of rising sea surface temperatures, weather patterns and prey availability (Cotton *et al.* 2005, Sequeira *et al.* 2014). Such changes are likely to become increasingly evident in South Africa as data collection and availability improves and research on climate impacts broadens.

Ocean acidification is also predicted to cause metabolic depression, mortality, corrosion of shells and teeth, reduce growth rates, delay embryonic development and alter species distribution. Many species will be particularly vulnerable to the effects of acidification during embryonic and early development (Fabry *et al.* 2008). Three-month-old Abalone, for example, demonstrate effects of shell dissolution within 48 hours of exposure to a pH of 7.5, a level already observed in the southern Benguela (Joubert 2017). The limited number of species tested under predicted pH conditions precludes the identification of general trends within groups (e.g. foraminifera, pteropods, sharks, and fish) and the responses of many taxa are completely unknown (e.g. sponges, bryozoans, annelids, brachiopods, tunicates and squid) (Fabry *et al.* 2008). The effects of ocean acidification in the deep ocean, in combination with warming and deoxygenation, are predicted to result in large-scale changes in habitat suitability for some species (including hake), while benefiting others (e.g. squid), affecting fisheries (both positively and negatively) that may target such species (Levin and Le Bris 2015, Barange *et al.* 2018).

Accelerated sea level rise and increase in the frequency of **severe weather** will likely result in 'coastal squeeze', leading to erosion of shallow intertidal areas and changes in intertidal profiles. Such areas are key nursery grounds for coastal species, and hence negative impacts on coastal species are likely, with cascading effects on marine biodiversity (Potts *et al.* 2015)**.** Many valuable subtidal fishery species spawn in the waters off of KwaZulu-Natal and rely on coastal zone currents to transport their

eggs and larvae (Beckley and Connell 1996). Predicted changes in the Agulhas Current could potentially disrupt the southern advection and survival of these species, with unknown consequences for fisheries and biodiversity (Potts and Götz 2011).

Intensified upwelling may cause increased frequency of **hypoxic events** in the Benguela Current system, resulting in algal decay and subsequent mass mortalities (Stephen and Hockey 2007). Altered river flow will trigger shifts in distribution of marine species that either rely on or avoid sediment and turbidity. Chokka Squid, for example, are likely to be pushed offshore to clearer waters, impacting the jig fishery (Augustyn *et al.* 2018). Introduced species may out-compete native species due to their broader physico-chemical tolerances (Whitfield *et al.* 2016), and environmental stress will increase susceptibility to disease (Hoegh-Guldberg and Bruno 2010). Predicted climate change impacts on South Africa's west coast ecosystems and species are summarised in Figure 74.

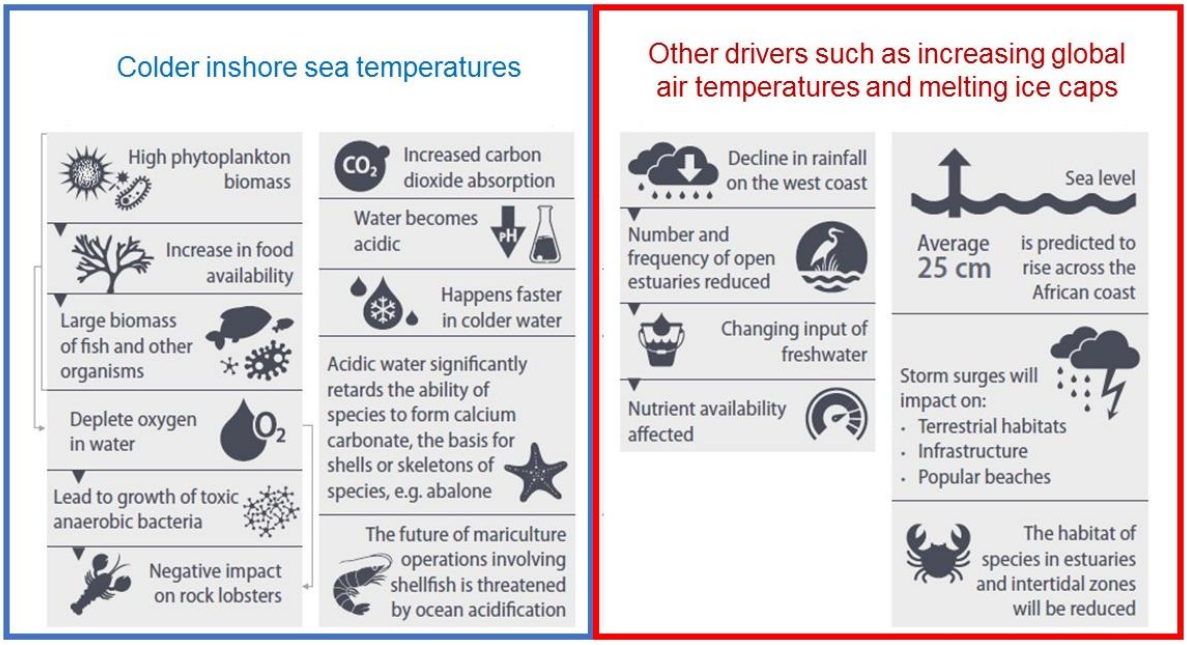


Figure 74. Predicted impacts of climate change on the marine environment of south Africa's West Coast (van Wilgen and Herbst 2017)

6.4 Consequences for people

6.4.1 Fisheries

Climatic changes will affect the distribution, abundance, size, body condition, physiology, behaviour and catchability of South Africa's marine **resource species** (DEA 2013a) with far-reaching economic impacts. South Africa's national economy was identified as moderately vulnerable to the impacts of climate change on fisheries under the IPCC B2 emissions scenario (Allison *et al.* 2009), but vulnerability would likely increase with the higher emissions now anticipated (DEA 2013a). South Africa's 22 commercial fisheries form a key part of the coastal economy (see Chapter 2). The Climate Change Adaptation and Mitigation Plan (CCAMP) vulnerability workshop ranked the commercial linefish, small-scale and netfish fisheries as the most vulnerable to climate change, followed by the fishery for small pelagic fish (Augustyn *et al.* 2018). Many of South Africa's resources are heavily- or overexploited (DEA 2016a), and heavily exploited stocks will be more vulnerable to the effects of climate change (DEA 2013a), exacerbating economic ramifications and job insecurity within the sector. The extent of

the impacts will be determined, in large part, by how quickly and successfully resource managers can implement effective adaptation measures.

Several **adaptation measures** for inshore and offshore fisheries have been identified, including *inter alia* product beneficiation and diversification, improved marketing, broadening the target base of exploited resources including new species, developing alternative catching methods, shifting fishing infrastructure (e.g. landing and processing facilities) to match changes in resource distribution, utilizing larger vessels to improve fishing range and increase efficiency and safety at sea, strengthening harbour defences, and developing early warning systems for adverse weather conditions (Hampton *et al.* 2017, van der Lingen and Hampton 2018). Improved **monitoring and research** programmes to better understand and possibly even predict climate changes on the marine environment, fishery resources, and associated socio-economic impacts are an important part of adaptation (Hampton *et al.* in prep, Gammage *et al.* 2017). The practicality and cost effectiveness of potential adaptation strategies should be considered carefully alongside socio-economic impacts to minimise consequences for local communities prevent maladaptation. For example, shifting fishing infrastructure could undermine the economic security of entire communities and increased travel costs could negatively impact carbon emissions, further contributing to the problem. Place-based approaches can help position local vulnerability within broader contexts of sustainability assessments (Cutter *et al.* 2008, Gammage *et al.* 2017).

6.4.2 Food security

Seafood is an important source of protein in South Africa with many citizens relying on marine resources for food security (see Chapter 2). Changes in intertidal species composition could lead to changes in nearshore fish communities, potentially impacting recreational fishers and intertidal subsistence fisheries (DEA 2013a). Major social restructuring has been observed resulting from Collapsed stocks, and more research is needed to understand the extent of **socio-economic impacts** (DEA 2013a). Different regions will experience these impacts differently, due in large part to varying degrees of dependency on the fishing industry. On the west coast, for example, entire families may depend on a single resource for income, whereas south coast household incomes tend to be more diversified (DEA 2013a).

6.4.3 Marine Tourism

Climate impacts on marine tourism may not be immediately apparent and more research is needed, but species distribution, population declines and other changes may limit growth or reduce profits from this growing industry (see Chapter 2 for further detail on marine tourism benefits). Furthermore, the permit system for both **whale and shark watching** is currently underpinned by spatial units. If these charismatic megafauna undergo sufficiently large range shifts, it could require a review of the entire permitting system.

Documented shifts in prey distributions (Table 17), sea level rise and increased extreme events could affect the long-term sustainability of **Penguin** colonies and thus the tourism revenue that they generate (Lewis *et al.* 2012, van Zyl and Kinghorn 2018).

The **Sardine run** in KwaZulu-Natal is a world renowned natural event attracting thousands of national and internatonal tourists (Hutchings *et al.* 2010). There has been a notable delay in the timing of Sardine run events, which are decreasing in frequency of observable shoals, at least partially due to climatic changes (Portwig 2016). If inshore waters continue warming in winter and surpass the

Sardine's temperature threshold, it could shift the Sardine run off KwaZulu-Natal into deeper waters where it is less accesible to beach-seines and tourists, or potentially end the event altogether (Portwig 2016, Augustyn *et al.* 2018).

Sodwana Bay, in the iSimangaliso Marine Protected Area, is South Africa's most popular s**cuba diving** destinations sustaining more than 60 000 recreational dives per year (Walters and Samways 2001). The region's coral reefs have an annual economic value of R143-R175 million, including direct expenditures from SCUBA divers and boat-based anglers (Schleyer *et al.* 2018). Coral bleaching has been observed in this region since 1998, and rising temperatures and ocean acidification will continue to affect reef biodiversity and ultimately reef-dependent industries (Celliers and Schleyer 2002, Schleyer and Celliers 2003b).

6.5 South Africa's Responses to Climate Change

South Africa has played an active and at times world leading role in responding to climate change. Responses along with recommendations for further actions on climate change policy, management, international partnerships, research and monitoring are discussed.

6.5.1 Policy

Implemented:

National policy responses:

In 2012, the former Department of Environmental Affairs (DEA) published a National Climate Change Response White Paper presenting the government's long term vision for an effective response to this global challenge (DEA 2012). In follow up to the white paper, the DEA established the **Long-Term Adaptation Scenario**s Flagship Research Program (LTAS) to conduct research and scenario planning for various industries. Climate Change Implications for Marine Fisheries in South Africa (DEA 2013a), a fisheries-specific publication by the LTAS, was published in 2013 to present a preliminary picture of potential impacts on the sector.

The fisheries branch of the Department of Environment, Forestry and Fisheries (DEFF) has been developing its own sector-specific Climate Change Adaptation and Mitigation Plan to identify possible adaptation measures for all of South Africa's marine fisheries and aquaculture (Augustyn *et al.* 2018). The Policy for the **Small-Scale Fisheries Sector** in South Africa explicitly acknowledges climate change threats and suggests ways to improve interaction between small-scale fishing communities, and between those communities and government, as possible adaptation measures (van der Lingen and Hampton 2018). Formal legislation is also starting to account for the impacts of climate change. South Africa's Integrated Coastal Management Act**,** for example**,** requires proposed coastal developments to consider future sea level rise, but there is not yet enough data available for robust assessments **(**Mather and Stretch 2012)**.**

International partnerships:

South Africa signed the **Benguela Current Convention** (BCC) in 2013, agreeing (along with Namibia and Angola) to promote a coordinated approach the "long-term conservation, protection, rehabilitation, enhancement and sustainable use of the Benguela Current Large Marine Ecosystem." The BCC has recently partnered with the Food and Agriculture Organization of the United Nations to

build resilience and reduce vulnerability to climate change in marine fisheries and mariculture sectors within the entire Benguela Current system (Barange *et al.* 2018)**.**

***Recommended*:**

Overall, **policies** should be **evidence-based, adaptive and timely** to maximise their effectiveness. Suggested examples include flexible permit structures and incorporation of climate non-stationarity into management frameworks (Augustyn *et al.* 2018). Simple decision support tools can be used to predict localized impacts of coastal flooding and erosion along southern and eastern coastlines (Mather and Stretch 2012).

Fisheries managers must prioritize adaptation measures to promote **the long-term security** of South Africa's marine resources. Strategies may include the identification and protection of valuable areas, marine spatial planning, monitoring programs, disaster risk management and broadening stakeholder engagement in climate change planning (Augustyn *et al.* 2018). The new Policy for the Small Scale Fisheries Sector in South Africa can be used to inform, educate, and engage with local communities about the effects of climate change (Barange *et al.* 2018). Increasing **outreach** through this mechanism could help secure community assistance with on the ground monitoring and reduce some of the long-term socio-economic impacts by helping them adapt (Barange *et al.* 2018). Encouraging diversification of activities and income generation will enhance social resilience through the promotion of education, entrepreneurial training, and training in marine tourism and sustainable aquaculture (DEA 2013a).

Maintaining high levels of protection and world heritage site status for South Africa's **coral reefs** will help ensure climate mitigation and adaptation benefits of this globally important MPA are secured into the future (Roberts *et al.* 2017). The role of the iSimangaliso MPA in climate adaptation and mitigation should be recognized (Simard *et al.* 2016) and the reefs acknowledged as nationally important natural barometers for indicating climate change (Porter *et al.* 2016). Further recommendations include the development of a **bleaching response plan** and its incorporation into the National Adaptation Plan as outlined in South Africa's Intended Nationally Determined Contribution submitted to the United Nations Framework Convention on Climate Change (UNFCCC) (Porter *et al.* 2016).

Aquaculture potential under future climate scenarios should be assessed, especially in light of the industry's projected growth (DEA 2013a). The South African **aquaculture industry** is projected to increase revenue to R3 billion and provide 15 000 jobs by 2033 (Operation Phakisa Lab Report 2014). An assessment of climate impacts (particularly the effect of ocean acidification) on growth of the industry will give a more complete view of its potential, and should include an analysis of socio-economic impacts (Engel and Salie 2017).

6.5.2 Management

***Implemented*:**

In October 2018, 20 new marine protected areas (MPAs) were approved by cabinet, with declaration in May 2019 and implementation on 1 August 2019 increasing protection of South Africa's mainland waters from 0.4% to 5%. South Africa's new network of 41 mainland MPAs now protects 87% of the country's 150 marine ecosystem types, providing crucial shelter for local biodiversity and unique ecosystems based on their current positions (see Chapter 7). However, much effort remains to ensure

that MPAs have the infrastructure, funding, and enforcement they need to fulfil their potential and continue to provide crucial protections as species shift and adapt to future climate conditions.

In the fisheries sector, **operational management plans** (OMPs) undergo regular revisions every four years to account for increased variability in resource abundance. Assessments are updated annually to ensure resource indicators remain within the boundaries considered likely at the time that the OMP was adopted. Incorporating climatic responses into the revision process has been identified as a management adaptation measure for offshore fisheries. There is also increased interest and investigation into new management measures, such as the transboundary management of shared stocks (e.g. Cape Hakes).

Strategies for safeguarding **endangered species** from the impacts of climate change include establishing a new penguin colony in De Hoop (Underhill *et al.* 2006), where prey is more readily available. Penguins are also moved to the South African Foundation for the Conservation of Coastal Birds (SANCCOB) for rescue and rehabilitation during storm surges that can destroy nests and drown chicks (pers. comm. A. Kock, South African National Parks)

Recommended:

One of the most important and impactful responses for strengthening climate resilience is to **reduce other anthropogenic stressors** (including overfishing, pollution, invasive species, poaching, disturbance, and excessive nutrient inputs) (DEA 2013a). Reducing stress in marine systems enhances the natural adaptive capacity of both species and habitats, increasing the likelihood that they will be able to absorb and recover from future disturbances. This is particularly true for coral reefs, for which the limiting stressors such as land-sourced pollution and human disturbance is recommended (Porter *et al.* 2016).

Prioritising sound **ecosystem-based management** practices can also help rebuild ecosystems and improve habitat quality (DEA 2013a). Preserving intact habitat and leaving underdeveloped shorelines undisturbed should be a top priority for strengthening coastal resilience, as these areas have the highest natural adaptive capacity (Harris *et al.* 2011d, SAEON 2011).

In the fisheries sector, existing resources and biodiversity should be secured while working towards the **recovery of impacted resources**. Critically depleted stocks (e.g. West Coast Rock Lobster) must be aggressively rebuilt to preserve vulnerable populations (Augustyn *et al.* 2018). An adaptive harvest strategy can provide a basis for integrating rapid changes in abundance of exploited stocks and regime-specific harvest rates can offer much needed flexibility (Cury and Shannon 2004). Sustainable management is critical to strengthening fish stocks' adaptation potential (DEA 2013a), which may depend on the population structure of exploited resources. For example, the South African Sardine population consists of three, semi-discrete stocks (van der Lingen *et al.* 2015), each of which will likely have different adaptation potential. Genetic potential can be preserved through sustainable fishing practices, appropriately zoned fishing areas and other spatial management approaches, as well as climate-resilient MPAs (DEA 2013a).

Management authorities should prioritise adaptation measures and incentivise fisheries towards risk reduction, market differentiation and engagement with new fish species and partners (Augustyn *et al.* 2018). The small pelagic fishery, for example, should explore methods of processing Anchovy and Round Herring for human consumption, and allow for greater variability in resource abundance and/or availability in management measures (Augustyn *et al.* 2018).

6.5.3 Monitoring and Research

Implemented:

The South African Environmental Observation Network (SAEON) provides crucial **long-term monitoring** through its Elwandle Node for coastal systems and Egagasini Node for marine offshore systems. The Elwandle Node includes the Algoa Bay Sentinel Site network of 41 permanently moored instruments along a 300 km stretch of southeast coastal waters, building on more than 40 years of focussed research. It also maintains monitoring programs through the National Coastal Temperature Network, National Estuaries Network and MPA Network (Bornman 2016). The Egagasini Node engages in observations and modelling of the southwest Indian and the southeast Atlantic Oceans, with specific focus on the Agulhas and Benguela Current systems. The Agulhas System Climate Array (ASCA) is coordinated by SAEON with strong collaboration with the Department of Environment Forestry and Fisheries (DEFF). Additionally, in collaboration with the DEFF, Egagasini implements a long-term benthic invertebrate monitoring program on the west and south coasts supporting advancement of taxonomic and ecological knowledge of these ecosystems.

In addition to collecting information on the species, quantities, locations and dates, and some biological characteristics (typically size but also occasionally other data) of commercially exploited living marine resources, the DEFF conducts regular research surveys and other field studies annually on the south and west coasts to assess the status and distributions of **commercially exploited marine resources**. These include swept-area and hydro-acoustic surveys to estimate the biomass of demersal (e.g. Cape Hakes, Kingklip, Monk, Sole and Squid) and pelagic (e.g. Anchovy, Sardine and Round Herring) fish species, respectively; standardised angling and remote underwater video, trap and diving surveys to monitor the abundance of linefish, West Coast Rock Lobster and Abalone, respectively; and observer programmes on several fisheries (Hutchings *et al.* 2009a, DAFF 2016). Environmental data are also collected during some of these surveys.

The DEFF conducts research programmes for integrated oceans and coastal management. For example, the **Integrated Ecosystem Programme**: Southern Benguela provides relevant, reliable and improved assessment of the Benguela Current Large Marine Ecosystem to enhance understanding of the mechanisms and processes that influence the system's structure and functioning, including the impact of climate change. Operation LIMPET currently serves as South Africa's national **rocky shore monitoring** programme, which aims, among other goals, to detect climate impacts on coastal biodiversity. DEFF is also developing a South African Monitoring Programme of Marine Plankton and is seeking funds to monitor HABs and water quality.

The Oceanographic Research Institute has been undertaking long-term monitoring of South Africa's **coral reefs** since 1993 (Porter and Schleyer 2017). The project is one of the oldest coral monitoring projects of such nature in the world, and includes the hourly monitoring of underwater temperature. Monitoring of coral communities is conducted annually within fixed transects and because the study commenced before 1998, it provides important baseline data prior to the first incidences of coral bleaching. Monitoring is, however, limited to only one site due to funding constraints.

Research on **climate impacts, risks, vulnerability and future scenarios** has increased markedly over the past decade. The NansClim Project (2009-2014) was established to identify and describe changes in ocean climate, marine biodiversity and fisheries in the Benguela Current system (Jarre *et al.* 2015b). In 2010, the South African Risk and Vulnerability Atlas (SARVA) was created to provide decision makers

with information on the impacts and risks of global change (Perrott 2012). That same year, the University of Cape Town founded the Marine Research in the Benguela and Agulhas Systems for supporting Interdisciplinary Climate-change Science Program (Ma-Re BASICS) (2010-2013) to promote interdisciplinary climate science (Blamey *et al.* 2015). The Kelp Ecosystem Ecology Network (KEEN) project is assessing the impacts of global change on kelp forests while the NRF-funded Effect of Climate Change on Cetaceans (E3C) project is using citizen science to help fill knowledge gaps for whales and dolphins. The SeaKeys project also included a component to build on earlier coral bleaching monitoring work (Sink unpublished data 2005-2013) with monitoring undertaken in 2014, 2015 and 2016. In 2016, the SeaKeys Monitoring Working Group convened a workshop to synthesize current monitoring efforts in South African waters (see Chapter 11) which identified the following gaps (Table 18) (Atkinson *et al.* 2016).

Table 18. Gaps in current South African marine monitoring as identified during the SeaKeys Monitoring Working Group Workshop Report [adapted from (Atkinson *et al.* 2016)]

Component	Region
Spatial gaps	West Coast (specifically north of Saldanha Bay)
	Transkei coast (specifically subtidal and offshore)
	Surf-zone/shallow subtidal (intertidal to 5m) coastwide
	East Coast offshore
	Entire offshore (>200m) region
	Shallow habitat systems
	Nationwide sandy beach monitoring
Phytoplankton taxonomy	National lists of phytoplankton and comprehensive monitoring of phytoplankton (links to harmful algal blooms)
Marine turtle monitoring	Only females are monitored in the shore-based programme. Male turtles require monitoring by means of telemetry tracking.
Marine phenology	The timing of natural marine events (e.g. arrival of whales, upwelling, turtle egg-laying season, sardine run, etc.)
Whole system monitoring	Links between systems (e.g. dams-rivers-estuaries-nearshore-offshore)
Benthic ecology	Nationwide (especially >200m)
Ocean acidification	Nationwide

Recommended:

Strategic coordination of **long-term research and monitoring** with a commitment to maintaining **uninterrupted time series** is vital for detecting and understanding change. Climate change vulnerability assessments can help fill knowledge gaps and identify appropriate responses. Expanding data collection, particularly for wild capture resources, near shore (<50 m depth), deep ocean systems, and ocean acidification will improve predictive capacity and allow timely, science-based policy changes (Augustyn *et al.* 2018). Monitoring networks should cover a range of ecosystems (from the land-sea interface to the deep sea) to broaden our understanding of impacts across the marine environment. Investigation into the processes through which environmental changes manifest from the individual to ecosystem level can help identify species and systems most affected by climate change and how best to preserve and/or enhance those species' evolutionary capacity (Lawler 2009). Predicting changes in species distributions from kelp to fish to apex predators can assist with marine spatial planning and MPA network design.

Scientific research on the vulnerability and adaptability of key habitat-forming species and fisheries species to changing ocean conditions is needed (Barange *et al.* 2018). Stock assessments must be robust (DEA 2013a), and subtidal monitoring can be improved where appropriate with camera surveys

and baited remote underwater video surveys (BRUVs) which are inexpensive and non-extractive (Blamey *et al.* 2015). Knowledge gaps in the adaptive capacity of some species can be filled through the investigation of their dispersal capacity, short-term phenotypic plasticity and long-term evolutionary adaptation to environmental change (DEA 2013a).

South Africa's **coral communities** are key strategic assets for the early detection of climate change (Box 27). Their marginal nature in terms of temperature, light, and aragonite saturation state makes them receptive to early signs of climate change and thus it was thought that changes on South African reefs may precede those on more typical, tropical reefs (Schleyer and Celliers 2003b). However, more typical tropical reefs have been extensively affected by global warming in the last two decades whereas South Africa's reefs have been only negligibly affected and sheltered from major bleaching events. Nevertheless, South African coral reefs are vulnerable to climate change by their very nature despite being located at relatively high latitude. The geographic advantage of South Africa's coral reefs and the sensitivity of coral reefs to climatic changes should be taken advantage of by providing increased support for routine monitoring efforts, not just during periods of El Niño or other threats. The establishment of a multi-disciplinary Centre of Excellence, with specialist skills in coral reef ecology, climate science and monitoring is recommended (Porter *et al.* 2016). The Centre should be identified and supported with consistent and adequate funding to track and investigate the potential effects of climate change, conduct bleaching monitoring, and general reef health assessments.

Differentiating between the **compounding effect** of multiple drivers should also be prioritized (DEA 2013a). Particularly disentangling climate and fisheries as drivers of biodiversity in the Benguela Current system (Blamey *et al.* 2015, Jarre *et al.* 2015b) and in deeper waters (Barange *et al.* 2018). MPAs and no-take zones can be used as control sites to help determine whether biological responses are due to climate change or other anthropogenic impacts (DEA 2013a). Interdisciplinary collaboration and coordinated ecosystem projects will be instrumental in this endeavour (Blamey *et al.* 2015).

Improving **regional climate models** will enhance our ability to detect, understand and predict localized impacts (DEA 2013a). This will require advancing our understanding of basin and shelf-scale dynamics (Jarre *et al.* 2015b). Cross-cutting process and ecosystem models can be used to analyse interactive effects of environmental and human drivers on ecosystem changes at regional scales (Jarre *et al.* 2015b).

Potential **adaptation strategies** should be investigated with the aim of defraying both biological and socio-economic consequences of climate change (Augustyn *et al.* 2018). Top-down versus bottom-up approaches to fisheries management that support resilience should be explored (DEA 2013a). However, social-ecological dynamics are not sector-specific, so care should be taken not to treat offshore and inshore subsystems separately as many fishers and their families derive their livelihoods from both (DEA 2013a).

6.5.4 Conclusions

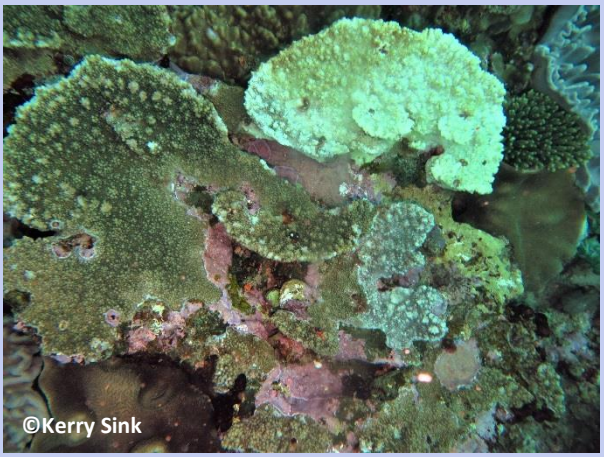
The global reach of climate change means that while impacts are experienced locally, potential solutions can come from far afield and may be just as appropriate and successful in widely separated regions (Hobday *et al.* 2016). Strengthening **engagement** with both local and global networks can facilitate shared learning while encouraging collaboration and increasing opportunities to test hypotheses. Local engagement and effective communication about the value of marine resources and ecosystems and the impacts of climate change can help strengthen the adaptive capacity and

cooperation of local communities. Fostering necessary skills within the science, policy, and practitioner communities and strengthening our capacity to research, monitor, predict and adapt to the impacts of climate change will not only strengthen the resilience of South Africa's marine resources, but the country as a whole.

Box 27. Case study: South Africa's coral reefs

South Africa hosts the southernmost coral reefs on the African continent. Unlike true accretive reefs, South Africa's marginal coral communities grow as a thin veneer on late Pleistocene sandstone substrata (Ramsay and Mason 1990). Characterized by high biodiversity, the reefs support at least 132 coral species, (Schleyer and Celliers 2003b), 400 fish species (Turpie *et al.* 2000) and 49 species of sponges and tunicates (Schleyer and Celliers 2000). Although the reefs fall almost entirely within Marine Protected Areas (MPAs), they are subject to a wide variety of anthropogenic pressures. For example, since 2010 reefs in Sodwana Bay are subject to more than 60 000 recreational dives per year resulting in physical disturbance, damage and sediment resuspension (Walters and Samways 2001). By far the most pressing threat, however, is climate change (Schleyer *et al.* 2008).

Coral bleaching, a climate change indicator, results from the loss of symbiotic dinoflagellates, triggered by elevated sea temperatures and other environmental stressors, leaving corals physiologically and nutritionally compromised (Hughes *et al.* 2018). Prolonged bleaching can cause widespread mortality (Spalding and Brown 2015) and regional-scale bleaching events are an increasingly common modern phenomenon (Carilli *et al.* 2010). The impact, severity, and response to bleaching events can vary widely (Hughes *et al.* 2018) and South African reefs provide a valuable model for the study and prediction of future global changes (Schleyer *et al.* 2008).



White discolouration in coral is an indication of bleaching

During the then-unprecedented worldwide bleaching event of 1998, many reefs in the Indian Ocean suffered coral mortalities in excess of 90% (Spalding and Brown 2015). In contrast, South African reefs sustained only minimal damage (1% bleaching). Quantifiable bleaching was later observed in 2000 and 2005, when increased water clarity and radiation are believed to have exacerbated the impacts of elevated temperatures (Celliers and Schleyer 2002, Porter and Schleyer 2017). Observed bleaching was patchily distributed and variable both within and among species (Celliers and Schleyer 2002). Hard corals were more susceptible, particularly the genera *Montipora* and *Alveopora,* although bleaching of some Alcyoniidae also occurred. An encrusting sponge, *Suberites kelleri*, also bleached and developed necrotic patches, often with cyanobacterial infections (Celliers and Schleyer 2002). During the most recent 3rd global coral bleaching event in 2016, South African coral reefs were again relatively unscathed with less than 10% of the coral cover bleaching (Porter *et al.* 2016).

Long-term monitoring has also revealed subtle, systemic changes in community composition including an increase in hard coral cover until 2005 (after which it remained stable) and gradual increase in the number of colonies (Porter and Schleyer 2017). Conversely, there has been a significant reduction (0.95% per annum) in soft coral cover and number of colonies (Porter and Schleyer 2017). This shift could be the result of competitive interaction, but ocean acidification is also a potential driver (Porter and Schleyer 2017). Understanding the main drivers of these changes will be critical to accurately predicting future impacts.

At a global scale, South African reefs appear to be well insulated from the extensive devastation experienced elsewhere. Subtropical conditions (Celliers and Schleyer 2002) and small-scale, localized upwelling (Riegl and Piller 2003, Hayman and Uken 2015) are moderating the influence of regional temperature increases and may actually be causing local temperatures to fall (Porter and Schleyer 2017). The unusual depth of South African reefs is also expected to provide

protection from warming temperatures and solar radiation (Schleyer and Celliers 2000). This has led to the prediction of South African waters as potential coral refugia as ocean conditions become increasingly hostile (Riegl and Piller 2003).

Survival strategies, however, are not that straightforward due to a variety of complicating factors. The localized upwelling that buffers rising water temperatures in Sodwana Bay could itself result in mortality if intensified, or reduced during times of warming (Riegl and Piller 2003). Poleward range expansion to cooler waters down the coast is unlikely in light of human population density and high river effluents (such as silt, sewage and agricultural runoff) detrimental to coral formation (Whitfield *et al.* 2016). Ocean acidification is also expected to limit southward expansion (Whitfield *et al.* 2016) and reduce coral growth rates, larval outputs and skeletal density (Fine and Tchernov 2007). These impacts will make corals more brittle and prone to destruction and bio-erosion, thereby diminishing habitat quality (Fine and Tchernov 2007).



Observations from the 2016 bleaching survey at iSimangaliso. *Acropora* coral with 80-100% bleaching

Globally, there is evidence that acclimatization and adaptation of corals is underway (Hughes *et al.* 2017). Effective reef management will be crucial to helping South African corals maximize their adaptation window. Efforts to reduce compounding drivers and accelerate positive changes should be coupled with a deeper understanding of underlying causes (Hughes *et al.* 2017). Managers can also manipulate ecological thresholds to make systems more resilient (e.g. adopting new fishing technologies to reduce environmental damage, or actively altering community compositions towards heat-tolerant species) (Hughes *et al.* 2017). Weakening feedback loops (such as providing incentives to exit a fishery when stocks decline) can reduce the risk of crossing a tipping point (Hughes *et al.* 2017). Management goals should be re-evaluated with an emphasis on preserving ecosystem function, and perhaps even active ecosystem intervention (Hughes *et al.* 2017). Developing international institutions for coral stewardship may expedite decision making at multiple scales (Hughes *et al.* 2018). Innovative partnerships can help broaden stakeholder engagement while changing social norms can help improve environmental behaviours (Hughes *et al.* 2017). Coral reefs are just one ecosystem pushing rapidly towards new uncharted territory, but their preservation will require a bold new approach to science, management and governance (Hughes *et al.* 2017).

For additional case studies on South African marine resources see (Augustyn *et al.* 2018).

7. ECOSYSTEM THREAT STATUS

Chapter Citation: Sink KJ, Holness S, Skowno AL, Franken M, Majiedt PA, Atkinson LJ, Bernard A, Dunga LV, Harris LR, Kirkman SP, Oosthuizen A, Porter S, Smit K, Shannon L. 2019. Chapter 7: Ecosystem Threat Status. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



Browns Bank Rocky Shelf Edge is considered to be one of two Critically Endangered marine ecosystem types in South Africa

Chapter Summary

The new national marine ecosystem map was used to assess the threat status for South Africa's 150 marine ecosystem types. A total of 31 pressures were considered individually and cumulatively as a surrogate for ecosystem degradation. Both the extent and intensity of pressures were considered in addition to an impact score per broad ecosystem type. An ecosystem condition map was produced with degradation assessed in four categories aligned to the IUCN Red List of Ecosystems (RLE) approach. IUCN RLE criterion C3, which focuses on ecosystem degradation, was the primary assessment criterion but ecosystem distribution was also considered in line with IUCN criterion B. The 2018 results are not directly comparable to the 2011 NBA results because of changes to the ecosystem maps and pressure data, and also differences in assessment methods. Key differences in 2018 include six additional pressures, finer-scale assessment at pixel level, application of four rather than three categories of ecosystem condition, and differences in thresholds for threat status categories. The IUCN global criteria generally use stricter thresholds than previously applied in the NBA 2011, and the 2018 results appear slightly more optimistic than those in the 2011 assessment. This should not be interpreted as an improvement in status, it represents a new baseline for future ecosystem level monitoring that is aligned with global standards. Further changes to this recent assessment are anticipated in the near future as more work is needed to interrogate the criteria, thresholds and input data. Currently, half of South Africa's 150 marine ecosystem types are threatened. By area this equates to only 5% of the ocean space around South Africa with more inshore and shelf ecosystem types threatened than those in the slope and abyss. Only two ecosystem types (1% of types) are considered Critically Endangered; the Agulhas Muddy Mid Shelf and Browns Bank Rocky Shelf Edge. A further 22 types are considered to be Endangered (15%) and 51 types are considered Vulnerable (34%). The most threatened broad ecosystem groups include bays, islands, muddy ecosystem types and rocky ecosystems on the shelf and shelf edge. The cold temperate Southern Benguela ecoregion has more threatened ecosystem types than the warm temperate Agulhas ecoregion, while the subtropical Natal and Delagoa ecoregions have the least threatened ecosystems. To improve this assessment, better data on ecosystem condition is needed and further international collaboration is required to determine the appropriate spatial scale for ecosystem red listing, and to refine thresholds for national assessments. Different time periods warrant consideration with more effort needed in defining reference condition. To improve alignment with the IUCN assessment methodology, conceptual models for all functional ecosystem types are needed. For future assessments of ecosystem degradation, methods should advance from a consensus-based approach to a more statistical method that accounts for any uncertainty in the effects of each pressure per broad ecosystem type. To mitigate pressures in priority areas, ecosystem-based marine spatial planning and strengthened marine environmental impact assessments are needed.

7.1 Introduction

Biodiversity indicators have received renewed attention recently amid calls to slow global losses of biodiversity (Nicholson *et al.* 2012, Tittensor *et al.* 2014, Geijzendorffer *et al.* 2015a). Indicators are a tool to i) improve general awareness and gain public attention for biodiversity; ii) meet international reporting requirements; iii) monitor conservation actions; and iv) inform policy and decision making by governments (Nicholson *et al.* 2012, 2015, Keith *et al.* 2013b, 2015, Geijzendorffer *et al.* 2015a, Tanentzap *et al.* 2017b). **Threat status** is a headline indicator that can be applied to both ecosystems and species. It is based on the IUCN risk assessment framework for species (Red List of Species) (IUCN 2012b) and ecosystems (Red List of Ecosystems) (Bland *et al.* 2017a). The IUCN Red List of Species is well established globally and in South Africa and has formed a part of the NBA reporting since 2005. The IUCN Red List of Ecosystems (RLE) is relatively new (v1.0 released in 2016) and prior to its development, South Africa developed its own ecosystem threat status assessment framework between 2004 and 2008 (Botts *et al.* in review, RSA 2011). In the NBA 2018, marine ecosystems were systematically assessed using an approach aligned with the IUCN RLE methods.

7.2 Approach to assess ecosystem threat status

South Africa is one of several countries to independently develop indicators of ecosystem threat prior to the **IUCN Red List of Ecosystems (RLE)** (Keith *et al.* 2013b) (www.iucnrle.org). The IUCN RLE aims to meet a recognised need for an indicator similar to the IUCN Red List of Species that could identify risk for higher-levels of biodiversity organisation such as ecological communities (Noss 1990, Rodríguez *et al.* 2011, Keith *et al.* 2013b, Bland *et al.* 2017a). The IUCN RLE is a framework for assessing the risks to ecosystems and identifying where ecosystems are threatened (Rodríguez *et al.* 2011). Using the familiar categories from the Red List of Species, and based on a set of criteria and thresholds developed collaboratively since 2008, the IUCN RLE was established to ensure that the assessment methods: (i) can be applied systematically across realms and geographic areas; (ii) are transparent and scientifically rigorous; (iii) are comparable and repeatable; (iv) can be easily understood by policy makers and the general public; and (v) complement the IUCN Red List of Threatened Species framework (Rodríguez *et al.* 2011, Keith *et al.* 2013b, Bland *et al.* 2017a).

The key **concepts and definitions** underpinning the IUCN RLE have been documented in several publications (Nicholson *et al.* 2009, Rodríguez *et al.* 2011, Keith *et al.* 2013b, 2015, Bland *et al.* 2017a, 2018a) and there is growing uptake of these standards (Bland *et al.* 2017a) with a number of published sub-global assessments (including North America, Philippines, Australia, Colombia, France, and Finland) adopting the RLE approach. Ultimately national and other sub-global assessments undertaken using these international standards will contribute towards establishing a **global database** of threatened ecosystems equivalent to the global Red List of Species.

The goal of the IUCN RLE is to identify ecosystems that are at risk of losing their constituent biodiversity. While there is substantial evidence that ecosystem function and services are linked with biodiversity (Bland *et al.* 2017a), the relationships between these three facets of ecosystems can be complex. Consequently, the RLE focusses specifically on **risks to biodiversity** (Keith *et al.* 2013b). The RLE framework used the concept of ecosystem collapse as the 'end point' of ecosystem decline; this is equivalent to species extinction in the RLS, and is defined operationally as a 'transformation of identity, loss of defining abiotic or biotic features and a state where characteristic native biota are no longer sustained' (Keith *et al.* 2013b).

The RLE requires consistent and clearly defined units of assessments (ecosystem types) that can be delineated spatially, and must be able to effectively assess risks across widely contrasting ecosystem types from all realms (Keith *et al.* 2013b). On land, vegetation types, have been suggested as appropriate and consistent units that represent biodiversity and communities at a relevant scale for use in the RLE (Keith *et al.* 2013b, Boitani *et al.* 2015). The IUCN guidelines (Bland *et al.* 2017a) note that South Africa's National Ecosystem Classification (Driver *et al.* 2012) represents a suitable typology to support RLE assessments of our national jurisdictions.

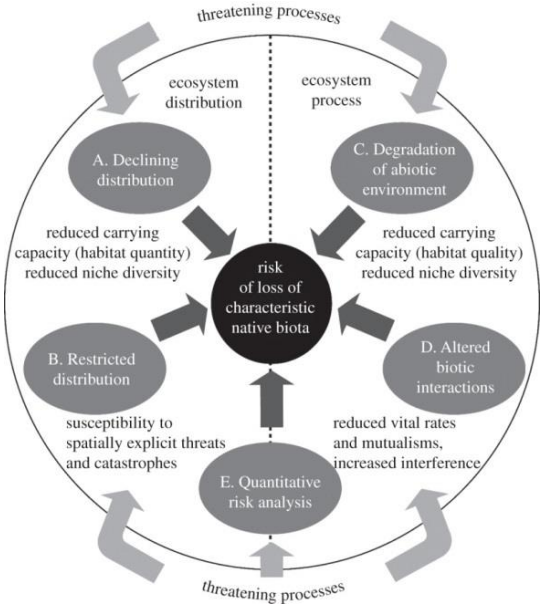


Figure 75. IUCN RLE framework for assessing the risk of ecosystem collapse. Source: (Keith *et al.* 2013b)

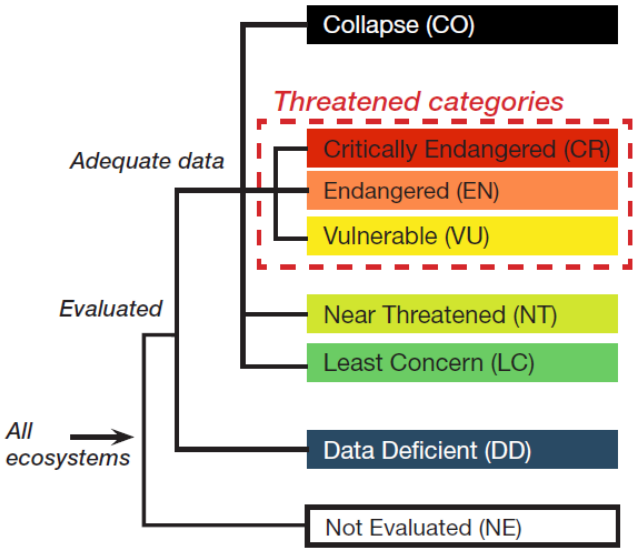


Figure 76. IUCN RLE threat categories, see glossary of terms of definitions. Source: (Bland *et al.* 2017a)

Despite the increasing application of the IUCN RLE approach, Bland *et al.* (2018b) note that only 10% of ecosystems (7 out of 71) on the global Red List belong to the marine realm and highlight the **limited application in the marine ecosystems** that dominate this planet. Their assessment of the Southern Benguela represents a first test of the RLE protocol on offshore marine ecosystems. Bland *et al.* (2018b) assessed the Southern Benguela as Endangered based on Criterion D3 with the result driven largely by declines in seabirds and predatory fish. However, the latter assessment is at the large marine ecosystem scale, whereas the IUCN guidelines recommend using ecosystem types for national assessments and note that assessments even at the scale of ecoregions are less appropriate as they contain too much variation (Bland *et al.* 2017a) and the scale is less relevant in terms of informing spatial management at a national scale. Keith *et al.* (2013b) used the IUCN RLE to assess the threat status of Alaskan Giant Kelp Forest and found a threat status of Endangered (plausibly Endangered - Critically Endangered) using Criterion D3. Bland *et al.* (2017b) assessed the Meso-American Reef Complex as Critically Endangered (plausibly Vulnerable to Critically Endangered) based on a range of empirical (field and remotely sensed) data and a stochastic ecosystem model to explore ecosystem dynamics under multiple threat scenarios.

The **risk assessment model** for the IUCN RLE is illustrated schematically in Figure 75. Declining distributions (Figure 75 oval A) and restricted distributions (Figure 75 oval B) are considered

distributional symptoms of decline; while degradation of the abiotic environment (Figure 75 oval C) and altered biotic function (Figure 75 oval D) are considered functional symptoms of decline. It is possible for these mechanisms to interact and produce additional symptoms of decline (Keith *et al.* 2013b). The mechanisms in the conceptual model translates into five rule-based criteria (Figure 76) with thresholds for the distributional and functional symptoms (Table 19).

The **South African List of Threatened Ecosystems** was conceptualised as a national indicator of ecosystem conservation status in the early 2000s. From its early applications as a project-based indicator (Botts *et al.* in review), it progressed into a legislated national listing of threatened terrestrial ecosystems (RSA 2011). South Africa has been reporting on the threat status of its ecosystems for more than a decade, and using this information to focus scarce resources on conservation priorities through a wide range of government policies (Driver *et al.* 2005b, 2005a, 2012). Ecosystem threat status was a major component of the evidence base used to establish an expanded network of Marine Protected Areas in South Africa (see Chapter 8). This demonstrates the value of a systematic assessment of ecosystems in providing evidence for improving protection in the marine environment. The ecosystem threat status has also been used in Environmental Impact Assessments and in activities to mainstream marine biodiversity in fisheries (De Beers Marine 2010, Sink *et al.* 2012b, Department of Environmental Affairs *et al.* 2013, Andrews *et al.* 2015). It has also been adopted South African Environmental Outlook reporting.

Assessment methods and **implications of the shift to the IUCN RLE approach** are best understood in the terrestrial realm where an established and stable national vegetation map is the foundation of assessment (Skowno *et al.* 2019a). Marine assessments are less mature and advances in ecosystem classification, changes in the pressure mapping approach, condition categories applied, and assessment methods and criteria limit the ability of the marine assessments to track changes and detect trends at this stage.

7.2.1 Marine Approach to Assessment

In South Africa's **first National Spatial Biodiversity Assessment** (Driver *et al.* 2005a), the threat status of 34 marine biozones (main units of marine biodiversity pattern reflecting depth and biogeographic patterns) was assessed using an expert based method that compared the relative threat from nine general pressure categories on marine biodiversity. In the **NBA 2011**, a first data driven assessment was conducted using cumulative pressure mapping of 27 pressures in a five by five minute grid to assess condition and ecosystem threat status of 136 marine ecosystem types (Sink *et al.* 2012a).

For the **NBA 2018**, the ecosystem threat assessments were based on the updated national marine ecosystem map (see Chapter 3) and the threat status of 150 marine ecosystem types was assessed using criteria aligned to the IUCN RLE approach. Intensity of pressure and ecosystem degradation were assessed in four categories (Table 19) aligned to the RLE categories of degradation (Bland *et al.* 2017a). This assessment sought to simultaneously assess all ecosystem types in a single systematic step. The value of this approach is that results may be more comparable than an approach where different data sets, authors, concepts and criteria are applied to assess individual ecosystem types. The latter approach is however also useful in exploring the application of other criteria and approaches and options for advancing this work in the future. In South Africa, a study on Kelp Forests provided an opportunity for the application of a broader range of assessment approaches and to examine assessments using the standard Criteria B as specified by the IUCN (Dunga LV. MSc thesis, University of Cape Town, in prep). Additional work on ground-truthing ecosystem condition is also taking place

on subtropical and warm temperate shallow and deep reefs (Smit K. in prep Nelson Mandela University, PhD thesis) that may guide future assessments. For coral reef ecosystems there is a regional initiative to assess threat status of coral reef ecosystems with participation by local scientists (Sean Porter, Oceanographic Research Institute and Kerry Sink, SANBI). As trawling is a key pressure on offshore ecosystem types, there is also work under development to examine the degradation effect of different trawl intensities on marine ecosystem condition and this may be useful for future assessments.

All the marine ecosystem assessments in this chapter were based on a pre-colonial 1750 historical reference condition, corresponding approximately to the earliest onset of global industrial-scale exploitation of ecosystems (Bland *et al.* 2017a). In contrast, the marine ecosystem assessment for the sub-Antarctic only considered the past 50 years (Whitehead *et al.* 2019) due to the shorter period of human activity in the offshore environment there. The **primary assessment method** applied in the marine NBA 2018 was based on **IUCN Criteria C3** (environmental degradation) as this was most similar to the established South African approach for marine ecosystem assessment which is based on cumulative pressure mapping (Sink *et al.* 2012a). This meant that the pressure data layers that were prepared for past assessments could be added to and updated and used for this assessment, as opposed to developing new data sets for an approach with dissimilar requirements. A key element of the NBA 2018 approach is the systematic assessment of every ecosystem type in a comparable approach. Note that due to the cumulative pressure mapping approach and the merging of benthic and pelagic components into a single ecosystem type (see Chapter 3), relevant updated pressure data were available for all ecosystem types, even deep water ecosystems beyond the shelf edge where key pressures are essentially at the surface (shipping, large pelagic fisheries).

The IUCN C3 approach aims to assess decline in ecosystem functions or processes based on **abiotic degradation** which is known to reduce the capacity of ecosystems to sustain characteristic biota (Keith *et al.* 2013b). Both the extent and severity of ecosystem degradation were considered and an ecosystem pressure matrix was used to score the impact of each pressure per broad ecosystem type (Table 21), in a similar approach to that employed in the NBA 2011 (Sink *et al.* 2012a). Key differences in 2018 include the finer scale pressure mapping, inclusion of six additional pressures (See Chapter 4), application of four rather than three categories of ecosystem degradation and differences in thresholds for threat status categories (Table 20). The latter two changes were driven by the desire to align with the emerging global RLE methodology with the potential benefits of a stronger scientific evidence base and international recognition and alignment. For further detail on the assessment methods see Section 7.4 below.

Table 19. The IUCN RLE criteria and thresholds for the assessment of ecosystem threat status.

A. Reduction in geographic distribution over ANY of the following time periods:				
		CR	EN	VU
A1	Present (over the past 50 years).	≥ 80%	≥ 50%	≥ 30%
A2a	Future (over the next 50 years).	≥ 80%	≥ 50%	≥ 30%
A2b	Future (over any 50 year period including the present and future).	≥ 80%	≥ 50%	≥ 30%
A3	Historic (since 1750).	≥ 90%	≥ 70%	≥ 50%

B. Restricted geographic distribution indicated by EITHER B1, B2 or B3:				
		CR	EN	VU
B1	Extent of a minimum convex polygon enclosing all occurrences (Extent of Occurrence)	≤ 2,000 km^2	≤ 20,000 km^2	≤ 50,000 km^2
	AND at least one of the following (a-c):			
	(a) An observed or inferred continuing decline in **EITHER**:			
	i. a measure of spatial extent appropriate to the ecosystem; **OR**			
	ii. a measure of environmental quality appropriate to characteristic biota of the ecosystem; **OR**			
	iii. a measure of disruption to biotic interactions appropriate to the characteristic biota of the ecosystem.			
	(b) An observed or inferred threatening processes that are likely to cause continuing declines in either geographic distribution, environmental quality or biotic interactions within the next 20 years.			
	(c) Ecosystem exists at …	1 location	≤ 5 locations	≤ 10 locations
B2	The number of 10 × 10 km grid cells occupied (Area of Occupancy)	≤ 2	≤ 20	≤ 50
	AND at least one of a-c above (same subcriteria as for B1).			
B3	A very small number of locations (generally fewer than 5) **AND** prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and thus capable of collapse or becoming Critically Endangered within a very short time period (B3 can only lead to a listing as **VU**).			VU

C. Environmental degradation over ANY of the following time periods:					
			Relative severity (%)		
		Extent (%)	≥ 80	≥ 50	≥ 30
C1	The past 50 years based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
		Extent (%)	≥ 80	≥ 50	≥ 30
C2	The next 50 years, or any 50-year period including the present and future, based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
		Extent (%)	≥ 90	≥ 70	≥ 50
C3	Since 1750 based on change in an abiotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 90	CR	EN	VU
		≥ 70	EN	VU	
		≥ 50	VU		

D. Disruption of biotic processes or interactions over ANY of the following time periods:					
			Relative severity (%)		
		Extent (%)	≥ 80	≥ 50	≥ 30
D1	The past 50 years based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
		Extent (%)	≥ 80	≥ 50	≥ 30
D2	The next 50 years, or any 50-year period including the present and future, based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
		Extent (%)	≥ 90	≥ 70	≥ 50
D3	Disruption of biotic processes or interactions since 1750 based on change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 90	CR	EN	VU
		≥ 70	EN	VU	
		≥ 50	VU		

E. Quantitative analysis …			
	CR	EN	VU
… that estimates the probability of ecosystem collapse to be:	≥ 50% within 50 years	≥ 20% within 50 years	≥ 10% within 100 years

Criterion B (restricted distribution) was also applied in a supplementary assessment to re-consider the threat status of ecosystem types of limited geographic extent. This criteria aims to identify ecosystems at risk because of a combination of small extent and / or limited distribution and ongoing decline (Bland *et al.* 2017a). The underlying theory is that the extent of the geographic distribution of an ecosystem type influences its risk of collapse when exposed to spatially explicit threats or catastrophes (Keith *et al.* 2013b). Ecosystems that span a more substantial extent i.e. are widely distributed or exist across many independent patches are generally at lower risk from threats that exhibit a degree of spatial contagion (e.g. invasions, pollution or regional climate change) (Bland *et al.* 2017a). The main role of criterion B is therefore to identify ecosystems whose distribution is so restricted that they are at risk of collapse from the chance occurrence of single or a few interacting, threatening events (Rodríguez *et al.* 2015). The IUCN recommends that ecosystem distributions are measured by considering two standardised metrics: the extent of occurrence (EOO) and the area of occupancy (AOO) (Gaston and Fuller 2009, Keith *et al.* 2013b) with a range of thresholds specified for each (see further details in Section 7.4.2 below). EOO is measured using a minimum convex polygon and AOO is measured using a number of grid cells to better estimate area of linear ecosystems.

In addition, assessment of criterion B requires a qualitative evaluation of whether **continuing declines** in spatial extent, environmental quality, or increasing disruption of biotic interactions are occurring or likely to occur as a result of threats. Quantitative pressure mapping was used to evaluate environmental quality in this context with details provided in Section 7.6 below. The number of threat-defined locations at which an ecosystem occurs was not estimated which is a requirement for sub-criteria B1c, B2c and B3 but this may be considered in future assessments. The recommended approach was followed in this assessment in that a standard grain size (10x10 km grid) was used for estimating AOO and a standard geometric method (minimum convex polygon) was used for estimating EOO. Note that grain size refers to the size of the spatial unit (e.g. grid cell, polygon segment) used to measure a distribution.

Criterion A (declining distribution) was considered but as the assessment team were not confident that marine ecosystem degradation has led to the complete loss of significant areas from most ecosystem types in the marine realm, this criterion was not applied. **Criterion D** is based on disruption of biotic processes and this was not applied because the team determined that insufficient information exists to comprehensively assess all marine ecosystem types in South Africa using this approach within the timelines for the NBA 2018. Therefore in the assessments, this criterion was considered Not Evaluated. Similarly, insufficient data and expertise were available to apply **Criterion E** which allows for multiple threats and symptoms to be integrated in a model of ecosystem dynamics to produce quantitative estimates of the risk of collapse.

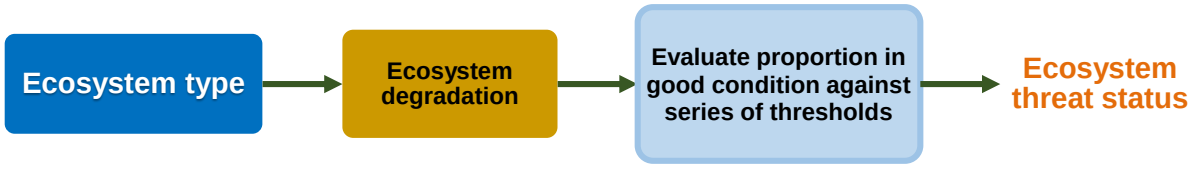


Figure 77. Steps in assessing ecosystem threat status and ecosystem protection level.

Table 20 compares the NBA 2011 and 2018 approaches. Overall, these two approaches define a similar threat space but the Critically Endangered and Endangered thresholds using the RLE approach are stricter in the international RLE approach used in 2018 compared to the NBA 2011 approach. As such,

fewer ecosystems qualified as threatened using the IUCN RLE approach applied in 2018, versus 2011 using the previous approach. Note that these results are also not comparable for other reasons, including differences in ecosystem delineation, pressure mapping and threshold differences. **Additional analyses** were conducted to compare ecosystem threat status results between 2018 and 2011 by applying the 2011 methods to the 2018 data, and applying the 2018 approach to the 2011 data. These analyses were undertaken to assess comparability, contrast the results and to provide feedback to the IUCN RLE team. Further work is underway to examine the influence of different scales of ecosystem classifications, assessment approaches and thresholds.

Both South Africa's national assessment approach for ecosystems that was applied in 2011 and the IUCN RLE were designed to be applied across all realms (marine, freshwater estuarine and terrestrial) and this has many benefits but also some limitations (Sink *et al.* 2012a). Very different approaches are used to measure ecosystem degradation in different realms but there is some synergy in concepts within aquatic ecosystems. For example, categories of ecosystem condition between the marine, freshwater and wetland and estuarine realms were compared and aligned as far as possible (Table 24 and Skowno *et al.* (2019a) for further details).

7.3 Input data and assessment

The revised Marine Ecosystem Classification and Map produced in 2018 was used to assess the threat status of each ecosystem type, and pressure mapping (see Chapter 4 and below) was used to assess **ecosystem degradation**. The RLE encourages the use of all available information on ecosystem degradation, including rates of habitat loss, disruption of biotic processes and environmental or abiotic degradation. Of these three components, the NBA 2018 focused on environmental (abiotic) degradation but several pressure types, especially fisheries, lead to both environmental degradation and biotic disruption. For example, demersal trawling disrupts sediments, and removes a substantial biomass of fish which is a form of biotic disruption that could lead to trophic changes and other biotic perturbations. As such, the impact of trawling can be considered to constitute both abiotic and biotic disruption owing to the physical impacts on the benthic environment and associated biota (see Chapter 4). Classifying pressures into a single category (i.e. biotic or abiotic degradation) is a challenge when assessing ecosystem types in which the pressures cover both aspects. However, given that the thresholds are identical for C3 and D3 this has no impact on results. Pressures were considered using three approaches; termed maximum, mean maximum across ecosystem types, and cumulative pressure (see details below). In terms of maximum, this approach refers to the specific pressure that has the highest impact per pixel, while mean maximum was the average of all maximum pressure values across all pixels per ecosystem type.

Table 20. Comparison between the conceptual framework and definition per threat category as used in the marine assessments for the NBA 2011 (Sink *et al.* 2012a) and the NBA 2018. The equivalent of the poor condition category used in 2011 include both severely and very severely degraded categories in 2018 and the 2011 fair condition is roughly equivalent to the moderately degraded or modified condition from 2018.

	NBA 2011	NBA 2018
Critically Endangered (CR)	These were types where there were very few remaining areas of pristine or natural habitat, and it is expected that important components of biodiversity pattern were lost and that processes had been heavily modified. • Ecosystem types where the area in good condition was less than the identified biodiversity target (20%). This meant that more than 80% of the ecosystem extent was assessed to be in fair or poor condition.	The IUCN RLE defines an ecosystem as CR when the best available evidence indicates that it is at extremely high risk of collapse. Under criteria C3 and D3, ecosystem types where more than 90% of the ecosystem extent is severely degraded. This is conceptually similar to 2011 but is a far more stringent criteria covering a narrower range (90 vs. 80%) and specifying a more severe degradation threshold. • Ecosystem types where more than 90% of the extent is very severely degraded (very poor condition).
Endangered (EN)	Conceptually, this was a "red flag" category for types that are approaching the point where it is expected that important components of biodiversity pattern and process were lost. • Ecosystem types where the area in good condition was less than the identified biodiversity target plus 15% (i.e. less than 35% in good condition). This means that more than 65% of the ecosystem extent was in fair or poor condition.	The IUCN RLE defines an ecosystem as EN when the best available evidence indicates that it is at very high risk of collapse. Conceptually, this is very similar to NBA 2011 but less stringent in terms of area and condition Under criteria C3 and D3, ecosystem types qualify as Endangered either because more than 70% (but less than 90%) of the ecosystem extent is very severely degraded or more than 90% is severely modified.
Vulnerable (VU)	These were habitat types where there were sufficient areas of intact biodiversity of this type to meet the biodiversity target, but outside of these areas there was habitat degradation and some loss of ecosystem processes. Ecosystem types where the remaining area in good condition was greater than 35% (20% biodiversity target plus 15% (i.e. are not Critically Endangered or Endangered), but where the remaining area of ecosystem type was in good or fair condition was less than 80%. i.e. More than 35% good but less than 80% good or fair	The IUCN RLE defines an ecosystem as Vu when the best available evidence indicates that it is at high risk of collapse. Conceptually, this is similar to the NBA 2011. Under criteria C3 (and D3), there are 3 ways ecosystem types qualify as Vulnerable. (i) more than 50% (but less than 70%) of the ecosystem extent is *very severely degraded* or (ii) more than 70% is *severely degraded* or (iii) more than 90% is *moderately degraded*
Near threatened	This category was not applied in NBA 2011.	The IUCN RLE defines an ecosystem as near threatened when it is evaluated against the criteria but does not qualify as threatened, but is close to qualifying or is likely to qualify in the near future. In the NBA 2018, any ecosystem type within 10% of the qualifying threshold for VU was considered as NT.
Least concern:	Ecosystem types that do not trigger a threatened category were considered least Concern. This occurred where the area that was estimated to be in good condition was greater than 35% (the biodiversity target plus 15%) (i.e. they are not Critically Endangered or Endangered), and where the area of habitat type in good or fair condition was greater than 80% (i.e. >80% good and fair). Conceptually, there were sufficient areas of intact biodiversity of this ecosystem type to meet the biodiversity target, and it is anticipated that there has been little broad modification of ecosystem processes. Relatively large portions of the ecosystem type were perceived to be in a relatively pristine or natural state based on the available pressure data.	The IUCN RLE defines an ecosystem as LC when it has been evaluated against the criteria but does not qualify for CR, EN, VU or NT. Widely distributed and relatively un-degraded ecosystems are in this category. Under criteria C3 (and D3), ecosystem types where the area in good condition is more than 50% qualify. Conceptually, this is similar to the NBA 2011 but more ecosystem types are considered LC in 2018 than in the 2011 NBA approach because the IUCN thresholds are stricter in terms of identifying threatened types.

7.3.1 Pressure data

Information on ecosystem degradation and ecosystem condition is a key input into ecosystem level assessments. As in 2011, for the NBA 2018, marine ecosystem condition is based on the mapping of the extent and intensity of multiple pressures and with consideration of the different impacts within different ecosystem types. A total of **31 pressures on marine biodiversity** were mapped to assess ecosystem degradation (see Chapter 4) using an ecosystem pressure matrix.

7.3.2 Ecosystem pressure matrix

An ecosystem pressure matrix was developed using scoring by 9 experts participating in a workshop to score pressures across all ecosystem types. Additional experts assisted on scoring impacts on kelp ecosystem types (Dunga LV, MSc Thesis, University of Cape Town, in prep.). The **scoring process** was supported by the literature and synthesis of information regarding the impacts of the marine pressures as presented in Chapter 4 and Appendix 2. The methodology used in these expert workshops to determine impact scoring was similar to that used in the NBA 2011 assessment, i.e. a guided group consensus method and scoring of "functional impact" and "recovery", simplified from the approach proposed by Teck *et al.* (2010). Considering the large numbers of ecosystem types (150) and drivers of ecosystem change or pressures (31), the ecosystem types were classified into 15 broad ecosystem groups based on the similarity of ecosystem type and their likely responses to drivers of change. This grouping was similar to that used by the NBA 2011 subject to minor changes made by the Marine Ecosystem Committee. For example, all the different sandy shore types were grouped together, as were rocky shore types regardless of wave exposure. However, where the evaluation process identified problems caused by the lumping of categories (e.g. subtropical reefs in shallow versus deeper water or muddy versus sandy shelves), these were then split into separate categories for evaluation. Similarly, where pressures were different between regions, two different impact scores were developed to account for this. The only case where this was required was for boat-based commercial and recreational linefishing. Linefishing on the south and east coasts was deemed to have a greater impact than on the west coast, due to targeting of long-lived reef fish and slower recovery times. The west coast linefish sector, has a greater focus on more resilient, nomadic and migratory species (DAFF 2016), resulting in differences in terms of linefishing impact on the west coast versus south and east coasts, and hence on the RLE for these regions.

Functional impact is a broad evaluation of the degree to which the natural state of any given ecosystem (including constituent species, community structure, physical habitat structure and ecosystem function) is impacted by a specific pressure. This component incorporates the issue of spatial scale or extent of a single act of an activity (pressure event), and impacts on trophic structure of communities, each of which are dealt with separately by Teske *et al.* (2010). Experts evaluated the functional impact of a specific pressure to an individual broad ecosystem group based on their own knowledge with the support of international and local peer-reviewed and grey literature. Experts were guided by (but not necessarily limited to) the scoring values and cut-offs presented in (Table 21), but also used intermediate values.

Table 21. Functional impact score guideline adapted from (Teske *et al.* 2010)

Score	Score Definition
Not Applicable	Pressure not present.
0	No impact.
1	Minor impact limited to a specific species with minimal impact on overall system functioning
2	Minor impact limited to a few (<10) specific species with minimal impact on overall system functioning
5	Moderate impact on natural state of habitat, including impacts on a range of species and some impacts on trophic structure and may include localised physical habitat damage
10	Extremely heavy impact on the natural state of an ecosystem (including major changes in trophic structure and/or damage to physical structure).

Recovery, the second component of impact scoring, was a measure of the time required for the ecosystem (including affected species, physical habitat structure, and community trophic structure) to return to a natural state following cessation of disturbance by a given activity. Once again, experts evaluated the recovery of an individual broad ecosystem group from a specific activity based on their own knowledge of the system and / or activity with the support of international and local peer-reviewed and grey literature. As with functional impact scoring, experts were guided by (but not limited to) the scale of 0-10 (Table 22) representing the anticipated time taken for recovery of an ecosystem once a specific pressure type has been removed from a site. Values should be interpreted as a relative evaluation of the recovery time of a habitat or ecosystem after being subjected to a pressure and of the relative recovery time between different ecosystem types after the same level of a specific pressure type has been experienced.

Table 22. Recovery score guideline adapted from (Teske *et al.* 2010)

Score	**Score Definition**
Not Applicable	Pressure not present.
1	Very quick recovery (less than 1 year)
2	Quick recovery (more than one year but less than 2 years)
5	Average recovery time (more than 2 years but less than 5 years)
8	Slow recovery time (more than 5 years but less than ten years)
10	Very slow recovery or permanent damage (e.g. by long term irreversible changes in habitat or trophic structure).

The group and individual interactions were guided by the same group moderator to ensure consistency of scoring.

The impact scores were calculated using a combination of the functional impact and recovery scores and converted to a value out of 100 for ease of applying the IUCN methodology (Figure 79). The draft values were iteratively refined and updated (with the involvement of key specialists with local knowledge) until stable values were obtained.

Table 23. Final Ecosystem-pressure matrix with impact scores reflecting the equal weighted average of the functional impact and recovery scores for different broad ecosystem groups per pressure. Red colouring reflects the pressures with the greatest impact per group, whereas orange reflects intermediate impacts and green representing pressures with the lowest expected impact.

Pressure	Sandy Shore	Mixed Shore	Rocky Shore	Bay	Island	Kelp	Reefs	Soft Inner Shelf	Soft Middle and Outer Shelf, and Shelf Edge	Shelf Mosaic	Muddy Shelf	Hard Middle and Outer Shelf, and Shelf Edge	Slope	Seamount	Abyss
Demersal Inshore Trawling	N/A	N/A	N/A	90	100	N/A	100	80	80	90	90	100	NA	N/A	N/A
Demersal Offshore Trawling	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	65	75	80	100	65	N/A	N/A
Crustacean Trawling	N/A	N/A	N/A	N/A	N/A	N/A	100	90	80	90	90	100	80	N/A	N/A
Midwater Trawling	N/A	N/A	N/A	70	70	N/A	70	70	70	70	70	70	70	N/A	N/A
Commercial Linefishing (East and South Coast)	N/A	N/A	N/A	85	80	80	80	80	60	80	60	80	NA	N/A	N/A
Recreational Boat-Based Linefishing (East and South Coast)	N/A	N/A	N/A	85	80	80	80	80	60	80	60	80	NA	N/A	N/A
Recreational Shore-Based Linefishing (East and South Coast)	50	50	50	50	50	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Commercial Linefishing (West Coast)	N/A	N/A	N/A	50	45	45	45	45	45	45	45	45	N/A	N/A	N/A
Recreational Boat-Based Linefishing (West Coast)	N/A	N/A	N/A	50	45	45	45	45	45	45	45	45	N/A	N/A	N/A
Recreational Shore-Based Linefishing (West Coast)	30	30	30	30	30	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Demersal Hake Longlining	N/A	N/A	N/A	55	N/A	N/A	75	55	55	60	55	75	55	N/A	N/A
Pelagic Longlining	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	55	55	55	55	55	55	55
Tuna Poling	N/A	N/A	N/A	35	35	N/A	35	35	35	35	35	35	35	N/A	N/A
Small Pelagics	N/A	N/A	N/A	55	55	N/A	55	55	55	55	55	55	55	N/A	N/A
Netfishing: Gill net	30	N/A	N/A	30	N/A	N/A	N/A	30	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Pressure	Sandy Shore	Mixed Shore	Rocky Shore	Bay	Island	Kelp	Reefs	Soft Inner Shelf	Soft Middle and Outer Shelf, and Shelf Edge	Shelf Mosaic	Muddy Shelf	Hard Middle and Outer Shelf, and Shelf Edge	Slope	Seamount	Abyss
Netfishing: Beach Seine	30	N/A	N/A	30	N/A	N/A	N/A	N/A	30	N/A	N/A	N/A	N/A	N/A	N/A
West Coast Rock Lobster Fishing	N/A	N/A	N/A	30	50	45	45	N/A	N/A	45	N/A	45	N/A	N/A	N/A
South Coast Rock Lobster Fishing	N/A	N/A	N/A	35	50	N/A	50	35	35	50	35	50	N/A	N/A	N/A
Squid fishing	N/A	N/A	N/A	20	20	N/A	20	20	20	20	20	20	N/A	N/A	N/A
Abalone Harvesting	N/A	35	35	35	35	50	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oyster Harvesting	N/A	25	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kelp Harvesting	N/A	30	20	N/A	N/A	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Subsistence Fishing	20	60	60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Shark Control	75	75	75	N/A	N/A	N/A	75	75	75	75	75	75	N/A	N/A	N/A
Sea-Based Aquaculture	70	70	70	75	N/A	N/A	70	70	70	70	70	70	N/A	N/A	N/A
Coastal Development	100	90	90	90	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Coastal Disturbance	35	35	30	N/A	70	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mining	80	80	60	80	90	60	70	75	75	80	90	90	N/A	N/A	N/A
Petroleum	N/A	N/A	N/A	60	N/A	N/A	60	50	50	60	50	60	50	N/A	N/A
Invasive species	N/A	50	50	50	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Port and Harbour Impacts	60	60	60	60	60	60	60	60	60	60	60	60	N/A	N/A	N/A
Shipping	N/A	N/A	N/A	30	30	N/A	30	30	30	30	30	30	30	30	30
Waste Water	30	30	20	60	30	50	50	50	40	50	40	40	N/A	N/A	N/A
Ammunitions Dumping	N/A	N/A	N/A	N/A	N/A	N/A	30	30	30	30	30	30	30	N/A	N/A
Dumping of Dredged Material	N/A	N/A	N/A	70	70	N/A	70	60	60	70	60	70	N/A	N/A	N/A
Freshwater Flow Reduction (River Influenced A)	N/A	N/A	N/A	N/A	N/A	N/A	80	80	80	80	80	80	N/A	N/A	N/A
Freshwater Flow Reduction (River Influenced B)	N/A	N/A	N/A	40	N/A	N/A	40	40	40	40	40	40	N/A	N/A	N/A

Table 24. Table showing condition categories for aquatic ecosystems with examples from wetland ecosystems and marine thresholds. For marine condition the categories for 2018 (with 2011 equivalent in parenthesis) are shown with some examples of scenarios leading to each condition category. DWS refers to the former Department of Water and Sanitation. The NBA 2018 River condition categories have the same description as the DWS ecological category for rivers.

DWS ecological category	Description of the DWS ecological category (Rivers)	NBA 2018 River Ecological condition category	DWS Wetland ecological category	Description of wetland ecological condition	Wetland Examples	NBA 2018 Marine Ecological condition category	Marine examples
A	Unmodified, natural	Natural					
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	Near-natural	DWS A/B	Natural or near-natural state with few modifications. A small change in natural habitats and biota but ecosystem functions essentially unchanged.	Low levels of grazing and infrequent subsistence use of ecosystem services by a small group of people.	Natural/ Near natural (Good condition)	Low levels or infrequent pelagic fishing or shipping. Untrawled seabed.
C	Moderately-modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	Moderately modified	DWS C	Moderately-modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	Historical ploughing; grazing, water abstraction; land uses with limited impact on dominant water supply; artificial wetlands, transport infrastructure or weirs in large systems. Water quality impacts in large systems.	Moderately modified (Fair condition)	Moderate levels of pelagic fishing or low levels or very infrequent events of higher impact activities such trawling. Low levels of linefishing.
D	Largely-modified. A large loss of natural habitat, biota and basic ecosystem functions have occurred.	Extensively modified				Severely modified	Moderate levels of multiple pressures (such as linefishing, pollution) or high levels of pressures that modify marine ecosystems such as intense demersal trawling (or even light trawling on sensitive habitat), heavy linefishing effort, coastal development and port and harbour construction.
E	Seriously-modified. The loss of natural habitat, biota and basic ecosystem functions are extensive.	Extensively modified				Very severely modified	Very high levels of activities that severely modify marine ecosystems (such as frequent, intensive trawling) or multiple high intensity pressures (e.g. flow reduction and trawling)
F	Critically/Extremely-modified. Modifications reached a critical level and system modified completely with an almost complete loss of natural habitat and biota. In the worst instances basic ecosystem functions have been irreversibly destroyed.	Critically modified	DWS D/E/F	Largely to severely/critically modified with large loss of natural habitat, biota & basic ecosystem functions. The system has been modified completely with an almost complete loss of natural habitat & biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	Waste water treatment facilities within 500 m of active or abandoned mine, large dams, canals, overgrazing, invasive species, peatlands burnt, medium to high water abstraction etc. Water quality has been severely affected etc.	Collapsed	Ports, harbours or coastal development that have completely transformed ecosystems.

7.4 Ecosystem Assessment Methods

7.4.1 Primary Assessment (Criterion IUCN C3)

The primary assessment approach employed IUCN Criterion C3 and comprised the following steps.

Step 1: Map the individual **intensity of each pressure** (0-100) (see Chapter 4) for these results and Chapter 4 and Annexure 1 for details on the processing of pressure data.)

Step 2: Build the **pressure – ecosystem matrix** (0-100) which indicates how serious a specific pressure intensity is for a particular broad ecosystem type (see results in Table 23).

Step 3: Build the individual **pressure impact layers** (Figure 78) by combining the pressure intensity layer and the ecosystem - pressure matrix for the applicable ecosystem found at a site (evaluation done for each 30 x 30 m pixel). Impact at a site for an individual pressure equals the intensity of a pressure multiplied by the pressure matrix score.

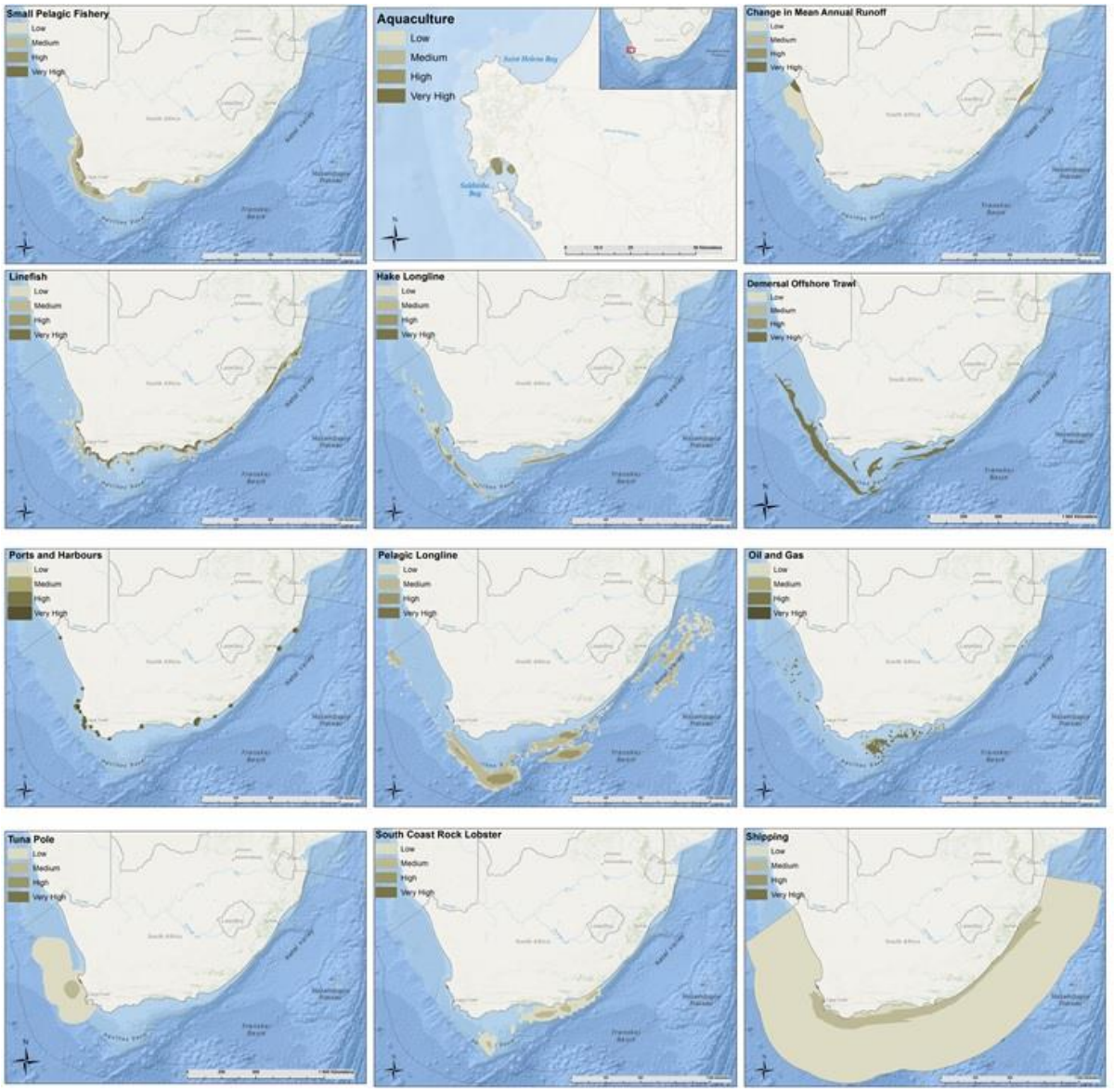


Figure 78: Thumbnails of pressure impact layers developed under step 3 of the assessment methodology.

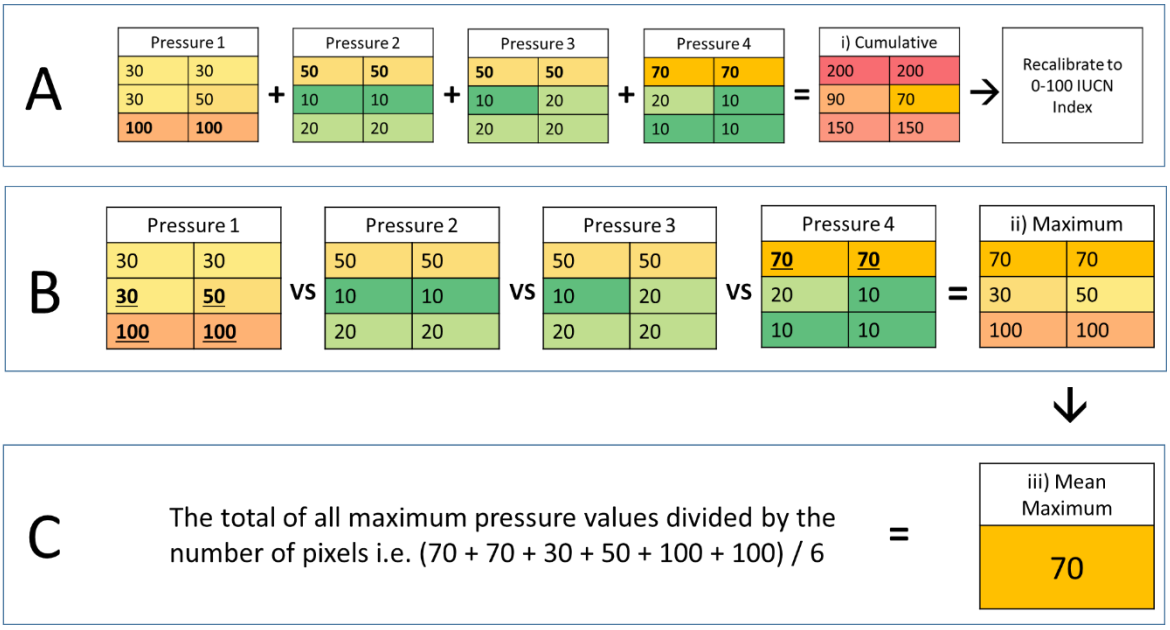
Step 4: Build a **cumulative impact layer** by summing all the 31 individual pressure impact layers. Degradation of an ecosystem at a site was classified based on the **cumulative impact scores** at that site (see example in Figure 79 Part a).

Step 5: Recalibrate the cumulative impact layer to build a **map of ecosystem degradation** by assigning the cumulative impact scores into 4 degradation categories. This recalibration was achieved by distributing the mapped impact scores into 4 categories to align with the IUCN thresholds of more than 50%, 70% and 90% degraded based on natural breaks and expert inputs (see results in Figure 81).

Step 6: **Evaluate threat status** by analysis of how much and how severely each ecosystem type is impacted. Three approaches in the assessment of threat status under Criterion C3 (see results in Figure 82) were employed. No single approach in assessment method is necessarily better than any other, because each is sensitive to different patterns of impacts.

- The first approach (A) was based on the cumulative impact scores (i.e. the results of step 4) (Figure 80) which were recalibrated to align with the IUCN ecosystem degradation thresholds and were then applied for the C3 evaluation (Figure 79 A). This analysis highlighted ecosystem types with multiple pressures at moderate to high intensities (e.g. they include several different fisheries and high shipping pressure).
- The second approach (B) considered only the particular pressure with the maximum impact on any given pixel (Figure 79 B). Each individual impact layer has a potential 0-100 range designed to align with 90/70/50 thresholds provided by the IUCN. This analysis helped highlight ecosystem types that were subject to specific pressures that are highly impactful e.g. ecosystem types with extensive trawling.
- The third approach (C) considers the overall impact on ecosystem types by averaging the maximum impact scores (calculated in approach two) across the entire extent of each ecosystem type (Figure 79 C). This highlighted ecosystem types that have areas of extremely high intensity pressure and larger areas of moderate pressure (e.g. some trawling in specific areas and broader use by other activities at lower intensities).

Four categories of ecosystem degradation were defined that are comparable with the condition categories used in the freshwater (van Deventer *et al.* 2019) and estuarine (van Niekerk *et al.* 2019) assessments although these other aquatic components have additional categories (Table 24).



Part (a)

	Degradation (Informed by Impact Score)		
Extent (% of area per ecosystem type)	Very severely degraded (impact score >90)	Severely degraded (impact score is >70)	Moderately degraded (impact score is >50)
>90	CR	EN	Vu
>70	EN	Vu	*qualifier for B*
>50	Vu	*	

Part (b)

Figure 79: Schematic illustrating (Part a) the three approaches applied in the assessment of the extent of degradation under Criterion C. The examples illustrates how degradation was considered / calculated using (A) a cumulative approach, (B) a maximum approach and a (C) a mean of the maximum which averages the degradation across an entire ecosystem type based on the average of the maximum impact score per pixel. The example represents impact scores for 6 different pixels per pressure in approach (A) and (C). Part (b) shows the deliberate alignment of the 4 IUCN categories with the impact score. Also shown is the *thresholds applied to qualify for degradation for ecosystem types of limited extent (Criterion B)

7.4.2 Supplementary Assessment (Consideration of Geographic Extent IUCN B)*

A **supplementary assessment** using a criterion similar to the **IUCN Criterion B (restricted distribution)** was also applied to re-consider the threat status of ecosystem types of limited geographic extent. This criterion aims to identify ecosystems that have such restricted distributions that they are at risk of collapse from the chance occurrence of single or few interacting threatening events (Rodríguez *et al.* 2015). Such ecosystems are at risk because of a combination of their small extent and / or limited distribution and ongoing decline (Bland *et al.* 2017a). The recommended IUCN approach to measure ecosystem distributions using extent of occurrence (EOO) and area of occupancy (AOO) (Gaston and Fuller 2009, Keith *et al.* 2013b) was applied. The IUCN provides **thresholds in geographic extent** that guide assessment results which together with ongoing ecosystem degradation can indicate threatened ecosystems. An ecosystem may be listed under criterion B if it meets thresholds for restricted distribution AND there is an observed or inferred continuing decline in spatial extent or environmental quality (Table 19 and see Bland *et al.* (2017a) for details) as determined by a measure of environmental quality or of disruption to biotic interactions appropriate to the characteristic biota of the ecosystem. Observed or inferred threatening processes that are likely to cause continuing

declines in geographic distribution, environmental quality or biotic interactions within the next 20 years can also qualify ecosystems as threatened under this criterion. The IUCN specifies 3 different thresholds for EOO (measured using a minimum convex polygon) with an extent of less than 2 000 km^2 potentially qualifying ecosystems in the category of Critically Endangered, less than 20 000 km^2 as Endangered and less than 50 000 km^2 as Vulnerable. Area of occupancy (AOO) is measured using the number of 10×10 km grid cells occupied by an ecosystem type with those occupying less than 2, 20 or 50 grid cells potentially qualifying as Critically Endangered, Endangered or Vulnerable respectively. The IUCN also provides for consideration of the number of threat defined locations but it was not feasible to systematically apply this during the marine assessment conducted for the NBA 2018.

Of South Africa's 150 marine ecosystem types, the EOO is less than 20 000 km^2 for 113 ecosystem types with 61 types having an EOO of less than 2000 km^2. Therefore, 75% of types would potentially qualify as highly threatened (Critically Endangered and Endangered) and 41% potentially qualify as Critically Endangered if they are experiencing any ongoing decline in condition. The marine reference group for the NBA noted that the fine delineation and high number of ecosystem types in South Africa's marine ecosystem map may lead to an over estimate of threat status when global thresholds are applied and hence a modified criterion (B*) was applied in the consideration of geographic extent. It is our perception that the thresholds for criterion B specified by the IUCN appear to be more suited to broader scale ecosystem classification. If the assessment had been applied at the scale of broad ecosystem groups, key patterns in threat between ecoregions would not be accounted for, limiting the intended application of this work in regional marine spatial planning efforts.

The supplementary assessment using the B criterion was therefore only applied for those ecosystem types that were assessed as not threatened (i.e. Least Concern and Near Threatened) under Criterion C. Only a **single size threshold for EOO** (<2000 km^2) **and for AOO** (<2 grid cells) was applied i.e. using only the strictest qualifier as specified by the IUCN. Further, the threat status of these small ecosystem types was **only downgraded to Vulnerable** i.e. the most severe status applied was Vulnerable. This was done because strict application of the IUCN thresholds would have made most of these ecosystem types far more threatened with most qualifying as Critically Endangered (see Table 25 and Table 26). For example, the uThukela Canyon was assessed as Least Concern under Criterion C3 but strict application of IUCN B3 renders the result as Critically Endangered whereas the rules applied by the NBA 2018 team resulted in Vulnerable which the reference group perceived as a far more plausible result (see Table 26 for other cases). The small extent and single location of this ecosystem renders it vulnerable to ecosystem collapse but since there has been limited ecosystem degradation in this ecosystem type it is not considered in imminent danger of ecosystem collapse. However, a single event such as a petroleum blowout could be considered to constitute such a case and some scientists may argue that Critically Endangered is a more appropriate status. Note that Bland *et al.* (2017a) do not recommend amendment of thresholds for regional assessments and that they note that current research is underway to examine the effect of the scale of ecosystem classification on results and investigate the implication of different thresholds. It is recognised that further work is needed before applying B1 and B2 as per the IUCN guidance. The number of threat-defined locations should also be considered in future South African assessments.

This criterion requires a qualitative evaluation of whether continuing declines in spatial extent, environmental quality, or increasing disruption of biotic interactions are occurring or likely to occur as a result of threats. Quantitative pressure mapping was used to evaluate environmental quality in this context. Two qualifiers of decline were specified that would not qualify ecosystem types as threatened

under IUCN criterion C3 but represent two thresholds of degradation that are approaching those to qualify as threatened (Figure 79 Part b). For ecosystems of restricted geographic extent those with more than 50% severely or very severely degraded or those with more than 70% as moderately degraded or worse were considered to qualify. The number of threat-defined locations at which an ecosystem occurs which is an additional sub-qualifier (see Table 19) for Criterion B1, B2 and a main qualifier for B3 which was not applied. This should be considered in future assessments.

7.4.3 Assigning Ecosystem Threat Status

In accordance with IUCN guidelines, the final ecosystem threat status reflects the most threatened (i.e. worst) category that is triggered (Bland *et al.* 2017a). The worst status calculated using the three different approaches to assess degradation (Figure 79) was applied and the status of those ecosystem types assessed to be of limited geographic extent with ongoing degradation (Figure 79) were further downgraded. In addition to the above, an ecosystem was considered Near Threatened if assessment results fall within 10% of the threshold for Vulnerable.

7.5 Ecosystem Assessment Results

7.5.1 Cumulative pressures and degradation

Degradation of an ecosystem at a site was classified based on the **cumulative impact scores** at that site (Figure 80 and Figure 81). Coastal development, mining, trawling and mariculture have the highest impact scores among the 31 pressures included in this assessment (Table 23) and led to higher cumulative impacts in some areas. Fishing is the greatest cause of degradation in the offshore environment, whereas coastal development and fishing are the greatest pressures on inshore ecosystems. All bays incurred high cumulative pressures, with the highest cumulative pressure recorded for Saldanha Bay. Additional high pressure areas include the area offshore of the Orange River, the shelf edge on the west and south coast, large portions of the Cape inner and middle shelf, the Agulhas Bank and the KwaZulu-Natal Bight.

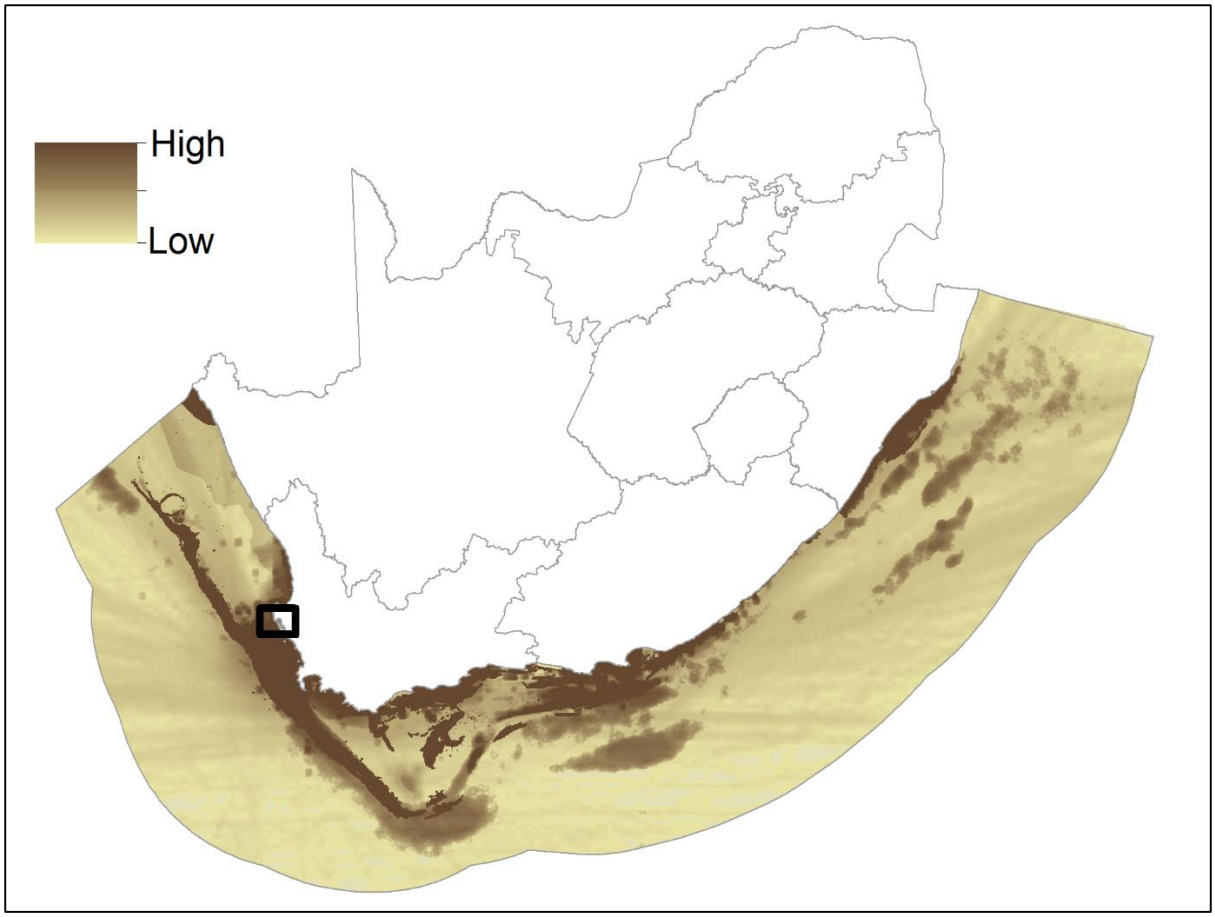


Figure 80. Cumulative impact scores across the South African seascape.

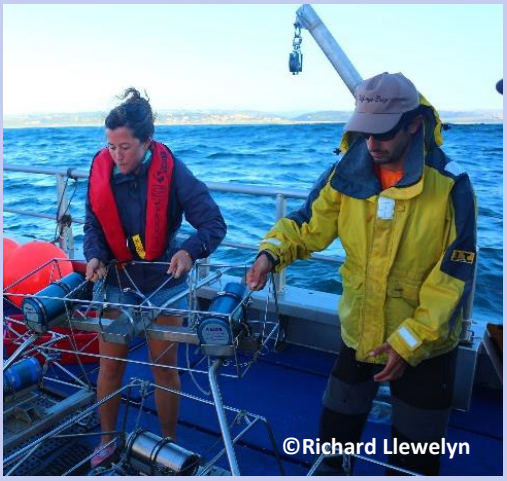
It must be clarified that although the assessment was conducted using 30 x 30 m pixels, this does not imply that the ecosystem map or the results are accurate to this level. Rather, this raster-based approach was used to allow for the calculations to be done at a sufficiently fine scale while accommodating the unique combinations of multiple pressures, pressure intensities, impacts and ecosystem types. The 30 x 30 m pixels reflect the size of the units used for the numerical calculations whereas the actual spatial accuracy is linked to the underlying accuracy of the ecosystem map and the pressure mapping. Improved finer-scale ecosystem and pressure mapping is a key priority for future assessments.

Field-based ecosystem-wide evaluations of site condition have yet to be established in South Africa for marine habitats (Box 28) and hence no reference sites exist against which the cumulative impact scores (and the classification thresholds used to subdivide categories) could be calibrated. Numerical thresholds in the cumulative impact scores had to be defined in order to classify ecosystem degradation into 4 categories aligned to the IUCN degradation thresholds. Further work is needed to investigate the use of different thresholds with better calibration guided by field surveys that measure condition representing the ideal approach.

Box 28. Progress in ground- truthing ecosystem condition: A case study from KwaZulu-Natal

By Kaylee Smit

Applying the IUCN RLE approach to assess the state of marine ecosystems requires detailed biological assessments and ecological data that is not always readily available. Criteria C of the IUCN approach was applied in the NBA 2018 by mapping cumulative impacts to assess the extent of environmental degradation. Few cumulative impact studies validate their assessments. In addition, defining reference conditions for ecosystem types is an important component of the IUCN risk assessment (Keith *et al.* 2013b). To help inform South Africa's marine ecosystem assessment work, this PhD project is using ecological data from rocky reef ecosystems to define reference conditions and validate condition estimates that were based on cumulative human impacts.



Scientists deploying stereo baited remote underwater videos (stereo-BRUVs) in Pondoland MPA

The no-take zone of the Pondoland Marine Protected Area (MPA) was used to define reference conditions of rocky reef ecosystems in the Natal ecoregion. Demersal fish and benthic community data were used to identify and test potential ecological indicators to measure the condition of marine ecosystems. A trait-based approach was applied to identify indicators that are sensitive to changes in cumulative impacts and to reflect potential differences in functional structure and ecological processes. Five localities were sampled using baited remote underwater stereo-video systems (stereo-BRUVs) to sample demersal fish and benthic communities across a range of site with varying levels of cumulative pressure, ranging from the no-take zone of the Pondoland MPA to more heavily used and accessible sites. Indicators that were based on species traits illustrated functional characteristics that can be used as references conditions to compare the risk status across ecosystems. Indicators included the proportion of predatory fish, average length of fish, species length range, biomass and abundance of target.

To ground-truth condition estimates, condition categories based on ecological data are being compared with those based on cumulative human impacts. So far, condition indices were significantly but weakly correlated with cumulative impact scores from the NBA with some discrepancies observed at a fine scale. Results suggest a need to improve pressure data and the understanding of pressures and ecosystem impacts. In some cases, rocky reef ecosystems were in fact in better ecological condition than what was predicted by the NBA. In other examples, the opposite was true. These results emphasise the importance of using ecological data to ground truth ecosystem condition maps that are based on cumulative impact scores, especially where that data is reported at a broad scale.

7.5.2 Ecosystem Degradation and Condition

The areas of high cumulative pressures translate into areas of severe ecosystem degradation and poor ecosystem condition, particularly in the inner shelf and shelf edge and in much of the KwaZulu-Natal Bight. Despite this degradation, 81% of the ocean around South Africa remains in natural or near natural condition. Areas of high cumulative pressures, or where single pressures have very high impacts, are assumed to translate into areas of high degradation i.e. poor ecological condition, and were identified particularly on the inner shelf, shelf edge and in much of the KwaZulu-Natal Bight (Figure 81).

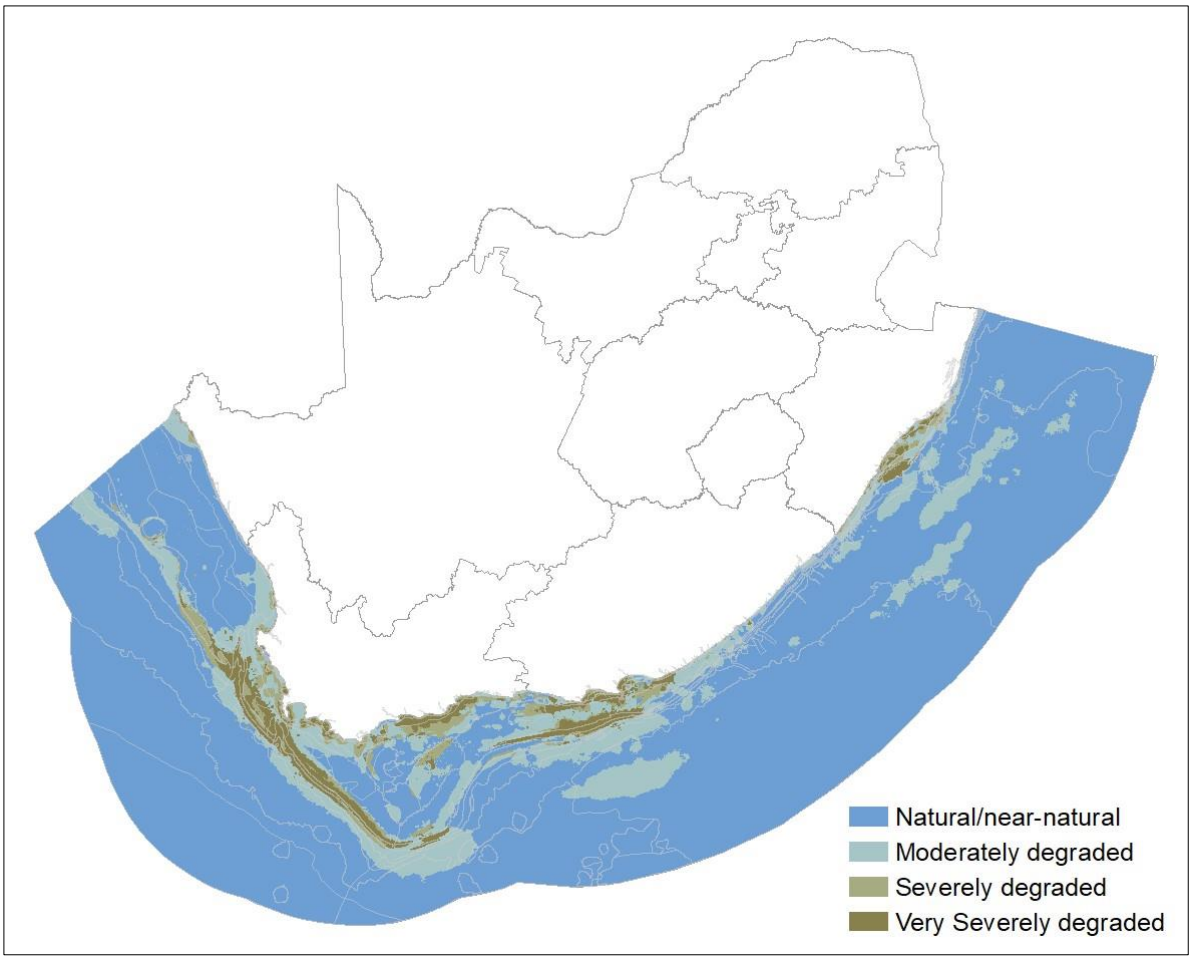


Figure 81. Map of ecosystem degradation showing the spatial distribution of marine areas in natural/near natural, moderately degraded, severely degraded or very severely degraded state.

The accessibility of the inner shelf contributes to the high diversity of pressures in this zone with many bay ecosystem types reflecting poor condition, a result of high cumulative pressures. Key pressures on the shelf edge that lead to poor condition in this area include the offshore hake trawl fishery, the mid-water trawl fishery, the crustacean trawl fishery in KwaZulu-Natal and the large pelagic long linefishery. In the KwaZulu-Natal Bight, inshore crustacean trawl fisheries, intensive linefishing and river flow reduction have degraded ecosystem condition.

7.5.3 Ecosystem Threat Status Results

Of the 150 marine ecosystem types assessed, 50% are threatened (Figure 82) but this equates to only 5% of the ocean space around South Africa (Figure 83). Only two ecosystem types, the Agulhas Muddy Mid Shelf and Browns Bank Rocky Shelf Edge, are Critically Endangered (1% of types); these only cover 0.3% of the ocean area. There are 22 Endangered ecosystem types (Table 25) (15%) which cover 1% by extent. Vulnerable ecosystem types cover 4% of the ocean space, with 51 ecosystem types (34%) falling within this category. The remaining ecosystem types, 17 (11%) and 58 (39%) were respectively, Near Threatened and Least Concern.

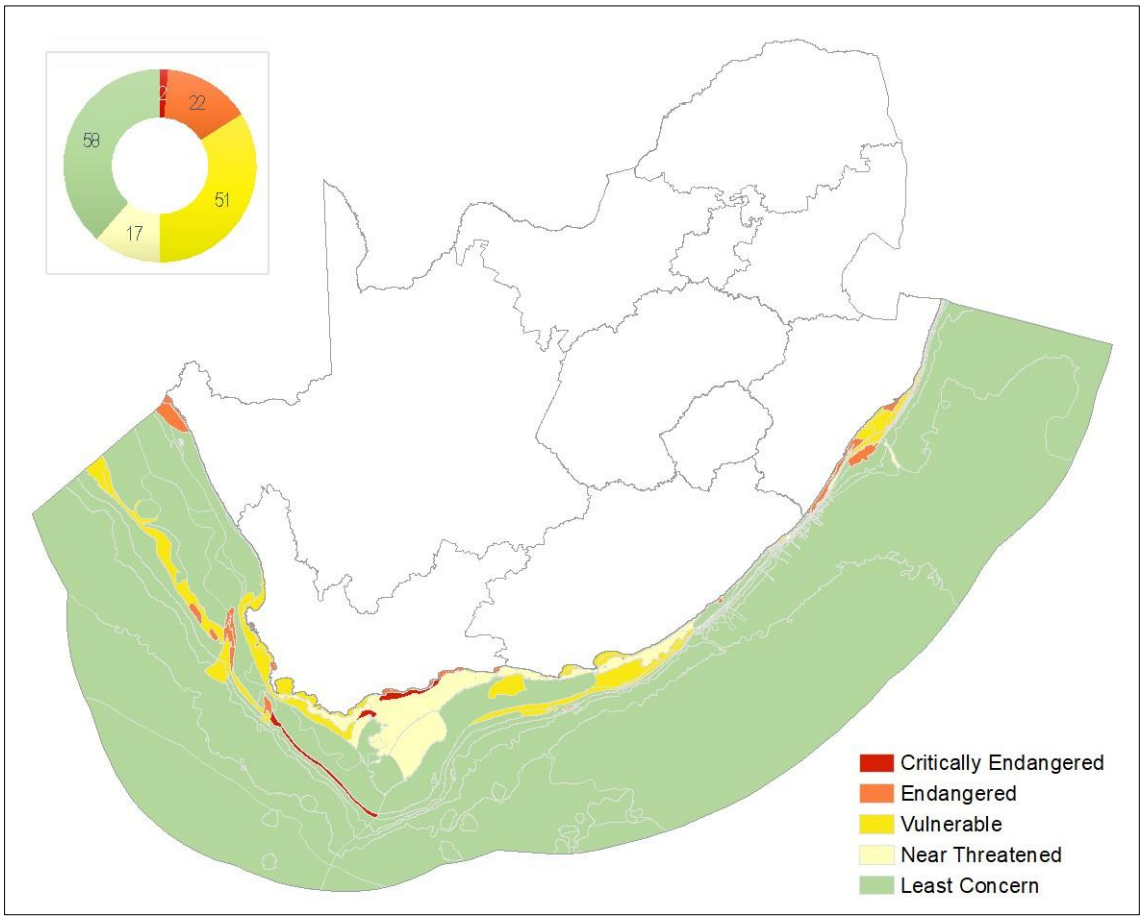


Figure 82. Map of the distribution of threatened ecosystem types.

Table 25. Threat status of South Africa's 150 marine ecosystem types assessed through the application of IUCN Criteria C3 (Degradation) and a supplementary assessment to consider ecosystem extent (B*, a criterion aligned to IUCN Criteria B) and ongoing decline. The Basis column reports which criterion each result can be attributed to and in instances where ecosystems qualified on multiple criteria this is reflected. The three approaches used to consider the extent of ecosystem degradation are explained in Section (Mean, Ma, Cumulative) multiple as explained in Section 7.4.

Ecosystem Type	2019 Threat Status	Basis
Agulhas Basin Abyss	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Agulhas Basin Complex Abyss	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Agulhas Blues	Near Threatened	IUCN C3 (Mean; Max)
Agulhas Boulder Shore	Near Threatened	IUCN B*(50)
Agulhas Coarse Sediment Shelf Edge	Vulnerable	IUCN C3 (Mean; Cumulative)
Agulhas Dissipative Intermediate Sandy Shore	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Agulhas Dissipative Sandy Shore	Near Threatened	IUCN C3 (Mean)
Agulhas Exposed Rocky Shore	Vulnerable	IUCN C3 (Mean; Cumulative)
Agulhas Exposed Stromatolite Rocky Shore	Vulnerable	IUCN B*(70)
Agulhas Inner Shelf Mosaic	Vulnerable	IUCN C3 (Mean)
Agulhas Inner Shelf Reef	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Agulhas Intermediate Sandy Shore	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Agulhas Island	Vulnerable	IUCN C3 (Cumulative)
Agulhas Kelp Forest	Vulnerable	IUCN C3 (Mean; Max; Cumulative)
Agulhas Lower Canyon	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Agulhas Mid Shelf Mosaic	Near Threatened	IUCN C3 (Mean; Cumulative)
Agulhas Mid Shelf Reef	Vulnerable	IUCN C3 (Mean; Cumulative)
Agulhas Mixed Shore	Near Threatened	IUCN B*(70)
Agulhas Muddy Mid Shelf	Critically Endangered	IUCN C3 (Max)
Agulhas Muddy Outer Shelf	Near Threatened	IUCN B*(50)
Agulhas Plateau	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Agulhas Plateau Mosaic	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Agulhas Reflective Sandy Shore	Vulnerable	IUCN C3 (Mean; Max; Cumulative)
Agulhas Rocky Outer Shelf	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Agulhas Rocky Plateau	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Agulhas Sandy Inner Shelf	Vulnerable	IUCN C3 (Mean; Cumulative)
Agulhas Sandy Mid Shelf	Near Threatened	IUCN C3 (Mean)
Agulhas Sandy Outer Shelf	Vulnerable	IUCN B*
Agulhas Sheltered Rocky Shore	Endangered	IUCN C3 (Mean)
Agulhas Stromatolite Mixed Shore	Vulnerable	IUCN C3 (Mean)
Agulhas Upper Canyon	Vulnerable	IUCN B*(70)
Agulhas Very Exposed Rocky Shore	Vulnerable	IUCN B*(70)
Agulhas Very Exposed Stromatolite Rocky Shore	Near Threatened	IUCN C3 (Mean; Cumulative)
Aliwal Shoal Reef Complex	Vulnerable	IUCN C3 (Mean; Max; Cumulative)
Alphard Bank	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Amathole Hard Shelf Edge	Vulnerable	IUCN B*
Amathole Lace Corals	Near Threatened	IUCN B*
Browns Bank Rocky Shelf Edge	Critically Endangered	IUCN C3 (Max)
Cape Basin Abyss	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Cape Basin Complex Abyss	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Cape Bay	Endangered	IUCN C3 (Cumulative)
Cape Boulder Shore	Vulnerable	IUCN C3 (Mean)
Cape Exposed Rocky Shore	Vulnerable	IUCN C3 (Mean)
Cape Island	Endangered	IUCN C3 (Cumulative)
Cape Kelp Forest	Vulnerable	IUCN C3 (Mean; Cumulative)
Cape Lower Canyon	Vulnerable	IUCN C3 (Mean; Cumulative)
Cape Mixed Shore	Vulnerable	IUCN C3 (Mean)
Cape Rocky Inner Shelf	Vulnerable	IUCN C3 (Cumulative)
Cape Rocky Mid Shelf Mosaic	Vulnerable	IUCN C3 (Cumulative)
Cape Sandy Inner Shelf	Vulnerable	IUCN B*
Cape Sheltered Rocky Shore	Endangered	IUCN C3 (Mean; Max; Cumulative)

Ecosystem Type	2019 Threat Status	Basis
Cape Upper Canyon	Endangered	IUCN C3 (Mean; Max; Cumulative)
Cape Very Exposed Rocky Shore	Near Threatened	IUCN B*
Central Agulhas Outer Shelf Mosaic	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Childs Bank Coral	Vulnerable	IUCN C3 (Mean; Max)
Childs Bank Plateau	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Delagoa Deep Shelf Edge	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Delagoa Lower Canyon	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Delagoa Mixed Shore	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Delagoa Rocky Mid Shelf	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Delagoa Sandy Inner Shelf	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Delagoa Sandy Mid Shelf	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Delagoa Shelf Edge	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Delagoa Upper Canyon	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Delagoa Very Exposed Rocky Shore	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Durnford Inner Shelf Reef Complex	Endangered	IUCN C3 (Cumulative)
Durnford Mid Shelf Reef Complex	Vulnerable	IUCN C3 (Cumulative)
Eastern Agulhas Bay	Vulnerable	IUCN C3 (Mean; Cumulative)
Eastern Agulhas Outer Shelf Mosaic	Least Concern	IUCN C3 (Mean; Max; Cumulative)
False and Walker Bay	Vulnerable	IUCN C3 (Mean; Cumulative)
Kei Fluvial Fan	Endangered	IUCN C3 (Mean; Max)
Kei Reef Mosaic	Endangered	IUCN C3 (Mean; Max)
Kingklip Koppies	Vulnerable	IUCN B*
Kingklip Ridge	Endangered	IUCN C3 (Mean; Max; Cumulative)
Kosi Coral Community	Least Concern	IUCN C3 (Mean; Max; Cumulative)
KZN Bight Muddy Shelf Edge	Vulnerable	IUCN C3 (Cumulative)
KZN Bight Deep Shelf Edge	Endangered	IUCN C3 (Mean; Max; Cumulative)
KZN Bight Mid Shelf Mosaic	Endangered	IUCN C3 (Cumulative)
KZN Bight Mid Shelf Reef Complex	Endangered	IUCN C3 (Cumulative)
KZN Bight Muddy Inner Shelf	Vulnerable	IUCN C3 (Mean; Max; Cumulative)
KZN Bight Outer Shelf Mosaic	Vulnerable	IUCN C3 (Mean; Cumulative)
KZN Bight Sandy Inner Shelf	Endangered	IUCN C3 (Cumulative)
Leadsman Coral Community	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Namaqua Exposed Rocky Shore	Vulnerable	IUCN C3 (Mean; Max; Cumulative)
Namaqua Kelp Forest	Vulnerable	IUCN C3 (Mean; Cumulative)
Namaqua Mid Shelf Fossils	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Namaqua Mixed Shore	Vulnerable	IUCN C3 (Mean; Max; Cumulative)
Namaqua Muddy Mid Shelf Mosaic	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Namaqua Muddy Sands	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Namaqua Sandy Inner Shelf	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Namaqua Sandy Mid Shelf	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Namaqua Sheltered Rocky Shore	Vulnerable	IUCN C3 (Mean; Max; Cumulative)
Namaqua Very Exposed Rocky Shore	Vulnerable	IUCN C3 (Mean; Max; Cumulative)
Natal Boulder Shore	Vulnerable	IUCN C3 (Mean; Max)
Natal Deep Shelf Edge	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Natal Delagoa Dissipative Intermediate Sandy Shore	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Natal Delagoa Dissipative Sandy Shore	Near Threatened	IUCN C3 (Mean)
Natal Delagoa Intermediate Sandy Shore	Near Threatened	IUCN C3 (Mean)
Natal Delagoa Reflective Sandy Shore	Vulnerable	IUCN C3 (Mean; Max)
Natal Exposed Rocky Shore	Near Threatened	IUCN C3 (Mean)
Natal Lower Canyon	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Natal Mixed Shore	Vulnerable	IUCN C3 (Mean)
Natal Upper Canyon	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Natal Very Exposed Rocky Shore	Near Threatened	IUCN C3 (Mean)
Orange Cone Inner Shelf Mud Reef Mosaic	Endangered	IUCN C3 (Mean; Max)
Orange Cone Muddy Mid Shelf	Endangered	IUCN C3 (Mean; Max)
Port St Johns Inner Shelf Mosaic	Vulnerable	IUCN C3 (Cumulative)
Port St Johns Muddy Mid Shelf	Vulnerable	IUCN C3 (Cumulative)

Ecosystem Type	2019 Threat Status	Basis
Port St Johns Muddy Shelf Edge	Vulnerable	IUCN C3 (Cumulative)
Protea Mid Shelf Reef Complex	Endangered	IUCN C3 (Mean; Max)
Sodwana Coral Community	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southeast Atlantic Lower Slope	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southeast Atlantic Mid Slope	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southeast Atlantic Seamount	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southeast Atlantic Slope Seamount	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southeast Atlantic Upper Slope	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southern Benguela Dissipative Intermediate Sandy Shore	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southern Benguela Dissipative Sandy Shore	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southern Benguela Intermediate Sandy Shore	Near Threatened	IUCN C3 (Mean)
Southern Benguela Muddy Outer Shelf Mosaic	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southern Benguela Muddy Shelf Edge	Endangered	IUCN C3 (Mean; Max; Cumulative)
Southern Benguela Outer Shelf Mosaic	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southern Benguela Reflective Sandy Shore	Endangered	IUCN C3 (Mean)
Southern Benguela Rocky Shelf Edge	Vulnerable	IUCN C3 (Mean; Max)
Southern Benguela Sandy Outer Shelf	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southern Benguela Sandy Shelf Edge	Vulnerable	IUCN C3 (Mean)
Southern Benguela Shelf Edge Mosaic	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southern KZN Shelf Edge Mosaic	Near Threatened	IUCN C3 (Mean)
Southern KZN Inner Shelf Mosaic	Endangered	IUCN C3 (Cumulative; Mean)
Southern KZN Mid Shelf Mosaic	Endangered	IUCN C3 (Mean)
Southwest Indian Lower Slope	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southwest Indian Mid Slope	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southwest Indian Seamount	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southwest Indian Slope Seamount	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Southwest Indian Upper Slope	Least Concern	IUCN C3 (Mean; Max; Cumulative)
St Helena Bay	Vulnerable	IUCN C3 (Mean; Cumulative)
St Lucia Mid Shelf Mosaic	Least Concern	IUCN C3 (Mean; Max; Cumulative)
St Lucia Sandy Inner Shelf	Least Concern	IUCN C3 (Mean; Max; Cumulative)
St Lucia Sandy Mid Shelf	Vulnerable	IUCN C3 (Mean)
Trafalgar Reef Complex	Endangered	IUCN C3 (Cumulative)
Transkei Basin Abyss	Least Concern	IUCN C3 (Mean; Max; Cumulative)
uThukela Canyon	Near Threatened	IUCN B*
uThukela Mid Shelf Mosaic	Vulnerable	IUCN C3 (Mean; Max; Cumulative)
uThukela Mid Shelf Mud Coarse Sediment Mosaic	Vulnerable	IUCN C3 (Mean; Max; Cumulative)
uThukela Outer Shelf Muddy Reef Mosaic	Vulnerable	IUCN C3 (Cumulative)
Western Agulhas Bay	Endangered	IUCN C3 (Mean)
Western Agulhas Outer Shelf Mosaic	Vulnerable	IUCN C3 (Cumulative)
Wild Coast Inner Shelf Mosaic	Vulnerable	IUCN C3 (Cumulative)
Wild Coast Mid Shelf Mosaic	Least Concern	IUCN C3 (Mean; Max; Cumulative)
Wild Coast Shelf Edge Mosaic	Least Concern	IUCN C3 (Mean; Max; Cumulative)

Table 26. Ecosystem types of limited geographic extent that were downlisted based on application of a criteria aligned to IUCN Criteria B (Geographic extent and ongoing decline). These ecosystem types were assessed as LC or NT under IUCN Criterion C but were Vulnerable or Near Threatened under criteria aligned to IUCN B1* (relying on EOO) or B2* (assessed using AOO) in terms of extent and ongoing decline.

Ecosystem Type	NBA 2018 Threat Status (basis)	Qualifier for Criterion B*	IUCN C3 (Comb)	Basis
Agulhas Exposed Stromatolite Rocky Shore	Vulnerable (B2)	MSVS70	NT	IUCN C3 (Mean)
Agulhas Upper Canyon	Vulnerable (B1)	MSVS70	LC	IUCN C3 (Mean; Max; Cumulative)
Agulhas Very Exposed Rocky Shore	Vulnerable (B2)	MSVS70	LC	IUCN C3 (Mean; Max; Cumulative)
Amathole Hard Shelf Edge	Vulnerable (B1)	MSVS70	NT	IUCN C3 (Cumulative)
Amathole Lace Corals	Near Threatened (B1)	MSVS70	LC	IUCN C3 (Mean; Max; Cumulative)
Cape Sandy Inner Shelf	Vulnerable (B1)	MSVS70	NT	IUCN C3 (Mean, Cumulative)
Cape Very Exposed Rocky Shore	Near Threatened (B1, B2)	MSVS70	LC	IUCN C3 (Mean; Max; Cumulative)
Kingklip Koppies	Vulnerable (B1)	MSVS70	NT	IUCN C3 (Mean)
uThukela Canyon	Near Threatened (B1)	MSVS70	LC	IUCN C3 (Mean; Max; Cumulative)

The two **Critically Endangered** ecosystem types are threatened by intensive fishing pressures over a long duration. Demersal trawling, demersal long lining and the large pelagic fishery are intensively active along the western edge of the Agulhas Bank, threatening the Browns Bank Rocky Shelf Edge ecosystem type (CR, Table 25). Historical and current inshore trawling and flow reduction threaten the Agulhas Muddy Mid Shelf (CR, Table 25).

The 22 **Endangered** ecosystem types include;

- Two ecosystem types off the Orange River in the Northern Cape, namely the Orange Cone Inner Shelf Mud Reef Mosaic and the Orange Cone Muddy Mid Shelf, threatened by flow reduction and mining. In addition historical trawling has probably led to additional historical degradation of this ecosystem type but as this historical pressure was not mapped tonnes captured in existing data sets and therefore threat status of these two ecosystem types is most likely an underestimate.
- Several inshore ecosystem types with high levels of ecosystem degradation, caused by high cumulative pressure including inshore fisheries, coastal development and flow reduction (Cape and Agulhas Sheltered Rocky Shores, Cape Island, Kei Fluvial Fan and the Natal Inner Shelf Reef Sand Mosaic).
- Two types of Bays, Cape Bay and Western Agulhas Bay where there are many accumulated pressures.
- Many reef types due to high fishing pressure, flow reduction or a combination of these pressures. Examples include the Protea Mid Shelf Reef Complex, Kei Reef Complex and Durnford Inner Shelf Reef Complex.
- Several shelf edge ecosystem types across the country including Cape Upper Canyons and the Southern Benguela Muddy Shelf Edge and the Natal Bight Deep Shelf Edge.

Vulnerable ecosystem types cover 4% of the ocean space, with 51 ecosystem types (34%) falling within this category. These include several ecosystem types affected by flow reduction including in the KwaZulu-Natal Bight (such as 3 types of uThukela mid- and outer shelf mosaics) and off Port St Johns; heavily fished shelf edge ecosystems in the Southern Benguela and several shore types affected by multiple pressures, including fishing and mining. These also include ecosystem types of limited spatial extent where there is evidence of ecosystem degradation. Such ecosystem types include the Amathole Hard Shelf Edge and Amathole Lace Corals along with 5 other ecosystem types assessed under a criterion aligned to IUCN B3 (listed in Table 26).

Of the remaining ecosystem types, 17 (11%) and 58 (39%) were respectively **Near Threatened and Least Concern**.

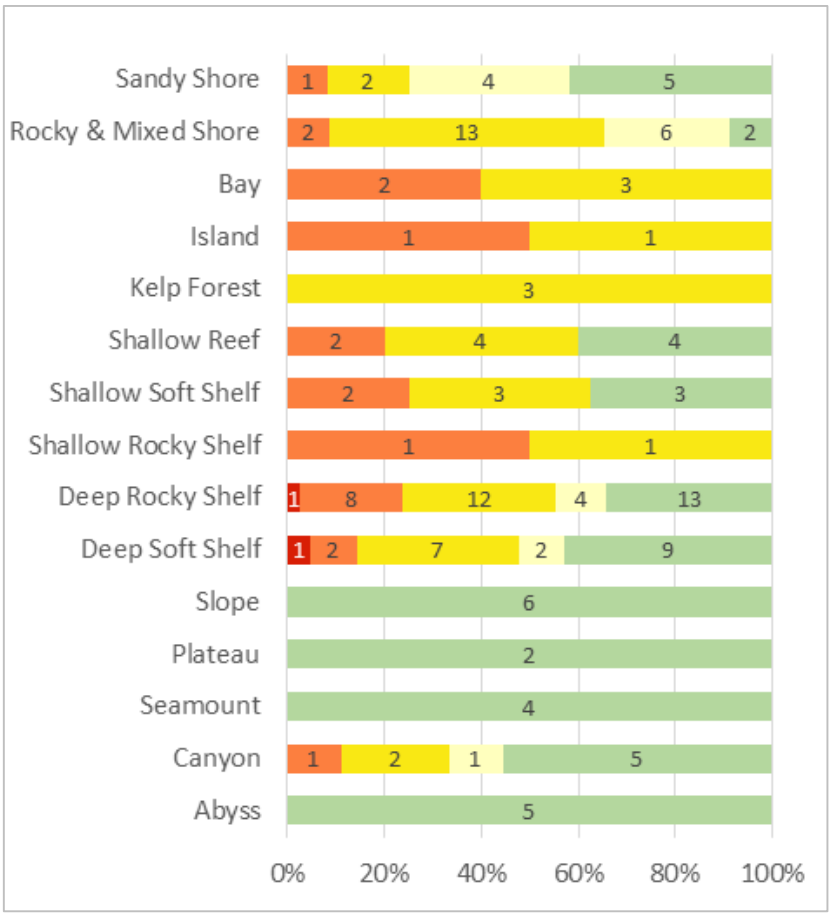


Figure 83. A graph illustrating the spread of threatened ecosystems by broad ecosystem group. The most threatened ecosystem groups included bays, islands, muddy ecosystem types and rocky ecosystems on the shelf and shelf edge

Figure 83 shows the number of threatened ecosystem types per **broad ecosystem group**. The most threatened ecosystem groups are shores, bays and ecosystem types on the shelf and shelf edge. Pressures are often high in these areas due to their accessibility (in the case of shores and bays) and productivity and consequent accumulation of pressures (in the case of the shelf edge and bays).

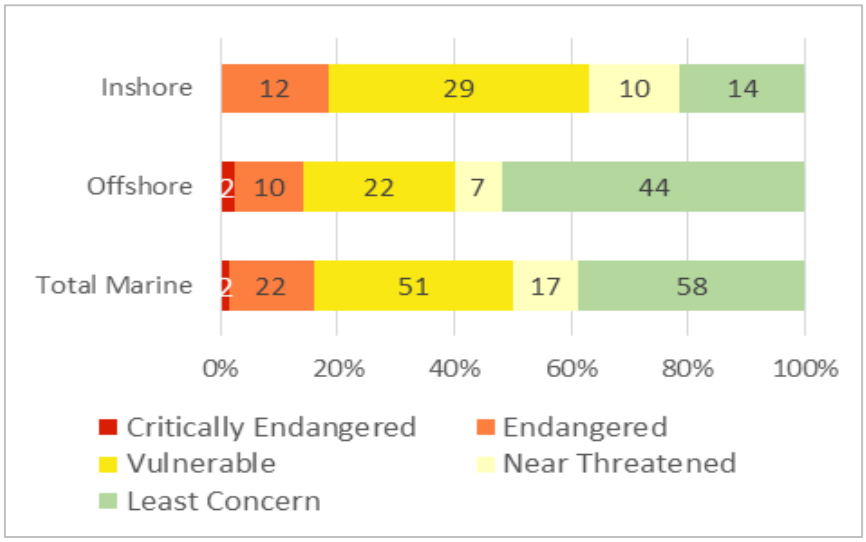


Figure 84. Inshore ecosystem types (within the shallower more wave influenced area) were more threatened than offshore ecosystem types with the inner shelf and shelf edge being more threatened than other depth zones.

Comparing **inshore versus offshore** ecosystem types (Figure 84), there are more threatened ecosystem types in the inshore component of the marine realm than offshore i.e. beyond the fair-weather wave base. This is similar to the pattern reported in the NBA 2011.

Threatened ecosystems are not evenly distributed across South Africa's regions (Figure 82). Ecosystem types in the cold temperate Southern Benguela ecoregion are more threatened than types in the warm temperate Agulhas ecoregion with the subtropical Natal and Delagoa ecoregions being less threatened. Of the shelf ecoregions, the current assessment found that Delagoa is less threatened than Natal but, **regional assessments** that account for the northern components of the Delagoa ecosystems, are needed for better comparison. As ecosystem types in the Delagoa ecoregion extend northwards into southern Mozambique (see Chapter 3), regional assessments are more appropriate for these ecosystem types. Similarly, a number of ecosystem types in the Southern Benguela require collaboration with Namibia to assess regional and/ or global threat status. The two deep ocean Ecoregions have the least threatened ecosystem types, reflecting the reduced number and intensity of pressures beyond the shelf edge (see Figure 82 and Figure 83).

7.5.4 Ecosystem threat status trends

Differences in input data, assessment approaches and thresholds limit the comparability of threat results between years. Despite these differences, similar threat patterns emerge between the NBA 2011 and 2018 (Figure 85).

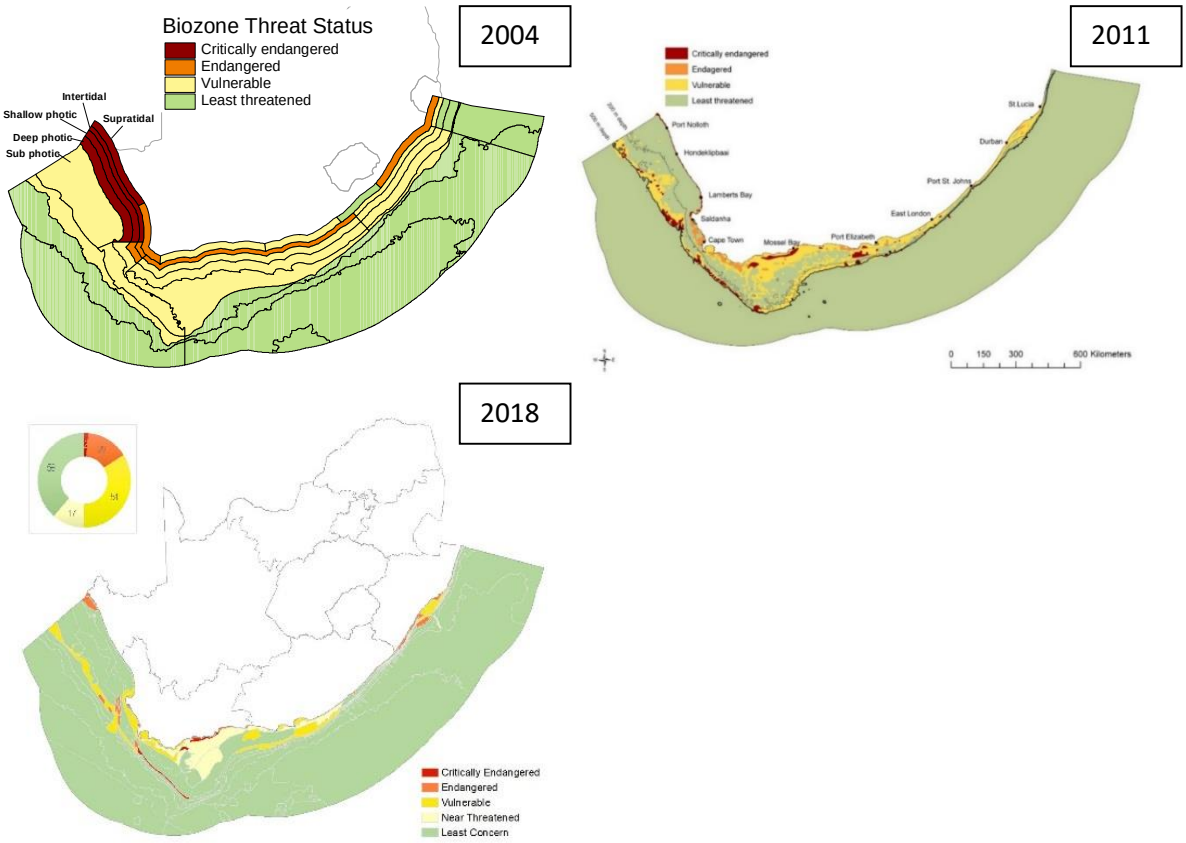


Figure 85. Comparison of the assessment of marine ecosystem threat status between years showing the changes in ecosystem threat status related to finer scale ecosystem mapping and assessment and the shift from 2004 to 2011 to a data driven assessment based on cumulative pressure mapping. Assessment results are not actually comparable due to these changes.

Although the assessment results between 2004, 2011 and 2018 are not really comparable due to differences in input data and assessment methods, results are broadly similar. The 2004 assessment was expert driven without mapping of pressures but a similar cumulative pressure mapping approach employed in both 2011 and 2018 yielded similar threat patterns. The 2004 assessment did not account for the high pressure and degradation of shelf edge ecosystems, and over-estimated mining impacts on the west coast. The more optimistic result from 2018 is due to the shift to stricter IUCN standards that are relevant at global scales.

7.6 Ecosystem threat status limitations and future steps

In future, further work will be undertaken as improved data becomes available and drawing from progress in broader international efforts in marine ecosystem assessment (see Bland *et al.* 2018b). South Africa is likely to advance towards a full IUCN RLE that lists South African marine ecosystems on the global red list, the methodology for which is likely to be refined in line with conceptual advances and further work to compare and standardise marine assessments. In the interim, the 2018 assessment serves as a useful baseline that reports on current threat status using criteria that aligns

with previous approaches and available data and also considers geographic extent to align towards emerging internal approaches. The South African ecosystem assessment team are engaging with the global red listing team to provide feedback from the 2018 assessments and draw from international experience in this regard.

Other indicator-based ecosystem assessment frameworks have been used to assess marine ecosystem status. Using a set of ecological indicators carefully selected for their global comparative qualities (Coll *et al.* 2016) and score-based and decision-tree approaches to weight and combine these indicators, the Southern Benguela ecosystem has been classified as not improving between 1980 and 2008 (Shannon *et al.* 2014) and possibly improving between 2004 and 2010 when environmental influences were also accounted for (Lockerbie *et al.* 2016). These large marine ecosystem-level assessment tools were designed to track changes in ecosystem status over time at the level of the full ecosystem. Disaggregating these assessments to ecoregions and further to ecotypes could provide a useful trophic-based comparison to support the IUCN-based approaches used in the NBA.

To further advance towards the IUCN RLE approach, **conceptual models** should be developed for each functional ecosystem type and assessors need to define the "collapsed state" for each of these groups to support improved assessment. Although cumulative pressure mapping provides a simple surrogate measure of ecosystem degradation and ecological condition that is relatively reliably collated from data provided by various sectors, there is a gap in our ability to understand thresholds of condition (tipping points) and there are challenges in measuring the subtler forms of degradation. As a result of this the impacts (especially food-web interactions that are hard to measure) of pelagic fishing in particular, may have been underestimated, resulting in an underestimation of ecological modification.

Bland *et al.* (2018b) note that maps of **cumulative threat impacts may not fully characterise ecosystem dynamics and pathways towards ecosystem collapse** and this is recognised. More work is needed to define the thresholds of ecosystem collapse in South African marine ecosystems, drawing from research that examines regime shifts, trophodynamics and a range of indicators of ecosystem condition. Thresholds in indicators need to be established, beyond which ecosystem collapse at functional levels is deemed likely to occur. Bland *et al.* (2018a) used the Namibian sardine stock collapse and subsequent shift in the Northern Benguela food web to assist in defining indicator thresholds of collapse for the Southern Benguela ecosystem. A next step could be intensive ecosystem modelling to generate indicator values under modelled conditions to more carefully examine collapse thresholds for the Southern Benguela, and more specifically South African ecoregions. This work could build on the modelling work already done to assess indicator behaviour and identify threshold responses of indicators in a comparative context as part of the IndiSeas project (www.indiseas.org) (Fu *et al.* 2019). While the IUCN RLE approach is based on ecosystem degradation, assessments of condition, based on biological data, are still necessary to identify indicators that can be used to ground-truth current assessments of the NBA, to improve the understanding of pressure-state relationships and to inform additional IUCN criteria for future assessments (Korpinen *et al.* 2012, Rodríguez *et al.* 2015, Clark *et al.* 2016).

Very few studies have assessed the ability of cumulative impacts to accurately **predict** ecosystem condition (Halpern *et al.* 2008, Andersen *et al.* 2015, Clark *et al.* 2016), with little consistency observed in the type of indicators used and their response to multiple human pressures. Ecological thresholds are difficult to quantify for marine risk assessment either because they require large amounts of data from inaccessible marine ecosystems (Bland *et al.* 2018b) or because in many cases they can only be

calculated retrospectively (Tam *et al.* 2017). Future steps could aim to identify a set of **ecological indicators** for each broad (or functional) ecosystem type to define reference conditions (Borja *et al.* 2012) and to determine the effect of cumulative impacts on ecosystem processes (IUCN Criterion D), building on current ground-truthing research to identify tipping points or thresholds of condition that can better relate to ecosystem degradation and assessment (Levin *et al.* 2010, Samhouri *et al.* 2010, Rapport *et al.* 2013, Bland *et al.* 2018a). Bland *et al.* (2018b) note that in marine ecosystems, complex changes in multiple functional groups, trophic pathways and environmental drivers can be symptomatic of ecosystem collapse, challenging the **quantification of collapse thresholds** (Bland *et al.* 2018a, 2018b). They argue that the large amounts of global data on trophic cascades and regime shifts could better inform the delineation of collapsed ecosystem states for risk assessment and these are currently under-used (Bland *et al.* 2018a). Such quantitative techniques should be further explored in South Africa to assess whether they could better inform potential local thresholds in regime shift and work to understand ecosystem perturbation and recovery. Even in a global context, there is a need to explore the effect of different thresholds in IUCN criteria C, D and E. A threshold of 100% loss of spatial distribution is considered the collapse threshold for criteria A and B.

The NBA 2018 applied criteria C3 i.e. only considered current state compared to a 1750 reference condition, noting however that limited data exists to define such reference conditions. **Different time periods warrant consideration in future assessemnets** with more effort needed in collecting data to support assessment againt the 1750 reference condition. All of the pressure data sets used in the 2018 marine assessment do not extend beyond the past fifty years. Considering this, Criteria C1 may have been more appropriate (i.e. conseration of degradation ver the past 50 years). This would have led to a less optimistic assessment that may be more accuarate. The IUCN also provides for assessment of future threats and this warrants further consideration in South African assessments. For example, observed or inferred threatening processes that are likely to cause continuing declines in geographic distribution, environmental quality or biotic interactions within the next 20 years, can also qualify ecosystems of limited geographic extent as threatened under criterion B and criteria A,C, D and E (see Table 19). During review workshops, some experts raised concerns that **future threats** were not included in this assessment, particularly considering South Africa's ambitious plans to develop its ocean economy. A specific example is the Eastern Agulhas Bay, an ecosystem type that includes the Bays of Cape St Francis and Algoa Bay but was assessed as less threatened than the Western Agulhas Bay and Cape Bay ecosystem types. Increasing development, new activities and many recent changes as well as planned new industry activities in Algoa Bay in particular may mean that this ecosystem is more threatened than assessed in the NBA 2018. For such ecosystem types with intensively increasing and expanding threats, threat status may be more accurately evaluated over a shorter time period that also consider future threats.

Future research and assessment priorities include:

- Finer resolution and **improved mapping of several pressures**, particularly fisheries data that are currently reported or provided in large summary grids. As noted in Chapter 4, fisheries data needs to improve in accuracy (e.g. linefish data in this assessment reflects no fishing effort at the Alphard Banks) and in spatial resolution. Additional effort in mapping historical impacts is also desirable. For example, historical inshore trawling on west coast has not been mapped or considered in the assessment of condition resulting in a possible underestimate of the muddy ecosystem types of the Orange Cone.
- Testing of **thresholds** for pressures and degradation.

- **Ground-truthing of ecosystem degradation** including testing condition inside and outside of MPAs to examine effect of pressure exclusion.
- Testing of the effect of the **scale** of ecosystem classification on ecosystem assessment results. The global thresholds may be less suitable to South Africa's finely delineated ecosystem types.
- The number of **threat-defined locations** should also be considered in future South African assessments.
- Site level confirmation of **ecosystem condition** using field research, the application of indicators and analyses.
- Employ **ecosystem models** to examine potential changes in ecosystem status under *future* climate scenarios (Ortega-Cisneros *et al.* 2018) and undertake an indicator-based ecosystem status assessment (Lockerbie and Shannon 2019).

8. ECOSYSTEM PROTECTION LEVEL

Chapter Citation: Sink KJ, Sibanda SM, Fielding P, Skowno AL, Franken M, Harris LR, Adams R, Baleta T. 2019. Chapter 8: Ecosystem Protection Level. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



South Africa's new MPA expansion improves protection of mesophotic reef ecosystems. This reef is at 54m at Sodwana.

Chapter Summary

The year 2018 was a significant year for Marine Protected Area (MPA) expansion with 20 new MPAs approved for declaration by the South African cabinet. These MPAs were proclaimed in 2019 increasing the number of South African MPAs from 26 to 42, inclusive of the Prince Edward Islands MPA in the Southern Ocean and noting that some existing MPAs were expanded, or merged and expanded, in the new MPA network. This National Biodiversity Assessment (NBA) chapter reports on progress in the protection levels of marine ecosystems around mainland South Africa with protection levels for the Southern Ocean examined in the NBA sub-Antarctic Technical Report. Protection of the marine environment around mainland South Africa increased from <0.5% (approximately 4 900 km^2) in 2018 to 5.4% (57 900 km^2) in 2019. Ecosystem Protection Level is a major biodiversity indicator calculated to assess the extent to which ecosystem types are represented in South Africa's protected area network. To calculate this indicator, the distribution of ecosystems in relation to the distribution of protected areas was assessed using a standard 20% biodiversity target, taking into account ecosystem condition. Protection level was determined on a scale that ranged from Not Protected (<0.2% of an ecosystem type in the protected area network) to Well Protected (≥20% of an ecosystem type in good condition in the protected area network). Protection level was calculated for each of South Africa's 150 marine ecosystem types, post-declaration of the expanded MPA network (2019) and for comparison, before declaration (2018). In 2018, when there were 25 mostly coastal MPAs in existence, only 20% of marine ecosystem types were Well Protected while 47% were Not Protected. Of the 70 ecosystem types that were Not Protected in 2018, 51 received their first protection with the declaration of the new MPAs in 2019. Thus, the introduction of the 20 new MPAs reduced the number of ecosystem types within the Not Protected category from 47% to 13%. Most Not Protected ecosystem types are located in the deeper offshore environment, particularly on the slope, with most of the slope and abyssal ecosystem types still Poorly Protected. Thirteen previously Not Protected and 4 Moderately Protected ecosystem types advanced to Well Protected, an improvement from 20% to 31% of ecosystem types in this category. A total of 87% of the 150 marine ecosystem types now have at least some representation in the MPA network. The MPA expansion thus translates into higher levels of protection in the marine realm than in the terrestrial realm in terms of South African ecosystem representation. The placement of these new MPAs not only resulted in a marked improvement in Ecosystem Protection Levels for many ecosystem types but also contributed to better representation of all ecoregions in the MPA network, with the Delagoa ecoregion now having the highest protection level and the Southern Benguela the lowest. There is opportunity to advance many of the Moderately Protected ecosystem types to Well Protected through ecosystem restoration, re-zonation of existing MPAs to reduce ecosystem degradation and other activities that can improve condition within MPAs. Additional MPAs will need to be established to represent the 19 ecosystem types that are still Not Protected and to advance Poorly Protected ecosystem types towards Well Protected.

8.1 Introduction

For centuries people have interacted with the marine environment, using the oceans for food, travel and economic opportunities. Until the beginning of the twentieth century, human interactions with, and influences on, the planet as a whole and the marine environment in particular were relatively benign in the sense that they were limited and were mainly recoverable. More recently, technological developments have greatly increased access to, and usage of, the ocean and its resources, to the point where the marine environment is undergoing increasing degradation (see Chapter 7). It is generally accepted that human well-being in both the developing and developed world is dependent upon the ability of marine and coastal ecosystems to provide a range of ecosystem services. However, unless these uses are managed sustainably, poorly managed multiple pressures on marine ecosystems can threaten the very ecosystems and services on which humans depend. Along with the increasing recognition of these rapidly intensifying pressures on marine species, ecosystems and ecological processes, there is a growing appreciation of the need to **protect and restore marine biodiversity**. The establishment of protected areas is a key strategy used to maintain and manage biodiversity and restore the health and productivity of marine and terrestrial ecosystems. Protected areas are also considered by many to be key interventions in adapting to climate change. As such, protected areas serve as the backbone of the ecological infrastructure network, and include areas that deliver important ecosystem services to people (Skowno *et al.* 2019a). South Africa has numerous well-managed terrestrial protected areas but until 2019, only a fraction of our rich coastal and ocean heritage was protected in formally declared protected areas.

This chapter outlines the **extent of protection** afforded to the marine environment of South Africa. The period between the NBA 2011 and this report has included a critical period of Marine Protected Area (MPA) expansion in the country. The chapter reports on the extent of that expansion in terms of ocean space and the representativeness of the marine ecoregions and ecosystem types in the expanded network.

Protected Areas Definitions

There are many definitions of Protected Areas and **consensus is difficult** to achieve in this regard. Globally, it has proved quite difficult to define a protected area because there are many different levels of protection and there are diverse institutional arrangements for regulating activities that impact on the environment. At the World Conservation Congress in Barcelona, Spain (2008) the International Union for Conservation of Nature (IUCN) adopted a refined definition of the term 'protected areas' that encompassed MPAs and the definition was retained in the recent application of IUCN's Global Conservation Standards to Marine Protected Areas (IUCN-WCPA 2018). A protected area was defined as:

"**A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values**."

In the South African context, protected areas are **defined** as areas of land or sea that are protected by the legislation for protected areas (National Environmental Management: Protected Areas Act, NEM: PAA, Act No 57 of 2003 referred to as NEM: PAA hereafter). In terms of the law, protected areas may be declared for the purpose of conserving biodiversity, preserving ecological integrity, protecting

ecosystems and species, maintaining the supply of environmental goods services and promoting economic development (NEM:PAA 2003).

Protected Area Expansion

There has been remarkable **growth in the number and spatial extent of MPAs globally** over the last few years. There has been a tenfold increase in MPA coverage since 2000 – from about 2 million km^2 (0.7% of the global ocean) in 2000 to almost 28 million km^2 (7.7% of the ocean) in 2019. Almost 14 million km^2 of this MPA coverage has occurred since 2010 (www.protectedplanet.net). This growth has been focused in national waters, while in areas beyond national jurisdiction, marine protected areas constitute less than 2% of total area (protectedplanet.net).

Growth in the extent of protection of the marine environment has partly been a response by countries to the increasing realisation of the accelerating changes in marine ecosystems and the critical role of marine ecosystems in food provision, climate regulation and ocean economies. In addition, MPA expansion has also been driven by the responses of countries to the Strategic Plan for Biodiversity developed in 2011 by the **Convention on Biological Diversity**. The mission of the Strategic Plan was to "take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication". Various targets (Aichi Biodiversity Targets) relating to the implementation of programmes across a range of factors that impact on biodiversity were set. With regard to protected areas **Aichi Target 11** states that "by 2020 at least 17% of terrestrial and inland water, and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures".

Further impetus to the recent drive to increase ocean protection was provided by the United Nations' **Sustainable Development Goals (SDGs).** The SDGs are meant to provide a blueprint to achieve a better and more sustainable future for all. They address the global challenges, including those related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. SDG 14 is about conserving and sustainably using the oceans, seas and marine resources. One of the targets of **SDG 14** is to conserve at least **10%** of coastal and marine areas by 2020 in recognition of the critical role the world's oceans play in the global systems that make the Earth habitable for humankind. Our rainwater, drinking water, weather, climate, coastlines, much of our food, and even much of the oxygen in the air we breathe, are ultimately provided and regulated by the sea.

Protected Areas in South Africa

The **Protected Areas Act (NEM: PAA 2003)** provides for several categories of protected areas, including special nature reserves, national parks, nature reserves, MPAs and protected environments. Due to the way that marine ecosystems have been defined in the NBA 2018, there may be shore components of terrestrial protected areas (which were not necessarily gazetted as part of the MPA) that have been included in the assessment of marine ecosystem protection levels.



Marine Protected Areas are recognised in the Protected Areas Act and are areas of land or sea protected by law and managed mainly for biodiversity conservation. ©Peter Chadwick.

In this report the **definition of the marine environment** includes the area extending from the dune base on the shore to the outer edge of the Exclusive Economic Zone and (Harris *et al.* 2019b) (see Chapter 1). However, the inshore boundary of all currently gazetted MPAs is the highwater mark. Thus, the area between the highwater mark and the dune base does not form part of the protected area in gazetted MPAs but where this falls within another category of protected area, this has been included in the assessment for the NBA 2018. Thus, in some cases non-marine protected areas sometimes make a contribution to the protection of shore ecosystems. These include protected areas such as the Namaqua National Park where the Admiralty zone (200 m inland of the highwater mark) falls under Park management, and Dassen Island Nature Reserve and the Dyer and Geyser Island Nature Reserves where the reserve boundary includes the marine environment up to 500 m offshore of the highwater mark. There are also a number of smaller coastal protected areas or special nature reserves where part of the shore is included in the protected area. Refer to Chapter 3 and (Harris *et al.* 2019a) for clarity on the definitions and approach in mapping marine ecosystems.

This chapter focuses on MPAs but recognises and assesses the contribution of other types of formally recognised protected areas to assess the level of protection of the marine environment. Until 2014, most MPAs in South Africa were established by way of Section 43 of the **Marine Living Resources Act** (MLRA) of 1998. Prior to the MLRA, MPAs were declared in terms of the Sea Fisheries Act (1973 and 1988) and its various amendments. Many of the coastal MPAs were initially declared as a means to protect intertidal resources for purposes of biodiversity conservation (Colin Attwood, University of Cape Town 2018 pers. comm). The idea that offshore resources needed protection came later and the potential role of MPAs in fisheries management only found its way into South African legislation as late as 1998. It is only relatively recently, since detailed biodiversity and habitat data and systematic conservation planning software have been available, that areas have been targeted for protection based on multiple biodiversity and economic attributes (Attwood *et al.* 1997b, Sink *et al.* 2011).

Partly as a result of growing awareness of the broader social and livelihood responsibilities of MPAs and partly as a result of an institutional reorganisation that had separated fisheries management from the management of MPAs and the marine environment generally, the promulgation and management of MPAs was removed from the MLRA in 2014 and placed under the same legislation that controlled terrestrial protected areas. The **declaration and management** of MPAs are now provided for in terms

of NEM: PAA. In terms of a provision that was inserted in NEM: PAA by the National Environmental Management: **Protected Areas Amendment Act, 2014** (which came into effect on 2 June 2014) all MPAs that were declared under the MLRA must be regarded as MPAs declared under NEM: PAA.

Under NEM: PAA an MPA is declared for one or more reasons:

a. To conserve and protect marine and coastal ecosystems
b. To conserve and protect marine and coastal biodiversity
c. To conserve and protect a particular marine or coastal species, or specific population and its habitat
d. If the area contains scenic areas or to protect cultural heritage
e. To facilitate marine and coastal species management by protecting migratory routes and breeding, nursery or feeding areas, thus allowing species recovery and to enhance species abundance in adjacent areas
f. To protect and provide an appropriate environment for research and monitoring to achieve the objectives of this Act
g. To restrict or prohibit activities which is likely to have an adverse effect on the environment

The more **specific and detailed MPA objectives** are, the easier it is to assess achievement of the objectives. A major criticism regarding several of South Africa's MPAs that were declared before the turn of the century, is that they were designated without sufficient information or programmes in place to assess whether the areas are performing useful functions (Attwood *et al.* 1997b). In these cases, there are contrasting views regarding the objectives of the MPAs, or objectives were not always stated in sufficient detail in declaration notices or management plans to allow for measurement of effectiveness. Specifying detailed MPA objectives in declaration notices and management plans enables proper evaluation of how effective MPA management is terms of protection or socio-economic benefits. Such evaluation is essential for enablement of improved planning and adaptive management. In 2017, the former Department of Environmental Affairs (DEA) and WWF South Africa initiated the MPA Effectiveness project, which aims to identify suitable goals (broad statements of what MPAs are trying to achieve) and objectives (specific measurable statements of what must be accomplished to obtain a related goal) for MPAs, taking into account ecological, social and economic considerations, and to develop an appropriate framework for assessment of MPA effectiveness against stated goals and objectives.

The Phakisa MPA technical team drew from lessons that emerged from the work of this team in **refining MPA objectives** for the expanded network. All of South Africa's newest MPAs specify detailed objectives in each declaration notice. Many of these include aspects of the objectives listed above but were specific in the case of relevant species and ecosystem types. In addition, MPA objectives were broadened to provide for the cultural, heritage and educational benefits of MPAs (see purposes g, h and i in the example below). There was also a greater focus on protection of critical linkages across realms for more effective coastal protection (see purpose a, d and h) and maintaining the 'sense of place' in important coastal areas.

By way of example, the stated **purposes** of the new iSimangaliso MPA in the declaration notice (Government Gazette No. 42478, 23 May 2019) includes the following **specific purposes**:

a. To contribute to a national, regional and global representative system of marine protected areas, by providing protection to linked coastal and offshore sites in a large contiguous conservation area that includes a World Heritage Site and Ramsar Site

b. To protect inshore ecosystems including the turtle nesting beaches and subtropical coral communities

c. To protect offshore benthic and pelagic ecosystems, including turtle foraging and inter-nesting area, entire submarine canyons which constitute known and potential Coelacanth habitat, and vulnerable and ecologically sensitive seabed habitats, including cold water corals and sponge grounds

d. To conserve and protect the biodiversity and ecological processes associated with these interconnected ecosystems

e. To protect important life history areas and migratory corridors for Whale Sharks and other sharks, marine mammals, turtles, migratory fish and bird species

f. To facilitate fisheries management by protecting spawning stock, allowing stock recovery, and enhancing stock abundance in adjacent areas, in particular, for reef fish such as Slinger, Scotsman and other seabreams, rockcods and large pelagic fish

g. To support sustainable nature-based tourism opportunities in the area through the protection of marine wildlife

h. To protect and regulate a scenic area to support sustainable nature-based tourism, cultural and spiritual assets and a functionally connected coastal marine system to retain a land-ocean 'sense of place'

i. To provide reference sites for research and monitoring, including areas in good ecological condition and areas which may show most clearly the impacts of climate change, and also to promote and contribute to environmental education

The IUCN definition of a protected area includes conservation areas that are not formally protected by law but may be informally protected by **other effective means**, and the scope of objectives is very broadly specified – "to achieve the long-term conservation of nature and associated ecosystems and cultural values". The conservation estate of South Africa also includes areas that are protected by other mechanisms distinct from formally gazetted protected areas. These areas are often referred to as **conservation areas** and include areas of UNESCO[5] biosphere reserves, areas declared in terms of the World Heritage Act, areas protected by local and provincial spatial planning laws, and areas protected by conservation servitudes. In the absence of legally binding measures that prevent loss of natural habitat and because many of these areas are not effectively managed, these other area-based conservation measures do not provide full and permanent protection in the South African context. For this reason, in its assessment of marine ecosystem protection level, the NBA report currently only

[5] UNESCO – United Nations Educational, Scientific and Cultural Organisation

includes formally protected areas and a narrow range of other legally secure effective conservation measures.

Benefits of Marine Protected Areas

In terms of food and economic opportunities, the world's seas and oceans are the locations for major commercial activities, including large-scale fishing, oil and gas exploration and extraction, commercial shipping, coastal development and various forms of aquaculture. Large numbers of coastal communities around the world depend on marine resources for their livelihoods and welfare, at subsistence, artisanal and a range of commercial levels. Interest in recreational activities in marine and coastal areas has also increased considerably and there are growing markets for marine curios and speciality sea-foods. All of these demands and activities represent pressures on marine biodiversity, and when the pursuits of food and economic gains in the marine environment are poorly managed, the benefits from marine biodiversity are at risk (Sherman 2017). The pressures on marine biodiversity in South Africa are detailed in Chapter 4 with additional interacting threats to marine biodiversity in terms of invasive species and climate change, covered in Chapter 5 and 6.



A factsheet on the benefits of MPAs was produced as part of SANBI's communications strategy to improve marine protection levels in South Africa (see Annexure 2)

Climate change is likely to continue to impact biodiversity and ecological processes at an accelerating rate. The establishment of MPAs is perhaps one of the most important tools available to governments trying to address increasing pressures and threats to ocean ecosystems.

Although the specific benefits delivered by individual MPAs related to ecosystem and species protection may differ from one MPA to the next (depending on region, ecosystem and species representation, zonation and management), MPAs can be considered to provide benefits across three broad categories:

- Maintenance of the **health and productivity** of marine ecosystems and species
- Contribution to the **socio-economic** welfare of communities and protection of social and cultural values
- Contribution to **climate resilience** i.e. combating climate change through protection of the coastlines and carbon sequestration and through maintenance of genetic and physiological diversity of exploited species

Within these broad categories, MPAs provide a far broader range of benefits for fisheries, local economies and the marine and coastal environment including:

- Conserving representative samples of biological diversity (ecosystems and species) and ecosystem processes that sustain this **biodiversity** (Bohnsack and Ault 1996, Roberts 1997). In South Africa, the role of MPAs in biodiversity conservation is well established (Hockey and Buxton 1989, Attwood *et al.* 1997b).



Endemic ecosystems such as this warm temperate reef ecosystem from the mid shelf of the Agulhas ecoregion are protected in Tsitsikamma MPA. © Geoff Spiby

- Providing sites in which the **genetic integrity** of exploited species is conserved (this can be altered in heavily fished populations) to enhance resilience (Roberts *et al.* 2017). Recent internationally acclaimed research demonstrated the role of the Tsitsikamma MPA in maintenance of fish genetic diversity (Duncan *et al.* 2019) showing the importance of genetic resilience in the face of climate change (see Box 29)

- Arresting and possibly reversing the global and local decline in fish populations and productivity by protecting **critical breeding, nursery and feeding areas** and by providing **refugia** in which breeding populations can reside and the reproductive potential of the stock as a whole can be significantly increased (Lester *et al.* 2009). South African MPAs where there is evidence of these benefits include Tsitsikamma (Buxton and Smale 1989, Tilney *et al.* 1996),

- De Hoop (Attwood and Bennett 1994, 1995), Goukamma (Kerwath *et al.* 2013b) and iSimangaliso (Mann *et al.* 2016). The Tsitsikamma MPA protects squid egg beds which are impacted by trawling and anchor damage outside of protected areas (Sauer 1995). The expanded MPA network includes specific objectives regarding protection of **spawning aggregations** of Red Steenbras *Petrus rupestris* (Kerwath *et al.* 2019), Seventy-four *Polysteganus undulosus* and Geelbek *Atractoscion aequidens*.



Protection of South Africa's endemic and Endangered Red Steenbras, the world's largest seabream, is a key objective of the Amathole Offshore MPA. © ACEP Imida Project

- Protecting **breeding areas** of other species including key nesting and calving areas. In South Africa, the role of MPAs in protecting seabird and seal breeding colonies and turtle nesting grounds has been recognised (Attwood *et al.* 1997b, Nel *et al.* 2013, Harris *et al.* 2018)


Seal pup in the new Namaqua National Park MPA © Peter Chadwick

- Providing sites where biomass and reproduction of exploited organisms increases, resulting in **spillover** or emigration of adults and the export of eggs and larvae, both of which benefit adjacent fisheries. (Bohnsack and Ault 1996, Bohnsack 1998, Lester *et al.* 2009, Edgar *et al.* 2014). South African scientists made substantial contributions to the international evidence base that shows the value of MPAs in sustaining fisheries (Buxton and Smale 1989, Attwood and Bennett 1994, 1995, Buxton 1996, Attwood *et al.* 1997a, Kerwath *et al.* 2013b)


Comorants roosting in the Rocherpan MPA © Kerry Sink

- Providing sites where critical **comparative fisheries monitoring data** can be collected (Kenchington *et al.* 2003). In South Africa there are numerous examples of this (Attwood and Bennett 1994, Tarr 1995, Attwood *et al.* 1997b). Such contrasts can support stock assessments.


Red Roman in the Tsitsikama MPA © Steve Benjamin

- Providing undisturbed reference sites for **long-term research**. Long term monitoring sites in South Africa's MPA network include the linefish (De Hoop, Dwesa-Cwebe and Pondoland). The Oceanographic Research Institute conducts long term monitoring of coral communities in the iSimangaliso MPA (Porter and Schleyer 2017).


Fish monitoring at De Hoop © Peter Chadwick

- Raising the profile of an area for marine, nature-based recreation, and broadening local economic options (Christie *et al.* 2003, Christie 2004, Leisher *et al.* 2007). South African MPAs that have helped **boost tourism** include De Hoop MPA with its renowned Whale Trail, Tsitsikamma MPA, which has its Otter Trail booked out years in advance, the Maputaland and St Lucia MPAs and their associated scuba diving tourism (now iSimanagaliso) (Annexure 4). The Robberg MPA is also attracting increasing tourism for its aesthetic and heritage assets including Nelson's Cave. In 1997, a lack of visitor facilities and


Boat based shark encounters are popular among tourists © Peter Chadwick

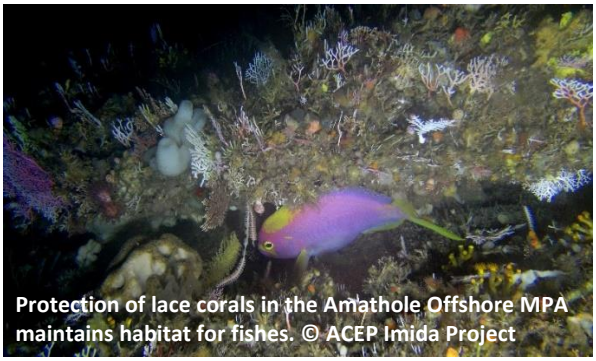
funding were cited as the key limitations in terms of MPAs reaching their potential in terms of tourism and environmental education.

- Providing focal points for **education and training** about marine ecosystems and human interactions with them. Locally, Potberg Education Centre in De Hoop and Mission Rocks in iSimangaliso are important sites for environmental education.


MPAs provide classrooms
© Oceonographic Research Institute

- Providing sites that contribute to the preservation of **heritage and culture** (see Annexure on Increasing Benefits from Marine Protected Areas). Historical and cultural assets protected in South Africa's MPA include the historic fish traps in the Still Bay MPA, Nelson's cave in the Robberg MPA, and several caves in MPAs in or adjacent to MPAs in the southern Cape. Historic shipwrecks in MPAs include the wreck of the East Indiaman the Doddington which ran aground at Bird Island in 1775, the steamship SS Maori that wrecked in the Karbonkelberg Restriced Zone of Table Mountain National Park MPA in 1909 and the slave trader Sao Jose that sank off Clifton in 1794. Shipwrecks such as the SS Maori and the Produce in the Aliwal Shoal MPA provide opportunities to diversify tourism and provide favoured dive sites. There is also a shipwreck trail in the Table Mountain National Park. Religious and cultural ceremonies are held in the Helderberg, Pondoland and iSimangaliso MPAs. The new Robben Island MPA adds new maritime aspects to the already globally significant historical and including shipwrecks, and protection of the kelp forests where prisoners including Nelson Mandela harvested kelp.

- Protecting intrinsically sensitive ecosystems such as **Vulnerable Marine Ecosystems** (VMEs) (Ardron *et al.* 2014). See Chapter 3 for more details on VMEs. The new Cape Canyon MPA, Southwest Indian Seamount MPA and Amathole Offshore MPA were designed to achieve multiple objectives including protection of sensitive canyon habitats, deep cold-water coral reefs, seamounts and lace coral gardens.


Protection of lace corals in the Amathole Offshore MPA maintains habitat for fishes. © ACEP Imida Project


MPAs such provide sites for spiritual and cultural ceremonies. Helderberg MPA © Peter Chadwick

Box 29. Role of Marine Protected Areas in maintaining the climate change resilience of fishes
By Murray Duncan and Warren Potts

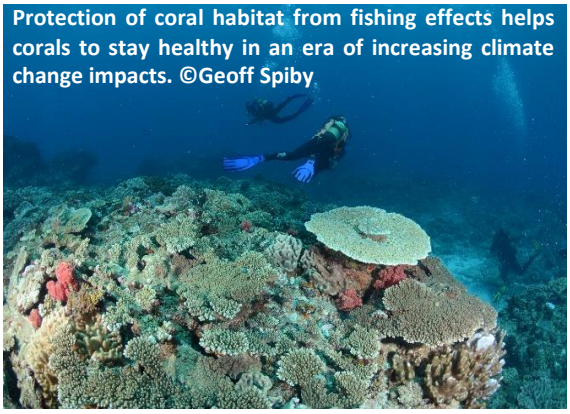


Marine protected areas (MPA) offer a refuge from exploitation for fish populations which can increase their resilience to climate change in a number of ways. For example MPA's have been shown to harbour more genetic diversity for adaptation and larger individuals, which provide resilience through their higher reproductive output. However, the immediate, direct effects of climate change on fish are driven by the ability of each individual to withstand the prevailing conditions. For those that do not move readily, this requires a physiological response. Recent laboratory research by Duncan *et al.* (2019) showed that fish populations living in the Tsitsikamma MPA have a greater physiological phenotype diversity and overall physiological capacity to handle temperature extremes when compared than nearby exploited populations. It is thought that fishing removes individuals with better physiological capacity to adapt to temperature extremes because these individuals are captured even when the water temperature is unfavourable. This finding has major implications for the way that we can adapt to the impacts of climate change as it suggests that the promulgation of new MPA's and improved compliance within existing MPA's will improve the resilience of our fishes.

These findings of Duncan et al (2019) have stimulated an African Coelacanth Ecosystem Program funded project led by Prof. Warren Potts at Rhodes University which aims to determine whether the improved physiological capacity of the fish in MPA's is passed on to their offspring? Understanding this is critical because it will help us determine if fishes in MPA's will seed resilient offspring to large areas through egg and larvae transport (via the ocean currents) or if it will only be resilient adults that spill-over to the adjacent areas (see Kerwath *et al.* 2013). The ACEP project also aims to compare the behavioural and metabolic responses of exploited and unexploited fish populations to climate extremes in the wild. Using the Tsitsikamma MPA as the reference protected population, the early results corroborate Duncan *et al's* (2019) laboratory findings and also show that individuals in unexploited populations are active at extreme temperatures when compared with those from exploited populations. This suggests that individuals from unexploited populations will be able to continue with their general activities, while those from exploited populations will remain inactive at extreme temperatures.

- Protecting sites with minimal direct human impact to help them **recover** from other stresses (Kenchington *et al.* 2003, Charles and Wilson 2008, Lester *et al.* 2009, Berglund *et al.* 2012, Roberts *et al.* 2017, Harris *et al.* 2019b). In South Africa, the protection of our coral communities in the iSimangaliso MPA is likely to have played a key role in maintaining the health of these ecosystems with limited coral bleaching observed to date (Porter *et al.* 2016).

- Contributing to **resilience against climate change** by protecting coastlines and sequestering carbon in coastal and marine vegetation (Roberts *et al.* 2017). Protection of seaweed beds and kelp forests supports the regulating functions of the ocean whereas dunes help armour shores against extreme events. These habitats constitute ecological infrastructure (See Chapter 2 and the


Protection of coral habitat from fishing effects helps corals to stay healthy in an era of increasing climate change impacts. ©Geoff Spiby

case study in the Benefits Compendium). This area warrants increased research in South Africa with the mapping of coastal ecological infrastructure considered an important research priority (See Chapters 2, 6 and 11).

MPAs provide a **climate change management tool** for exploited fish species by harbouring populations with greater physiological phenotype diversity (Duncan *et al.* 2019) Providing sites where enforcement and compliance activities are **simplified and cost-effective management measures** can be implemented (Kenchington *et al.* 2003, Lester *et al.* 2009, Berglund *et al.* 2012, Roberts *et al.* 2017)

- Providing sites that help to develop models of fair and transparent **governance** (IUCN-WCPA 2018). South African MPAs are challenged in this regard because of our political history, historical injustices and limited opportunities for local community participation in MPA governance (Sowman and Sunde 2018). Since 2003, there is increasing recognition of the effects of MPAs on social cohesion, gender relations, cultural identity, food security and livelihoods (Christie *et al.* 2003, Kenchington *et al.* 2003, Christie 2004, Charles and Wilson 2008, Lester *et al.* 2009, Ferse *et al.* 2010, Mascia *et al.* 2010, Berglund *et al.* 2012, Roberts *et al.* 2017, Harris *et al.* 2019b). There are opportunities to strengthen the governance and planning of South African MPAs to advance towards a more effective, sustainable and equitable MPA network (Sowman *et al.* 2014, Sowman and Sunde 2018).


Monitoring of launch sites and collection of data for fisheries management is a key management activity in MPAs in MPAs. ©Peter Chadwick.

MPA benefits generally increase with increasing protection levels (Kenchington *et al.* 2003, Charles and Wilson 2008, Lester *et al.* 2009, 2009, Berglund *et al.* 2012, Edgar *et al.* 2014, Roberts *et al.* 2017, Bobiles and Nakamura 2019, Harris *et al.* 2019b). This is a challenge for South Africa where the complex socio-political dynamics have recently led to reduced protection in established MPAs.

Expansion of South African MPAs

Tsitsikamma MPA was South Africa's first MPA declared in 1964 and since then MPAs have steadily been added to South Africa's marine conservation estate (Table 27, Figure 86 and Figure 87). There are also multiple revisions, expansions or revised zonations. Note that the **Pondoland** MPA has had several names including the Pondoland: Mkhambathi and Greater Pondoland .Until 2019, the **Amathole** MPA (declared in 2011) was the most recent addition to the coastal MPA network. Up until May 2019, South Africa had **25 formally declared coastal MPAs** that included 4749 km^2 (<0.5%) of the mainland Exclusive Economic Zone (EEZ) (Table 27, Figure 86), and one very large offshore MPA centred on the Prince Edward Islands in the Southern Ocean.

Table 27. Overview of MPAs promulgated between1964 and 2018 (listed from west to east). MPA sizes estimated by SANBI in ArcMap 10.4 using Albers equal area projection. Note that Rocher Pan is not currently included in the SAPAD database and parts of the Walker Bay Whale Sanctuary are zoned as "*Restricted" but include fishing. #1 July-30 Nov

	Marine Protected Area	Year Established	Size (km^2)	Zoned
1	Rocherpan	1976 revised in 1990, 1992	1,5	Controlled with shore angling permitted
2	Malgas Island	1985, revised in 2000	0,9	Controlled
3	Marcus Island	2000	0,24	Controlled
4	Jutten Island	2000	1,1	Controlled
5	Langebaan Lagoon	1973, revised 1985, 1987	47	Controlled, Restricted & Sanctuary
6	Sixteen Mile Beach	1985, revised 1987	105	Controlled
7	Table Mountain National Park	2004	954	Controlled & Restricted (6 no-take zones)
8	Helderberg	1991 revised 2000	2,4	Restricted
9	Betty's Bay	1981 revised 2000	20	Controlled (only shore angling permitted)
10	Walker Bay Whale sanctuary #	2001	112	Sanctuary & Restricted*
11	De Hoop	1985 revised 2000	287	Restricted
12	Still Bay	2008	32	Controlled & Restricted (2 no-take zones)
13	Goukamma	1990 revised 2000	34	Controlled (only shore angling permitted)
14	Robberg	1998 revised 2000	26	Controlled (only shore angling permitted)
15	Tsitsikamma	1964 revised 1974, 2000, 2016	293	Controlled (shore angling) & Restricted
16	Sardinia Bay	1990 revised 2000	13	Restricted
17	Bird Island	2004 revised 2008	71	Restricted
18	Amathole	2011	247	Controlled (only shore angling permitted)
19	Dwesa-Cwebe	1991 revised 2000, 2015	265	Controlled & Restricted
20	Hluleka	1991 revised 2000	41	Restricted
21	Pondoland:	1991, revised 2004	1236	Controlled & Restricted (3 no- take areas)
22	Trafalgar	1979	8,3	Controlled (shore angling permitted)
23	Aliwal Shoal	2004	125	Controlled & Restricted (1 no-take area)
24	St Lucia	1979 revised 2016	442	Controlled & Restricted (2 no-take areas)
25	Maputaland	1986 revised 2016	380	Controlled & Restricted (2 no-take areas)

The NBA 2011 reported 4539 km^2 total MPA estate including the Amathole MPA declared in 3 sections adding 246.5 km^2 in that year. Note that Rocher Pan and Walker Bay were not included in the NBA 2011 leading to differences in reported statistics. No new MPAs were declared around South Africa between 2012 and 2018 although the Prince Edward Islands MPA was declared in 2013 and covers 36% of South Africa's sub-Antarctic territory (Whitehead *et al.* 2019). Key changes in MPA estate between 2011 and 2018 include revised zonation at Dwesa-Cwebe in 2015 and Tsitsikamma in 2016. Increased access for shore fishing was provided for in both MPAs with extensions (largely offshore) to compensate for losses in protection. The Dwesa-Cwebe MPA expanded from 192 km^2 (Sink *et al.* 2012a) to 265 km^2 in 2015, an increase of 73 km^2. Tsitsikamma expanded from approximately 264 km^2 as reported in 2011 to 293 km^2, an addition of 29 km^2 to compensate for reduced protection of shore ecosystems. Note that there is approximately 50 km^2 of non-MPA protected areas that provide some protection to shore ecosystem types. The largest contributions are made by the Garden Route National Park (11 km^2), Dassen Island (9 km^2) and the West Coast National Park (6 km^2).

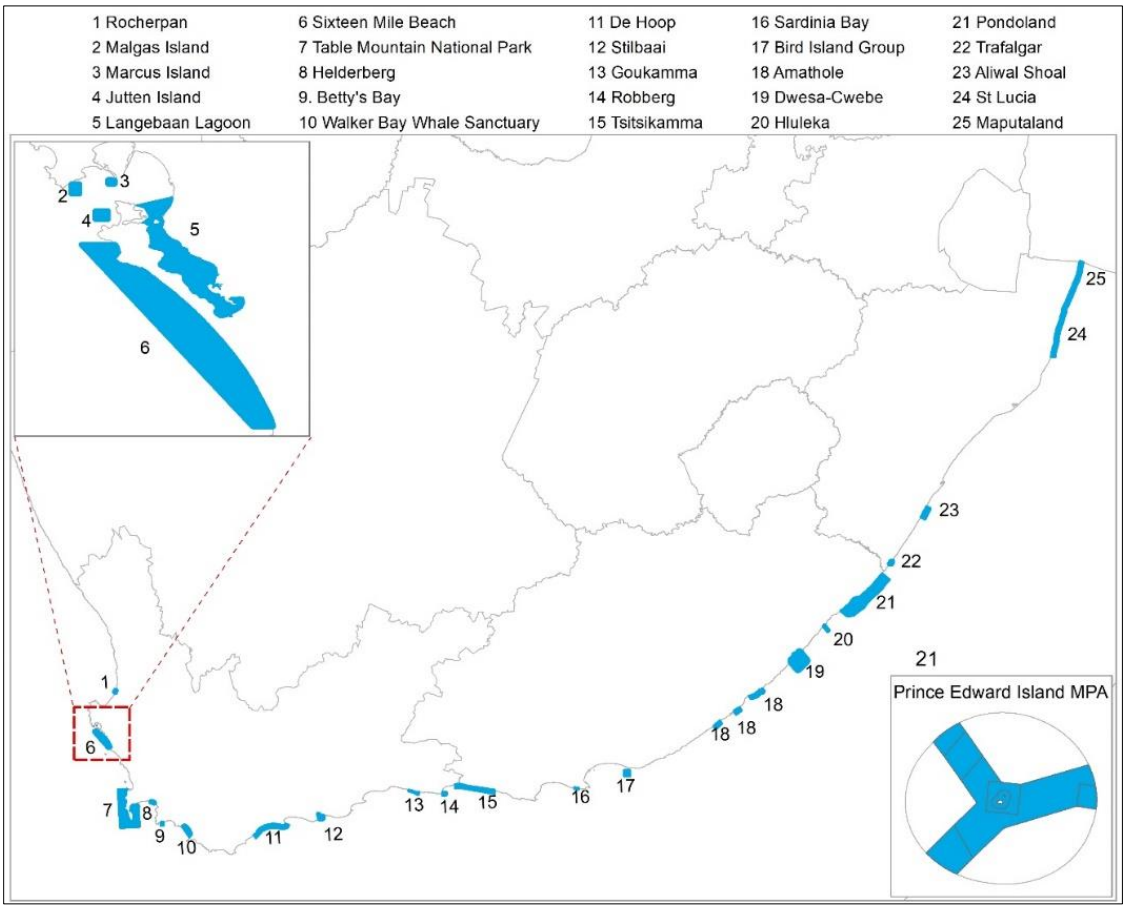


Figure 86: South Africa's MPA estate in 2018 comprising 25 coastal MPAs and the Prince Edward Island MPA.



The National Protected Area Expansion Strategy motivated for increased protection of deep and offshore ecosystems and species for future protection within MPAs.
© Geoff Spiby

The NPAES of 2008 was revised in 2016 (DEA 2016b) and prioritised the conservation of the marine areas gazetted for comment after the Phakisa process. In May 2019, 20 of the 22 MPAs that had been gazetted for comment in 2016 were formally promulgated and regulations were defined for their management (Government Gazettes No's 42478 and 42479 of 2019). Two proposed MPAs (Benguela Bank and Browns Bank Complex) were omitted from the network and the sizes of individual MPAs were reduced slightly in most cases such that the total area proclaimed was approximately 54 000 km^2 rather than the originally proposed 68,578km^2 (Table 29, Figure 87). Note that this statistic cannot be simply added to the existing MPA network statistics as it includes overlapping area. The declaration of these new MPAs very significantly contributes to the achievement of the United Nations SDG 14.5 target, moving South Africa forward from <0.5% protection of the mainland marine territory to 5.4% of the ocean around South Africa protected. The new MPA network will help to protect marine ecosystems, rebuild fish stocks, support climate resilience and sustain South Africa's emerging ocean economy.

South Africa now has 41 MPAs in the marine environment around its mainland as well as the very large MPA surrounding the Prince Edward Islands that covers more than 30% of the Southern Ocean territory (Whitehead *et al.* 2019). Three of the newly promulgated MPAs are expansions of existing coastal MPAs that replace the de-proclaimed smaller MPAs embedded within them. These expanded MPAs are iSimangaliso, Aliwal Shoal and Addo Elephant National Park MPA which include the former St Lucia and Maputaland MPAs, the former Aliwal Shoal MPA and the former Bird Island MPA. Of great significance is the proclamation of the Namaqualand MPA on the west coast of South Africa where historically there had been no protected marine environment between Rocherpan near Saldahna Bay and the Orange River at the border with Namibia. The new Namaqua National Park MPA is the first MPA in the Northern Cape. Twenty six of the 41 MPAs have a shore component and could be considered coastal MPAs while 15 are entirely offshore and range from those including inshore ecosystems to those including abyssal ecosystem types more than 3500 m deep. Within this multi-purpose expanded MPA network there is a range of types of management areas including sanctuary zones (no access, no resource use), restricted zones (no resource use but access for tourism encouraged) and controlled zones (certain kinds of fishing, often with limitations on gear or species, are permitted). There are some completely no-take MPAs, Ramsar sites, a World Heritage Site (WHS) and two UNESCO Biosphere Reserves. There is even a MPA that is effectively a MPA only between 1 July and 30 November of any given year, thus a seasonal MPA (Walker Bay Whale Sanctuary).

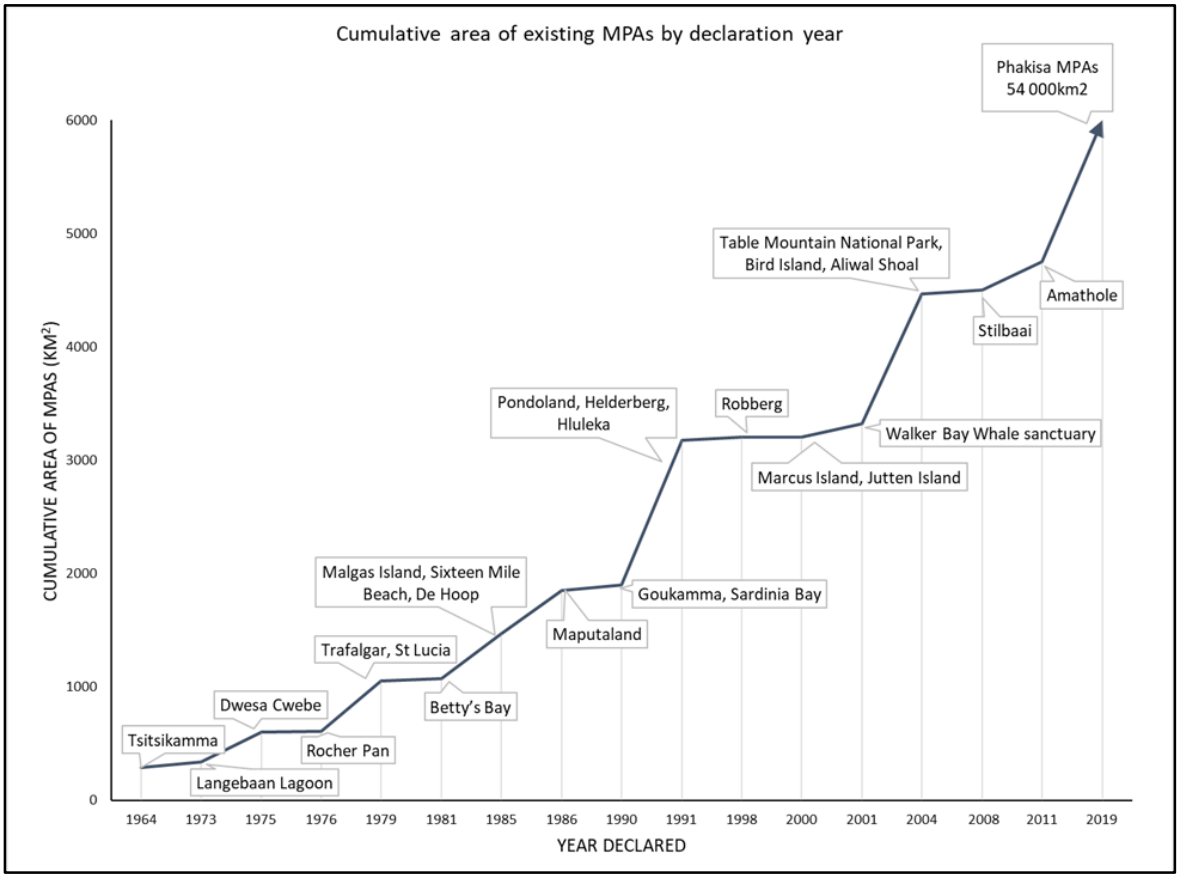


Figure 87. The cumulative area (km²) of South African Marine Protected Area estate from the year Tsitsikamma was proclaimed (1964) until the latest proclamations in 2019.

It is interesting to note the cumulative extent of the protected area estate since the proclamation of the first MPA in 1964 (Figure 87). Significant additions have occurred at regular intervals indicating an

active environmental department responding to national protected area targets. The declaration of 20 new MPAs in 2019 is however the most significant increase in MPA estate in South Africa's history. Protection of the marine environment around mainland South Africa increased from less than 0.5% in 2018 to 5.4 % in 2019 with the addition of 51 477 km^2 protected area estate (Figure 88, Figure 89).

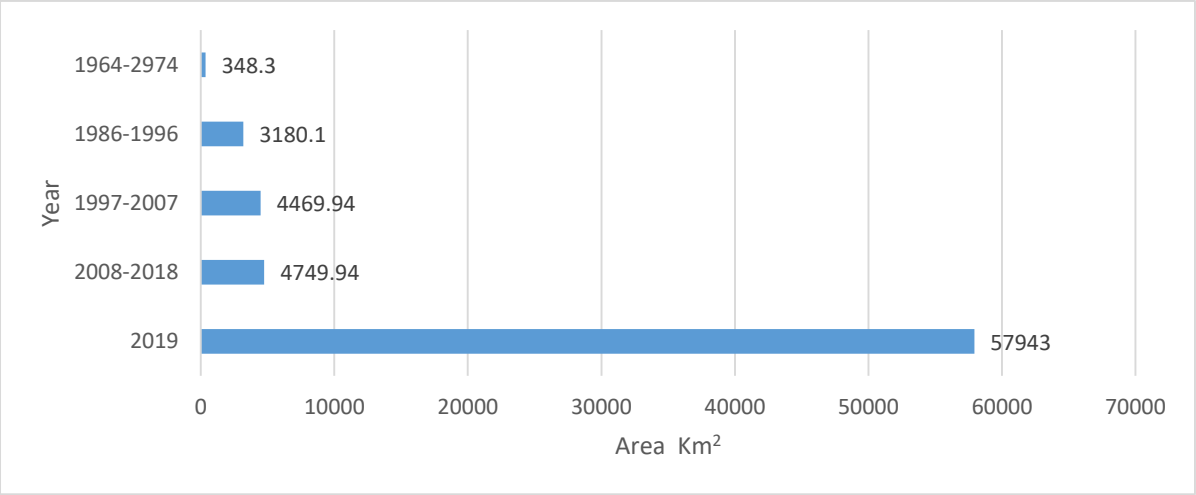
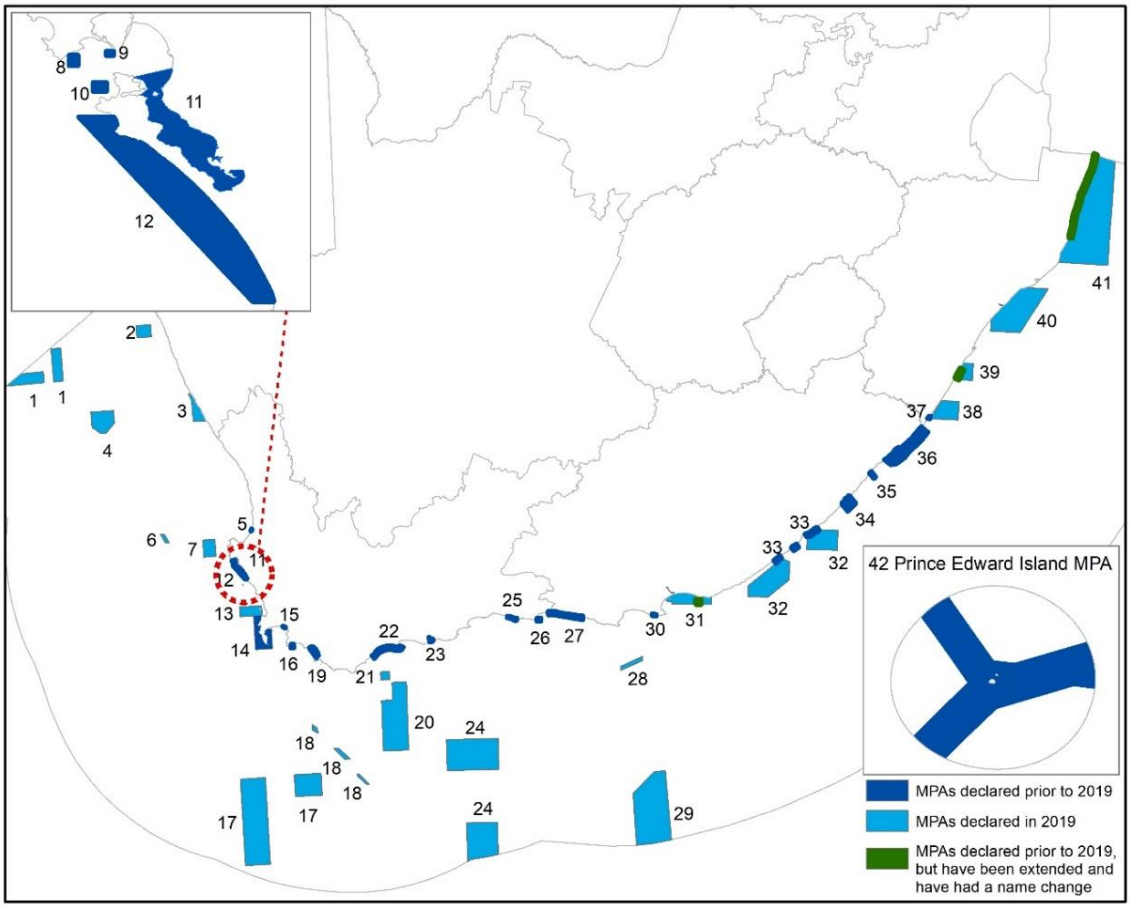


Figure 88. Expansion of MPA estate from 1964 to 2019.

Of the 15 proposals considered by the 1997 Marine Reserves Committee (Attwood *et al.* 1997b), all except one (Tongaat) have now been implemented with limited protection of Dassen Island. In 1997, progress on these proposals was reported, with no protection in Namaqualand at that time (Attwood *et al.* 1997b). These authors reported that negotiations for the Namaqua MPA "were at an advanced stage" although this first MPA in the Northern Cape took a further 22 years before implementation, 42 years after recommendation for protection. The Pondoland and Table Mountain National Park MPAs were proclaimed in 2004, building on existing restricted areas but even though the proposed Namaqua MPA was published for public comment at the same time, petroleum, diamond mining and commercial fishing interests sparked significant objections in the consultation process (including from other government departments) and comments submitted cited a lack of evidence for offshore protection and an absence of baseline studies against which the effectiveness of protection could be assessed (Sink 2008). Although the importance of protection of Dassen Island and its surrounding seas has been recognised since 1997, still only the island is effectively protected.

Table 28. MPA proposals considered by the 1997 Marine Reserves Committee

Proposed site	Committee decision	1997 Status	Present status (year proclaimed/ expanded)
Namaqualand coast	Approved	National Park still planned	Namaqua National Park MPA (2019)
Langebaan Lagoon	Approved	West Coast National Park	West Coast National Park
Posberg coast	Approved	De Hoop Marine Reserve	De Hoop MPA
Leven Point	Approved	St Lucia Marine Reserve	iSimangaliso MPA (expanded 2019)
Part of False Bay	Approved	Millers Point Marine Reserve	Table Mountain National Park (2004)
Natal south coast	Approved	Trafalgar Marine Reserve	Trafalgar Marine Reserve
Dassen Island	Further investigation needed	Island protected only	Island protected only
Tongaat	Further investigation needed	No MPA	No MPA
*Knysna Lagoon	Further investigation needed	Knysna National Lake Area	Knysna National Lake Area
Woody Cape	Further investigation needed	Restricted area	Addo MPA
Rocherpan	Further investigation needed	Rocherpan Marine Reserve	Rocherpan MPA
De Hoop	Further investigation needed	De Hoop Marine Reserve	De Hoop MPA
Goukamma	Further investigation needed	Goukamma Marine Reserve	Goukamma MPA
Transkei and Ciskei	Further investigation needed	Restricted area	Pondoland MPA (2004)
Tongaland	Further investigation needed	Maputaland Marine Reserve	iSimangaliso MPA (expanded 2019)



1	Orange Shelf	15	Helderberg	29	Agulhas Front MPA
2	Namaqua Fossil Forest	16	Betty's Bay	30	Sardinia Bay
3	Namaqua National Park	17	Southeast Atlantic Seamounts	31	Addo Elephant National Park
4	Childs Bank	18	Browns Bank Corals	32	Amathole Offshore
5	Rocherpan	19	Walker Bay Whale Sanctuary	33	Amathole
6	Benguela Muds	20	Agulhas Bank Complex	34	Dwesa-Cwebe
7	Cape Canyon	21	Agulhas Muds	35	Hluleka
8	Malgas Island	22	De Hoop	36	Pondoland
9	Marcus Island	23	Stilbaai	37	Trafalgar
10	Jutten Island	24	Southwest Indian Seamount	38	Protea Banks
11	Langebaan Lagoon	25	Goukamma	39	Aliwal Shoal
12	Sixteen Mile Beach	26	Robberg	40	uThukela
13	Robben Island	27	Tsitsikamma	41	iSimangaliso
14	Table Mountain National Park	28	Port Elizabeth Corals		

Figure 89. South Africa's expanded MPA network (2019) .The Prince Edward Island MPA is also shown although the statistics in this chapter exclude this area (Whitehead *et al.* 2019).

Table 29. Overview of 20 Marine Protected Areas declared in 2019. MPAs are zoned as Restricted, Controlled and / or Sanctuary with 10 MPAs including multiple types of zonation, 5 excluding all fishing (#) and 4* designed mostly to protect the seabed environment while accommodating some form of pelagic fishing.

No	Marine Protected Area	Area in Km^2	Zoned
1	Orange Shelf Edge MPA	1843	Sanctuary#
2	Namaqua Fossil Forest MPA	494	Controlled*
3	Namaqua National Park MPA	550	Restricted & Controlled
4	Childs Bank MPA	1211	Controlled*
5	Benguela Muds MPA	92	Controlled*
6	Cape Canyon MPA	583	Restricted#
7	Robben Island MPA	612	Restricted & Controlled
8	Southeast Atlantic Seamounts MPA	7725	Restricted & Controlled
9	Browns Bank Corals MPA	340	Controlled*
10	Agulhas Bank Complex MPA	4313	Restricted & Controlled
11	Agulhas Muds MPA	207	Sanctuary#
12	Southwest Indian Seamount MPA	7558	Restricted#
13	Agulhas Front MPA	6255	Restricted#
14	Port Elizabeth Corals MPA	270	Controlled
15	Addo Elephant National Park MPA	1127	Restricted & Controlled
16	Amathole Offshore MPA	4206	Restricted & Controlled
17	Protea Banks MPA	1191	Restricted & Controlled
18	Aliwal Shoal MPA	678	Restricted & Controlled
19	uThukela MPA	4100	Restricted & Controlled
20	iSimangaliso MPA	10715	Restricted & Controlled
	Total area	54070	

NBA 2018 KEY MESSAGE B3

Protected areas: investment success in the ocean and on land

Protected areas have expanded in the ocean and on land and are a source of pride for South Africans (well established). Continued expansion will help to ensure biodiversity conservation, ecological sustainability and even more social and economic benefits from biodiversity production, livelihoods, tourism and future climate change resilience.

Skowno et al. 2019.

A summary of the extent of protection of the South African marine environment in 2018 before the declaration of 20 new MPAs, versus after their declaration in May 2019 is provided in Table 30. Clearly, in 2019, South Africa took a significant step towards achieving globally desirable protection levels for the marine environment.

Key MPA Statistics for South Africa

Reporting of marine protection statistics in South Africa has been characterised by inconsistencies. This has been brought about by (a) whether reporting has been limited to formal MPAs or has included other protection; (b) mixed understanding of the number of MPAs or other areas that may qualify as being adequately protected; (c) differences in the boundaries considered between analyses, such as whether the high-water mark or fore-dune base is used as the landward boundary of marine area under consideration and different EEZ shape files and (d) differences in map projections between analyses. The shapefile that is published by DEA based on their South Africa Protected Areas Database (SAPAD) has a slightly different EEZ to the one used in the NBA 2018 which is that provided by the South African Navy Hydrographers Office (SANHO). As of 30 August 2019, the SAPAD layer also excludes Rocherpan MPA and two large newly proclaimed MPAs that border on the EEZ boundary (Agulhas Front MPA and Southwest Indian Seamount MPA.

The statistics below are for the marine environment around mainland South Africa as defined in Chapter 1 of this assessment, i.e. from the dune base as mapped by Harris *et al.* 2019 to the outer bounds of the Exclusive Economic Zone as mapped by the South African Navy. All protected areas (not only MPAs) that contribute to the protection of the marine environment are considered, including those parts of terrestrial protected areas that contribute to protection of marine ecosystem types. Key differences between these statistics and those reported in 2011 include the inclusion of Rocherpan and Walker Bay MPA, the additional 220 km^2 of marine territory that was within the iSimangaliso World Heritage Site but excluded from the St Lucia and Maputaland Marine Reserves. This latter area is within the new iSimangaliso MPA. There are several fragments of non-MPA protected areas that do provide some protection to shore ecosystem types in the marine realm.

Table 30. Overview of the extent of current protection of coast and EEZ for South Africa before and after the gazetting of 20 MPAs in 2019. (MPA areas from SANBI 2019).

Feature	No. MPAs	Territory Area km^2	Area MPAs km^2	% Protection (Applicable Territorial Sea & EEZ)
MPAs 2018	25	1 072 716	4748	0.46%
MPAs post-2019	41	1 072 716	57943	5.4%

Despite the recent advances that South Africa has made in the proclamation of MPAs, it is important to remember that the shore, shelf and deep water benthic and pelagic environments between the Orange River and Mozambique border comprise many varied ecosystem types (See Chapter 3). The representation of these different ecosystem types in the protected area network is an essential consideration if South Africa is to meet the goal of a representative protected area network. The key to effective conservation of biodiversity, ecosystems and ecological processes is the effective protection of representative areas of all the varied ecosystem types. South Africa is fortunate to have many data sources that contribute to fine scale definition of 150 ecosystem types in the area between the foredune and the outer edge of the EEZ. In the next section the extent of protection of these different ecosystem types is assessed.

8.2 Ecosystem Protection Level Inputs and Approach

The ecosystem classification, mapping and distribution of South Africa's marine ecosystems is described in Chapter 3: Sink *et al.* 2019, according to which there are 150 different marine and coastal ecosystem types distributed around mainland South Africa between the base of the fore-dunes and the outer edge of the EEZ. These 150 ecosystem types have been grouped into 15 broad groups to examine and report on patterns in threat status (see Chapter 7) and protection level. To monitor and report on the status of biodiversity in South Africa, the NBA focuses on high level indicators such as the threat status and protection level for species and ecosystems. The Ecosystem Protection level indicator has been developed by South Africa to report on protection status of all ecosystem types in all realms of South Africa. In 2004, South Africa reported on the protection level of 34 marine biozones (equivalent to the bathyregions defined in Chapter 3) (Lombard *et al.* 2004, Driver *et al.* 2005a) and in 2011 the protection level of 136 marine ecosystem types was determined (Sink *et al.* 2012a).

A South African Protected Areas Database (SAPAD) is maintained by the Department of Environmental Affairs (DEA). This spatial data set formed the core of the protection level analysis. However, the database does not yet represent all existing protected areas, and also required restructuring and cleaning to allow for protection level analyses. The spatial data used for the NBA 2018 protection level analysis was produced by: correcting overlapping polygons; resolving inconsistencies; compiling, checking, appending and deleting information; and finally, merging and cleaning all data sources into a single topologically correct shapefile with a consistent set of attribute data for analysis (see the realm report(s) for full details). This layer of protected areas (Figure 90) was used in the protection level assessment for the marine realm.



Figure 90. South Africa's protected area network indicated in dark green.

Assessment method

Protection level analyses require information on the distribution of different ecosystem types (see Chapter 3), the distribution and types of protected areas, and the biodiversity targets for each ecosystem type. Ecosystem classification and distribution are discussed in Chapter 3, protected area types and distribution are outlined in the earlier part of this chapter and biodiversity targets are discussed below. Ecosystem types are categorised as Not Protected, Poorly Protected, Moderately Protected or Well Protected, based on the proportion of each ecosystem type that occurs within a protected area recognised in the NEM: PAA (Table 31).

Table 31. Categories of protection levels used in the marine biodiversity assessments in South Africa.

Protection Status	Description
Well protected	≥20% of an ecosystem type in good condition in the Protected Area Network
Moderately protected	>10% but <20% of an ecosystem type in the Protected Area Network
Poorly protected	>0.2% but <10% of an ecosystem type in the Protected Area Network
No protection	<0.2% of an ecosystem type in the Protected Area Network

Biodiversity Targets

A biodiversity target for an ecosystem is the minimum proportion of each ecosystem type that needs to be kept in good ecological condition (a natural or near-natural state) in the long term in order to maintain viable representative samples of all ecosystem types and the majority of species associated with them. It is expressed as a percentage of the historical extent of an ecosystem type (measured as area, length or volume) (SANBI 2016).

A standard 20% biodiversity target is used for marine ecosystems in South Africa. This was informed by a review of international research efforts to determine marine biodiversity targets (Porter *et al.* 2011b) and a dedicated NBA target determination workshop held in 2016. Historically, the 20% target was established at the World Parks Congress in 2003, adopted in the NSBA 2004 and used in NBA 2011. Currently, the IUCN recommends a 30% target for marine protection.

Consideration of ecosystem degradation and condition

The map of ecosystem condition (see Chapter 7) was used to refine protection level categories to ensure that targets for ecosystem types reported as Well Protected are met in areas that are not moderately, severely or very severely degraded. If the biodiversity target is not met in areas that are in natural or near natural condition within Protected Areas, an ecosystem type is downgraded to Moderately Protected. Thus, only ecosystem types with sufficient protection of the ecosystem in areas that are not degraded can be considered Well Protected. This is similar to the approach taken in 2011 where MPA zonation (fishing allowed/not allowed) was considered in assigning protection level. Where fishing was allowed an area was considered to be impacted i.e. not in a natural condition. In 2018, the approach considered the impact of additional pressures and not just fishing, a decision made at a dedicated NBA workshop to discuss and decide on biodiversity targets and protection level methods. The 2018 method included consideration of the impact of other pressures such as pipelines, coastal development and areas of established high levels of poaching. By considering ecosystem degradation and ecological condition (see Chapter 4 and Chapter 11), the risk of falsely considering ecosystems as Well Protected is reduced. Note that improved coastal pressure mapping that includes pressures resulting from recreational, small-scale commercial and commercial linefishing have been identified as priorities for future improvement. Figure 91 provides an overview of the steps involved in assigning protection level to marine ecosystem types.

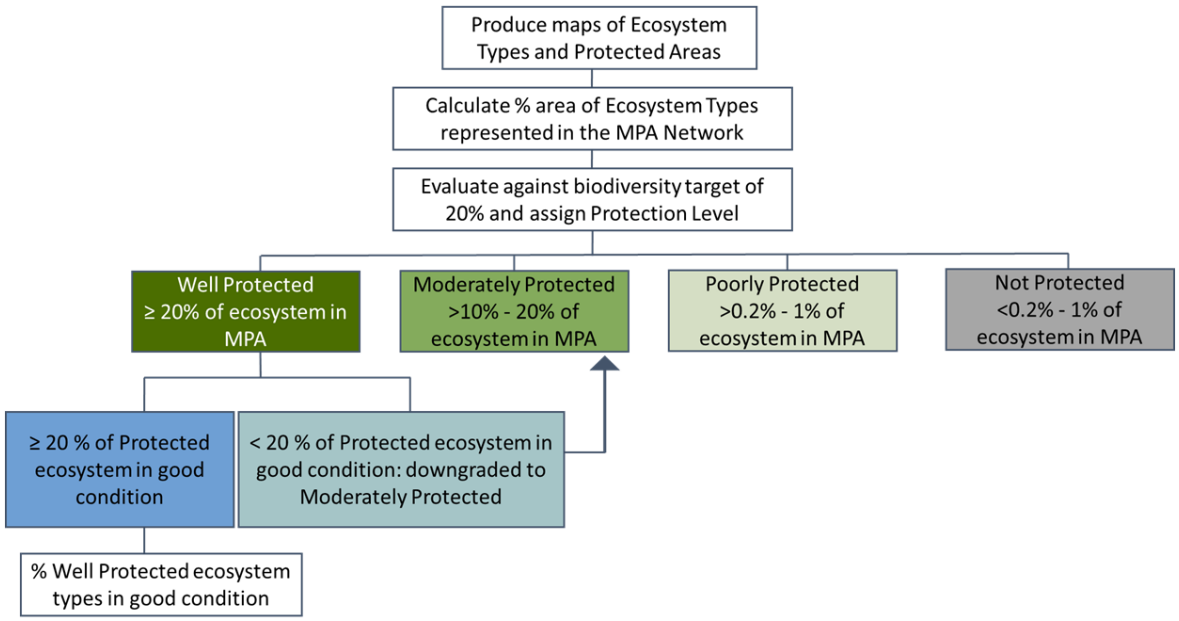


Figure 91. Schematic to show steps in determining the marine ecosystem type protection level (Adapted from Sibanda in prep. University of Cape Town).

8.3 Ecosystem protection level

Ecosystem protection levels were estimated for the period before (2018) and after (2019) the expansion of South Africa's MPA network with the proclamation of 20 new MPAs (Figure 92). Although this assessment is for 2018 and the 20 new MPAs were declared in 2019, the cabinet decision to declare these new MPAs was made in October 2018 and it was undesirable to omit the anticipated new MPAs in the NBA 2018 as it would become outdated in 2019. The protection level analyses took into account the newly developed ecosystem map of **150 distinct marine ecosystem types** in the South African marine environment (Chapter 3); their distribution relative to the MPA networks of 2018 and 2019 (see Section 8.4), and the extent of pressures and ecosystem degradation (Chapter 4 and Chapter 7). Results are detailed in Table **32** and illustrated in Figure 92.

The most striking feature of Figure 92 is the great reduction in the percentage of ecosystems with no protection i.e. **Not Protected ecosystem types declined from 47% to 13%.** Most unprotected ecosystems in 2018 were located in the deeper offshore environment. Despite the increased protection levels in 2019, it is clear that much of the slope and deeper environment is still Poorly Protected, with most of the Moderately and Well Protected ecosystems occurring inshore. Importantly, ecosystem protection levels have increased in the general area of the Agulhas Bank, a region of high endemism and where many of the South Africa's richest fisheries occur (Figure 92). The deep water environment to the south and west of the country is also significantly better protected in 2019. This is mainly due to the declaration of the Agulhas Front Complex MPA and two MPAs that include Seamounts. These are very large MPAs that are completely or partially restricted.

With the gazetting of the 2019 MPAs, the percentage of **Well Protected ecosystems increased from 20% to 31%** and the percentage of **Moderately Protected ecosystems almost doubled** (increasing from 22 to 41%). The distribution of Well Protected ecosystems is skewed towards the eastern part of the ocean (Figure 92), mainly because there are now several very large MPAs situated there (Addo

National Elephant Park MPA, Amathole Offshore MPA, Protea Banks MPA, uThukela MPA and iSimangaliso MPA). Offshore MPAs in the Southern Benguela ecoregion are relatively small, providing less protection to ecosystems in this ecoregion. This is a cause for concern because this area supports key fisheries, has higher mining impacts and interests, and has more threatened ecosystem types. It also evident that bathyl and two abyssal ecosystem types in the Southwest Indian Ocean ecoregion still have insufficient protection. Ecosystems at these great depths in the Southeast Atlantic Ecoregion are somewhat better protected, but the entire lower slope bathome in both the Southwest Indian Ocean and Southeast Atlantic Ocean Provinces is without any protection (Figure 92, Table 31).

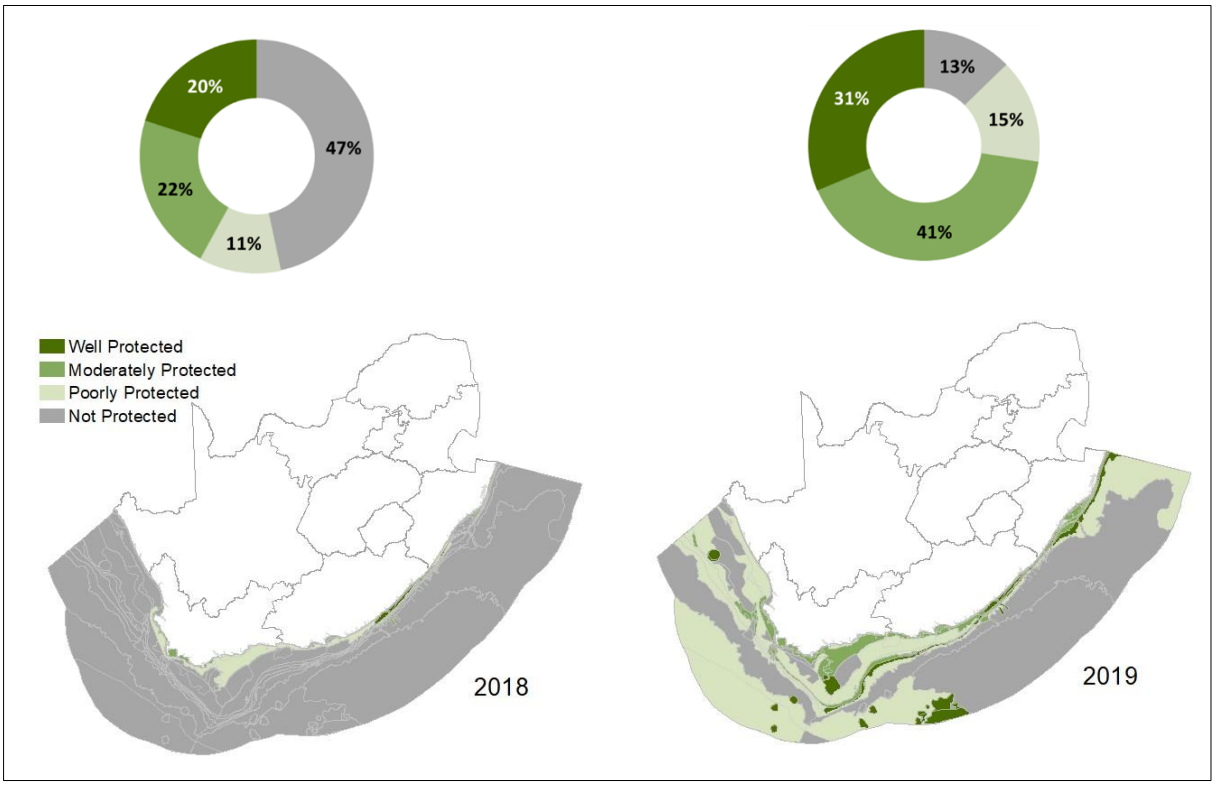


Figure 92. Ecosystem protection levels for ecosystem types before (2018) and after the addition of 20 new MPAs in 2019. Note that the graphs above each map reflect the percentage rather than the number of ecosystem types in each threat category.

Table 32. List of marine ecosystem types and their protection level categories before proclamation of the Phakisa MPA network (2018) and after proclamation of the Phakisa MPA network in 2019. To support prioritisation of protection, ecosystem threat status as determined in Chapter 7 (Sink *et al.* 2019) is also shown for each ecosystem type.

Ecosystem Type Name	PL2018	PL2019	Threat Status
Agulhas Basin Abyss	No Protection	Poorly Protected	Least Concern
Agulhas Basin Complex Abyss	No Protection	No Protection	Least Concern
Agulhas Blues	No Protection	No Protection	Near Threatened
Agulhas Boulder Shore	Well Protected	Well Protected	Near Threatened
Agulhas Coarse Sediment Shelf Edge	No Protection	Poorly Protected	Vulnerable
Agulhas Dissipative Intermediate Sandy Shore	Moderately Protected	Well Protected	Least Concern
Agulhas Dissipative Sandy Shore	Well Protected	Well Protected	Near Threatened
Agulhas Exposed Rocky Shore	Moderately Protected	Moderately Protected	Vulnerable
Agulhas Exposed Stromatolite Rocky Shore	Poorly Protected	Poorly Protected	Vulnerable
Agulhas Inner Shelf Mosaic	Moderately Protected	Moderately Protected	Vulnerable
Agulhas Inner Shelf Reef	Well Protected	Well Protected	Least Concern
Agulhas Intermediate Sandy Shore	Moderately Protected	Moderately Protected	Least Concern
Agulhas Island	Well Protected	Well Protected	Vulnerable

Ecosystem Type Name	PL2018	PL2019	Threat Status
Agulhas Kelp Forest	Moderately Protected	Moderately Protected	Vulnerable
Agulhas Lower Canyon	No Protection	Moderately Protected	Least Concern
Agulhas Mid Shelf Mosaic	Poorly Protected	Moderately Protected	Near Threatened
Agulhas Mid Shelf Reef	Moderately Protected	Moderately Protected	Vulnerable
Agulhas Mixed Shore	Moderately Protected	Moderately Protected	Near Threatened
Agulhas Muddy Mid Shelf	Poorly Protected	Poorly Protected	Critically Endangered
Agulhas Muddy Outer Shelf	No Protection	Poorly Protected	Near Threatened
Agulhas Plateau	No Protection	Well Protected	Least Concern
Agulhas Reflective Sandy Shore	Poorly Protected	Poorly Protected	Vulnerable
Agulhas Rocky Outer Shelf	No Protection	Well Protected	Least Concern
Agulhas Rocky Plateau	No Protection	Well Protected	Least Concern
Agulhas Rocky Shelf Edge	No Protection	Moderately Protected	Least Concern
Agulhas Sandy Inner Shelf	Moderately Protected	Moderately Protected	Vulnerable
Agulhas Sandy Mid Shelf	Poorly Protected	Moderately Protected	Near Threatened
Agulhas Sandy Outer Shelf	No Protection	Poorly Protected	Vulnerable
Agulhas Sheltered Rocky Shore	Moderately Protected	Moderately Protected	Endangered
Agulhas Stromatolite Mixed Shore	Moderately Protected	Moderately Protected	Vulnerable
Agulhas UPoorly Protecteder Canyon	No Protection	Well Protected	Vulnerable
Agulhas Very Exposed Rocky Shore	Moderately Protected	Moderately Protected	Vulnerable
Agulhas Very Exposed Stromatolite Rocky Shore	Moderately Protected	Moderately Protected	Near Threatened
Aliwal Shoal Reef CoModerately Protectedlex	Moderately Protected	Moderately Protected	Vulnerable
Alphard Bank	No Protection	Well Protected	Least Concern
Amathole Hard Shelf Edge	No Protection	Well Protected	Vulnerable
Amathole Lace Corals	No Protection	Moderately Protected	Near Threatened
Browns Bank Rocky Shelf Edge	No Protection	Moderately Protected	Critically Endangered
Cape Basin Abyss	No Protection	Poorly Protected	Least Concern
Cape Basin CoModerately Protectedlex Abyss	No Protection	Poorly Protected	Least Concern
Cape Bay	Poorly Protected	Moderately Protected	Endangered
Cape Boulder Shore	Moderately Protected	Moderately Protected	Vulnerable
Cape Exposed Rocky Shore	Moderately Protected	Moderately Protected	Vulnerable
Cape Island	Moderately Protected	Moderately Protected	Endangered
Cape Kelp Forest	Moderately Protected	Moderately Protected	Vulnerable
Cape Lower Canyon	No Protection	No Protection	Vulnerable
Cape Mixed Shore	Moderately Protected	Moderately Protected	Vulnerable
Cape Rocky Inner Shelf	Moderately Protected	Moderately Protected	Vulnerable
Cape Rocky Mid Shelf Mosaic	Poorly Protected	Moderately Protected	Vulnerable
Cape Sandy Inner Shelf	Moderately Protected	Moderately Protected	Vulnerable
Cape Sheltered Rocky Shore	Poorly Protected	Poorly Protected	Endangered
Cape UPoorly Protecteder Canyon	No Protection	Moderately Protected	Endangered
Cape Very Exposed Rocky Shore	Well Protected	Well Protected	Near Threatened
Central Agulhas Outer Shelf Mosaic	No Protection	Moderately Protected	Least Concern
Childs Bank Coral	No Protection	Well Protected	Vulnerable
Childs Bank Plateau	No Protection	Well Protected	Least Concern
Delagoa Deep Shelf Edge	Moderately Protected	Well Protected	Least Concern
Delagoa Lower Canyon	Well Protected	Well Protected	Least Concern
Delagoa Mixed Shore	Well Protected	Well Protected	Least Concern
Delagoa Rocky Mid Shelf	Well Protected	Well Protected	Least Concern
Delagoa Sandy Inner Shelf	Well Protected	Well Protected	Least Concern
Delagoa Sandy Mid Shelf	Well Protected	Well Protected	Least Concern
Delagoa Shelf Edge	Well Protected	Well Protected	Least Concern
Delagoa UPoorly Protecteder Canyon	Well Protected	Well Protected	Least Concern
Delagoa Very Exposed Rocky Shore	Well Protected	Well Protected	Least Concern
Durnford Inner Shelf Reef CoModerately Protectedlex	No Protection	Moderately Protected	Endangered
Durnford Mid Shelf Reef CoModerately Protectedlex	No Protection	Moderately Protected	Vulnerable
Eastern Agulhas Bay	No Protection	Moderately Protected	Vulnerable
Eastern Agulhas Outer Shelf Mosaic	No Protection	Poorly Protected	Least Concern
False and Walker Bay	Moderately Protected	Moderately Protected	Vulnerable
Kei Fluvial Fan	Moderately Protected	Moderately Protected	Endangered
Kei Reef Mosaic	Moderately Protected	Moderately Protected	Endangered
Kingklip KoPoorly Protectedies	No Protection	No Protection	Vulnerable
Kingklip Ridge	No Protection	Moderately Protected	Endangered
Kosi Coral Community	Well Protected	Well Protected	Least Concern
KZN Bight Muddy Shelf Edge	Poorly Protected	Moderately Protected	Vulnerable

Ecosystem Type Name	PL2018	PL2019	Threat Status
KZN Bight Deep Shelf Edge	No Protection	Moderately Protected	Endangered
KZN Bight Mid Shelf Mosaic	No Protection	Poorly Protected	Endangered
KZN Bight Mid Shelf Reef CoModerately Protectedlex	No Protection	No Protection	Endangered
KZN Bight Muddy Inner Shelf	No Protection	Moderately Protected	Vulnerable
KZN Bight Outer Shelf Mosaic	No Protection	Moderately Protected	Vulnerable
KZN Bight Sandy Inner Shelf	No Protection	Moderately Protected	Endangered
Leadsman Coral Community	Well Protected	Well Protected	Least Concern
Namaqua Exposed Rocky Shore	Poorly Protected	Moderately Protected	Vulnerable
Namaqua Kelp Forest	No Protection	Moderately Protected	Vulnerable
Namaqua Mid Shelf Fossils	No Protection	Well Protected	Least Concern
Namaqua Mixed Shore	Poorly Protected	Moderately Protected	Vulnerable
Namaqua Muddy Mid Shelf Mosaic	No Protection	Poorly Protected	Least Concern
Namaqua Muddy Sands	No Protection	No Protection	Least Concern
Namaqua Sandy Inner Shelf	No Protection	Moderately Protected	Least Concern
Namaqua Sandy Mid Shelf	No Protection	Poorly Protected	Least Concern
Namaqua Sheltered Rocky Shore	No Protection	Poorly Protected	Vulnerable
Namaqua Very Exposed Rocky Shore	Poorly Protected	Moderately Protected	Vulnerable
Natal Boulder Shore	Well Protected	Well Protected	Vulnerable
Natal Deep Shelf Edge	Poorly Protected	Moderately Protected	Least Concern
Natal Delagoa Dissipative Intermediate Sandy Shore	Well Protected	Well Protected	Least Concern
Natal Delagoa Dissipative Sandy Shore	No Protection	No Protection	Near Threatened
Natal Delagoa Intermediate Sandy Shore	Well Protected	Well Protected	Near Threatened
Natal Delagoa Reflective Sandy Shore	Well Protected	Well Protected	Vulnerable
Natal Exposed Rocky Shore	Well Protected	Well Protected	Near Threatened
Natal Lower Canyon	Moderately Protected	Well Protected	Least Concern
Natal Mixed Shore	Well Protected	Well Protected	Vulnerable
Natal UPoorly Protecteder Canyon	Well Protected	Well Protected	Least Concern
Natal Very Exposed Rocky Shore	Well Protected	Well Protected	Near Threatened
Orange Cone Inner Shelf Mud Reef Mosaic	No Protection	No Protection	Endangered
Orange Cone Muddy Mid Shelf	No Protection	No Protection	Endangered
Port St Johns Inner Shelf Mosaic	Moderately Protected	Moderately Protected	Vulnerable
Port St Johns Muddy Mid Shelf	Moderately Protected	Moderately Protected	Vulnerable
Port St Johns Muddy Shelf Edge	Moderately Protected	Moderately Protected	Vulnerable
Protea Mid Shelf Reef CoModerately Protectedlex	No Protection	Moderately Protected	Endangered
Sodwana Coral Community	Well Protected	Well Protected	Least Concern
Southeast Atlantic Lower Slope	No Protection	No Protection	Least Concern
Southeast Atlantic Mid Slope	No Protection	Poorly Protected	Least Concern
Southeast Atlantic Seamount	No Protection	Well Protected	Least Concern
Southeast Atlantic Slope Seamount	No Protection	Well Protected	Least Concern
Southeast Atlantic UPoorly Protecteder Slope	No Protection	Poorly Protected	Least Concern
Southern Benguela Dissipative Intermediate Sandy Shore	Moderately Protected	Well Protected	Least Concern
Southern Benguela Dissipative Sandy Shore	Well Protected	Well Protected	Least Concern
Southern Benguela Intermediate Sandy Shore	Poorly Protected	Poorly Protected	Near Threatened
Southern Benguela Muddy Outer Shelf Mosaic	No Protection	No Protection	Least Concern
Southern Benguela Muddy Shelf Edge	No Protection	Moderately Protected	Endangered
Southern Benguela Outer Shelf Mosaic	No Protection	No Protection	Least Concern
Southern Benguela Reflective Sandy Shore	Poorly Protected	Moderately Protected	Endangered
Southern Benguela Rocky Shelf Edge	No Protection	Moderately Protected	Vulnerable
Southern Benguela Sandy Outer Shelf	No Protection	Poorly Protected	Least Concern
Southern Benguela Sandy Shelf Edge	No Protection	Poorly Protected	Vulnerable
Southern Benguela Shelf Edge Mosaic	No Protection	No Protection	Least Concern
Southern KZN Shelf Edge Mosaic	Well Protected	Well Protected	Near Threatened
Southern KZN Inner Shelf Mosaic	Moderately Protected	Moderately Protected	Endangered
Southern KZN Mid Shelf Mosaic	Poorly Protected	Moderately Protected	Endangered
Southwest Indian Lower Slope	No Protection	No Protection	Least Concern
Southwest Indian Mid Slope	No Protection	Poorly Protected	Least Concern
Southwest Indian Seamount	No Protection	Well Protected	Least Concern
Southwest Indian Slope Seamount	No Protection	No Protection	Least Concern
Southwest Indian UPoorly Protecteder Slope	No Protection	Well Protected	Least Concern
St Helena Bay	No Protection	No Protection	Vulnerable
St Lucia Mid Shelf Mosaic	Well Protected	Well Protected	Least Concern
St Lucia Sandy Inner Shelf	Well Protected	Well Protected	Least Concern

Ecosystem Type Name	PL2018	PL2019	Threat Status
St Lucia Sandy Mid Shelf	Moderately Protected	Moderately Protected	Vulnerable
Trafalgar Reef CoModerately Protectedlex	Moderately Protected	Moderately Protected	Endangered
Transkei Basin Abyss	No Protection	No Protection	Least Concern
uThukela Canyon	No Protection	No Protection	Near Threatened
uThukela Mid Shelf Mosaic	No Protection	Moderately Protected	Vulnerable
uThukela Mid Shelf Mud Coarse Sediment Mosaic	No Protection	Moderately Protected	Vulnerable
uThukela Outer Shelf Muddy Reef Mosaic	No Protection	Moderately Protected	Vulnerable
Western Agulhas Bay	Poorly Protected	Poorly Protected	Endangered
Western Agulhas Outer Shelf Mosaic	No Protection	No Protection	Vulnerable
Wild Coast Inner Shelf Mosaic	Moderately Protected	Moderately Protected	Vulnerable
Wild Coast Mid Shelf Mosaic	Well Protected	Well Protected	Least Concern
Wild Coast Shelf Edge Mosaic	Well Protected	Well Protected	Least Concern

2018 Ecosystem Protection Levels

- Only 30 (20%) marine ecosystem types were **Well Protected**, and all of these ecosystems were inshore. Most of the Well Protected ecosystem types occurred in the Delagoa ecoregion.

- A total of 33 (22%) of marine ecosystem types were **Moderately Protected**. These were concentrated in the inshore component of the Cape region in the Southern Benguela and in the Agulhas ecoregion. Many of these were downgraded from Well Protected to Moderately Protected as a result of fishing impacts in MPAs that compromised ecosystem condition.

- A total of 17 (11%) of marine ecosystems were **Poorly Protected**. Ten of these were in the inshore region and seven were in the offshore region.

- Almost half of South Africa's recognised marine ecosystem types (47%) were **Not Protected**. This meant that 70 ecosystem types were not represented in South Africa's Protected Area network. Eight of these were inshore and 62 were offshore types.

2019 Ecosystem Protection Levels

The following improvements in protection level were achieved with the declaration of 20 new MPAs.

- A total of 47 (31%) marine ecosystem types are **Well Protected**, an increase of 11%.

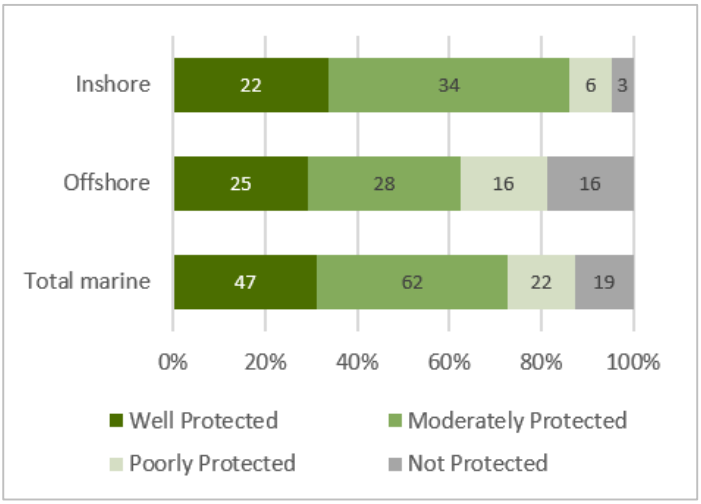
- A total of 62 (41%) marine ecosystem types are **Moderately Protected**. Most of these ecosystem types are inshore or on the shelf edge. Moderately Protected ecosystem types increased by 19%.

- A total of 22 (15%) marine ecosystem types are **Poorly Protected**. Sixteen (10.6%) ecosystem types improved from Not Protected to Poorly Protected. Most of the ecosystem types in this category are very large. For example, the Cape Basin Complex Abyss in the Southeast Atlantic is 73 071.65 km^2 and the Southwest Indian Mid Slope ecosystem is 78270.72 km^2. These areas are larger than provinces such as Mpumalanga, or countries such Lesotho and Swaziland.

- A total of 19 (13%) ecosystem types remain **Not Protected**. This is a significant decrease from the 47% of types that fell into this category in 2018. These ecosystems are largely offshore

and include some of the largest ecosystem types like Transkei Basin Abyss (210 710 km^2) and Southwest Indian Lower Slope (197 988 km^2).

Patterns in protection level



The declaration of the 20 new MPAs in May 2019 has had a major impact on the **protection status of offshore ecosystem types** in the South African marine environment. There are now more offshore ecosystem types than inshore ecosystem types in the Well Protected category (Figure 93) although proportionally, the percentage of types is slightly higher inshore (33% versus 30%). A greater proportion of inshore ecosystem types than offshore ecosystems are Moderately Protected.

Figure 93. A comparison in the extent of ecosystem protection level for the 150 ecosystems that make up the inshore zone (shore to fair weather wave base at -30 to -50 m) and the offshore zones in the South African marine environment.

However, an important finding is that 32 offshore ecosystem types are still under-protected (either Poorly Protected or Not Protected at all) compared with 9 inshore ecosystem types within these categories. The value of this indicator is that it provides a signal as to where future protection effort should be directed. It is also notable that only 31% of the total complement of ecosystem types is Well Protected. Effort should be directed at resolving the issues that prevent Moderately Protected ecosystems from becoming Well Protected. In this regard, there should be a focus on addressing the degradation factors that caused downgrading of 41 ecosystem types from Well Protected to Moderately Protected (see Section 8.6).

In terms of **patterns between ecoregions**, the Delagoa Shelf is the ecoregion with most Well Protected ecosystem types. The four Shelf ecoregions continue to have greater protection than Southeast Atlantic Deep Ocean and Southwest Indian Deep Ocean ecoregions. In the Deep Ocean, 6 of 22 (27%) ecosystem types remain Not Protected and a further 27% are Poorly Protected, whereas only 13 of 128 ecosystem types within the Shelf Provinces (10%) are Not Protected. Many ecosystem types of the Southern Benguela, Agulhas and Natal Shelf Provinces are Moderately Protected (47%). There is a clear requirement for further formal protection in bathyal and abyssal areas of the EEZ.

Downgraded ecosystem protection levels due to degradation in MPAs

It was noted above that ecosystem degradation (e.g. the occurrence of pressures such as fishing or the presence of pipelines, coastal development, reduction of freshwater flows or very high levels of poaching) was used to refine protection level categories to ensure that targets for ecosystem types reported as Well Protected are met in areas that are not moderately, severely or very severely degraded. If the biodiversity target is not met in areas that are in natural or near natural condition within Protected Areas, protection level of that ecosystem type was **downgraded to Moderately Protected**. A total of 41 ecosystem types (27% of the total number) were included in this category.

The ecosystems whose protection levels were downgraded as a result of degradation are listed in Table 33. Improving the condition of these 41 ecosystem types is a priority for improving the status of these marine ecosystems. **Reducing fishing impacts in MPAs** (including illegal fishing for abalone, west coast rock lobster and linefish) would improve the status of many of these ecosystem types particularly for rocky shore, kelp forest, bay and reef ecosystems. **Restoring freshwater flow** would improve condition and hence protection of muddy ecosystem types such as those from the KwaZulu-Natal Bight, muddy ecosystems off Port St Johns and the Kei River. **Improvements in water quality** and reduced fishing impacts would improve condition and protection of the Aliwal Shoal Reef Complex. Note that the assessment of ecosystem condition was determined in 2018 prior to the implementation of the new MPAs. Some of these MPAs include areas that are not currently in good ecosystem condition although the recent implementation of the new MPAs will improve condition of these areas if the MPAs are effectively managed and enforced (Table 32). Examples of ecosystem types anticipated to have improvements in their ecosystem condition as a result of increased protection (indicated with an asterix in Table 32) include the Agulhas Lower Canyon, Kei Reef Mosaic, Protea Mid Shelf Reef Complex, Durnford Mid Shelf Reef Complex and St Lucia Sandy Mid Shelf.

Table 33. The 41 ecosystem types that were downgraded from Well Protected to Moderately Protected due to insufficient good condition area in MPAs. Improvements in ecosystem condition due the recent proclamation of the new MPAs in 2019 are anticipated for those ecosystem types marked with an asterix although it is important that further freshwater flow reductions does not compromise expected improvements for flow dependent types.

Marine Ecosystem Types		
Agulhas Exposed Rocky Shore	Cape Mixed Shore	*Natal Deep Shelf Edge
Agulhas Intermediate Sandy Shore	Cape Rocky Inner Shelf	Port St Johns Inner Shelf Mosaic
Agulhas Kelp Forest	Cape Rocky Mid Shelf Mosaic	Port St Johns Muddy Mid Shelf
*Agulhas Lower Canyon	Durnford Inner Shelf Reef Complex	Port St Johns Muddy Shelf Edge
Agulhas Mid Shelf Mosaic	*Durnford Mid Shelf Reef Complex	*Protea Mid Shelf Reef Complex
Agulhas Mixed Shore	Eastern Agulhas Bay	*Southern KZN Inner Shelf Mosaic
Agulhas Sandy Inner Shelf	False and Walker Bay	*Southern KZN Mid Shelf Mosaic
Agulhas Sheltered Rocky Shore	Kei Fluvial Fan	*St Lucia Sandy Mid Shelf
Aliwal Shoal Reef Complex	*Kei Reef Mosaic	*Trafalgar Reef Complex
Cape Bay	*Kingklip Ridge	*uThukela Mid Shelf Mosaic
Cape Boulder Shore	*KZN Bight Muddy Shelf Edge	*uThukela Mid Shelf Mud Coarse Sediment Mosaic
Cape Exposed Rocky Shore	*KZN Bight Muddy Inner Shelf	*uThukela Outer Shelf Muddy Reef Mosaic
Cape Island	*KZN Bight Outer Shelf Mosaic	Wild Coast Inner Shelf Mosaic
Cape Kelp Forest	Namaqua Sandy Inner Shelf	

The remainder of the Moderately Protected ecosystem types require **additional extent** within protected areas to advance to Well Protected (Table 31). Examples of such ecosystem types include Namaqua Kelp Forest, Southern Benguela Muddy Shelf Edge and Browns Bank Rocky Shelf Edge.

Protection levels across Broad Ecosystem Groups

The 150 ecosystem types found in the South African marine environment are grouped into 15 broad, functionally similar ecosystem groups. **All 15 of the broad ecosystem groups receive some level of protection** since offshore MPAs have been included in the protected area estate in 2019 (Figure 94). However, the extent of protection varies greatly across the groups. Four of these ecosystem groups

received their first protection in 2019. These are Seamounts, Slope, Plateau and the Abyssal ecosystem groups.

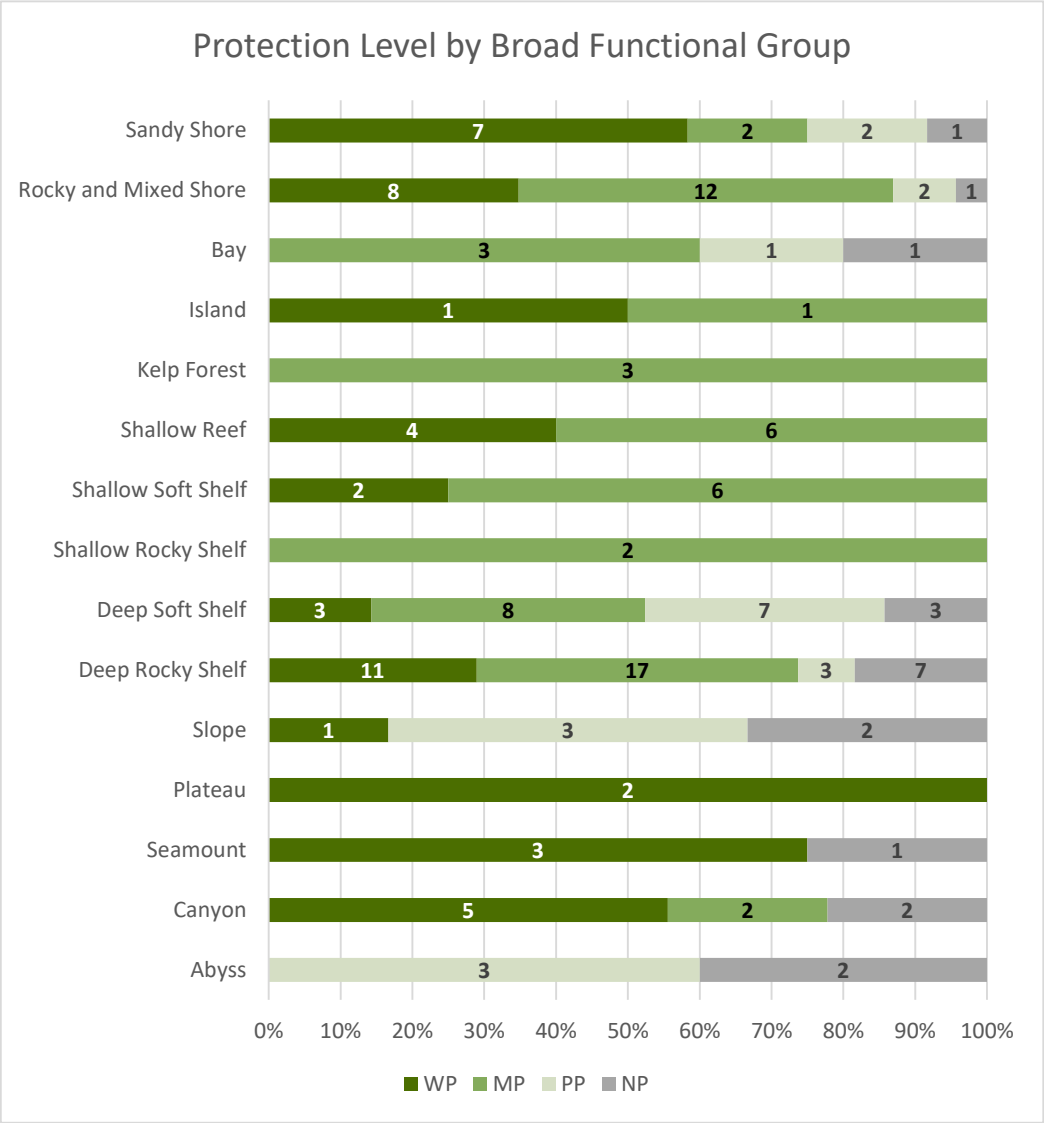


Figure 94. A graph illustrating the spread of 2019 Protection Level of ecosystem types by broad ecosystem group. The most Well Protected ecosystem groups include shores, islands, plateau and shallow ecosystem types on the shelf. Deeper abyssal, lower canyon and deep rocky shelf ecosystem types have lower protection levels.

Several ecosystem types in deep water environments remain without protection, including two abyssal, two canyon, one seamount, seven deep rocky shelf and three deep soft shelf ecosystems (Table 35). The fact that no Abyssal ecosystems are Well Protected or even Moderately Protected suggests that these ecosystem types will require further protection efforts in the future. Although the inclusion of protection for slope and very deep water environments was originally planned for during MPA planning for Operation Phakisa, some MPA boundaries were revised before final gazetting as a result of inputs from multiple stakeholders during the final consultation processes. This resulted in the exclusion of some deep water and shelf ecosystem types, and on the slope, protection is confined to the mid- and upper slope. The area that comprises the lower slope in both the Southwest Indian Ocean and Southeast Atlantic Ocean Provinces is without any protection. This means that **an entire depth zone (1800-3500 m) is without protection**. Future work could target industry negotiations that would

see the inclusion of ecosystem types in these areas into the protected area network – particularly as the allocation of petroleum leases is very dynamic.

Seamounts are a unique and highly productive feature of the open ocean environment. The protection level of Seamount ecosystems improved dramatically with the declaration of offshore MPAs and now three of four Seamount ecosystem types are Well Protected (Figure 94). Previously none were protected.

Canyons are also distinct, highly productive and sensitive ecosystems that stretch over several bathomes and were poorly represented in the 2018 MPA network. After declaration of the new MPAs in 2019, protection level of canyons has improved from two ecosystem types to seven of the nine canyon ecosystem types and more than half of the ecosystem types are Well Protected (Figure 94). Two canyon ecosystem types (Cape Lower Canyon and uThukela Canyon) remain without protection. The former is sensitive to impacts from demersal trawling and the latter was excluded from original plans for protection due to petroleum interests.

Other ecosystem groups that are cause for concern are **Bays, Kelp Forests and Shallow Rocky Shelfs**. Ecosystem types in all of these groups have some level of protection but none of the ecosystems are Well Protected (Figure 94). All of these ecosystem groups are particularly vulnerable to anthropogenic pressures and threats, and future planning should target the upgrading of protection levels in these areas.

Protection level and threat status of ecosystems

The ecosystem-specific protection levels, before (2018) and after the declaration of the new MPAs in 2019 is shown for each of the 150 ecosystem types in Table 32. The threat status of individual ecosystems is also reflected. It is useful to cross-tabulate the ecosystem threat status with the level of protection because this provides a valuable indication of where effort is needed in the further development of marine protected areas (Table 34). Of the 19 ecosystem types that are Not Protected, seven are Endangered or Vulnerable and require further protection

Table 34. Cross tabulation of marine ecosystem threat status versus 2019 protection levels

Threat Status	Not Protected	Poorly Protected	Moderately Protected	Well Protected
Critically Endangered	0	1	1	0
Endangered	3	3	16	0
Vulnerable	4	6	34	7
Near Threatened	3	2	5	7
Least Concern	9	10	6	33
Total	19	22	62	47

Protection is needed in the KwaZulu-Natal Bight and offshore of the Orange River to improve protection of the three **Endangered ecosystem types** (Table 35). These systems are impacted by fishing activities in KwaZulu-Natal and by fishing and mining activities in the Southern Benguela. Effort should be directed at reducing the impact these activities have on the environment and consulting with industry to negotiate further MPAs. The four Vulnerable and three Near Threatened ecosystem types that currently have no protection (Table 35) also warrant future efforts directed at the conservation of their biodiversity. The **Kingklip Koppies** and **Cape Lower Canyons** constitute VMEs which are sensitive to trawling impacts and these are priority ecosystem types for protection. Expansion of the Port Elizabeth Coral and Cape Canyon MPAs respectively could help protect these

ecosystem types. St Helena Bay is a unique ecosystem type threatened by high levels of cumulative pressure but protection efforts should focus on lest impacted good condition areas as informed by South Africa's new Coastal and Marine Critical Biodiversity Area (CBA) map (Harris and Sink 2019) See Chapter 11 for an explanation of CBA maps.

Neither of the two most threatened ecosystem types, Browns Bank Rocky Shelf Edge and Agulhas Muddy Mid Shelf, are Well Protected (Table 31) and further **effort is needed to improve protection of these Critically Endangered ecosystem types**. Improved protection levels might be addressed by zoning part of the Browns Bank Corals MPA as a restricted zone to further reduce fishing pressure and by increasing the extent of protection (currently 12% is protected). Improved mapping and further research to better understand the community composition, sensitivity and distribution of coral habitats is recommended in this ecosystem type. Expanding the size of the Agulhas Muds MPA to include more extent of the muddy ecosystem types could improve protection of threatened muddy ecosystem types. Although the Agulhas Muds is zoned as a Sanctuary its small size makes it vulnerable to edge effects from fishing. Ideally, all highly threatened (Critically Endangered and Endangered) ecosystem types should be Well Protected but this may be difficult to achieve.

Apart from the Critically Endangered Agulhas Muddy Mid Shelf there are another nine **Poorly Protected ecosystem types** located on the coast, inshore, and on the inner, mid and outer shelf, that are either Vulnerable or Endangered (Table 35). Clearly, future planning should direct attention at these ecosystems to increase their protection and reduce pressures that impact on these ecosystems. The Southern Benguela Muddy Shelf Edge is relatively heavily trawled and until the establishment of the new Benguela Muds MPA was trawled over its entire extent. Now 11% of this ecosystem type falls within a protected area and research should be conducted to assess potential recovery within this MPA. As indicated in Chapter 3, research to support an improved understanding of **muddy ecosystem types** is a high priority including their classification (and understanding whether authigenic muds support different assemblages to muds derived from fluvial input), species composition across depth strata and sensitivity to trawling. Baseline surveys in the Orange shelf Edge MPA are also recommended with better information needed to understand the extent of coral habitats and the sensitivity of the Southern Benguela Rocky Shelf Edge.

Some reef mosaic and deep coral habitats in the trawl grounds of the Agulhas ecoregion are Vulnerable and need increased protection (Table 35). These include In the Southern Benguela eco-region, St Helena Bay, which is a unique ecosystem type, and the slope component of the Cape canyons are also Vulnerable ecosystems that lack any representation in South Africa's Marine Protected Area Network.

Table 35. A list of Not Protected ecosystem types by threat status

Threat Status	Ecosystem Type
Endangered	KZN Bight Mid Shelf Reef Complex
	Orange Cone Inner Shelf Mud Reef Mosaic
	Orange Cone Muddy Mid Shelf
Vulnerable	Cape Lower Canyon
	Kingklip Koppies
	St Helena Bay
	Western Agulhas Outer Shelf Mosaic
Near Threatened	Agulhas Blues
	Natal Delagoa Dissipative Sandy Shore
	uThukela Canyon

Threat Status	Ecosystem Type
Least Concern	Agulhas Basin Complex Abyss
	Namaqua Muddy Sands
	Southeast Atlantic Lower Slope
	Southern Benguela Muddy Outer Shelf Mosaic
	Southern Benguela Outer Shelf Mosaic
	Southern Benguela Shelf Edge Mosaic
	Southwest Indian Lower Slope
	Southwest Indian Slope Seamount
	Transkei Basin Abyss

Protected Areas and EBSAs

In the marine realm, South Africa also has a network of Ecologically or Biologically Significant Marine Areas (EBSAs[6]), based on the original focus areas for offshore MPAs (Sink *et al.* 2011), which were adopted by the CBD in 2014 at the 12th Convention of Parties. EBSAs were initially conceptualised to be a tool by which MPAs could be identified and established in the high seas; however, their value within national jurisdiction, and for helping countries to achieve their Aichi targets, was soon apparent. Through a series of regional workshops, EBSAs were identified by evaluating sites against seven criteria, and delineated within country EEZs, in the high seas, and transboundary (country-country, or country–high seas). Currently, 279 sites have been identified, globally. The Benguela Current Commission (BCC) and its member states, in cooperation with GIZ on behalf of the German government, have been working on a regional Marine Spatial Management and Governance Programme (MARISMA; 2014-2020). The intent is to refine the boundaries of existing EBSAs and identify relevant new ones, assess their status and management requirements, and incorporate these into Marine Spatial Planning (MSP) processes in each country to achieve sustainable ocean use in the Benguela Current (Harris *et al.* 2019b). Through the MARISMA Project, South Africa has refined the boundaries of its EBSAs and identified new EBSAs (Figure 95). Note that only EBSAs that are entirely within South Africa's EEZ or are transboundary with other countries in the project (Namibia and Angola) were included; those EBSA that are transboundary with other countries (Mozambique, shown) or the high seas (not shown) remain unchanged. South Africa has 18 recognised EBSAs excluding those that extend into the high seas area and some protection in 16 of these 18 areas. The Orange Cone and Mallory Trough are the only two EBSAs entirely within national jurisdiction that currently lack any form of protection.

The Seven EBSA Criteria

1. Uniqueness or rarity
2. Special importance for life history stages of species
3. Importance for threatened, endangered or declining species and/or habitats
4. Vulnerability, fragility, sensitivity, or slow recovery
5. Biological productivity
6. Biological diversity
7. Naturalness

See the MARISMA EBSA Portal for more details on the criteria.

[6] https://www.cbd.int/ebsa; see also the MARISMA EBSA Portal

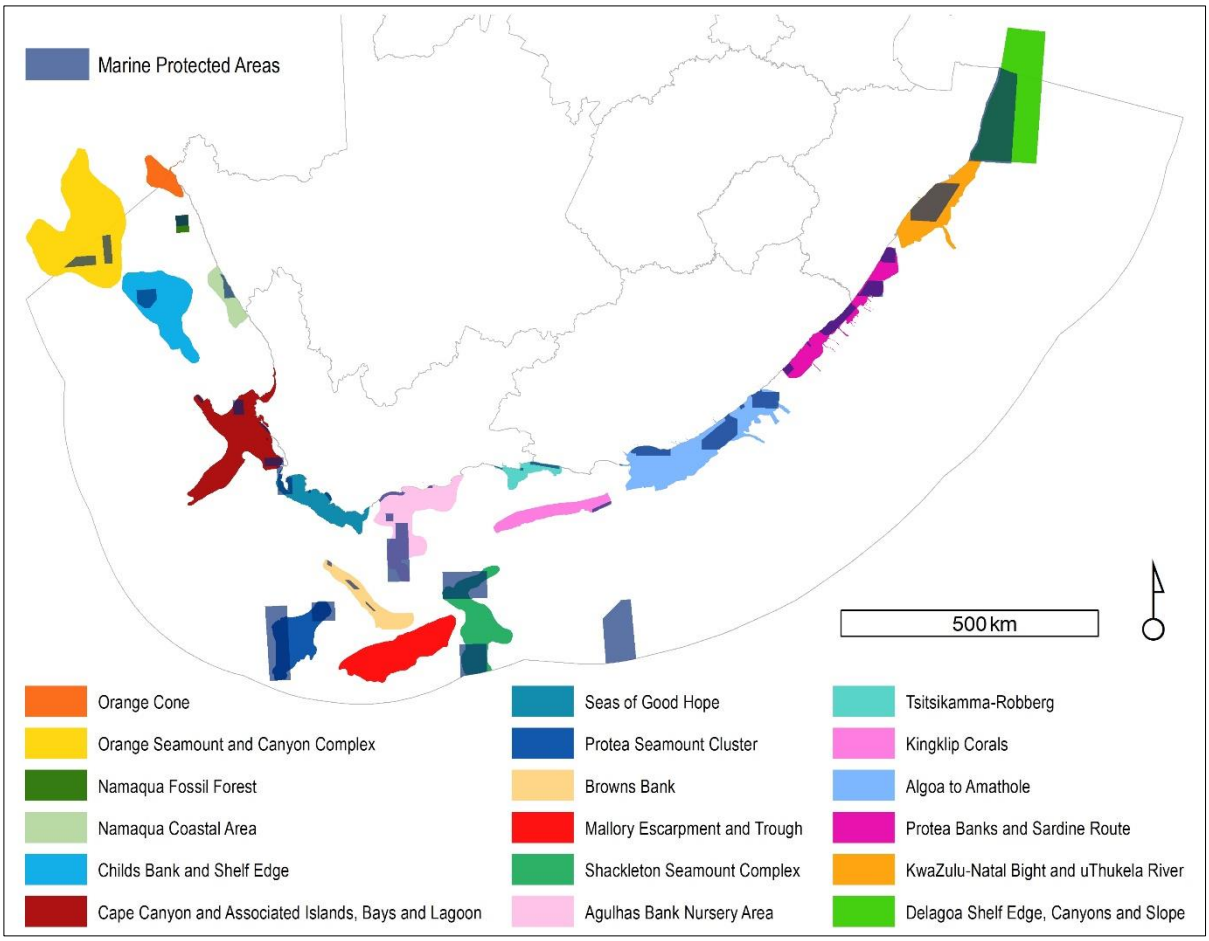


Figure 95. MPAs within South Africa's Ecologically and Biologically Significant Marine Areas (EBSAs) showing that 16 of these 18 EBSAs receive some protection. The Orange Cone and Mallory Trough are the only two EBSAs entirely within national jurisdiction that currently lack any form of protection. The Agulhas Front MPA is also within an EBSA that extends into the high seas.

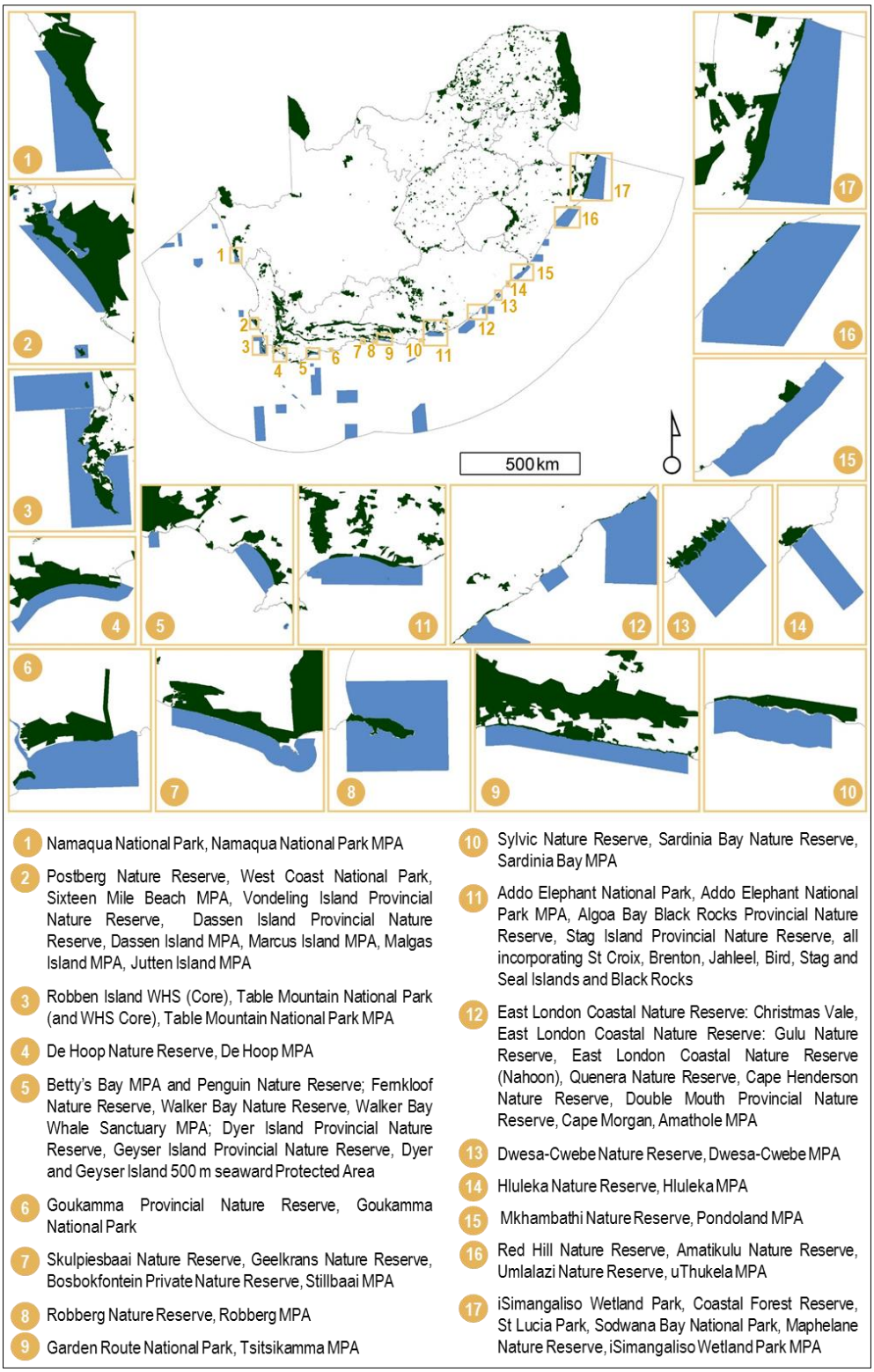


Figure 96. Effective coastal protection relies on protection of the interconnected ecosystems at the land-sea interface. These MPAs areas are providing better protection of coastal ecosystem types which require effective protection of the land sea interface. See NBA Coast Report for details. Using the high water mark as an MPA boundary not only fails to protect shores but it also a challenge in terms of boundary demarcation and law enforcement. Figure from NBA Coast report – see Harris et al 2019 for more information.

Protection of coastal ecosystems

The Phakisa MPA network made significant progress in protection of marine ecosystems but improving the protection of coastal ecosystems remains a high priority. The increasing pressure for access to coastal resources has been previously discussed (see Attwood *et al.* 1997b) and was the greatest concern raised by scientists and managers attending the marine inception workshop of the NBA marine component held in 2015. Reducing pressures on coastal ecosystems including estuaries is a key response to both. A further impediment to effective **coastal protection** has been the practice of declaring protected areas with the high water mark as a boundary. The coastal report of the NBA 2018 addresses this challenge in greater detail but in summary, this practice fails to effectively protect the inter-connected shore and surf zone ecosystems. Figure 95 shows the distribution of protected areas that provide protection to coastal ecosystem types by contributing to both terrestrial and marine components. The need for increased shore and coastal ecosystem protection is particularly evident on the west coast (Figure 96). See the NBA Coast report for better information.

8.4 Trends in Protection Level

Protection level analysis in the NBA 2018 is **not strictly comparable** to the analysis of the NBA 2011 or that of 2004 (Driver *et al.* 2005a), because ecosystem delineation has been steadily refined over the years between 2011 and 2018. As more and better data have become available, the principal drivers of marine biodiversity pattern have been revised, bio-regions, ecoregions and bio-zones have been re-configured and re-defined, some ecosystems types have changed, new ecosystem types have been identified and minor changes in broad ecosystem groups have been implemented. The assessment of ecosystem threat status has also been refined to align with the IUCN Red List of Ecosystem approach (Bland *et al.* 2017a). Details are explained in Chapter 7. Furthermore, in the NBA 2011, two ecosystem maps were created to represent the pelagic and benthic marine environment. In this NBA the protection analyses are applied on a single map that integrates both benthic and pelagic ecosystem components. This decision was based on management requests but is also a requirement for ecosystem accounting which requires only a single ecosystem type in anyone planning and assessment unit. Chapter 3 provides detail on changes to the ecosystem delineation between assessments.

Until quite recently biodiversity conservation was focused on the protection of biodiversity at species level. Although the IUCN Red List of Threatened Species has been a feature of conservation planning for decades, the process to develop Red List criteria for ecosystems was launched at the Fourth IUCN World Conservation Congress in 2008 and consolidated and adopted by the Fifth World Conservation Congress in 2012. This culminated in the adoption of the **IUCN Red List of Ecosystems Categories and Criteria** by the IUCN Council in May 2014 providing a new global framework for monitoring the status of ecosystems. The conceptual thinking underlying the ecosystem protection level assessment that forms the basis of this report is aligned with the IUCN approach of providing a consistent method for assessing ecosystems that allows global comparisons of the extent and effectiveness of biodiversity conservation on both temporal and spatial scales. There is currently no global equivalent method of assessing ecosystem protection levels. The **protection level indicator** developed by SANBI, like the IUCN Red List of Ecosystems (REL) assessment framework, depends on a description and map of ecosystem types.

The 2018 and 2019 protection level results are comparable as they are based on the same ecosystem types. These results show that there has been **significant improvement in the protection of 66 (44%)**

of South Africa's 150 marine ecosystem types. The trends in protection levels are summarised in Table 36 and below:

- 13 ecosystem types advanced from Not Protected to Well Protected
- 22 ecosystem types advanced from Not Protected to Moderately Protected
- 16 ecosystem types advanced from Not Protected to Poorly Protected
- 0 ecosystem types advanced from Poorly Protected to Well Protected
- 11 ecosystem types advanced from Poorly Protected to Moderately Protected
- 4 ecosystem types advanced from Moderately Protected to Well Protected
- 19 ecosystem types remained Not Protected
- None declined in protection status

Table 36. Comparative status of protection for 150 ecosystem types - 2018 versus 2019 (underlined). Blue numerals signify numbers of ecosystems which changed status (from – to), red signifies numbers of ecosystems which did not change status.

		2019 Protection Status			
		Not Protected	Poorly Protected	Moderately Protected	Well Protected
2018 Protection Status	Not Protected	19	16	22	13
	Poorly Protected		6	11	0
	Moderately Protected			29	4
	Well Protected				30

The most **positive trend** is in the number of previously unprotected ecosystem types that obtained at least some degree of protection with the implementation of the expanded MPA network in 2019. Of the 70 ecosystem types that were previously unprotected, 51 advanced to a point where they now have at least some degree of protection and 35 of these are now either Well Protected or Moderately Protected. Thirteen types advanced from Not Protected to Well Protected. There was limited progress in improving protection of Poorly or Moderately Protected ecosystem types. No ecosystem types advanced from Poorly Protected to a Well Protected status. This is because much of the newly protected environment is in the offshore region where there was historically very limited protection whereas in the coastal region there were already MPAs that provided varying degrees of protection to coastal ecosystems. These coastal ecosystems were not the major focus of the expanded MPA network. In addition, the exclusion of several pressures from the expanded network and effectively managing and enforcing these new MPAs should improve ecosystem condition with some ecosystem types to Well Protected in the long term.

The purpose of the marine component of the NBA 2018 report is to evaluate the status of the marine biodiversity in South Africa's marine environment. The level of protection afforded to the marine realm in terms of both the area of the EEZ protected (5.4%), and at the level of the various ecosystem types (31% Well Protected; 41% Moderately Protected; 15% Poorly Protected and 13% Not Protected) has been outlined above. The increased protected area estate has played a very significant role in helping South Africa move towards the United Nations Sustainable Development Goals (SDG) relating the marine environment. **SDG 14** states that countries should aim to conserve at least **10%** of their

marine estate in effectively managed protected areas. If the disputed French territories are disregarded, in the Western Indian Ocean, only the Seychelles has a greater protected area estate (26%) than South Africa. All the other countries of the Western Indian Ocean currently have <2% of their marine territory protected. Clearly South Africa is in the forefront of marine biodiversity conservation on the African continent. However, despite these impressive figures, it is also important to assess how well the country meets the IUCN's Global Standards for MPAs in order to secure ocean health and sustainable development (IUCN-WCPA 2018). See Section 8.6 below for this insight.

8.5 Future MPA expansion priorities

There are seven **priority marine ecosystem types** that are both threatened and Not Protected. The highest priority are the Endangered ecosystems; two muddy ecosystem types on the shelf off the Orange River and a reef complex in the mid shelf of the KwaZulu-Natal Bight. Reef mosaic and deep coral habitats in the trawl grounds of the Agulhas ecoregion are vulnerable and need protection. In the Southern Benguela, St Helena Bay is a unique ecosystem type, and the slope component of the Cape canyons still needs to be represented in South Africa's Marine Protected Area Network.

Future work should also focus on obtaining protection for the Southwest Indian Ocean Slope Seamount ecosystem type. This is challenging because of petroleum interests in this area which is part of the Agulhas Falklands Fracture Zone. Originally, was proposed for inclusion in the initial design of the Southwest Indian Seamount (SWIS) MPA which was a single smaller area **Mallory Seamount** ranging from the shelf edge to the abyssal ecosystems on the EEZ boundary. To improve agreement of proposed MPA boundaries, Davies Seamount was then proposed as an alternative within the SWIS MPA being gazetted for comment in 3 parts in 2016. The SWIS 2 area which included Davies Seamount was omitted as a further compromise. The recent Brulpadda petroleum discovery (Bond 2019) close to Davie Seamount further complicated the protection of lower slope seamount ecosystem types. It is clear that better information on petroleum resource potential is needed to support seamount and lower slope protection in the future. From a biodiversity perspective Mallory Seamount is the preferred seamount as available information suggests it has the broadest depth range, greater pelagic habitat diversity (Roberson *et al.* 2017) and less fishing effort.

Other deepsea ecosystem types that require protection include two abyssal types (in the Agulhas Basin and Natal Valley), two canyon (Cape Lower Canyon and uThukela Canyon), seven deep rocky shelf and three deep soft shelf ecosystem types (Figure 97).

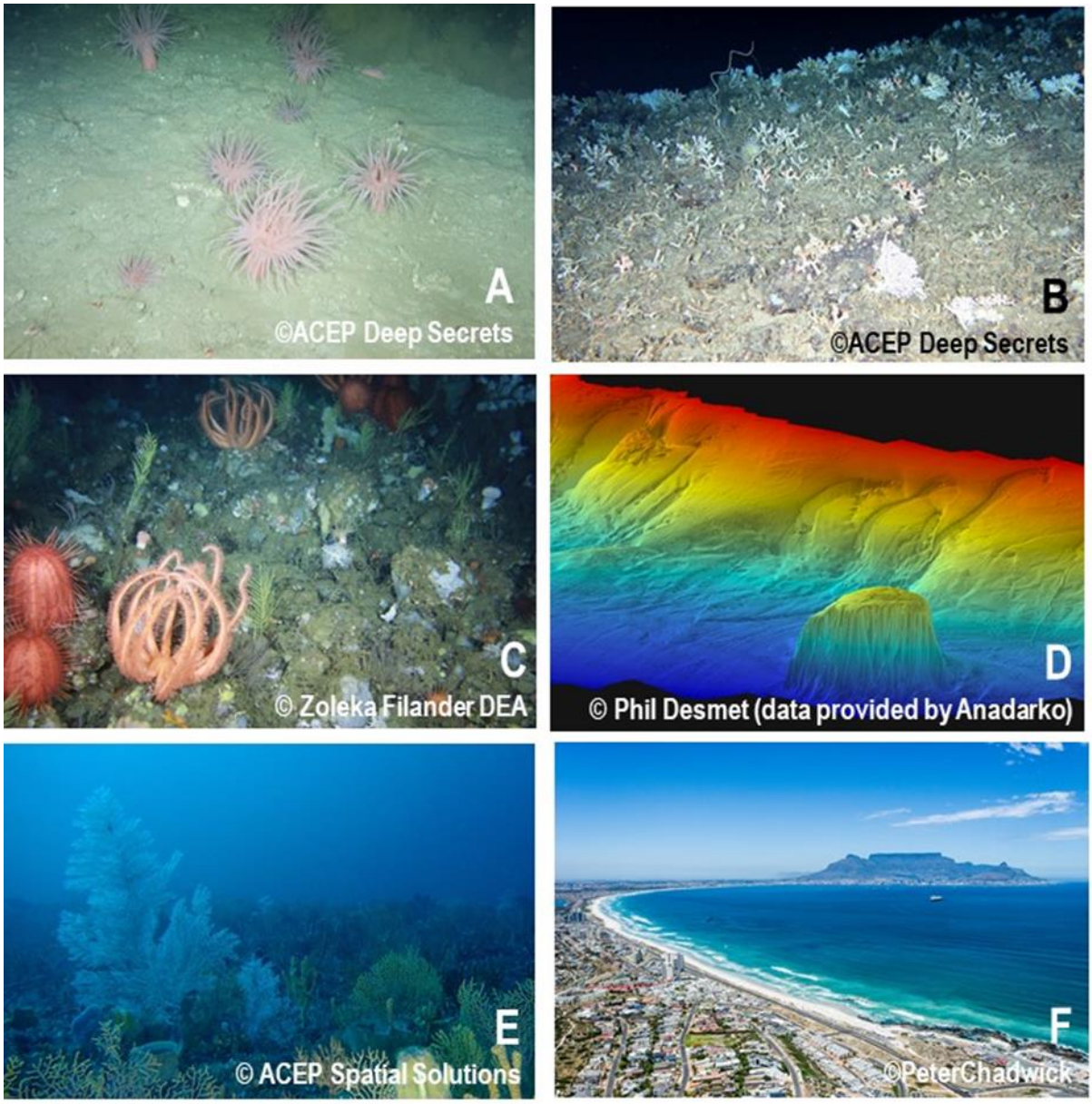


Figure 97. Ecosystem protection level result highlights. A) The Agulhas Outer Shelf advanced from Not Protected to Partially Protected; B) The King Klip Koppies is Vulnerable but Not Protected; C) The Cape Lower Canyon remained Not Protected; D) The Southeast Atlantic Slope Seamount advanced from Not Protected to Well Protected.; E) The Durnford Mid Shelf Reef Complex advanced from Not Protected to Moderately Protected; F) Some ecosystem types did not improve in terms of protection levels. Although False and Walker Bay are threatened ecosystem types they remain Moderately Protected and poaching needs to be reduced and protection increased in order to improve the status.

A revised **process** is needed to support further **MPA expansion** and this will require close co-operation with communities, fisheries sectors and the petroleum and mining sectors. See Chapter 11 for further priority actions related to MPAs.

The **limitations** of existing efforts in the design and implementation of MPAs in South Africa warrants discussion and further research attention. Shortfalls in historical efforts to establish MPAs have been discussed and South Africa should endeavour to redress and avoid past mistakes (Hockey and Buxton 1989, Attwood *et al.* 1997b, von der Heyden 2009, Sowman and Sunde 2018). Future efforts should strive to improve the connectivity and climate resilience of MPAs. Improving the connectivity of MPAs

relies on genetic research (Pujolar *et al.* 2013, Jenkins and Stevens 2018), knowledge of patterns in larval dispersal (Pujolar *et al.* 2013, Magris *et al.* 2018) and movement research (see Chapter 11 and Harris and Sink 2019). The integration of movement and connectivity data across different life history stages is advocated to design more ecologically connected MPAs (D'Aloia *et al.* 2017, Smith and Metaxas 2018). Well managed MPAs can help people and marine ecosystems adapt to climate change impacts (Roberson *et al.* 2017), but there are also opportunities to better include climate data in biodiversity planning. To improve climate resilience, recommended approaches include the protection of stable areas and refugia (Ban *et al.* 2011, Rilov *et al.* 2019) and increasing protection of ecosystems that sequester and store carbon (Roberts *et al.* 2017). Increasing integration of physiology, ecology and evolution in biodiversity planning is recommended in helping design for increased resilience (Rilov *et al.* 2019). The integration of climate velocity data is also recommended in predicting climate sensitive areas and refugia and pro-active large scale regional planning efforts will be needed to facilitate cross-country cooperation at the appropriate scale to mitigate climate impacts which transcend jurisdictional boundaries (Molinos *et al.* 2016). South Africa needs to conduct more research to support such improved design and can draw from international experience and collaboration in this regard.

Drawing from work to improve the understanding of the current and future benefits of MPAs (see Annexure 4), new approaches in **designing MPAs to increase benefits to people** should be also explored. Initial work suggests that inclusion of additional tourism assets (such as lighthouses, hiking trails and charismatic species for ecotourism), key ecological infrastructure (see Chapter 2), long term monitoring sites and educational facilities offer opportunities to diversify the benefits of new MPAs. In addition, work to examine the benefits of trawl closures, rock lobster and abalone reserves, military areas and other potential sites that could help identify potential Other Effective Area based Measures (OECMs) is recommended.

8.6 Improving MPAs and Protection Level Assessment in South Africa

Limitations of this assessment

The most significant limitations of assessing ecosystem protection level is challenges in assessing effectiveness of protection and the lack of alignment particularly for seashore ecosystem types. In terms of **effectiveness**, a simple filter was applied to ensure that targets for well protected ecosystem types are met only in good condition area. Further effort is needed to better incorporate protection level taking into account different types of MPA zonation and management effectiveness of individual protected areas. In terms of **misalignment in the coastal zone**, the seaward boundary of terrestrial protected areas and the landward boundary of marine protected areas are not mapped to the same line, despite them both supposedly extending to the same "high-water mark". This is more than just a negligible, technical issue: the misalignment fundamentally precludes accurate assessment of the protection level of seashore ecosystem types (see also Harris *et al.* (2019a) for details). It is recommended that the dune base line (equivalent to a decadal-scale high-water mark) that is used to separate the shore and backshore zones in the ecosystem type map, thus marking the ecosystem-type and realm boundary between the terrestrial and marine realms, is used as the baseline to which these high-water-mark-bounded protected areas extend.

Global MPA Standards

The IUCN's Global Standards for MPAs specify that for an area to qualify and be recognised as an MPA in terms of the IUCN it needs to have certain essential characteristics which include:

- **Conservation focused** with nature as the priority
- Defined **goals and objectives** which reflect these conservation values
- Suitable **size, location, and design** that deliver the conservation values
- Defined and fairly agreed **boundary**
- **Management plan** or equivalent, which addresses the needs for conservation of the MPA's major values, and achievement of its social and economic goals and objectives
- **Resources and capacity** to effectively implement (IUCN-WCPA 2018).

Several of these requirements are fulfilled by South Africa's MPA network but in the interests of future planning it is worth examining the IUCN stipulations in detail. An understanding of the elements and criteria outlined below can be used to evaluate and improve the performance of MPAs.

The key difference between MPAs and other area-based measures is that, whatever form the MPAs take, the **primary focus** must be **conservation of biodiversity**. Fishing and other resource use activities are not necessarily incompatible with the concept of an MPA provided the scale and extent are aligned with the MPA objectives. However, they must have a low ecological impact, must be sustainable and well managed to fit within the IUCN definition of a protected area. The IUCN notes that any industrial activities such as **industrial fishing** are not compatible with MPAs (IUCN-WCPA 2018) even if the main goal is seabed protection and the industrial fishing targets pelagic fish. There are fishing methods that have been accommodated in the Controlled zones of both coastal and offshore MPAs in the South African marine environment. These include some that are industrial (pelagic longline, purse seine), or semi-industrial (trap) in their operations, and may not qualify as low ecological impact fisheries (such as pelagic fishing). There is also inclusion of some coastal fisheries that have serious management challenges such as Abalone and West Coast Rock Lobster, both of which have high levels of poaching that may compromise sustainability.

As indicated above, the **objectives** of South Africa's older MPAs are being re-examined as the need to provide more specific detailed objectives has long been recognised (Attwood *et al.* 1997b). The MPAs declared in 2019 addressed these shortfalls and detail the protection of specific ecosystem types, species, maintenance of key ecological processes and ecosystem services including cultural, educational and spiritual benefits where relevant.

In terms of good practice in MPA design, South Africa has improved in terms of systematic **design** approaches and in stakeholder consultation. The IUCN guidelines do not recommend a specific **size** although other researchers note that large MPAs (100 km^2 or more) have greater conservation outcomes (Edgar *et al.* 2014). Of the new MPAs, all but one exceed 100 km^2 whereas 11 of 25 MPAs declared prior to 2019 meet this size recommendation. Note that these sizes do not consider zonation. The IUCN specifically recommends that MPAs are not vertically zoned but 5 of the new MPAs are **vertically zoned** and some well-established MPAs have zones that allow pelagic fishing in areas where bottom fishing is prohibited.

MPAs should demonstrate sound planning and design. Although the **boundaries** of South African MPAs are generally well defined, the siting of MPAs is the outcome of multiple negotiations and a

series of compromises. Economic and industrial considerations, particularly with regard to fishing, mining and oil and gas interests were a key element in the work to design offshore MPAs in South Africa (Sink 2016). The lengthy negotiations required for the proclamation of the expanded MPA estate of 2019 required some compromise of ecologically important areas to reach approval for final proclamations. In addition, although the offshore MPAs proclaimed in 2019 cannot be expected to have **management plans** within a month of taking effect, there are also some established coastal MPAs that have no management plans. The Amathole and Rocher Pan MPAs require MPA management plans and management plans for the new MPAs are anticipated within a year of proclamation.

A further IUCN requirement for MPAs is that they demonstrate good **governance**. Although the rights of indigenous people and local communities are enshrined in national protected area legislation and there is a commitment to include the interests of civil society and stakeholders in MPA management process, there are a number of unresolved issues in the governance of South African MPAs (Sowman and Sunde 2018). The governance arrangements and the decision making processes would benefit from improved transparency, better communication and improvements in stakeholder liaison.

MPAs should have **adequate resourcing and staff capacity for effective management** as this is a key determinant for management effectiveness and success (IUCN-WCPA 2018). The coastal MPAs in South Africa are managed by national or provincial conservation agencies or municipalities (City of Cape Town and Nelson Mandela Metropolitan) contracted by DEFF to undertake management planning and implementation. Most of these agencies are poorly resourced and under-staffed and thus have very limited compliance and monitoring capacity. This is particularly true for provincial agencies and metros. A lack of staff also limits the ability of agencies to undertake the arrangements required to ensure legitimate stakeholder participation in planning and other management activities.

South African conservation agencies need to build on recent efforts to capacitate MPA staff and ensure that MPA skills are incorporated into the skills planning, development and evaluation responsibilities of the environment and fisheries sectors. The **Mangament Effectivess Tracking Tool** (METT) has assisted managers in improving MPA management effectiveness but needs to be broadened to assess overall MPA effectivess. More consideration should be given to governance, socio-economic and ecological effectiveness of MPAs. A skills audit would be a valuable addition to existing processes that contribute to the assessment of management capacity and effectiveness. Key competencies that MPA staff need include basic water skills and more specialised training for management in the marine environment including the care and maintance of marine equipment. In several cases, more than half of the MPA staff cannot swim. Skippers at several MPAs do not have a restricted marine radio license, a legal requirement for working at sea. Long term job security is needed to support retention of scarce and specialised MPA management skills. Short term budget arrangements pose a risk in this regard and MPA professionals should be permanent staff.

Poor **compliance and enforcement** is an ongoing challenge with some key actions recommended to improve this situation. Firstly, more effort is needed to address challenges identified in terms of the human dimensions of South Africa's MPA network. Recommendations have been made as to steps to address these issues but in a compliance context it is critical to improve community involvement in MPA governance. There is a need to increase an understanding of the realities of resource abundance, the value of highly protected areas in sustaining resources and to build relationships to involve communities in decisions. Improved stakeholder relations are an essential element in improving

compliance and helping South Africa's MPAs deliver more benefits to coastal communities. The NBA 2011 priority actions to increase the delivery of MPA benefits, including the need for diversified non-consumptive tourism, are still very relevant. The diversification and sustainable expansion of **non-consumptive activities** with Marine Protected Areas through small enterprise development in local communities will increase employment opportunities and community beneficiation. It is critical that such initiatives meaningful involve communities adjacent to MPAs rather than the usual approach which frequently provides more benefits for people outside of the communities most affected by MPAs.

Even when stakeholder relationships are good and communities are aware of the realities of resource status and the benefits of protection, evidence suggests that there is still a need for the presence of **trained marine protected area professionals** (Causey 1995). Better collaboration between provincial and municipal management agencies is needed to improve compliance. MPA managers report that in many cases there are too few Fishery Control Officers (FCO) in MPAs (in some cases none) and there are challenges in the aministration processes to renew expired FCO appointment cards. Finally, MPA staff report the need for better co-operation, sharing of training opportunities and further scope to share lessons and experience in the key elements of enforcement success. It is critical to strengthen collaborative efforts and financing to ensure that managmeent authorities are better capacitated and resourced to monitor and enforce MPA management regulations. With regard to enforcement of the regulations pertaining to MPAs in the offshore environment, South Africa needs increased co-operative enforcement arrangements with other institutions and other countries to improve the performance and reliability of systems that can accurately track and identify vessels.

Finally, a **lack of monitoring capacity** is of particular concern for South Africa's MPAs. Without monitoring, it is not possible to track performance, inform adaptive management, document and demonstrate management effectiveness and report that conservation goals, objectives, and defined biodiversity conservation targets are being achieved.

The description of potential shortcomings in the management of South Africa's MPAs should not detract from the impressive advances the country has made in the conservation of its marine biodiversity. The expanded MPA estate has resulted in a network of MPAs that extends both laterally along the coast of South Africa and outwards to the limits of national marine jurisdiction, protecting more than 5% of South Africa's mainland ocean area. Perhaps more importantly, the location of MPAs has been informed by the biodiversity priorities developed through co-ordinated systematic biodiversity planning that optimised design and was implemented within an initiative that sought to sustainably develop South Africa's ocean economy.

9. THE STATE OF INDIGENOUS SPECIES

Chapter Citation: van der Bank MG, Adams R, Raimondo DC, Sink KJ, van der Colff D, Makhado A, Kock A, Porter S, Seakamela SM, Louw S, Mann BQ, Bürgener M. 2019. Chapter 9: The State of Indigenous Species. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



Well- managed species assemblages are essential to secure long-term ecological and socio-economic benefits
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Chapter summary

This chapter provides a summary of the state of knowledge of indigenous marine species by reporting on the pressures on marine species, stock status and IUCN threat status. More than 770 marine species are harvested in South Africa, yet updated stock assessments are only available for 54 stocks (equating to at least 42 species). Of the 54 stocks assessed, 39% are considered Overexploited or Collapsed. Effective science-based management has supported recovery of Deep-water Hake (*Merluccius paradoxus*) and some linefish species such as Carpenter (*Argyrozona argyrozona*), demonstrating that marine fish species can recover if managed effectively. Several of South Africa's iconic seabreams and/or linefish species such as Red Steenbras (*Petrus rupestris*) and Dageraad (*Chrysoblephus cristiceps*) have not yet shown recovery since the linefish "State of Emergency" declared in 2000. Inshore resources such as Abalone (*Haliotus midae*) and West Coast Rock Lobster (*Jasus lalandii*) are in crisis owing to their highly Overexploited stock status and escalating levels of poaching. A total of 376 South African marine species have been assessed to date using either national, regional or global IUCN Red List assessments. Of these, approximately 18.6% (70) are threatened, representing a relatively high threat status. Seabirds, endemic seabreams and marine reptiles are particularly threatened with more than a third (37%) of South Africa's seabirds threatened. A meta-analysis of the key pressures impacting on taxa of conservation concern revealed that fishing remains the greatest pressure on marine species. Key additional pressures include pollution (plastics, underwater noise, waste water and effluent) and freshwater flow reduction, while key threats include climate change and marine alien and invasive species. More than 30% of endemic seabream species are threatened with a further 27% assessed as Near Threatened and four of five turtle taxa are threatened. Of the 56 marine mammal species assessed, 16% are threatened. Almost 20% of 121 commercially important bony fishes are threatened while 34% are Data Deficient. Approximately 7% of the 26 cartilaginous fishes (sharks, skates and rays) are threatened while 50% are Data Deficient. To date, very few national IUCN Red List assessments have been conducted for marine invertebrate species owing to inadequate taxonomic knowledge, limited distribution data, a lack of systematic surveys and limited capacity to advance species red listing for these groups. Marine species have the highest levels of data deficiency across all realms signalling the need to address knowledge gaps and increase capacity for marine species red listing. Given the importance of marine species for food and job security in South Africa, and the importance of apex predators such as marine mammals, birds and sharks for tourism in the growing ocean economy, well- managed species assemblages informed by science-based decision making is essential to secure long-term ecological and socio-economic benefits. The development and implementation of effective fisheries management plans coupled with the modernisation, coordination and integration of data collection, storage and access with state of the art technology are key priority actions for improving species assessment, monitoring and compliance.

9.1 Introduction

South Africa's **exceptional marine biodiversity** provides a wide range of benefits to the economy, society and human wellbeing through the provision of food, coastal livelihoods, rural development and employment opportunities (Sowman *et al.* 2013, 2014). Globally, South Africa is reported to have the third highest marine endemism (Costello *et al.* 2010a). It is estimated that between 26% and 33% of the 12 914 marine species reported for South Africa's mainland territory, are endemic to South Africa (Gibbons 1999, Awad *et al.* 2002, Costello *et al.* 2010b, Griffiths *et al.* 2010, Griffiths and Robinson 2016). South Africa holds 10% of the world's marine fish species (of which approximately 13% are endemic) (Smith and Heemstra 1986). South Africa also has one of the world's most diverse cartilaginous fish (chondrichthyans) assemblages (sharks, skates, rays, and chimeras), representing 15% of known species (Compagno 1999, Ebert and van Hees 2015). Of the 185 cartilaginous fish species (109 sharks, 68 skates and rays and 8 chimaeras) occurring in South Africa, 15 (8%) are endemic (Compagno 2002a, 2002b). With such high levels of endemism and South Africa holding high proportions of certain species groups, it is crucial that the status of these taxa be assessed.

The harvesting of marine resources forms part of South Africa's rich heritage and the diversity of resources harvested is also mirrored in the patterns of human use (see Chapter 2). South Africa has a long history of **fisheries management** grounded in science, focused mainly on managing total catch and fishing effort for individual species informed by rigorous stock assessments. The state of fishery stocks across South Africa's 22 commercial fisheries can be assessed using different stock assessment models depending on the data available. Species are classified as being either Uncertain in cases where stock assessment model assumptions cannot be met or there is ambiguity in model results; alternatively species are classified as either Underexploited, Optimally Exploited, Overexploited or Collapsed informed by threshold reference points aimed at measuring the risk of stock collapse (Griffiths *et al.* 1999). While stock assessments estimate a species status to inform fisheries management in terms of optimal use, the International Union for Conservation of Nature (IUCN) Red List Categories and Criteria, assess extinction risk and can be used by policy makers to guide and inform the development of protected species lists and other laws and policies aimed at conserving threatened species and help identify priority taxa and areas for biodiversity management (Vié *et al.* 2008).

The **IUCN Red List** classifies species as either Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered or Critically Endangered (IUCN 2012b). The trend in the status of species reflected on the IUCN Red List is regarded as an important international indicator of the state of biodiversity (Vié *et al.* 2008). Nationally, the Department of Environment, Forestry and Fisheries (DEFF) publishes protected species lists as part of its **Threatened and Protected Species (TOPS)** List under the National Environmental Management: Biodiversity Act (NEMBA, Act 10 of 2004). The purpose of the TOPS regulations is to control restricted activities defined by NEMBA and therefore support permitting rather than to reflect on species actual conservation status. TOPS lists species as Critically Endangered, Endangered, Vulnerable, or Protected however there is currently misalignment for some Marine TOPS listings compared with global or national IUCN Red List. As many as 258 South African marine species are currently listed under The **Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)** (checklist.cites.org) reflecting that these taxa are still impacted by international trade. CITES is an agreement between 183 Parties to which South Africa is a signatory (Box 30) CITES aims to regulate international wildlife trade and seeks to ensure that trade does not threaten the survival of species in the wild (Abensperg-Traun 2009). Species that are

vulnerable to trade have varying degrees of protection under the CITES Appendices. The main appendices that control the international trade of wildlife are Appendix I and II (Box 30). Appendix I lists species that are threatened (high risk of extinction) and aims to restrict international commercial trade of such species. Appendix II lists species that are not necessarily threatened with extinction but aims to regulate international trade through CITES trade permits in order to avoid activities that may undermine the survival of listed species (cites.org). In addition to the aforementioned Appendices, CITES also includes Appendix III which contains species listed by at least one country in the native range of the species, and requires assistance from CITES parties in controlling or monitoring the trade (Burns 1990).

Box 30. Overview of CITES

The 183 Parties to the CITES Convention are called the Conference of the Parties (CoP), who meet every three years, to review the implementation of the Convention. The meeting of CoP is attended by the delegates representing each CITES Party, United Nations agencies, and many NGOs involved in conservation and trade related work (cites.org). There are currently 258 South African marine species listed on CITES, of which 19 are listed under Appendix I and 239 are listed under Appendix II. There are currently no marine species listed under Appendix III for South Africa. The Management Authority and Enforcement Focal Point for South Africa is the Department of Environment, Forestry and Fisheries, and the Scientific Authority for South Africa is Chaired by South African National Biodiversity Institute (SANBI).

Priority actions to improve CITES listings for marine species include:

- Building the capacity of front-line compliance officials - primarily SARS Customs - on CITES implementation.
- Providing officials responsible for CITES implementation with the necessary tools - for example species identification guides and support for wildlife forensics.
- Building inter-departmental collaboration and facilitating information-sharing on wildlife trade issues.

In light of SA's focus on building its ocean economy, the health of marine species plays a critical role in realizing and maintaining long-term socio-economic benefits. The aim of this chapter is to provide a summary of the state of knowledge of indigenous marine species by collating information to report on stock status and IUCN threat status. This chapter is not a spatial analysis of pressures on species, and was therefore not directly used to inform ecosystem threat status. For an overview of pressures on marine biodiversity refer to Chapter 4. While there is a separate NBA Technical Report for South Africa's Sub-Antarctic Territory (Whitehead *et al.* 2019), this report does not include a dedicated species overview and therefore species with occurrence within the Sub-Antarctic Territory were included as part of the this chapter.

9.2 Assessment Approach

Four main approaches were used to report on the status of marine species. Firstly, a list of **harvested marine species** was compiled across several fishing sectors to determine the number of marine species caught by South African fisheries. The second approach involved collating available temporal **stock information** for South African fisheries species in order to report the current state of fishery stocks, highlight any success stories and areas for improvement. The third approach was to collate **IUCN Red List data** for South Africa's marine species to report on species extinction risk and conservation priorities. Lastly, a **meta-analysis of the key pressures** impacting on taxa of conservation

concern (those that are either classified as Data Deficient, Near Threatened, Vulnerable, Endangered or Critically Endangered on the IUCN Red List) in the marine realm was conducted in order to compare pressures within and between sample species groups.

9.2.1 Harvested species

A list of **harvested marine species** was compiled across several fishing sectors using several literature sources as well as data from the National Marine Linefish System. Harvested species were collated across the following sectors: beach seine, crustacean trawl, demersal shark fishery, demersal inshore trawl, demersal hake trawl, demersal offshore trawl, gillnet, linefish (commercial), midwater trawl, oyster fishery, Patagonian toothfishery, pelagic longline, purse seine, recreational fishery (which includes estuarine, intertidal, shore based and boat based fishing), seaweed fishery, small-scale fishery (which included subsistence), South Coast Rock Lobster, squid fishery, tuna pole and West Coast Rock Lobster fishery. The harvested species analysis was not exhaustive and did not draw distinction between primary targeted, secondary targeted, discarded bycatch, retained bycatch and incidental bycatch (Annexure 5). This list is intended by be a living dataset which can be updated and expanded by SANBI and collaborators.

9.2.2 Stock status

Fisheries resources are managed through regulating total catch or total effort as stipulated in relevant permit conditions (Marine Living Resources Act No 18 of 1998). Total allowable catch refers to the maximum amount of permitted catch while total allowable effort may refer either to the maximum number of vessels or fishers allowed to fish at a given time, or to a specific time-period when fishing may or may not be permitted (see Chapter 4). There are many different **stock assessment approaches** and models, and their use is dependent on the data that are available and whether inherent model assumptions can be met, which can be challenging especially in multi-species fisheries such as the South African linefishery (de Moor *et al.* 2015) (see Box 31 for more detail).

A key **challenge in fisheries stock assessments** is that scientists do not have perfect knowledge about resource dynamics. For example, it is not possible to know with certainty how many fish die annually from natural causes or as a result of illegal catches. Some of the most frequently encountered uncertainties in the assessments reviewed by (de Moor *et al.* 2015) relate to: (a) the stock-recruit relationship; (b) recruitment estimates and projections; (c) illegal, unregulated and unreported (IUU) catches; d) natural mortality; (e) aging; and (f) the number of stocks that make up a particular fish population. A standardised time series of catch-per-unit-effort (CPUE), covering a substantial period (typically longer than 20 years), may be considered as a relative abundance trend in conjunction with fishery stock assessment to inform management recommendations (DAFF 2010). CPUE provides a relative measure of fish abundance, but care should be taken in interpreting spatial components of the data (Attwood 2003) and the targeting behaviour by fishers (Winker *et al.* 2013). Stock assessment models are most successful when historical catch time series are available from a time at or near the start of the fishery and when the CPUE trend provide sufficient contrast to estimate stock dynamics (Hilborn and Walters 1992). Contrast, as opposed to a “one way downhill trip” (Polacheck *et al.* 1993), is usually achieved when the CPUE time series captures both the fully- or overexploited period that is followed by an upward signal as a result of reduced exploitation. Re-establishing historical baselines of catch, abundance and size structure of a stock can significantly improve the correct quantification of a species’ exploitation status and productivity which can support better management and resource recovery in the long term. Where historical data are unavailable, such contrast can alternatively be

found by assessing population structure and abundance estimates from exploited areas against unfished reference sites within Marine Protected Areas (MPAs). This is a major reason for the recommendation to maintain no-take MPAs to support fisheries management (Attwood 2003).

Box 31. Stock assessment methods and thresholds

There are many different stock assessment approaches and models, and their use is dependent on data availability and satisfying model assumptions. Historically per recruit models such as yield- (YPR) and spawner biomass-per-recruit (SBR) were extensively used, especially for linefish assessments, and are aimed at providing a reliable estimate of the stock status with regards to its depletion from the assumed pristine state (SB/SB0, written as %SB0). Additionally, target and threshold reference points, set at 40% and 25% SB0 respectively are used to indicate stock status and level of exploitation and aids to inform management strategies (Griffiths 1997b).

Uncertain: The species was assessed but the status was not conclusive

Underexploited: > 50 % of pristine

Optimally Exploited: 40-50 % of pristine

Overexploited: 25-40 % of pristine

Collapsed: < 25 % of pristine

YPR and SBR inherently rely on the assumptions that: 1) the age or size composition of a stock is representative of the population structure; 2) recruitment is constant; and 3) that the population is at an equilibrium (Attwood 2003).

Unlike per recruitment models, production models [such as aggregated biomass dynamic models (Schaefer 1957) and age-structured production models] can track the population dynamics over time, but this relies on the availability of long-term time series of abundance data such as catch-per-unit-effort (CPUE), and total catch. Production models measure the current biomass or population size (B) relative to the maximum sustainable yield (B_{MSY}). The MSY is the highest theoretical equilibrium yield that can be continuously taken (on average) from an under- or optimally exploited stock under existing (average) environmental conditions without affecting significantly the reproduction process.

Unknown (Uncertain): B=?

Abundant (Underexploited): B> MSY

Optimally Exploited: B~ MSY

Depleted (Overexploited): B< MSY

Heavily depleted (Collapsed): B<<MSY

Some other stock assessment methods range from complex models such as virtual population analysis (VPA), and statistical age-and length-structured assessments, to applying indicators such as the trend in a, standardized CPUE time series.

South African scientists from the DEFF and their collaborators, have been leading the development and implementation of **modelling frameworks** named JABBA (Winker *et al.* 2018) (but see Box 32 for more detail) which have aided in the rapid uptake in applications for conducting stock assessments. This new framework has already allowed recent assessments for key linefish species (see Box 32), and is envisioned to regularly track the status of the main commercial South African line fish and many other cartilaginous fish stocks in future.

In this chapter, stock assessment information was collated over time to determine the past and present stock status of harvested species, and to inform priority species for assessment. Stock information was obtained from published DEFF data (DAFF 2010, 2012, 2014, 2016) and a host of other literature sources summarized in Table 38. Stocks were grouped into Uncertain, Underexploited,

Optimally Exploited, Overexploited and Collapsed categories for bony fish, cartilaginous fish, invertebrates and seaweeds. Where a stock was assessed as being between two categories (for example at the upper limit of Optimally Exploited and lower limit of Overexploited), the worst of the two categories were used for the assessment. The frequency at which stock assessments are conducted is informed by the management approach (operating models) used by each fishery and usually updated every three to five years (Butterworth 2007). For linefish the frequency of assessment is informed by the life history of the species but linefish species should usually be assessed at intervals equivalent to half of its maximum lifespan (DAFF 2010). Decision making around whether or not a stock assessment is considered up to date was therefore based on the relevant fishery management approach and where relevant, the life history of the species.

Box 32. Advances in Stock Assessment Methodology- JABBA "Just Another Bayesian Biomass Assessment"

JABBA (Just Another Bayesian Biomass Assessment) is an open-source modelling software that can be used for biomass dynamic stock assessment applications. JABBA is based on a generalized Bayesian State-Space Surplus Production Model (SPM) framework (Winker *et al.* 2018). The motivation for developing JABBA was to provide a unified approach to SPM-based assessments that is reproducible, well-documented, and easily implemented for a variety of fisheries. JABBA is hosted within the open source platform Github which promotes the sharing of stock assessment procedures amongst fisheries scientists globally and enables rapid continuous modification of code and models over time. JABBA has been applied in numerous assessments of tuna, billfish and shark stocks in the Atlantic and Indian Ocean. The novel JABBA-Select extension (Winker *et al.* 2019 in press) has been developed to address the specific challenges of line fish assessments and was instrumental for completing the 2017 assessments of Slinger (Maggs *et al.* 2017b), Santer (Maggs *et al.* 2017a), Yellowtail (Parker *et al.* 2017a), Silver kob (Winker *et al.* 2017b), Hottentot (Kerwath *et al.* 2017a), Snoek (Kerwath *et al.* 2017b) and Carpenter (Winker *et al.* 2017a).

9.2.3 Species threat status

IUCN Red List assessments guide monitoring and reporting efforts and assist in the identification of research priorities. The IUCN has developed standard Categories and Criteria for assessing species conservation status (IUCN 2012b). The categories and the criteria thresholds are summarised in Table 37. This is an objective system that can be consistently applied across a broad range of taxonomic groups. The quantitative criteria are based on scientific studies of populations of a range of different species and the biological conditions under which they are highly likely to go extinct (Mace *et al.* 2008). The quantitative nature of the system demands that assessments are justified by supporting data and methodological advances have been made to standardize Red List assessments (Box 33).

IUCN Red List Assessments are conducted by expert networks (a worldwide network of over 8,000 volunteer scientists divided into over 100 SSC **Specialist Groups** that for part of the IUCN Species Survival Commission (SSC), applying the Red List criteria to the available data and, in the absence of strong data, making decisions on their approach to uncertainty. Red List Authority coordinators based within each specialist group ensure each assessment is independently peer-reviewed before it is submitted for publication on the IUCN Red List.

Regional and national Red List projects proceed in a similar way as a global revision but with one added step – applying the regional criterion. The word regional and/or national is used to indicate any

sub-global geographically defined area, such as a continent, country, state, or province. Regional and national Red Lists are important as they are used to: (1) inform regional and national conservation policies and legislation; (2) identify regional and national research gaps and stimulate monitoring programs; (3) monitor the status of biodiversity and report on the state of the environment (through use of indices such as the Red List Index); (4) regulate the development and use of wildlife resources; (5) target areas for conservation planning; (6) increase public awareness of pressures on biodiversity; and (7) set priorities for the allocation of limited conservation resources (Miller *et al.* 2007). Users include conservation planners, research scientists, managers of conservation organisations, landowners and protected area managers, environmental impact agency workers, civil servants compiling governmental reports, officials involved in land-use planning and marine spatial planning, environmental educators and concerned members of the public engaging on development applications.

South African species assessment work is coordinated by **SANBI's Threatened Species Unit** but is conducted by groups of species specialists. Each species group has a champion who acts as the key contact person with whom SANBI coordinates the work. Specialist groups are made up of: taxonomists working in collection institutions; research scientists based either at SANBI or at academic institutions; scientists responsible for monitoring species from the provincial conservation agencies; experienced amateurs and conservation practitioners from NGOS.

Substantial efforts were made to **collate assessments** for South African marine species drawing from national, regional and global IUCN Red Lists and efforts towards these endeavours. For endemic species the scope of the assessment was the entire global population. For near endemic species and wide ranging species such as marine turtles, assessments of the global population by the IUCN SSC were adopted for use at the national level. For all other species the population occurring within South African waters was assessed and the IUCN regional criteria were applied.

Only four taxonomic groups [birds (n= 72), mammals (n= 56), reptiles (n= 6) and seabreams (n= 42)] have been **comprehensively assessed** to date while a sample of other bony and cartilaginous linefish (n= 79 and n= 26 respectively) and hard corals (n= 95) were assessed. Due to limited comprehensive species group assessments and a lack of repeat Red List assessments at different time intervals, tracking the change in status of species over time using the Red List Index (RLI) was not possible.

Box 33. Advances in methods for assessing species using the IUCN Red List categories and criteria: JARA (Just Another Red List Assessment)

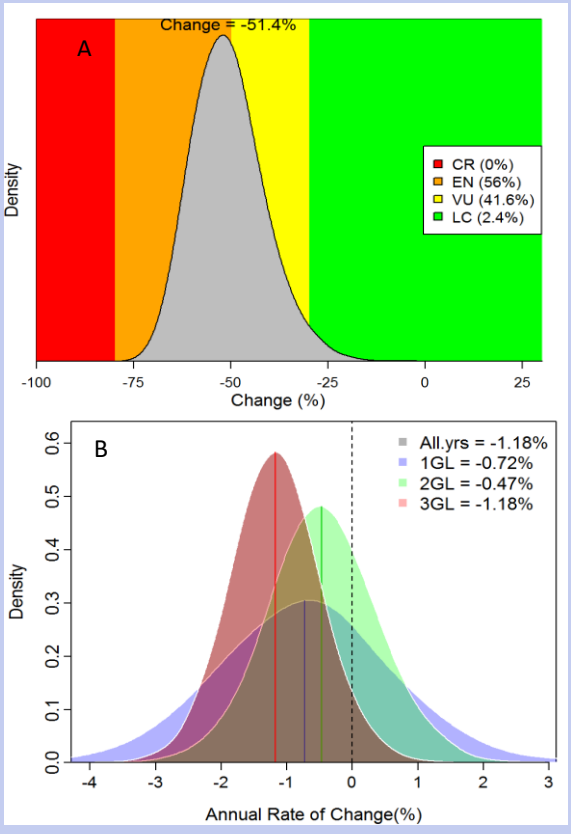
By Henning Winker and Richard Sherley

South African scientists from the Department of Environment, Forestry and Fisheries (DEFF) and their collaborators, have been leading the development and implementation of modelling frameworks named JARA (Just Another Red List Assessment) (Winker and Sherley 2019). JARA is a Bayesian state-space trend analysis decision-support tool that is designed to objectively incorporate process error and uncertainty into IUCN Red List assessments under criterion A. JARA's model notation for relative abundance indices builds on the approach used on the open-source fisheries stock assessment software, JABBA (see Box 32) for averaging relative abundance indices. JARA is designed to be easy to use, rapid and widely applicable, so conservation practitioners can apply it to their own count or relative abundance data. To ensure to a high degree of transparency and reproducibility, JARA is hosted online on the global open-source platform GitHub (https://github.com/henning-winker/JARA). Although the IUCN Red List provides a set of unified quantitative decision rules for assigning threatened categories based on population decline thresholds, data quality and analytical approaches can differ greatly (Wilson *et al.* 2011). In this regard, tools like JARA can help to standardise Red List assessments, increasing objectivity and lowering the risk of misclassification. JARA has aided in the rapid uptake in applications for IUCN Red List assessments.

JARA was officially used to support the 2018 IUCN assessment of Cape Gannet (*Morus capensis*) (see below and Box 39). The IUCN Shark Specialist Group (SSG) has adopted JARA as their quantitative assessment tool of choice for the ongoing global shark Red List assessments (Winker H, DEFF, pers. comm). JARA has supported the assessment of more than 60 sharks and rays as part of the IUCN Shark Specialist Group (SSG)' ongoing update of chondrichthyan assessment globally, but most of these assessments are still pending publication.

JARA results for Cape Gannet:

JARA outputs easy to interpret graphics showing the posterior probability of population decline displayed against the IUCN Red List categories, and assigns each category with an associated probability given process and observation uncertainty (A). Based on only the median % Change (−51.4%), the species meets the criteria for classification as Endangered (A). However, the uncertainty spans Least Concern to Endangered; assessors may, therefore, also want to consider that while 56% of the posterior probability distribution falls into Endangered, 41.6% also falls into Vulnerable (A). The percentage annual population change plots (B) show that the decline has slowed and then accelerated over the last 2 generation lengths (B). Assessors could then make an informed decision on whether to list the Cape Gannet as Vulnerable or Endangered, depending on how risk prone or adverse they wanted to be in their assessment and the presence of other mitigating factors. For the 2018 IUCN Assessment Cape Gannet was listed as **Endangered.**



9.2.4 Species pressure meta-analysis

A **meta-analysis of the key pressures** for taxa of conservation concern (those that are either Data Deficient, Near Threatened, Vulnerable, Endangered or Critically Endangered) (Figure 98) in the marine realm was conducted in order to compare pressures within and between sample species groups. The species meta-analysis was based on the observed or inferred impacts of pressures and sub-pressures as described in the IUCN-CMP Unified Classification of Direct Threats v 3.2 and expresses the percentage (%) of taxa of conservation concern within an assessed taxonomic group affected by a particular pressure. Full descriptions of the IUCN pressures and sub-pressures can be accessed here: https://www.iucnredlist.org/resources/threat-classification-scheme. All pressures which impacted less than 5% of species within the assessed groups were excluded from the analysis.

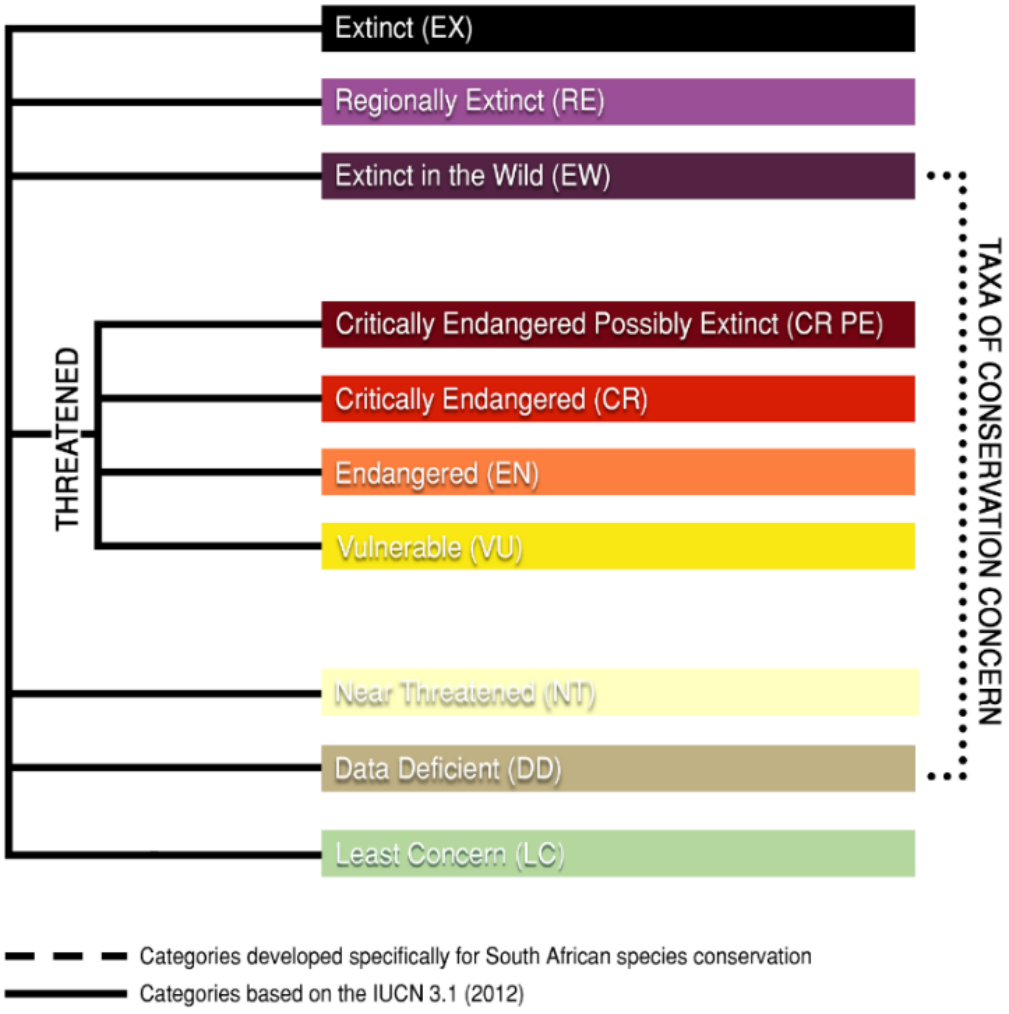


Figure 98. Categories for species red list assessment work, note South Africa uses the IUCN Red List Categories and Criteria, version 3.1 (IUCN 2012b)

Table 37. IUCN 3.1. IUCN Red List Categories and Criteria. Version 3.1, summary of criteria that trigger threat status

A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered	Endangered	Vulnerable
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.

A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) *[(a) cannot be used for A3]*.

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

based on any of the following:

(a) direct observation *[except A3]*

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality

(d) actual or potential levels of exploitation

(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)

	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented **OR** Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline observed, estimated, inferred or projected in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** area, extent and/or quality of habitat; **(iv)** number of locations or subpopulations; **(v)** number of mature individuals			
(c) Extreme fluctuations in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** number of locations or subpopulations; **(iv)** number of mature individuals			

C. Small population size and decline

	Critically Endangered	Endangered	Vulnerable
Number of mature individuals	< 250	< 2,500	< 10,000
AND at least one of C1 or C2			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):	25% in 3 years or 1 generation (whichever is longer)	20% in 5 years or 2 generations (whichever is longer)	10% in 10 years or 3 generations (whichever is longer)
C2. An observed, estimated, projected or inferred continuing decline AND at least 1 of the following 3 conditions:			
(a) **(i)** Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
(ii) % of mature individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals			

D. Very small or restricted population

	Critically Endangered	Endangered	Vulnerable
D. Number of mature individuals	< 50	< 250	**D1.** < 1,000
D2. *Only applies to the VU category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.	-	-	**D2.** typically: AOO < 20 km² or number of locations ≤ 5

E. Quantitative Analysis

	Critically Endangered	Endangered	Vulnerable
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

9.3 Species status and pressures

9.3.1 Overview

NBA 2018 KEY MESSAGE A5

Benefits from fishing are at risk, including food and job security

Marine ecosystems provide South Africans with food and livelihoods by providing a basis for fishing – whether commercial, subsistence or recreational. Yet many fish stocks are overexploited and many fish species are threatened. While a range of plans are in place to ensure that fisheries are sustainable, better practices to rebuild stocks of priority species are needed, as well as reliable data and sufficient capacity for undertaking regular stock assessments.

Skowno et al. 2019.

Globally, the state of **marine fishery resources** is on a declining trajectory with the proportion of fish stocks that are considered harvested at biologically unsustainable levels (below MSY) having increased from 10% in 1974 to 33% in 2015 (FAO 2018a). The proportion of stocks fished within biologically sustainable levels is an important indicator used to measure progress towards the United Nations Sustainable Development Goals (UN SDGs) target for marine fisheries.

More than 770 marine species are harvested in South Africa (Annexure 5) yet updated stock assessments are only available for 54 stocks. Of the **54 stocks with updated stock assessments**, 19% are Overexploited and 20% Collapsed with many others showing trends of decline (Figure 99, Table 38). Approximately 22% are considered Optimally Exploited and 19% are considered Underexploited (Figure 99, Table 38).

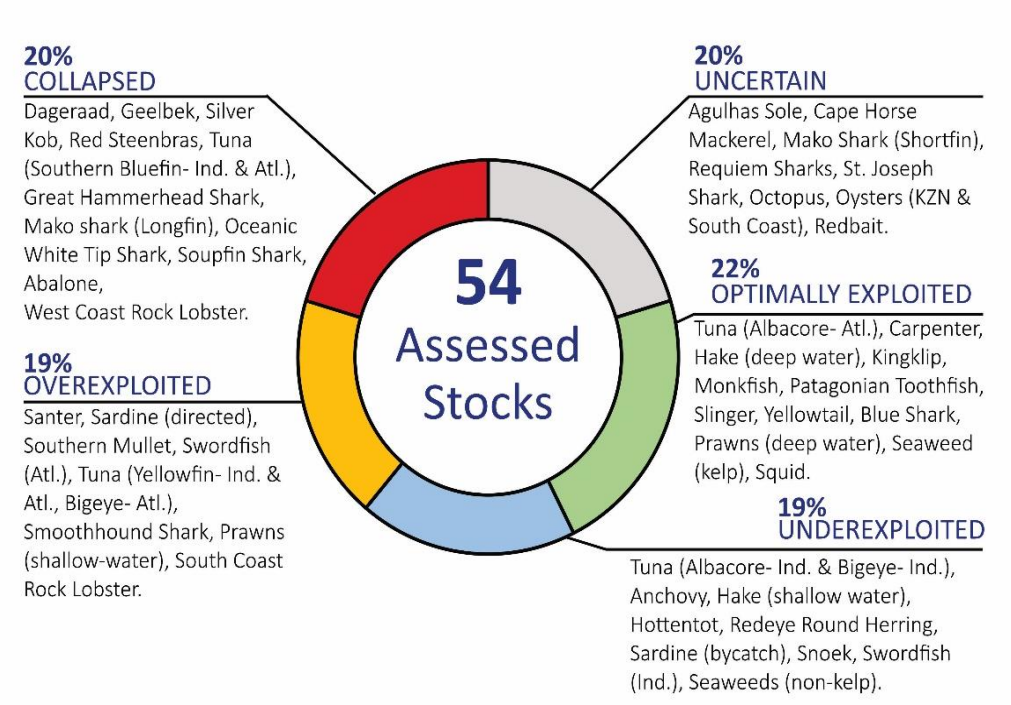


Figure 99. Summary of exploitation status of those stocks with updated national stock assessments. Some stocks included in Table 38 are not included here either because they are not considered updated or they are not considered as being representative of the state of the National stock (i.e. only a portion of stock assessed). Species for which stock assessments were not conducted, but for which other appropriate updated assessments of stocks were available, were included here (e.g. seaweed, kelps, Red Steenbras, Dageraad, shallow-water prawns)

Stock status results reflect poor confidence or **Unknown stock status** of several resources (20%) (Figure 99, Table 38) primarily due to failure to satisfy stock assessment model assumptions. Of the 27 linefish stocks with up to date stock assessments, 11% are considered Uncertain, 15% are considered Underexploited, 22% are considered Optimally Exploited, 19% are considered Overexploited and 33% are considered Collapsed (Figure 99, Table 38).

Of the 12 **invertebrate** stocks assessed, 6 (50%) are considered Uncertain, 2 are Optimally Exploited, 2 are Overexploited and 2 are considered Collapsed (Table 38). **Kelp and seaweeds** were assessed as Optimally Exploited and Underexploited respectively (Table 38). Many of our important **linefish** stocks have outdated assessments, some assessed more than 20 years ago (e.g. White steenbras Lithognathus lithognathus last assessed in 1993; **Catface Rockcod** *Epinephelus andersoni*, White-Edged Rockcod *Epinephelus albomarginatus*, Yellowbelly Rockcod *Epinephelus marginatus* and Halfmoon Rockcod *Epinephelus rivulatus* all last assessed in 1998) (Bennett 1993b, Fennessy 2000a) (Table 38).

Inshore resources such as West Coast Rock Lobster and Abalone are priority species for national IUCN Red List assessment.

Inshore resources such as Abalone (*Haliotus midae*) and West Coast Rock Lobster (*Jasus lalandii*) remain in crises with escalating levels of poaching (Table 38, see Box 34, Box 35). Both these inshore resources are Collapsed and have experienced severe declines over the past decades with Abalone legal commercial catch having declined from 613 tonnes in 1993 to 95 tonnes in 2015 (84.5% decline) (DAFF 2016). West Coast Rock Lobster commercial catch declined from 18 000 tonnes in the 1950's to 10 000 tonnes in the 1960's and have continued to decline in recent years with landings in 2016 being approximately 2000 tonnes (90.6% decline since the 1950's) and male biomass above the legal size limit (75 mm) estimated at less than 2.5% of pre-fished levels (DAFF 2016). While declines in West Coast Rock Lobster can be attributed to a combination of factors, including changes in fishing methods, spatial shifts in distribution, changes in management measures, reduced growth rates and overexploitation (Pollock *et al.* 1997, Cockcroft and Payne 1999, DAFF 2016), declines in Abalone are predominantly a result of illegal harvesting coordinated largely through complex criminal syndicates (de Greef and Raemaekers 2014, Warchol and Harrington 2016).

Of the **376 South African marine species assessed** using either national, regional and global IUCN assessments, **18.6% are threatened** (falling either into the Vulnerable, Endangered or Critically Endangered category) (Figure 100) representing a relatively high threat level compared with species from other realms (Skowno *et al.* 2019a). This threat level may however not be completely representative of actual threat patterns because of a focus on assessment of perceived threatened and utilised taxa and the relatively low National redlisting effort in the marine realm when compared to other realms (Skowno *et al.* 2019a). Key pressures impacting marine species include fishing (targeted, bycatch and/or incidental capture), pollution (plastic, effluent), and freshwater flow modification while additional threats include competition from alien invasive species and habitat modification as a result to climate change (Figure 101).

Marine reptiles and seabirds are amongst the **most threatened species groups** (Figure 100) and represent 2 out of the 4 groups which were comprehensively assessed. Four out of the 5 turtles assessed were threatened, mainly by fishing (as bycatch), coastal development and pollution in the form of plastic pollution and entanglement in fishing gear (Figure 100, Figure 101, see section 9.3.5 for more detail). More than a third (37%) of South Africa's seabirds are threatened (Figure 100). The

threatened status of seabirds is primarily driven by fishing pressure, invasive species and problematic native species (Figure 101. see section 9.3.3 for more detail). A sample of 105 commercially important bony and cartilaginous fish species were assessed of which 11% were threatened, and 46% were Data Deficient (Figure 100). More than 30% (42 assessed, 15 endemics) of our endemic sparid seabreams are threatened while 27% are Near Threatened (Figure 100. See section 9.3.4 for more detail). Of the 56 marine mammal species assessed, 16% are threatened while more than 20% are Data Deficient (Figure 100). The threatened status of marine mammals is primarily driven by fishing, habitat alteration as a result of climate change, ocean noise and pollution (Figure 101. See section 9.3.2 for more detail).

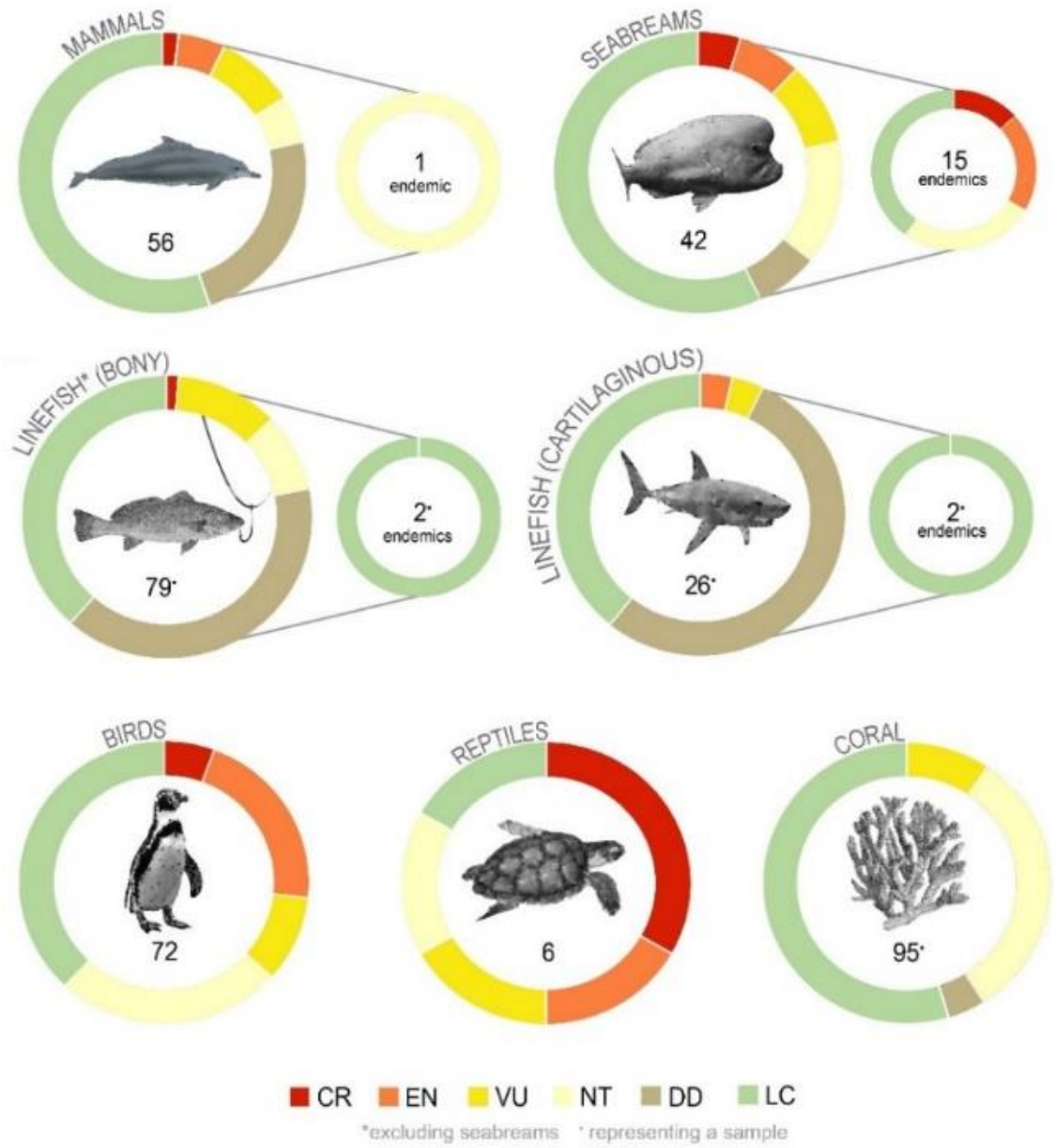


Figure 100. The proportion of indigenous marine species assessed to date in each of the IUCN Red List Categories of extinction risk: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Data deficient (DD), Least Concern (LC). Numbers display the number of taxa assessed and number of South African endemics.

To date, very few national IUCN Red List assessments have been conducted for **marine invertebrate** species due to data deficiency and limited capacity to advance species red listing. For example two

endemic molluscs with partial marine habit, *Siphonaria compressa* and *Tomichia tristis*, were assessed as Critically Endangered in 1996 and 2007 respectively and are in need of reassessment (Kilburn 1996, Kristensen *et al.* 2010). Many invertebrate species are under pressure and should be prioritised for IUCN assessment (see Box 34, Box 35 and Box 36).

To date, **no national seaweed IUCN assessments** have been conducted. There is considerable recent flux in seaweed species diversity (Bolton J, University of Cape Town, pers comm), and the recognition of high levels of cryptic species, for example the recognition using molecular species concepts of 8 species within *Porphyra capensis* (Reddy *et al.* 2018) and 4 species within South African *Portieria hornemannii* (Leliaert *et al.* 2018), as well as four new taxa recently described within the genus *Laurencia* (Francis *et al.* 2017). There are high levels of species endemism among taxa with temperate affinities, with many west coast taxa shared with Namibia, but also many more warm temperate endemic taxa on the south coast, confined to South Africa. Warmer coastal waters of eastern South Africa represent the westernmost records of many taxa occurring across the extremely large and biologically diverse Indo-West Pacific. Many of these are being shown to be complexes, comprising many cryptic species. Fucales, a group of large brown algae, are particularly interesting, with 5 monospecific genera endemic to South or southern Africa (*Anthophycus, Axillariella, Bifurcariopsis, Brassicophycus, Oerstedtia*). Most of these have relatively short coastal distributions, and are in need of population genetic studies to assess IUCN Redlist status. In addition '*Cystophora fibrosa*', described from the Cape Agulhas region, appears to actually belong to the genus *Cystoseira*, and has a very short distribution on both sides of Cape Agulhas.

Marine taxa have the highest levels of data deficiency (17% of all species assessed) across all realms (Skowno *et al.* 2019a). Knowledge gaps in taxonomy, long term population trends and life history limit our understanding of marine species status and threatened species may go undetected. Addressing knowledge gaps can guide management to help secure the benefits from marine species. Given the important contribution of fisheries to South Africa, it is essential that the collection of reliable data for stock assessments is increased in order to ensure well managed fisheries and develop strong interventions to rebuild stocks to ensure long term food and job security.

As it is not feasible to manage all South Africa's harvested species using traditional fisheries management tools, **spatial management measures** such as a representative Marine Protected Areas Network and other Effective Area-Based Conservation Measures, can play an essential role in ensuring the long-term integrity and recovery of marine resources and the ecosystems that support them.

Box 34. West Coast Rock Lobster (*Jasus lalandii*) in Crisis

By Nicola Okes and George Branch

West Coast Rock Lobster, *Jasus lalandii*, is considered one of the most valuable fisheries resources in South Africa (Johnston and Butterworth 2005, DAFF 2016). This is a cold-water species, occurring between Walvis Bay in Namibia and East London in South Africa, and supports a commercial fishery operating between the Orange River Mouth and Danger Point (DAFF 2016). The fishery currently has an estimated market value of R260 million and provides at least 4000 people with employment (Cockcroft *et al.* 2008, DAFF 2016). West Coast Rock Lobster is also caught in the near shore by subsistence and recreational fishermen and is the third most caught species by seasonal fishers on the west coast (Branch *et al.* 2002, DAFF 2016, WWF-SASSI 2016).



West Coast Rock Lobster is one of the most valuable fishery resources in South Africa

As the commercial fishery has grown since its inception in the 1880's, its management has had to adapt to numerous challenges. Lobster landings peaked in the 1950's at 18 000 tonnes, but declined sharply to 10 000 tonnes by the 1960's and have continued to decline in recent years with landings in 2016 being approximately 2000 tonnes (DAFF 2016). Annual commercial landings on the west coast have declined from 60% to 40% and biomass for Rock Lobster above 75 mm (legal minimum limit) is estimated to be less than 2.5% of what is considered 'pristine' (DAFF 2016). The observed decline in catches is believed to be due to a combination of factors, including changes in fishing methods, the eastward shift in the distribution of Rock lobster populations, changes in management measures, reduced growth rates and overexploitation including increasing poaching (Pollock *et al.* 1997, Cockcroft and Payne 1999, DAFF 2016).

Prior to the 1960s, hoopnets were mainly used to harvest Rock lobsters commercially. However, the type of fishing gear has shifted and more efficient traps and motorised deck boats now account for 75% of Rock Lobster landings (Cockcroft and Payne 1999). In the early 1990's, a major south-eastward shift in the natural distribution of West Coast Rock Lobsters from the west coast to more southern fishing grounds was observed (Cockcroft *et al.* 2008). Subsequent reduced catches in the traditional west coast fishing grounds has had a devastating impact on the economy of coastal communities (DAFF 2016). In addition, the eastward movement of Rock lobster has resulted in top down changes in community composition including compromising recruitment of already overexploited Abalone *Haliotis midae* (Cockcroft *et al.* 2008, Blamey *et al.* 2010). West Coast Rock Lobsters have also been subjected to increased levels of poaching especially within the Table Mountain National Park Marine Protected Area (Cockcroft and Payne 1999, Brill and Raemaekers 2013).

An Operational Management Procedure (OMP) was put in place in 1997 in an attempt to rebuild stocks to a sustainable level, and allow management to adapt to uncertainties in trends, growth rates and recruitment in the population (Johnston and Butterworth 2005). The OMP provides a robust framework for setting the annual Total Allowable Catch (TAC) through the Rock Lobster Scientific Working Group (SWG) of the Department of Environment, Forestry and Fisheries (DEFF), considering uncertainties in resource status and trends as well as risk to the resource and industry (Plagányi *et al.* 2007).

In recent years, however, concerns were raised when TAC recommendations from the Scientific Working Group were not implemented, and instead a TAC was set at more than 70% of what would maintain the resource at its current level (WWF-SA 2018). In 2018, WWF South Africa initiated court action against the former Department of Agriculture, Forestry and Fisheries (DAFF) seeking an order declaring that the Department's conduct in declaring a TAC far above the SWG recommendation to be invalid. WWF stated that the department's decision to set the 2017/18 total allowable catch for the West Coast Rock Lobster at this level fundamentally undermines its long-term survival and the future of the fishers who depend on this valuable resource (WWF-SA 2018). In September, 2018, the court ruled that the WCRL TAC set for the 2017/2018 was inconsistent with the constitution as per the Marine Living Resources Act. In November 2018, the TAC allocation for the 2018/2019 WCRL season was announced as 1 084 tonnes – a 43.6% reduction when compared to the 2017/2018 fishing season (DAFF 2018). This recommendation was made as part of a two-phased package in which it was recognised that a further reduction would be necessary in the subsequent year (2019).

Box 35. Abalone (Haliotis midae): History and Current Status
By Markus Bürgener

An excerpt adapted from "Empty Shells: An assessment of Abalone poaching and trade from southern Africa (Okes *et al.* 2018).

Abalone, *Haliotis midae*, locally known as 'perlemoen' is a large marine snail that is highly prized as a seafood delicacy in predominantly East Asian markets. *H. midae* is the only commercially viable species of Abalone in South Africa (Lau 2018) and is endemic to South Africa, occurring in shallow inshore water between Cape Columbine on the west coast of South Africa and Port St Johns on the east Coast.

Historically, South Africa was considered one of the major Abalone-producing countries in the world (Cook and Gordon 2010), but has suffered severe declines over the last 20 years, mostly due to illegal harvesting coordinated largely through complex criminal syndicates. The relative ease of access combined with a 'vulnerable reproductive strategy' (slow growing and maturing) mean they are vulnerable to overexploitation (Tarr 2000, de Greef and Raemaekers 2014).

History

The commercial Abalone fishery began in the 1945 as an open-access fishery, operating out of the Western Cape province of South Africa. After years of largely unregulated fishing, unsustainable harvesting (with peak catches of 2 800t in 1965) led to a decline in landings to the point that quota restrictions were implemented first in 1968 with further reductions resulting in a Total Allowable Catch (TAC) of 615t in 1995. As South Africa's apartheid-era isolation came to an end in the 1990's and borders opened, the fishery went through a politically complex reform process whereby rights were being reallocated. This process began in the mid-1990's and followed a policy decision to redistribute the existing rights in the Western Cape from a few corporately owned companies, to individual boat-based divers and marginalized traditional fishers from the local communities (Raemaekers *et al.* 2011). This process was complex: despite management of allocations being continuously adapted as challenges emerged, increasing the number of people with access to the fishery while the resource was in decline due to growing illegal catches meant fewer rights available for allocation as well as reductions in the TAC (Raemaekers *et al.* 2011). Tensions between fishing authorities and traditional fishers who felt they had a historical entitlement to the resource ultimately resulted in distrust in the process and disregard for regulations implemented (Raemaekers *et al.* 2011). Thus, many of those whose livelihoods depended on Abalone fishing but were now excluded, continued to fish and sell their catch (Raemaekers *et al.* 2011).



Empty Abalone shells washed up on the beach

As demand for South African Abalone grew; prices increased radically and opportunities for trade between South Africa and Hong Kong expanded (Raemaekers *et al.* 2011). A culmination of factors, including the high prices on offer as well as the socio-political climate and attitudes around the rights and legalities of Abalone fishing, fostered an environment for the illegal fishery to grow (de Greef and Raemaekers 2014, Warchol and Harrington 2016). The traditional informal Abalone fishery grew into a highly organised illegal fishery facilitated by international syndicates exporting product to Hong Kong (Gastrow 2001, Raemaekers *et al.* 2011). From the early 1990s, Abalone aquaculture facilities were being developed in South Africa, and as the industry expanded, farming of Abalone was also initiated in Namibia – the only sub-Saharan African country outside of South Africa to produce Abalone for the export market.

During this same time period, a recreational fishery was operating out of a similar area and was subject to increasing regulation due to the decline in stock. However, despite the implementation of closed seasons, size restrictions and reduced bag limits, the recreational fishery had to be suspended in 2003 due to difficulties experienced in controlling the high levels of illegal fishing. The commercial fishery followed a similar route and faced increasing regulations and eventual closure for one season in 2008-9. Despite sound scientific research and informed management of the resource, it was suggested that the resource-focused fishery management system did not have the capacity to incorporate the complex social, political and economic conditions at play (Raemaekers *et al.* 2011). The socio-economic conditions experienced within the fishery, together with the presence of established sophisticated criminal syndicates, added complexity to the fight against Abalone poaching outside the realm of fisheries management. Chinese criminal networks have been known to be operating in South Africa since the 1970's (Gastrow 2001), initially trading in shark fins and evolving to include a range of other illicit activities, including Abalone poaching as well as the recreational drug trade (de Greef and Raemaekers 2014). It is widely known that East Asian criminal groups have bartered precursor ingredients for first Mandrax and later methamphetamines for Abalone, forging cash-free trade relationships with Cape gangs that control the local drug market (Steinberg 2005, de Greef and Raemaekers 2014).

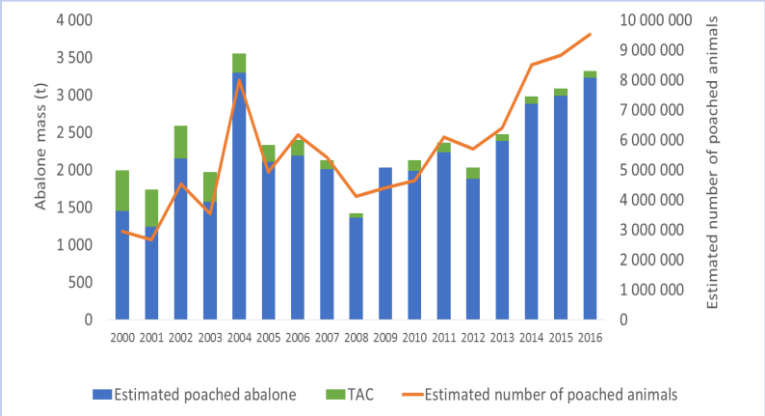
Threats and interventions



Abalone, locally known as Perlemoen

Apart from these challenges, the key elements thought to be contributing to Abalone poaching and associated criminal activities were the high value of the resource, the low risk of detection and weak deterrence due to low penalties, as well as poor conviction rates (Snijman 2005, Warchol and Harrington 2016). As such, numerous interventions were attempted at various stages of the supply chain to curb illegal fishing and regulate trade. These included fishery closures; enforcement operations in response to increasingly organised illegal fishing networks (e.g. Operation Trident and Operation Neptune – operations through collaborations between the military, police and local anti-poaching initiatives); the establishment of environmental courts specifically focused on Abalone poaching (Steinberg 2005); and the listing by South Africa of its species of Abalone (*H. midae*) within Appendix III of CITES in 2007. Each intervention was, however, relatively short lived and resulted in little long-term impact. For example, the environmental courts that were opened in 2003 and showed considerable success, increasing the conviction rates of not only poachers, but also buyers and processors, were closed in 2005 due to a lack of government funding (Snijman 2005). Similarly, the commercial fishery was closed in 2008, yet reopened in 2010 despite increased levels of poaching and little recovery of the stock (DAFF, 2014). Furthermore, Abalone was listed on Appendix III of CITES in 2007 only to be delisted in 2010 due to administrative and compliance capacity challenges experienced by South Africa in implementing the listing (Bürgener 2010). On the market end, the Chinese austerity campaign implemented in 2013 had potential to impact the import of Abalone, but it is not known for certain what impact this had on imports by Hong Kong.

Despite these numerous and diverse interventions, imports of South African Abalone continued to climb. Today South Africa legally produces approximately 1,800 tonnes of Abalone in live, dried, frozen or canned form from a combination of the growing aquaculture industry, and a wild-caught fishery which has had an annual TAC of 96t since 2013. However, customs figures suggest much higher imports into market destinations, and calculations suggest that an average of 2 174 tonnes of Abalone has been poached per annum since 2000. Apart from the legal production of Abalone for the export market, confiscations of illegally harvested Abalone have, until May 2018, also entered the market via a legal route. This was made possible through an arrangement whereby the former Department of Agriculture, Fisheries and Forestry (DAFF) supplied the confiscated Abalone to a local processing facility where it was prepared for export. There is almost no domestic market for Abalone, and over 95% of production is exported (industry pers. comm. to M. Bürgener, 2018). As there are no international or national trade regulations applicable to South African Abalone in transit or destination countries, illegally harvested abalone that leaves South Africa can be legally imported by market states.



Trends in Abalone legal versus illegal harvesting 2000-2016 (TRAFFIC)

Priority Actions:

The increasing imports of dried South African Abalone combined with the high value of the product and the presence of organized crime syndicates suggest that interventions and collaborations at international level are required in order to address the trade in illegally harvested Abalone. Local initiatives required to stem the poaching of Abalone include increased multi-agency collaboration between different government departments to encourage solutions that address the combined effects of social, political and economic conditions surrounding the illegal fishery. Regional collaboration within sub-Saharan Africa is required to ensure that countries through which poached Abalone is traded have the necessary resources and legal framework to thwart attempts to route Abalone through their ports. International trade regulation in the form of a Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix listing is highly recommended. As most of the illegally harvested Abalone is traded in dried form, usually by air to Hong Kong, a focused and collaborative effort is required to ensure the effective administering and implementation of the CITES documentation.

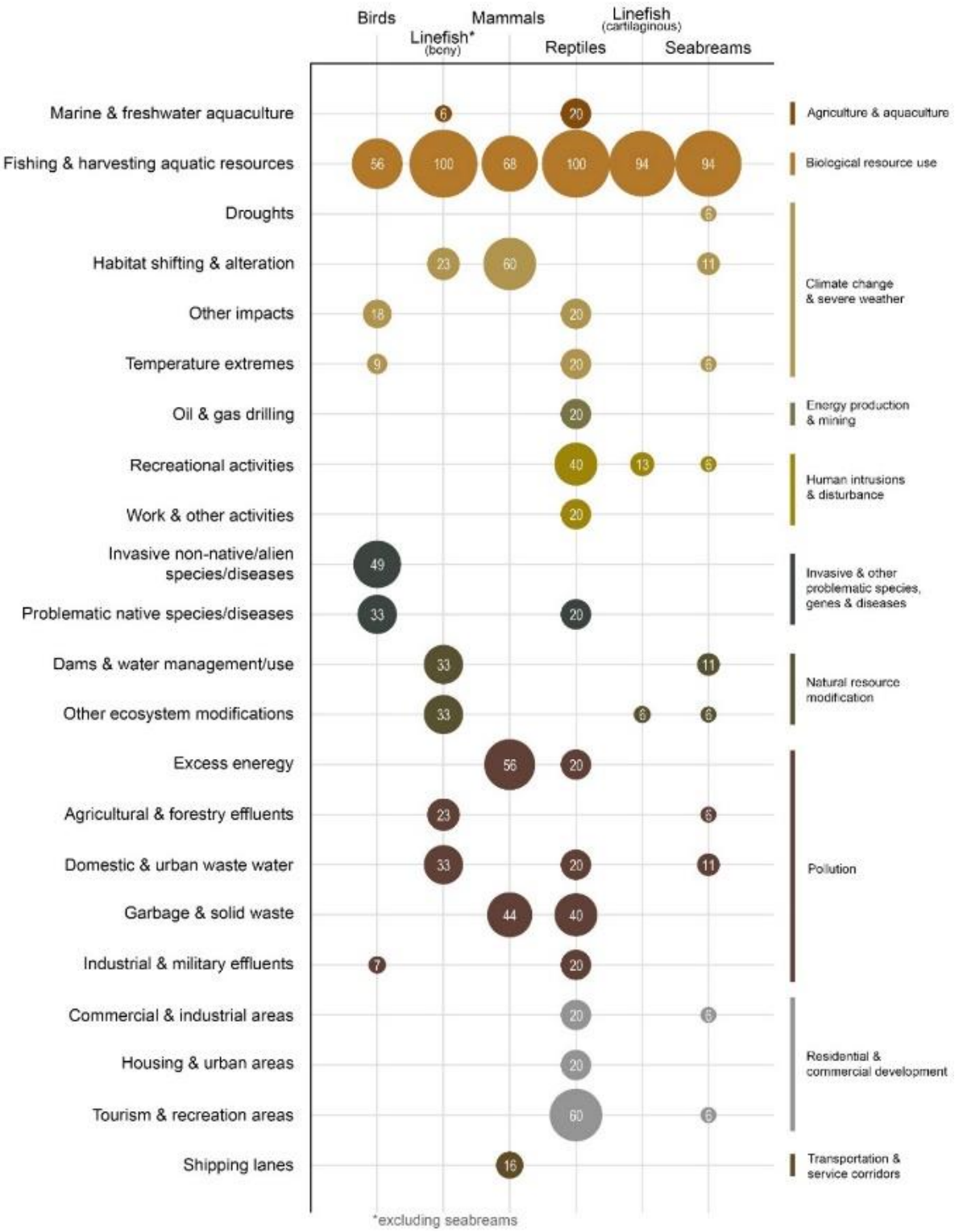


Figure 101. The key pressures for taxa of conservation concern in the marine realm based on a meta-analysis of the South African Species Red List Database. The pressures categories follow the IUCN threat classification system. Pressures are presented on the right axis and sub-pressures on the left axis. The size of the bubble corresponds to the percentage of taxa of conservation concern in the taxonomic group that is subject to each pressure.

Table 38. Summary of harvested species' stock status. Species' stocks indicated with (*) have up to date stock assessments but these were not included in Fig 2 because these assessments cover a limited portion of the stock and are not considered representative of the state of the National stock. Citations indicated by (numerals). Stocks with outdated assessments are indicated with (citation) year of assessment

Scientific Name	Common Name	Pre- 2010	2010	2012	2014	Present
Bony fish						
Acanthopagrus vagus	Riverbream	Collapsed (25) 2001				
Argyrosomus inodorus	Silver Kob		Collapsed (10)	Collapsed (11)	Collapsed (12)	Collapsed (49)
Argyrosomus japonicus	*Dusky Kob (Eastern Cape)	Collapsed	Collapsed (10)			Collapsed (47)
Argyrosomus thorpei	Squaretail Kob	Collapsed (14) 1993				
Argyrozona argyrozona	Carpenter	Collapsed		Overexploited (11)	Optimally exploited (12)	Optimally exploited (48)
Atractoscion aequidens	Geelbek		Collapsed (10)			Collapsed (6)
Austroglossus pectoralis	Agulhas Sole		Uncertain (10)	Underexploited (11)	Uncertain (12)	Uncertain (13)
Cheimerius nufar	Santer					Overexploited (30)
Chrysoblephus anglicus	Englishman	Collapsed (33) 2004				
Chrysoblephus cristiceps	Dageraad	Collapsed				Collapsed (38)
Chrysoblephus laticeps	Red Roman	Optimally exploited (17) 2004				
Chrysoblephus puniceus	Slinger	Collapsed	*	Optimally exploited (46)	Optimally exploited (12)	Optimally exploited (31)
Dichistius capensis	Galjoen	Collapsed (2) 2003				
Diplodus hottentotus	*Zebra (Eastern Cape)					Overexploited (47)
Diplodus sargus capensis	*Blacktail (Eastern Cape)					Overexploited (47)
Dissostichus eleginoides	Patagonian Toothfish		Uncertain (10)	Uncertain (11)	Uncertain (12)	Optimally exploited (13)
Engraulis encrasicolus	Anchovy		Optimally exploited (10)	Optimally exploited (11)	Underexploited (12)	Underexploited (13)
Epinephelus albomarginatus	White-edged Rockcod	Collapsed (16) 1998				
Epinephelus andersoni	Catface Rockcod	Optimally exploited (16) 1998				
Epinephelus marginatus	Yellowbelly Rockcod	Overexploited (16) 1998				
Epinephelus rivulatus	Halfmoon Rockcod	Underexploited (16) 1998				
Etrumeus whiteheadi	Redeye Round Herring		Underexploited (10)	Underexploited (11)	Underexploited (12)	Underexploited (13)
Galeichthys ater	Black Seabarbel	Underexploited (43) 1990				
Galeichthys feliceps	White Seabarbel	Overexploited (43) 1990				
Genypterus capensis	Kingklip					Optimally exploited (13)

Scientific Name	Common Name	Pre- 2010	2010	2012	2014	Present
Lichia amia	Leervis	Collapsed (42) 2008				
Lithognathus lithognathus	White Steenbras	Collapsed (3) 1993				
Liza richardsonii	Southern Mullet		Overexploited (10)	Collapsed (11)	Collapsed (12)	Overexploited (13)
Lophius vomerinus	Monkfish					Optimally exploited (13)
Merluccius capensis	Shallow-water Hake	Optimally exploited	Optimally exploited (10)	Optimally exploited (11)	Underexploited (12)	Underexploited (13)
Merluccius paradoxus	Deep-water Hake		Overexploited (10)	Overexploited (11)	Optimally exploited (12)	Optimally exploited (13)
Neoscorpis lithophilus	*Stone Bream (Eastern Cape)	Optimally exploited (32) 2002				Optimally exploited (47)
Otolithes ruber	Snapper Kob	Overexploited (35) 2007				
Pachymetopon blochii	Hottentot			Optimally exploited (11)	Underexploited (12)	Underexploited (26)
Pachymetopon grande	*Bronze Bream (Eastern Cape)					Optimally exploited (47)
Petrus rupestris	Red Steenbras	Collapsed			Collapsed (12)	Collapsed (28)
Polysteganus praeorbitalis	Scotsman	Collapsed (33) 2004				
Polysteganus undulosus	Seventy-four	Collapsed (8) 1996, (33) 2007	Collapsed			
Pomadasys commersonnii	*Spotted Grunter (Eastern Cape)	Overexploited (15) 2000				Collapsed (47)
Pomadasys olivaceus	Piggy/Pinky	Optimally exploited (45) 2002				
Pomatomus saltatrix	*Elf/Shad (Eastern Cape)	Overexploited (10,20) 1996				Collapsed (47)
Pterogymnus laniarius	Panga	Underexploited (5) 1994-1995				
Rhabdosargus globiceps	*White Stumpnose (Saldanha Bay)	Collapsed (1) 2002-2006	Collapsed (10)			Collapsed (40)
Rhabdosargus sarba	Natal Stumpnose	Overexploited (24) 2004				
Sardinops sagax	Sardine (bycatch)					Underexploited (13)
	Sardine (directed)					Overexploited (13)
	Sardine (bycatch + directed)		Optimally exploited (10)	Optimally exploited (11)	Optimally exploited (12)	
Sarpa salpa	Strepie	Underexploited (44) 1994-1995				
Scomber japonicus	Chub Mackerel			Overexploited (35)		
Scomberomorus commerson	King Mackerel	Overexploited (18) 1995			Optimally exploited (29)	
Scomberomorus plurilineatus	Queen Mackerel	Optimally exploited (7) 1996				
Seriola lalandi	Yellowtail		Optimally exploited (10)	Optimally exploited (11)	Optimally exploited (12)	Optimally exploited (39)
Thunnus alalunga	Albacore (Atl.)		Optimally exploited (10)	Overexploited (11)	Optimally exploited (12)	Optimally exploited (13)

Scientific Name	Common Name	Pre- 2010	2010	2012	2014	Present
	Albacore (Ind.)		Optimally exploited [10]	Overexploited [11]	Optimally exploited [12]	Underexploited [23]
Thunnus albacares	Yellowfin Tuna (Atl and Ind)		Optimally exploited [10]			
	Yellowfin Tuna (Ind.)			Underexploited [11]	Underexploited [12]	Overexploited [23]
	Yellowfin Tune (Alt.)			Overexploited [11]	Overexploited [12]	Overexploited [13]
Thunnus maccoyii	Southern Bluefin Tuna (Ind. and Atl.)		Overexploited [10]	Collapsed [11]	Collapsed [12]	Collapsed [13]
Thunnus obesus	Bigeye Tuna (Ind.)		Optimally exploited [10]	Optimally exploited [11]	Optimally exploited [12]	Underexploited [23]
	Bigeye Tuna (Atl.)		Optimally exploited [10]	Optimally exploited [11]	Optimally exploited [12]	Overexploited [22]
Thyrsites atun	Snoek		Optimally exploited [10]	Optimally exploited [11]	Optimally exploited [12]	Underexploited [27]
Trachinotus botla	Largespot Pompano			Underexploited [37]		
Trachurus trachurus capensis	Cape Horse Mackerel		Uncertain [10]	Optimally exploited [11]	Optimally exploited [12]	Uncertain [13]
Umbrina robinsoni	Baardman	Collapsed [21] 2003-2004				
Xiphias gladius	Swordfish (Atl.)		Underexploited [10]	Optimally exploited [11]	Uncertain [12]	Overexploited [22]
	Swordfish (Ind.)		Optimally exploited [10]	Overexploited [11]	Optimally exploited [12]	Underexploited [23]
Sharks, skates and rays						
Callorhinchus capensis	St Joseph Shark			Uncertain [11]	Uncertain [12]	Uncertain [13]
Carcharhinus longimanus	Oceanic White Tip Shark		Overexploited [10]		Collapsed [12]	
Galeorhinus galeus	Soupfin Shark	Optimally exploited		Overexploited [11]	Overexploited [12]	Collapsed [9]
Isurus oxyrinchus	Shortfin Mako Shark	Overexploited [41] 2005			*	Uncertain [13]
Isurus paucus	Longfin Mako Shark		Overexploited [10]	Collapsed [11]	Collapsed [12]	
Order: Carcharhiniformes	Requiem Sharks				*	Uncertain [13]
Prionace glauca	Blue Shark	Underexploited		Optimally exploited [11]	Optimally exploited [12]	Optimally exploited [13]
Sphyrna mokarran	Great Hammerhead Shark		Overexploited [10]		Collapsed [12]	
Sphyrna zygaena	Smoothhound Shark	Optimally exploited		Optimally exploited [11]	Optimally exploited [12]	Overexploited [9]
Squalus acanthias	Spiny Dogfish		Overexploited [10]			
Invertebrates and seaweeds						
Bullia laevissima and Ovalipes trimaculatus	Whelks					Uncertain [13]
Donax serra	White Mussel		Uncertain [10]	Uncertain [11]	Uncertain [12]	Uncertain [13]

Scientific Name	Common Name	Pre- 2010	2010	2012	2014	Present
Ecklonia maxima, Laminaria pallida	Seaweed (kelp)		Optimally exploited (10)	Optimally exploited (11)	Optimally exploited (12)	Optimally exploited (13)
Fennereopenaeus indicus, Metapenaeus monoceros, Penaeus monodon, Marsupenaeus japonicas	Prawns (shallow-water)			Overexploited (11)	Overexploited (12)	Overexploited (13)
Gelidium spp., Gracilaria spp., Gracilariopsis spp.	Seaweeds (non-kelp)		Underexploited (10)	Underexploited (11)	Underexploited (12)	Underexploited (13)
Haliotis midae	Abalone		Collapsed (10)	Collapsed (11)	Collapsed (12)	Collapsed (13)
Haliporoides triarthus, Metanephrops mozambicus, Palinurus delagoae, Chaceon macphersoni	Prawns (deep water)			Optimally exploited (11)	Optimally exploited (12)	Optimally exploited (13)
Jasus lalandii	West Coast Rock Lobster		Collapsed (10)	Collapsed (11)	Collapsed (12)	Collapsed (13)
Loligo renaudi	Squid		Optimally exploited (10)	Optimally exploited (11)	Optimally exploited (12)	Optimally exploited (13)
Octopus vulgaris	Octopus					Uncertain (13)
Palinurus gilchristi	South Coast Rock Lobster		Overexploited (10)	Overexploited (11)	Overexploited (12)	Overexploited (13)
Pyura stolonifera	Redbait					Uncertain (13)
Striostrea margaritacea	Oysters (KZN)		Optimally exploited (10)	Optimally exploited (11)	Uncertain (12)	Uncertain (13)
	Oysters (South Coast)		Overexploited (10)	Uncertain (11)	Uncertain (12)	Uncertain (13)
see above	Prawns (deep water + shallow water)		Optimally exploited (10)			

Note: Species for which stock assessments were not conducted, but for which other appropriate updated assessments of stocks were available, were included here (e.g. seaweed, kelps, Red Steenbras, Dageraad, prawns)

1. (Arendse 2011); 2. (Attwood 2003); 3. (Bennett 1993b); 4. (Beyer *et al.* 1999); 5. (Booth and Buxton 1997); 6. (Boyd 2017); 7. (Chale-Matsua 1996); 8. (Chale-Matsau *et al.* 2001); 9. (da Silva *et al.* 2018); 10. (DAFF 2010); 11. (DAFF 2012); 12. (DAFF 2014); 13. (DAFF 2016); 14. (Fennessy 1994a); 15. (Fennessy 2000b); 16. (Fennessy 2000a); 17. (Götz 2005); 18. (Govender 1995); 19. (Govender 1996); 20. (Govender 1997); 21. (Hutchings and Griffiths 2010); 22. (ICCAT 2018); 23. (IOTC 2018); 24. (James *et al.* 2004); 25. (James *et al.* 2008a); 26. (Kerwath *et al.* 2017a); 27. (Kerwath *et al.* 2017b); 28. (Kerwath *et al.* 2019); 29. (Lee 2013); 30. (Maggs *et al.* 2017a); 31. (Maggs *et al.* 2017b); 32. (Mann *et al.* 2002a); 33. (Mann *et al.* 2005); 34. (Mann 2007); 35. (Mann 2013a); 36. (Olbers and Fennessy 2007); 37. (Parker *et al.* 2013); 38. (Parker *et al.* 2016); 39. (Parker *et al.* 2017a); 40. (Parker *et al.* 2017b); 41. (Petersen *et al.* 2009b); 42. (Smith 2008); 43. (Tilney 1990); 44. (van der Walt and Govender 1996); 45. (Wellington 2002); 46. (Winker *et al.* 2012); 47. (Winker *et al.* 2015); 48. (Winker *et al.* 2017a); 49. (Winker *et al.* 2017b)

Box 36. Traditional use of marine species in South Africa
By Siyasanga Miza and Shakirah Rylands



Subsistence harvesting of brown mussels (*Perna perna)* by women on the East Coast.

Harvesting of intertidal resources is thought to date back to at least 100 000 years which is supported by the findings of coastal middens comprising of mussels, patellid limpets, whelks and periwinkle shells (Clark *et al.* 2002). Some of the oldest records of shellfish consumption date back to the Middle Stone Age in a cave at Pinnacle Point, Mossel Bay (Jerardino and Marean 2010, Branch and Branch 2018). Common molluscs found in middens documented by Jerardino and Marean (2010) include *Perna perna, Choromytilus meridionalis, Donax serra, Scissodesma spengleri, Cymbula oculus, Scutellastra argenvillei, Scutellastra cochlear, Scutellastra longicosta, Scutellastra tabularis, Turbo sarmaticus, Nucella squamosa, Dinoplax gigas, Glycymeris connollyi,* and *Phalium labiatum*. Dutch colonialists in the 17th century defined 'strandlopers' as the local people of the Cape who made their living along the shore while harvesting the many accessible invertebrate resources as a source of high-value protein (Parkington 2018). While the flesh of the molluscs was eaten, the shells served many different uses as tools; for example plates and paint holders, as well as jewellery. Even remnants of rock lobsters, an important fishery resource today, were found in 10 000 year old strandloper middens in the Western Cape (Branch and Branch 2018). Along the Transkei coast, harvesting of shellfish for food has been a practice dating back 1300 years or more with the most abundant and heavily harvested of these shellfish being the Brown Mussel (*Perna perna*). Agro-pastoralist communities that resided along the Transkei coast relied on shellfish-derived protein as a supplement and substitute for animal protein (Hockey *et al.* 1988, Sobekwa 1995).

Traditional netfishing activities extend back to the 1600s, when, after the establishment of a refreshment station by European travellers at the Cape, Dutch-introduced slaves engaged in shore-based fishing to support their livelihoods. Their most important food source was linefish such as Snoek *Thyrsites atun*, Southern Mullet *Liza richardsonii,* Hottentot *Pachymetopon blochii,* White Steenbras *Lithognathus lithognathus,* Galjoen *Dichistius capensis*, and Dusky Kob *Argyrosomus japonicus* (Isaacs 2013). These species were historically caught by handline and beach seine, which are methods still in use today by traditional fishermen (see Chapter 2) for more on traditional fishing methods).

Harvesting of intertidal rocky shore resources for food security is still prominent throughout the eastern parts of the country, while the harvesting of nearshore resources requiring a boat is the most important marine activity in the western region (Clark *et al.* 2002). The reliance on intertidal resources by people in the western region has largely been replaced by the rapid growth of a commercial fisheries sector, whereby traditional subsistence fishers would have transitioned to the use of modern technologies of fishing in a changing society (Clark *et al.* 2002).

A diversity of marine taxa are currently used for medicine, divining sets and regalia worn by traditional healers (Herbert *et al.* 2003). Commonly used marine species include marine shells (e.g. Blotched Nerite *Nerita albicilla*, olive snails *Olivia sp*. and cowries *Cypraea sp*.), other molluscs such as chitons (e.g., *Chiton salihafui* and *Ischnochiton oniscus*), corals (e.g. Organ Pipe coral *Tubipora musica*) and fish (e.g. Sole, Eel, sharks, skates and rays). Helmet and cowrie shells are often used by diviners (iZangoma) during their spiritual practices and the size of the shells is thought to represent the gender of ancestors while those with black spots signify the spirits of grandparents (Sizakele Sibanda pers. comm.). Tentacles of the octopus are used by young men as a love potion in the Bomvana and Pondo groups. Rock lobster livers are used to calm troublesome crying children, while rock lobster eggs mixed with certain herbs are given to cows, ewes and hens to increase their chances of fertility. It is also believed that a diet containing a large proportion of shellfish helps a woman to conceive.

Ensuring sustainable use of traditionally harvested marine species is vital for preserving South African cultural practices. Very little is known about the stock status of shellfish species, other than Abalone *Haliotis midae*. While stock assessments have been attempted for White Mussels *Donax serra*, Whelks *Bullia laevissima*, and Octopus *vulgaris*, a lack of long-term datasets of good quality hampers conclusive stock assessment outcomes. Given our knowledge gaps in invertebrate distribution, stock status, long term abundance datasets and datasets on the use of marine species for traditional use, it is essential that suitable programmes for long-term monitoring of invertebrate harvesting (and other species used for traditional purposes) be implemented to ensure the sustainability of these historically important resources.

9.3.2 Mammals

There are an estimated 128 extant marine mammal species worldwide, but there are about 214 distinct taxa taking subspecies and distinctive races into account (Committee on Taxonomy 2018). An analysis of 120 marine mammal taxa showed that 36% are classified as threatened, 5.8% are near-threatened, 33% are Least Concern and 38% are Data Deficient (Schipper *et al.* 2008). Another analysis (Polidoro *et al.* 2008), based on 134 taxa, showed that 25% were threatened and 35% were Data deficient, and a third analysis (Lascelles *et al.* 2014) found that 15% of 102 taxa were threatened and 42% were Data Deficient. Our **knowledge of marine mammals** is disproportionately poor compared to that of land mammals, and it is estimated that declines in marine mammal species which should otherwise result in at least a Vulnerable IUCN listing, go undetected at least 70% of the time due to difficulty in conducting field-based population surveys (Taylor *et al.* 2007). Globally, major pressures impacting on marine mammals include fishing (direct harvesting and entanglement in fishing gear), boat strikes and pollution (debris, noise pollution) and these are exacerbated by the impacts of climate change (Schipper *et al.* 2008, Davidson *et al.* 2012, Pirotta *et al.* 2019). Spatial analysis of the spread of marine mammal extinction risk across the world's oceans suggests that most high-risk hotspots and most at-risk species occur in coastal areas due to high levels of human impact (Davidson *et al.* 2012, Avila *et al.* 2018).

In South Africa, our understanding of pressures and their impacts on marine mammal species at individual and/or population level is relatively poor. Of the 56 marine mammal taxa that have been assessed for the South African region, 16% are categorised as threatened, 5.3% are Near Threatened, 55% are Least Concern and 23% are Data Deficient (Figure 100). Taxa with the highest extinction risk include a subspecies of the Antarctic Blue Whale (*Balaenoptera musculus intermedia*, Critically Endangered), Sei Whale (*Balaenoptera borealis*, Endangered), Southern Hemisphere Fin Whale (*Balaenoptera physalus*, Endangered) and the Indian Ocean Humpback Dolphin (*Sousa plumbea*, Endangered) (Table 39). The **most important pressures**, in terms of the percentage of species of conservation concern that are impacted (observed and inferred impacts) by each pressure (following the IUCN threat categories), are fishing (68%), habitat alteration as a result of climate change (60%), excess energy in the form of ocean noise (56%), garbage and solid waste through ingestion of or entanglement in marine debris (44%) and transportation in the form of shipping (16%) (Figure 101).

While the **direct harvesting** (commercial and subsistence) of marine mammals is not a direct pressures in South Africa, harvesting is still ongoing in some parts of the world (Robards and Reeves 2011). Due to their life history characteristics, historical harvesting had and continues to have a significant impact on some marine mammal species with many listed under CITES (see Box 38). **Population recovery** has been slow for species such as the Antarctic Blue Whale for example, which was assessed as Critically Endangered for the South African region (Findlay and Child 2016). This species was reduced by whaling to a small fraction of its original population levels. The pre-whaling population of Antarctic Blue Whale is estimated at 239 000 and was reduced to an estimated 360 individuals by 1973 (Branch *et al.* 2004). The population is currently at 0.9% of its pre-exploitation levels with a recovery rate of 7.3% per annum (Findlay and Child 2016). Contrary to the latter trend, Humpback Whale (*Megaptera novaeangliae*) stocks around Africa have shown clear signs of recovery (with exponential population growth) since the end of commercial whaling in 1979 (Findlay *et al.* 2017). The continued recovery of large whale populations in South Africa's coastal waters are likely to result in an increased frequency of interactions between whales and human activities such as fishing, shipping and recreational activities, calling for increased efforts to mitigate potential impacts (Meÿer *et al.* 2011, DEA 2016a).

Impacts of fishing on marine mammals include **incidental bycatch and entanglement** in fishing gear (e.g. trawls, purse-seines, ropes and traps associated with the West Coast Rock Lobster fishery or experimental octopus fishery, KwaZulu-Natal sharknets), illegal killing by fishermen and competition with fisheries for food (Wickens *et al.* 1992, David and Wickens 2003, Meÿer *et al.* 2011). Data collected between 1975 and 2009 showed that Southern Right Whales (*Eubalaena australis*) and Humpback Whales made up 60% and 17% of all recorded whale entanglements between Lambert Bay on the west coast and Sodwana Bay in northern KZN (Meÿer *et al.* 2011). Of particular concern is a small assemblage of Humpback Whale (B2 subpopulation, Vulnerable) that visits the West Coast in spring and summer (Barendse *et al.* 2011). Cape Fur Seals (*Arctocephalus pusillus pusillus*) are commonly entrapped and drowned in trawl fisheries, and are frequently shot and killed by fishermen especially of handline or longline fisheries (Wickens *et al.* 1992, Stewardson 2001, David and Wickens 2003).

The **KwaZulu-Natal (KZN) shark nets** are aimed at reducing bather-shark interactions but at the same time cause entanglement (and sometimes mortality) of a range of marine mammal species such as Humpback Whales, the Southern Right Whale, Minke Whales (*Balaenoptera spp*.), Sperm Whale (*Physeter macrocephalus*) and Bryde's Whale (*Balaenoptera brydei*) (Meÿer *et al.* 2011). Entanglement of Humpback Whales made up 61% of large whale caught in sharknets between 1981 and 2009 with a rate of increase estimated at 15.1% per year for the period 1990 to 2009. Increases in Humpback Whale entanglements were attributed to population recovery and an increase in numbers of this species using the KZN coast as migratory corridor (Meÿer *et al.* 2011). Shark nets have had adverse impacts on the Endangered Indian Ocean Humpback Dolphin. Over 200 individuals were caught in shark nets between 1980 and 2009 (Atkins *et al.* 2013) with evidence of high site fidelity at Richards Bay which accounts for 60% of the shark net bycatch of this species (Atkins *et al.* 2016) (Box 37). Mitigation measures such as the further reduction in shark net extent could assist in reducing entanglements in South African waters. **Marine mammal interactions with fisheries** are inevitable and a national plan of action is needed if detrimental impacts on marine mammals are to be reduced, e.g. through the development of national marine mammal bycatch mitigation policy regulations which set explicit biological allowable catch limits. Increasing entanglement of marine mammals in rock lobster traps is a growing concern with a need for trend analysis and possible innovation in trap design.

Box 37. Conservation status of the Indian Ocean Humpback Dolphin (*Sousa plumbea*)

The impacts of fishing (as incidental bycatch) of Endangered Indian Ocean Humpback Dolphin (*Sousa plumbea*) is exacerbated by shipping, pollution and coastal development due to its shallow water habit (Plön *et al.* 2016). Developments in estuaries and the alteration or loss of rocky shores, both critical habitat for the Indian Ocean Humpback dolphin, affect this species both directly and indirectly (Barros and Cockcroft 1999, Jefferson *et al.* 2009, Plön *et al.* 2011). Recent research has shown that the population size of this species is possibly much smaller (500 individuals) than the 1000 individual population size used during its 2016 IUCN Red List Assessment (Vermeulen *et al.* 2017). The development of a National Biodiversity Management Plan (BMP) aimed at ensuring the long-term survival of the species in South Africa is strongly recommended. National and international collaboration will need to be strengthened to ensure a thorough assessment of the species' conservation status within and beyond the border of South Africa (Vermeulen *et al.* 2017).

Marine noise pollution is a growing concern nationally and internationally. All marine mammals have well-developed auditory systems and can detect a wide range of sounds, often over long distances

(Mooney *et al.* 2012, Reichmuth *et al.* 2013). They rely on sound for most of their fundamental biological and ecological processes; these include navigation, prey location and capture, predator avoidance, breeding and general communication (Gordon *et al.* 2003, Weir and Dolman 2007, Hastings 2008). However, noise pollution from a variety of sources (e.g. naval sonar, hydrocarbon exploration, maritime traffic, coastal and offshore developments) has the ability to mask critical sound signals with potential detrimental effects on marine mammals (Soto *et al.* 2006, Stone and Tasker 2006, Di Iorio and Clark 2009, Miller *et al.* 2009). While effects of **noise pollution** may vary amongst marine mammals, there is consensus on negative impacts of noise pollution on marine mammal behaviour. In South Africa, formal research on the effects of ocean noise on marine mammals is limited, and research on potential impacts on marine mammals in spatially and temporally affected areas is urgently required (Koper and Plön 2012). Regionally, there is evidence to show that Humpback Whales in their breeding grounds off northern Angola, significantly decreased their singing activity with increasing received levels of sound from seismic surveys (Cerchio *et al.* 2014). Singing is critical in male Humpback Whale breeding competitive behaviours, and the masking of song can have population level effect on their breeding success (Cerchio *et al.* 2014, Herman 2017). South Africa, while having a fairly organised marine mammal stranding response network, is still limited by a lack of scientific tools needed to fully investigate potential links between marine mammal mortalities and ocean noise pollution. Current mitigation measures for the impacts of seismic surveys include geographic and temporal restrictions (activity restricted to specific areas or times of year), source-based mitigation (sound containment and improvement or replacement of current equipment used), and operational mitigation (to follow a protocol of operation).

Marine litter, in particular macro-plastic debris affects marine mammals worldwide (Panti *et al.* 2019). Ingestion of and entanglement in debris can cause chronic and acute injuries, and increase pollutant loads, resulting in morbidity and mortality (Baulch and Perry 2012). Entanglement in macro-plastic can result in injury, drowning or strangulation, however ingestion may lead to blockage of the digestive tract, to suffocation and starvation (Laist 1997). Monitoring efforts in South Africa are sparse but ongoing. Stranded dead Cape Fur Seals are dissected and their stomachs checked for plastic in Nelson Mandela Bay. Cape Fur Seals that regularly frequent Alfred Basin, an inner section of the docks of Table Bay Harbour (Shaughnessy and Chapman 1984), are regularly monitored (through site visits) for entanglements, which are removed where possible. Materials associated with the fishing industry contributed the most to entanglements; these included raffia cords (used in the tuna fishery), polypropylene box bands (used for strapping bait boxes) and monofilament fishing lines (DEFF unpublished data). Coastal whales such as migratory baleen whales are exposed to plastic ingestion due to their filter feeding strategy and exacerbated by frequenting areas of high human activity. There have been a number of legislative responses to limit marine pollution e.g. The 1978 Protocol to the International Convention for the Prevention of Pollution from Ships (MARPOL) however enforcement and international cooperation is essential to ensure compliance with legislative and management responses. In light of the fact that land-based pollution usually ends up in the sea, improved awareness, education and community involvement on land is essential to try and reduce plastic pollution.

The **impacts of shipping on marine mammals** are being addressed at an international level by the International Whaling Commission through its Scientific and Conservation Committees (http://iwcoffice.org/sci_com/shipstrikes.htm). There were 39 reported incidents of ships (of various sizes and designs) colliding with whales in South Africa since 2007 (DEFF unpublished data). The

migratory Humpback and Southern Right Whales were the most impacted whale species with 15 and 10 reported incidents respectively (DEFF unpublished data). Though the numbers could be considered too low for conservation concerns; identifying hotspots of whale and shipping interaction will guide appropriate management interventions. Management interventions may include modification of shipping lanes or reducing vessel speed spatially or temporally when approaching areas of high marine mammal abundance. Improved research on the movement and habitat utilization of coastally distributed marine mammals especially is needed to better inform maritime traffic.

Climate change is likely to have wide-ranging impacts on many marine mammal species throughout the world's oceans but these are only beginning to be understood. Climate change may result in alterations in seawater chemistry and physics, including ocean acidification, anoxia, ocean circulation shifts, changes in stratification, and changes in primary productivity which will ultimately impact the reproductive success and survival of marine mammal species (Learmonth *et al.* 2006). Changes in primary productivity with known bottom-up trophic cascades suggests that the impacts of climate change on marine mammals are mediated chiefly by changes in prey distribution and abundance (Simmonds and Isaac 2007). The recovery of Southern Right Whales has slowed with reduced numbers and changes in population structure being reported, including a decline in the number of non-cow or calf pairs observed (Roux *et al.* 2015a). The cause of these changes are not yet understood but can potentially be linked to climatic changes and associated decreased krill abundance in their Southern Ocean feeding grounds (Seyboth *et al.* 2016). While our understanding of the potential impacts of climate change on data-rich species is challenging, this is even more so for Data Deficient species. Inconspicuous offshore species such as pygmy sperm whales (*Kogia breviceps* and *Kogia sima*) (Plön and Relton 2016) and beaked whales (such as *Mesoplodon spp., Indopacetus pacificus and Ziphius cavirostris*) (Relton *et al.* 2016) are anticipated to experience habitat shifts and alteration in the form of range shifts as a result of shifts in their prey base (Learmonth *et al.* 2006). In South Africa, climate driven changes (combined with anthropogenic impacts) have led to an eastward shift in the distribution of key prey species (Sardines *Sardinops sagax* and Anchovy *Engraulis encrasicolus*) in the Benguela Current System (Roy *et al.* 2007, Coetzee *et al.* 2008, Jarre *et al.* 2015b) but the observed impacts of these prey shift are not yet clear and requires long-term research effort. See Chapter 6 for more on climate change.

South Africa has initiated programmes aimed at understanding and mitigating anthropogenic impacts on marine mammals. These include establishment of the South African National **Stranding Network** (SANSN), Seal Entanglement Monitoring (SEM) and the South African **Whale Disentanglement** Network (SAWDN). These efforts have been running for over a decade and are in the process of being incorporated under NEMBA. Reporting of marine mammals in distress has improved since these concerted efforts were initiated. Improved cooperative governance between national government departments and municipalities has resulted in improved response, intervention and marine mammal data collection along the South African coastline. Currently, regions with operational stranding and/or entanglement response teams include the south coast (Mossel Bay, Plettenberg Bay), west coast (Cape Town including False Bay, Yzerfontein/Dassen Island) and east coast (East London, Nelson Mandela Bay, eThekwini). Other areas such as the Northern Cape and areas along the Wild Coast are slowly establishing response teams with guidance from DEFF.

Marine eco-tourism provides livelihoods for coastal communities including supplementing income in fishing communities (Roques *et al.* 2018). Eco-tourism is generally thought to be a non-invasive form of nature-based tourism that has low impact on marine animals if it is ethically managed (Stronza *et*

al. 2019). Globally, published short-term behavioural responses to eco-tourism include changes in surfacing, acoustic, and swimming behaviour and changes in travel direction, group size, and coordination (Garcia-Cegarra *et al.* 2018, IWC 2019). Currently, there are two types of marine mammal based eco-tourism activities conducted in South Africa which include are swim-with-seals and boat-based whale (and dolphin) watching (BBWW) activities. South Africa's BBWW effort is regulated through permitting regulations that are continuously revised as new information surfaces and international norms change as outlined in the International Whaling Commission's (IWC's) Whale Watching Handbook. The BBWW regulations provide eco-tourism operators with clear guidelines on marine mammal interaction protocols; such as distance from where to view, avoiding cow-calf pairs, approach speeds, time spent at an encounter and how to identify stress behaviour (Vinding *et al.* 2015). Swimming-with-seals is not a permitted activity in South Africa but is guided by a clear code of conduct. While the impacts of these activities are thought to be negligible in South Africa, they are poorly studied and understood. Given South Africa's drive to build its oceans economy and to promote non-consumptive tourism activities, ongoing revision of regulations based on updated scientific information is key for ensuring science-based decision making and sustainability.

Box 38. Mammal listing on CITES

CITES currently lists 49 South African marine mammals. Of these 14 are listed under Appendix I and 35 under Appendix II. The majority of these are not currently directly affected by wildlife trade, however, previous commercial hunting of Appendix I species such as Blue Whales (*Balaenoptera musculus*), Indian Humpback Dolphin (*Sousa plumbea*), and Sperm whale (*Physeter macrocephalus*) severely impacted populations in the past, and any commercial trade in these species might threaten populations in the wild. Appendix II species, such as the Heaviside Dolphin (*Cephalorhynchus heavisidii*), Bottlenose Dolphin (*Tursiops aduncus*), and some whale species (*Kogia breviceps*; *Indopacetus pacificus*; and *Globicephala melas* to name a few), are not currently significant within the trade, however previous illegal hunting and current opportunistic hunting/bycatch needs to be monitored in order to assess the impacts on wild populations.



A Bottlenose Dolphin, previously affected by the wildlife trade, travelling in the Amathole MPA.

Table 39. IUCN Red List status of regionally assessed South African marine mammals with year published and associated listing on the South African list of Threatened or Protected Species (TOPS). NE= Near Endemic, E= Endemic, Regional = South Africa, Lesotho and Swaziland. Regional dates given as data of publication; Global dates given as dates of Assessment.

Family	Scientific name	Common name	South African Regional Assessments	Global Assessment	TOPS
Balaenidae	*Eubalaena australis*	Southern Right Whale	Least Concern (2016)	Least Concern (2017)	Not listed
Balaenopteridae	*Balaenoptera acutorostrata subsp.*	Dwarf Minke Whale	Least Concern (2016)	Least Concern (2018)	Not listed
Balaenopteridae	*Balaenoptera bonaerensis*	Antarctic Minke Whale	Least Concern (2016)	Near Threatened (2018)	Not listed
Balaenopteridae	*Balaenoptera borealis*	Sei Whale	Endangered (2016)	Endangered (2018)	Not listed
Balaenopteridae	*Balaenoptera edeni* (inshore subpopulation)	Bryde's Whale (inshore)	Vulnerable (2016)	Least Concern (2017)	Not listed
Balaenopteridae	*Balaenoptera edeni* (offshore form)	Bryde's Whale (offshore)	Data Deficient (2016)	Least Concern (2017)	Not listed
Balaenopteridae	*Balaenoptera musculus brevicauda*	Pygmy Blue Whale	Data Deficient (2016)	Not assessed	Not listed
Balaenopteridae	*Balaenoptera musculus intermedia*	Antarctic Blue Whale	Critically Endangered (2016)	Critically Endangered (2018)	Not listed
Balaenopteridae	*Balaenoptera physalus*	Southern Hemisphere Fin Whale	Endangered (2016)	Vulnerable (2018)	Not listed
Balaenopteridae	*Megaptera novaeangliae*	Humpback Whale	Least Concern (2016)	Least Concern (2018)	Not listed
Balaenopteridae	*Megaptera novaeangliae* (B2 subpopulation) [NE]	Humpback Whale (B2 stock)	Vulnerable (2016)	Not Evaluated	Not listed
Delphinidae	*Cephalorhynchus heavisidii* [NE]	Heaviside's Dolphin	Least Concern (2016)	Near Threatened (2017)	Not listed
Delphinidae	*Delphinus capensis*	Long-beaked Common Dolphin	Least Concern (2016)	Data Deficient (2008)	Not listed
Delphinidae	*Delphinus delphis*	Short-beaked Common Dolphin	Least Concern (2016)	Least Concern (2008)	Not listed
Delphinidae	*Feresa attenuata*	Pygmy Killer Whale	Least Concern (2016)	Least Concern (2017)	Not listed
Delphinidae	*Globicephala macrorhynchus*	Short-finned Pilot Whale	Least Concern (2016)	Least Concern (2017)	Not listed
Delphinidae	*Globicephala melas*	Long-finned Pilot Whale	Least Concern (2016)	Least Concern (2018)	Not listed
Delphinidae	*Grampus griseus*	Risso's Dolphin	Least Concern (2016)	Least Concern (2018)	Not listed
Delphinidae	*Lagenodelphis hosei*	Fraser's Dolphin	Least Concern (2016)	Least Concern (2018)	Not listed
Delphinidae	*Lagenorhynchus cruciger*	Hourglass Dolphin	Least Concern (2016)	Least Concern (2018)	Not listed
Delphinidae	*Lagenorhynchus obscurus*	Dusky Dolphin	Least Concern (2016)	Data Deficient (2018)	Not listed
Delphinidae	*Lissodelphis peronii*	Southern Right Whale Dolphin	Least Concern (2016)	Least Concern (2018)	Not listed
Delphinidae	*Orcinus orca*	Killer Whale	Least Concern (2016)	Data Deficient (2017)	Not listed
Delphinidae	*Peponocephala electra*	Melonheaded Whale	Least Concern (2016)	Least Concern (2008)	Not listed
Delphinidae	*Pseudorca crassidens*	False Killer Whale	Least Concern (2016)	Near Threatened (2018)	Not listed
Delphinidae	*Sousa plumbea*	Indian Humpback Dolphin	Endangered (2016)	Endangered (2015)	Not listed
Delphinidae	*Stenella attenuata*	Pantropical Spotted Dolphin	Least Concern (2016)	Least Concern (2018)	Not listed
Delphinidae	*Stenella coeruleoalba*	Striped Dolphin	Least Concern (2016)	Least Concern (2018)	Not listed
Delphinidae	*Stenella longirostris*	Spinner Dolphin	Least Concern (2016)	Least Concern (2018)	Not listed
Delphinidae	*Tursiops aduncus* (Ifafa-False Bay subpopulation) [E]	Indian Ocean Bottlenose Dolphin	Near Threatened (2016)	Not Evaluated	Not listed
Delphinidae	*Tursiops aduncus* (Ifafa-Kosi Bay subpopulation)	Indian Ocean Bottlenose Dolphin	Vulnerable (2016)	Not Evaluated	Not listed
Delphinidae	*Tursiops aduncus* (seasonal subpopulation)	Indian Ocean Bottlenose Dolphin	Data Deficient (2016)	Not Evaluated	Not listed
Delphinidae	*Tursiops truncatus*	Common Bottlenose Dolphin	Least Concern (2016)	Least Concern (2018)	Not listed

Family	Scientific name	Common name	South African Regional Assessments	Global Assessment	TOPS
Mustelidae	*Aonyx capensis*	Cape Clawless Otter	Near Threatened (2016)	Near Threatened (2014)	Protected
Mustelidae	*Hydrictis maculicollis*	Spotted-necked Otter	Vulnerable (2016)	Near Threatened (2014)	Not listed
Neobalaenidae	*Caperea marginata*	Pygmy Right Whale	Least Concern (2016)	Least Concern (2018)	Not listed
Otariidae	*Arctocephalus gazella*	Antarctic Fur Seal	Least Concern (2016)	Least Concern (2014)	Protected
Otariidae	*Arctocephalus pusillus*	Cape Fur Seal	Least Concern (2016)	Least Concern (2015)	Protected
Otariidae	*Arctocephalus tropicalis*	Subantarctic Fur Seal	Least Concern (2016)	Least Concern (2014)	Protected
Phocidae	*Mirounga leonina*	Southern Elephant Seal	Near Threatened (2016)	Least Concern (2014)	Protected
Physeteridae	*Kogia breviceps*	Pygmy Sperm Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Physeteridae	*Kogia sima*	Dwarf Sperm Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Physeteridae	*Physeter macrocephalus*	Sperm Whale	Vulnerable (2016)	Vulnerable (2008)	Not listed
Ziphiidae	*Berardius arnuxii*	Arnoux's Beaked Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Ziphiidae	*Hyperoodon planifrons*	Southern Bottlenose Whale	Least Concern (2016)	Least Concern (2008)	Not listed
Ziphiidae	*Indopacetus pacificus*	Longman's Beaked Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Ziphiidae	*Mesoplodon densirostris*	Blainville's Beaked Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Ziphiidae	*Mesoplodon grayi*	Gray's Beaked Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Ziphiidae	*Mesoplodon hectori*	Hector's Beaked Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Ziphiidae	*Mesoplodon layardii*	Strap-toothed Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Ziphiidae	*Mesoplodon mirus*	True's Beaked Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Ziphiidae	*Ziphius cavirostris*	Cuvier's Beaked Whale	Data Deficient (2016)	Least Concern (2008)	Not listed
Ziphiidae	*Mesoplodon densirostris*	Blainville's Beaked Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Ziphiidae	*Mesoplodon grayi*	Gray's Beaked Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed
Ziphiidae	*Mesoplodon hectori*	Hector's Beaked Whale	Data Deficient (2016)	Data Deficient (2008)	Not listed

9.3.3 Seabirds

Seabirds are among the most vulnerable groups of marine vertebrates, with populations of 162 of 346 extant global species declining (Paleczny *et al.* 2015). Of the 346, **28% are globally threatened** (Croxall *et al.* 2012). Seabirds are more threatened than all other groups of birds with similar numbers of species: 26% of parrots (Psittacidae: 374 species), 19% of pigeons/doves (Columbidae; 318 species) and 18% of raptors (Accipitridae; 238 species) are threatened. This likely reflects upon their life history strategies, with many seabirds having small clutch sizes relative to other bird species and taking longer to mature. This reduces their capacity to absorb human-induced mortality and slows recovery following cessation of impacts (Croxall *et al.* 2012). Most seabirds, especially open ocean species, have naturally small breeding populations. Demographic characteristics, which severely limit their rate of recovery, and the restricted number and range of their breeding sites make seabirds disproportionately vulnerable to a wide range of pressures (Croxall *et al.* 2012, Wakefield *et al.* 2014).

A total of 72 seabird species have been assessed regionally for South Africa of which **37.5% are considered threatened** (Table 40, Figure 100), including eight (11%) Vulnerable, 15 (21%) Endangered and four (6%) Critically Endangered species (Table 40, Figure 100). A further **18 (25%) were assessed as Near Threatened** (Table 40, Figure 100). Of the species that breed on southern Africa's islands (excluding PEI) and along the mainland coast, seven are regionally endemic (46.7%) as species and two (13.3%) as races. This **high proportion of regional endemism** results from southern Africa's islands being separated by vast distances from seabird breeding localities to the north (in the Atlantic and Indian Oceans) or south (in the Southern Ocean) (Crawford *et al.* 2008a). It also means that southern Africa has the primary responsibility for the conservation of these seabirds. Of the seven seabirds endemic to southern Africa, four are classified as Endangered: Cape Gannet (*Morus capensis*), African Penguin (*Spheniscus demersus*) (see Box 39 and Box 40), Bank Cormorant (*Phalacrocorax neglectus*), Cape Cormorant (*Phalacrocorax capensis*) (Table 40) while the Damera Tern (*Sterna balaenarum*) is listed as Vulnerable (Table 40).

Fishing is the greatest pressure on southern African seabirds, impacting 56% of seabirds of special concern, followed by alien invasive species (49%), problematic native species (33%), climate change (18%) and industrial and military effluent in the form of oil spills (7%) (Figure 101).

Interactions with fishing operations, either through **incidental bycatch or competition for food** resources, is a key pressure on seabirds. Four of the seabirds assessed as Endangered compete with South Africa's fisheries for food (Crawford *et al.* 2014): African Penguins, Cape Gannets and Cape Cormorants for Sardines (*Sardinops sagax*) and Anchovies (*Engraulis encrasicolus*), and Bank Cormorants for Rock Lobsters (*Jasus lalandii*) (Cooper 1985, Sherley *et al.* 2012, Crawford *et al.* 2015). Populations of seabirds have recently shown significant decreases, particularly off South Africa's west coast. The population numbers of Endangered African Penguins for example is currently at 2.5% of what the population was 80 years ago, having had 1 million breeding pairs in the 1920s, 25000 pairs in 2009 and 15000 in 2018 (DEA unpublished data) (see Box 40). Demersal and pelagic longline fishing are key contributors to mortality of albatrosses, petrels, shearwaters and Cape Gannets through accidental capture (bycatch and/or entanglement in fishing gear), with an estimated mortality of 2851 individuals (450 per year) of 14 species for the period 2006 to 2013 (Rollinson *et al.* 2017). White-Chinned Petrel (*Procellaria aequinoctialis*) has been the most frequently killed species (66%), followed by shy Albatrosses (*Thalassarche cauta/steadi*) (21%), Black-Browed albatross *T. melanophris* (7%),

Indian and Atlantic Yellow-Nosed Albatross *T. carteri* (3%) and Cape Gannet (2%) (Rollinson *et al.* 2017). All these species are all listed as Vulnerable or Endangered (Table 40).

South Africa has implemented several **bycatch mitigation strategies**, including setting lines at night, bird scaring devices (tori lines), weighting of fishing lines, limiting lighting on deck at night and requiring offal discard on the opposite side of the deck from hauling (Cooper and Ryan 2004, Domingo *et al.* 2017). The use of bird scaring lines in the demersal hake trawl fishery, has reduced seabird mortality by 90%, and has proven to have a significant impact on reducing albatross mortality, which has seen a 99 % reduction in bycatch mortality (Taylor and Peacock 2018). Since 2000, South Africa has been deploying independent fisheries observers in order to collect data on bycatch and fishing practices among other things (Petersen *et al.* 2008a). While initially this was effective at reducing seabird bycatch and increased compliance with regulations, observer coverage has not been consistent across fisheries (Petersen *et al.* 2007, Rollinson *et al.* 2017). There is greater compliance by international ships, with 100% observer coverage, than South African flagged vessels, which only had 6% of its fishing effort observed and required independent fisheries observer programmes (Rollinson *et al.* 2017).

Mice (*Mus musculus*) were accidentally introduced to Marion Island in the 1800 and due to insufficient control mechanisms, have become the dominant **invasive species** at South Africa's sub-Antarctic territory (Prince Edward Islands) (McClelland *et al.* 2018), predating on Petrel and Albatross chicks and eggs (Dilley *et al.* 2016a, 2016b). The mouse population at Marion Island has is estimated to have increased by 430% between 1979 and 2011 (McClelland *et al.* 2018) with an estimated 9% mortality (of the birds attacked) in surface breeding birds and up to 100% mortality in burrowing seabirds (Dilley *et al.* 2016a, 2016b, 2018). Since 2015, there has been a marked increase in the frequency of mice attacking surface-breeding seabird chicks (Dilley *et al.* 2016a) and if invertebrate biomass continues to decline, the impact of mouse predation on Marion's seabird chicks is likely to become even more serious (Preston *et al.* 2019). The Department of Environment Forestry and Fisheries, spearheaded by its Working for Water Programme, are planning to mount an eradication attempt on Marion Island in austral winter of 2021 in a bid to safeguard Marion's globally important seabird population (Preston *et al.* 2019). When completed, this will be the largest island-wide eradication of rodents in the world. For more detail visit (www.mousefreemarion.org.za).

Problematic native species interact with seabird populations, both those nesting on South Africa's mainland and islands. Cape Fur Seals (*Arctocephalus pusillus*) compete with seabirds for space and food resources and feed on certain birds both on land and at sea, having significant population level impacts (Crawford *et al.* 1989, Makhado *et al.* 2006, 2013, Weller *et al.* 2016). Great White Pelicans (*Pelecanus onocrotalus*) have been observed preying on chicks of several seabirds and had a significant impact on the breeding success of Kelp Gulls (*Larus dominicanus vetula*), Crowned Cormorants (*Microcarbo coronatus*), Cape Cormorants and Bank Cormorants (de Ponte Machado 2007, Mwema *et al.* 2010). Kelp Gulls are predators of eggs and small chicks of African Penguins (Van Heezik and Seddon 1990, du Toit *et al.* 2003), Bank Cormorants (du Toit *et al.* 2003), Cape Cormorants (Voorbergen *et al.* 2012, Makhado *et al.* 2013) and Crowned Cormorants (du Toit *et al.* 2003). Birds breeding on offshore islands have an advantage over those breeding on the mainland as they are not preyed upon by naturally occurring mainland predators such mongooses, Leopards (*Panthera pardus*) and Caracal (*Caracal caracal*) (Crawford *et al.* 2017).

Box 39. The threat status of Cape Gannet (*Morus capensis*)

By Azwianewi Makhado, Rob Crawford and Richard Sherley

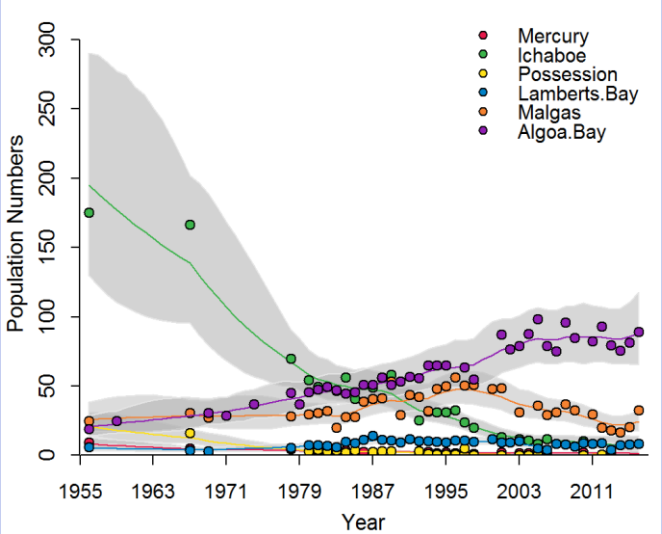
Africa's only gannet, the Cape Gannet, is endemic to southern Africa. Cape Gannets breed at three localities in South Africa: Bird Island (Lambert's Bay) and Malgas Island on the west coast and Bird Island in Algoa Bay on the south coast. They also breed on three islands in Namibia - Mercury, Ichaboe and Possession Islands. The Cape Gannet colony at Lambert's Bay attracts substantial numbers of tourists and supports the local economy (Saul and Fortuin 2015). The colony at Lamberts Bay (Bird Island) was deserted in 2005 following encroachment by seals but efforts by the local community, the Department of Environmental Affairs and CapeNature through the deployment of Gannet decoys, saw the return of Gannets in the next breeding season.



Cape Gannet taking flight at Malgas Island

IUCN status:
2015 National Assessment: Vulnerable
2018 Global Assessment: Endangered

Population trend: The overall population decreased from about 250 000 pairs in the 1950s and 1960s to approximately 130 000 in 2018. This was primarily a result of a decrease of >90% of Namibia's population following the collapse of Namibia's Sardine resource in the 1970s. Namibia held approximately 80% of the global Gannet population in 1956. Numbers in South Africa increased since 1956 with SA now holding >90% of the global population. Recently numbers have decreased in the Western Cape but increased in Algoa Bay (Eastern Cape) mirroring the southward and eastward shift of mature Sardine and Anchovy off South Africa. Algoa Bay currently holds approximately 75% of the South African Gannet population (Sherley *et al.* 2019 in press). Following these declines, the species was officially assessed as ***Endangered*** on the IUCN Red List in 2018 (BirdLife International 2018a). However, a recent assessment of the conservation status of this species has suggested a global listing of Vulnerable, based on a new methodology and a revise generation length (Sherley *et al.* 2019 in press).



Bayesian state-space model estimates (coloured lines) and 95% credible intervals (grey polygons) of the number of Cape Gannet breeding pairs at the six extant colonies, 1956–2018. See Box 33 for more on Bayesian state-space models.

Priority Actions: In order to improve the conservation status of Cape Gannets it will be necessary to maintain the current adult survival rates while at the same time increasing recruitment. The major pressures limiting adult survival include mortality caused by fisheries, seal predation, oiling and outbreaks of disease, which can be countered by implementing best practice by-catch mitigation, marine spatial planning that minimises the risk of oil spills near colonies (where Gannets have their highest densities) and by implementing standard protocols to reduce the possibility of pathogens spreading, e.g. rapid disposal of carcases (Khomenko *et al.* 2018).

Disease is a major ecological force that has the potential to cause significant effects especially to threatened populations of seabirds (Friend *et al.* 2001, Heard *et al.* 2013). If a species is negatively affected by a major pressure other than disease, that species is more likely to be simultaneously threatened by disease (Heard *et al.* 2013). While a single **disease outbreak** could decimate a population, the true cost of disease may be associated with chronic attrition of the population (Friend *et al.* 2001) and thereby influence metabolic rate, life history traits and social status (Barbosa and Palacios 2009). For example, outbreaks of avian cholera on Dyer Island caused large mortality (about 9733 adults and 4794 juveniles) of Cape Cormorants between 2004 and 2005 (Waller and Underhill 2007). An outbreak on Avian flu caused mortality of about 5000 swift terns, ~1600 Cape gannets, ~100 African penguins and about 250 common Terns (*Sterna hirundo*) (Khomenko *et al.* 2018). Modern conservation efforts can be enhanced by the availability of comprehensive health assessment data at a population level (Karesh and Cook 1995). Therefore, health assessments and the compilation of baseline data on the presence of parasites and potential pathogens fill a critical data gap, particularly for endangered species.

Climate change will undoubtedly have profound long-term effects on seabirds, not only through impacts on productivity regimes and food webs, but also through the spread and introduction of new diseases and toxic poisoning (Shumway *et al.* 2003). Abundances of several marine bird species are correlated with environmental variability, including El Nino conditions, which may reduce prey availability (Barbraud and Weimerskirch 2001, Le Bohec *et al.* 2008, Rolland *et al.* 2010, Baylis *et al.* 2012). Global climate change has been associated with change in environmental conditions, which caused an eastward shift in distributions of pelagic forage fish species, and thereby reducing their availability for both seabirds and the small pelagic fishery (Coetzee *et al.* 2008, Pichegru *et al.* 2009, Doney *et al.* 2012). Climate change may result in heat stress in several seabird species including Bank Cormorants, Cape Gannets and African Penguins leading to death or nest abandonment (Ward and Williams 2004, Crawford *et al.* 2017). Increased storms and flooding can result in the abandonment of nests, eggs being washed away, and chicks drowning (Sherley *et al.* 2012). See Chapter 6 for further detail on climate change.

Despite, the rarity of **large oil spills**, they remain a major contributor to seabird declines, as oil results in several negative physiological effects and impacts seabird breeding success. One of the solutions to oil spills is rapid direct human intervention as was observed during the oil spill of the bulk carrier 'Treasure', which sank in June 2000 off the Western Cape coast between two islands (Dassen and Robben) that housed large colonies of African Penguins. This spill resulted in 20% of the penguin population being oiled, however, only about 2000 penguins died as approximately 38 500 oiled and unoiled penguins were rescued, cleaned and relocated (Crawford *et al.* 2000). Rapid human intervention is however difficult for other seabird species such as cormorants, gulls, terns and shorebirds (Crawford *et al.* 2000). Smaller oil spills occur on an ongoing basis and cause ongoing substantial damage to penguin populations (Wolfaardt *et al.* 2009).

Concerted effort at the regional and global scale is needed to reduce the pressures on seabirds to mitigate any future population declines (Trathan *et al.* 2015). A major challenge is understanding the impacts of multiple pressures at the community or ecosystem scale. A **precautionary management** approach based on the most up-to-date scientific data is required for decision making (Trathan *et al.* 2015). Although, very little can be done to mitigate the impacts of climate change; habitat degradation, pollution, and fishing can all be managed at appropriate spatial and temporal scales.

While seabird conservation efforts have been successful in reducing mortality of some species, for example, banning some direct exploitation (Hasegawa and DeGange 1982), eradicating selected introduced predators (Muller *et al.* 2000, Bester *et al.* 2002, Jones and Kress 2012) and reducing entanglement in fishing gear for certain populations (Anderson *et al.* 2011), these efforts are evidently not sufficient to halt or reverse large-scale seabird declines. The impacts of emerging pressures, notably increased **seismic activities** (Pichegru *et al.* 2017), **plastic pollution** and **vessel traffic** are poorly understood and quantified. Ecosystem-based management should implement forage thresholds (Cury *et al.* 2011, Crawford *et al.* 2019), marine spatial planning (Distiller *et al.* 2012) and Marine Protected Area expansion (Kelleher 1999) to ensure sufficient seabird food availability (Sherley *et al.* 2015, 2017). The expansion of biodiversity management planning to include other TOPS seabirds (currently only African Penguin Biodiversity Management Plan is in place) is advocated to ensure the achievement of favorable conservation status for seabirds in South Africa taking into consideration ecological, cultural and socio-economic objectives.

The most important and urgent **actions recommended** to secure conservation of seabirds in South Africa is to prioritise threatened seabirds in the implementation of Marine Spatial Planning, in fisheries management and in environmental authorizations. Seabird scientists recommend the following specific considerations:

a. limitations on purse-seine (and in some instances rock lobster) fishing within 20 km of the ten most important seabird breeding localities (Lambert's Bay, Malgas Island, Dassen Island, Robben Island, Boulders, Stony Point, Dyer Island, St Croix Island and Bird Island in Algoa Bay), and

b. limitations on shipping and bunkering within a 10 km radius of important breeding colonies, and restricting seismic activities within important foraging grounds.

In addition it is advised that additional breeding habitat be provided for Bank Cormorants and other seabird species at selected localities. To improve the status of the African Penguin, the establishment of new breeding colonies and release of captive-bred chicks to the wild is needed.

Table 40. IUCN Red List status of regionally assessed South African seabirds with year assessed and associated listing on the South African list of Threatened or Protected Species (TOPS). BR= Breeding in SA, BR (PEI) = Breeding on PEI, RE= Regional Endemic. Regional= South Africa, Swaziland and Lesotho. Regional dates given as data of publication; Global dates given as dates of Assessment.

Family	Scientific Name	Full Name	South Africa's Regional Assessment	Global Status from IUCN Red List	TOPS
Chionidae	*Chionis minor*	Lesser Sheathbill	Near Threatened (2015)	Least Concern (2016)	Vulnerable
Diomedeidae	*Phoebetria fusca* BR (PEI)	Sooty Albatross	Endangered (2015)	Endangered (2018)	Endangered
Diomedeidae	*Phoebetria palpebrate* BR (PEI)	Light-mantled Sooty Albatross	Near Threatened (2015)	Near Threatened (2018)	Vulnerable
Diomedeidae	*Thalassarche carteri* BR (PEI)	Indian Yellow-nosed Albatross	Endangered (2015)	Endangered (2018)	Endangered
Diomedeidae	*Thalassarche cauta*	Shy Albatross	Near Threatened (2015)	Near Threatened (2018)	Not listed
Diomedeidae	*Thalassarche chlororhynchos*	Atlantic Yellow-nosed Albatross	Endangered (2015)	Endangered (2018)	Not listed
Diomedeidae	*Thalassarche chrysostoma* BR (PEI)	Grey-headed Albatross	Endangered (2015)	Endangered (2018)	Vulnerable
Diomedeidae	*Thalassarche melanophris*	Black-browed Albatross	Endangered (2015)	Least Concern (2018)	Not listed
Haematopodidae	*Haematopus moquini* RE,BR	African Black Oystercatcher	Least Concern (2015)	Least Concern (2017)	Protected
Hydrobatidae	*Hydrobates pelagicus*	European Storm Petrel	Least Concern (2015)	Least Concern (2018)	Not listed
Hydrobatidae	*Hydrobates leucorhous* BR	Leach's Storm Petrel	Critically Endangered (2015)	Vulnerable (2018)	Critically Endangered
Laridae	*Chlidonias hybrida*	Whiskered Tern	Least Concern (2015)	Least Concern (2016)	Not listed
Laridae	*Chlidonias leucopterus*	White-winged Tern	Least Concern (2015)	Least Concern (2016)	Not listed
Laridae	*Chroicocephalus cirrocephalus* BR	Grey-headed Gull	Least Concern (2015)	Least Concern (2018)	Not listed
Laridae	*Chroicocephalus hartlaubii* RE,BR	Hartlaub's Gull	Least Concern (2018)	Least Concern (2018)	Protected
Laridae	*Larus dominicanus* BR	Kelp Gull	Least Concern (2015)	Least Concern (2018)	Not listed
Laridae	*Sternula albifrons*	Little Tern	Least Concern (2015)	Least Concern (2018)	Not listed
Laridae	*Sternula balaenarum* RE,BR	Damara Tern	Vulnerable (2018)	Vulnerable (2018)	Critically Endangered
Laridae	*Hydroprogne caspia* BR	Caspian Tern	Vulnerable (2015)	Least Concern (2018)	Vulnerable
Laridae	*Sterna dougallii* BR	Roseate Tern	Endangered (2015)	Least Concern (2018)	Endangered
Laridae	*Sterna hirundo*	Common Tern	Least Concern (2015)	Least Concern (2018)	Not listed
Laridae	*Sterna paradisaea*	Arctic Tern	Least Concern (2015)	Least Concern (2018)	Not listed
Laridae	*Sterna virgata* BR (PEI)	Kerguelen Tern	Endangered (2015)	Near Threatened (2018)	Endangered
Laridae	*Sterna vittata* BR (PEI)	Antarctic Tern	Endangered (2015)	Least Concern (2018)	Vulnerable
Laridae	*Thalasseus bengalensis*	Lesser Crested Tern	Least Concern (2015)	Least Concern (2018)	Not listed
Laridae	*Thalasseus bergii* BR	Swift Tern	Least Concern (2015)	Least Concern (2018)	Protected
Laridae	*Thalasseus sandvicensis*	Sandwich Tern	Least Concern (2015)	Least Concern (2018)	Not listed
Laridae	*Xema sabini*	Sabine's Gull	Least Concern (2015)	Least Concern (2018)	Not listed
Oceanitidae	*Fregetta tropica* BR (PEI)	Black-bellied Storm Petrel	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Oceanitidae	*Garrodia nereis*	Grey-backed Storm Petrel	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Oceanitidae	*Oceanites oceanicus*	Wilson's Storm Petrel	Least Concern (2015)	Least Concern (2018)	Not listed
Pelecanidae	*Pelecanus onocrotalus* BR	Great White Pelican	Vulnerable (2015)	Least Concern (2018)	Vulnerable

Family	Scientific Name	Full Name	South Africa's Regional Assessment	Global Status from IUCN Red List	TOPS
Phalacrocoracidae	*Phalacrocorax capensis* RE,BR	Cape Cormorant	Endangered (2018)	Endangered (2018)	Endangered
Phalacrocoracidae	*Microcarbo coronatus* RE,BR	Crowned Cormorant	Near Threatened (2018)	Near Threatened (2018)	Protected
Phalacrocoracidae	*Leucocarbo atriceps* BR (PEI)	Crozet Shag	Critically Endangered (2015)	Least Concern (2018)	Critically Endangered
Phalacrocoracidae	*Phalacrocorax neglectus* RE,BR	Bank Cormorant	Endangered (2018)	Endangered (2018)	Endangered
Phalacrocoracidae	*Phalacrocorax (carbo) lucidus* RE,BR	White-breasted Cormorant	Least Concern (2015)	Least Concern (2018)	Not listed
Procellariidae	*Calonectris borealis*	Cory's Shearwater	Least Concern (2015)	Least Concern (2018)	Not listed
Procellariidae	*Daption capense*	Cape Petrel	Least Concern (2015)	Least Concern (2018)	Not listed
Procellariidae	*Diomedea dabbenena*	Tristan Albatross	Critically Endangered (2015)	Critically Endangered (2018)	Not listed
Procellariidae	*Diomedea epomophora*	Southern Royal Albatross	Vulnerable (2015)	Vulnerable (2018)	Vulnerable
Procellariidae	*Diomedea exulans* BR (PEI)	Wandering Albatross	Vulnerable (2015)	Vulnerable (2018)	Vulnerable
Procellariidae	*Diomedea sanfordi*	Northern Royal Albatross	Endangered (2015)	Endangered (2018)	Not listed
Procellariidae	*Fulmarus glacialoides*	Southern Fulmar	Least Concern (2015)	Least Concern (2018)	Not listed
Procellariidae	*Halobaena caerulea* BR (PEI)	Blue Petrel	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Procellariidae	*Aphrodroma brevirostris* BR (PEI)	Kerguelen Petrel	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Procellariidae	*Macronectes giganteus* BR (PEI)	Southern Giant Petrel	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Procellariidae	*Macronectes halli* BR (PEI)	Northern Giant Petrel	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Procellariidae	*Pachyptila desolata*	Antarctic Prion	Least Concern (2015)	Least Concern (2018)	Not listed
Procellariidae	*Pachyptila salvini* BR (PEI)	Salvin's Prion	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Procellariidae	*Pachyptila turtur*	Fairy Prion	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Procellariidae	*Pachyptila vittata*	Broad-billed Prion	Least Concern (2015)	Least Concern (2018)	Not listed
Procellariidae	*Pelecanoides georgicus*	South Georgian Diving Petrel	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Procellariidae	*Pelecanoides urinatrix*	Common Diving Petrel	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Procellariidae	*Procellaria aequinoctialis* BR (PEI)	White-chinned Petrel	Vulnerable (2015)	Vulnerable (2018)	Vulnerable
Procellariidae	*Procellaria cinerea* BR (PEI)	Grey Petrel	Vulnerable (2015)	Near Threatened (2018)	Vulnerable
Procellariidae	*Procellaria conspicillata*	Spectacled Petrel	Vulnerable (2015)	Vulnerable (2018)	Not listed
Procellariidae	*Pterodroma macroptera* BR (PEI)	Great-winged Petrel	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Procellariidae	*Pterodroma mollis* BR (PEI)	Soft-plumaged Petrel	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Procellariidae	*Puffinus assimilis*	Little Shearwater	Least Concern (2015)	Least Concern (2018)	Not listed
Procellariidae	*Ardenna carneipes*	Flesh-footed Shearwater	Least Concern (2015)	Near Threatened (2018)	Not listed
Procellariidae	*Ardenna gravis*	Great Shearwater	Least Concern (2015)	Least Concern (2018)	Not listed
Procellariidae	*Ardenna grisea*	Sooty Shearwater	Near Threatened (2015)	Near Threatened (2018)	Not listed
Procellariidae	*Puffinus puffinus*	Manx Shearwater	Least Concern (2015)	Least Concern (2018)	Not listed
Spheniscidae	*Aptenodytes patagonicus* BR (PEI)	King Penguin	Near Threatened (2015)	Least Concern (2018)	Vulnerable
Spheniscidae	*Eudyptes chrysocome* BR (PEI)	Southern Rockhopper Penguin	Endangered (2015)	Vulnerable (2018)	Endangered
Spheniscidae	*Eudyptes chrysolophus* BR (PEI)	Macaroni Penguin	Vulnerable (2015)	Vulnerable (2018)	Vulnerable

Family	Scientific Name	Full Name	South Africa's Regional Assessment	Global Status from IUCN Red List	TOPS
Spheniscidae	*Pygoscelis antarcticus*	Chinstrap Penguin	Least Concern (2015)	Least Concern (2018)	Not listed
Spheniscidae	*Pygoscelis papua* [BR (PEI)]	Gentoo Penguin	Endangered (2015)	Least Concern (2018)	Endangered
Spheniscidae	*Spheniscus demersus* [RE,BR]	African Penguin	Endangered (2018)	Endangered (2018)	Endangered
Stercorariidae	*Catharacta Antarctica* [BR(PEI)]	Subantarctic Skua	Endangered (2015)	Least Concern (2018)	Vulnerable
Stercorariidae	*Stercorarius longicaudus*	Long-tailed Jaeger	Least Concern (2015)	Least Concern (2018)	Not listed
Stercorariidae	*Stercorarius parasiticus*	Parasitic Jaeger	Least Concern (2015)	Least Concern (2018)	Not listed
Stercorariidae	*Stercorarius pomarinus*	Pomarine Jaeger	Least Concern (2015)	Least Concern (2018)	Not listed
Sulidae	*Morus capensis* [RE,BR]	Cape Gannet	Endangered (2018)	Endangered (2018)	Vulnerable

Note: IUCN Red List Assessments that assess the entire global population were adopted for regional endemics as these are all near endemic species. Damara Tern= Breeding population South Africa, Namibia, Angola; African Penguin, Bank Cormorant, Cape Gannet, Crowned Cormorant and Hartlaubs Gull, breeding populations occur in South Africa and Namibia. Cape Cormorant breeding populations occur in South Africa, Namibia, Angola and Mozambique.

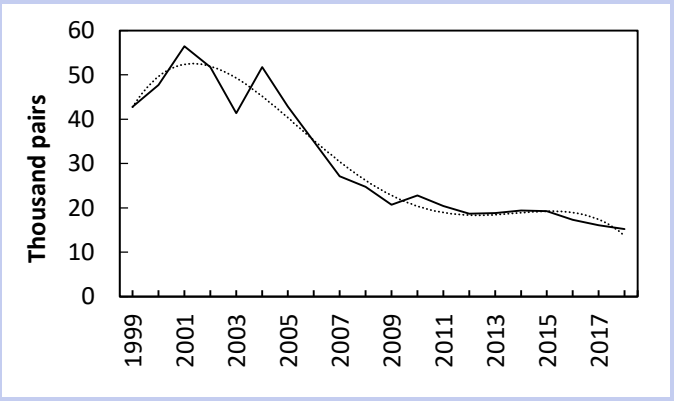
Box 40. Threatened status of the African penguin (*Spheniscus demersus*)

By Katrin Ludynia, Lauren Waller and Azwianewi Makhado

The African Penguin is endemic to southern Africa where it breeds at 28 localities in Namibia and South Africa (Crawford *et al.* 2013a) with occurrences recorded as far north as Gabon and Mozambique (Crawford *et al.* 2013a). The Namibian population declined from 12 162 pairs in 1978 (Shelton *et al.* 1984) to ~5,800 pairs in 2015 (Simmons *et al.* 2015) while the South African population decreased from ~70,000 pairs in 1978/79 (Shelton *et al.* 1984) to ~50 000 pairs in 2002. The latest population estimate for South Africa was 15 200 breeding pairs in 2018 (DEFF unpubl. data). This species was therefore listed as ***Endangered*** both in the southern African region due to ongoing population decline of more than 50% (BirdLife International 2018b) over the three most recent generations. This trend currently shows no sign of reversing, and immediate conservation action is required to prevent further declines (BirdLife International 2018b).



An African Penguin emerges from the water at the Betty's Bay penguin colony.



Trends in the national African Penguin population, 1999-2018. DEFF Unpublished data

Historical egg collection and guano scraping, together with the associated habitat degradation and disturbance were key drivers of this decline in the early 19th century (Frost *et al.* 1976, Shannon and Crawford 1999). Currently, the main driver of the population decline is thought to be a lack of food due to industrial fishing and ecosystem changes driven by climate change (Crawford *et al.* 2011). Further contributing factors are marine pollution (in particular oil spills and chronic oiling (Weller *et al.* 2016) but also predation, marine plastic pollution, habitat destruction, disturbance and diseases (DEA 2013b).

In an effort to halt the ongoing decline of the African penguin, in2013 the South African government gazetted a Biodiversity Management Plan (BMP) for the African Penguin in terms of the National Environmental Management: Biodiversity Act (No. 10 of 2004) and Threatened or Protected Marine Species (TOPS) Regulations, 2017 (Government Notice No. 40876 of 30 May 2017) . This 5 year plan identified all known pressures on African Penguins and actions to mitigate impacts and facilitate the down listing of the species in terms of its status on the IUCN Red List.

Priority actions include implementing recommendations from marine spatial planning tools and localized fishing closures around breeding colonies. Reducing adult mortality from oiling and predation events is also critical in ensuring reproductively active adults continue to breed. Habitat restoration through nest boxes and other restoration activities, rehabilitation of all oiled, injured and diseased individuals, hand-rearing of abandoned chicks and the establishment of a new breeding colony located closer to the main food sources (mainly Sardines and Anchovy) are important conservation actions to reduce mortality, promote recruitment into the population and improve breeding success.

Increased research efforts to better understand survival and recruitment (using subcutaneous transponders), breeding success, foraging of adult Penguins during breeding, pre- and post-moult and juvenile dispersal are critical to assess the effectiveness of conservation actions. Furthermore, studies highlighting the socio and economic benefit of Penguins to the South African economy and their value as an environmental asset to the public are critical to facilitate further decision making. The success of conservation measures for improving the plight of the African penguin, will rely on the ongoing cooperation between National, Provincial and Local governments, NGO's and other interested and affected stakeholders.

9.3.4 Linefish

Linefish is a collective term used to refer to multiple unrelated **bony and cartilaginous fish species** (marine and estuarine), caught by multiple users mainly by means of hook and line (excluding long-line) (Mann 2013b). Linefish are primarily caught within the South African linefishery but are also caught in other fisheries, including commercial demersal- and pelagic-trawl, trek-net and demersal and pelagic long-line, either as bycatch, incidental bycatch or target species. The linefishery is comprised of three major sectors namely the traditional commercial linefishery, the small-scale commercial linefishery (which includes subsistence fishing) and the recreational linefishery (see Chapter 4). South Africa has approximately 250 linefish species (Mann 2013b) which make up approximately 10% of our marine fish diversity (Attwood *et al.* 2013). Many of our linefish species were historically overexploited or collapsed and in 2000 a State of Emergency was declared to enable a substantial reduction in commercial fishing effort (~70%) (Mann 2013b). At the same time a Linefish Management Protocol was developed and implemented (Griffiths *et al.* 1999) to guide the management of stocks according to biological reference points largely based on per-recruit stock assessment methods (see Box 31 for more detail). Subsequently methods of conducting linefish stock assessments have improved substantially using standardised long-term CPUE data sets and age-structured production models (Winker *et al.* 2013).

Since the cut in commercial fishing effort between 2003 and 2006, the populations of a number of important commercial target species have shown a **positive response** (e.g. Carpenter, Hottentot, Slinger and Santer). Nomadic, fast-growing species such as Snoek and Yellowtail, which sustain over 70% of the total commercial linefish catch, are fortunately still Optimally Exploited. However, other linefish species with more vulnerable life history characteristics (e.g. slow growth, late maturity, residency, forming predictable spawning aggregations, estuarine dependency, etc.) have shown less evidence of recovery and many remain in an **Overexploited or Collapsed state**. National IUCN Red List assessments for linefish have been limited and species selection for assessments has largely been informed by the perceived threat status of those species. In this assessment, 147 linefish species were assessed using the IUCN Red List criteria. The family Sparidae (seabreams), containing 42 species with South African distribution (of which 15 are endemic to South Africa) were assessed comprehensively at the global scale, while a subset of 79 bony and 26 cartilaginous linefish were assessed at the national scale.

Bony linefish (including seabreams)

Many important linefish stocks such as Silver Kob (*Argyrosomus inodorus*) and Geelbek (*Atractoscion aequidens*) still remain Overexploited due to the cumulative impact of the linefishery and the commercial inshore-trawl fishery (Boyd 2017, Winker *et al.* 2017b). Recent assessments of stock abundance of **inshore linefish species** along the Eastern Cape coast indicated that Bronze Bream (*Pachymetopon grande*) and Stone Bream (*Neoscorpis lithophilus*) are Optimally Exploited; Blacktail (*Diplodus sargus capensis*) and Zebra (*Diplodus hottentotus*) are Overexploited; Spotted Grunter (*Pomadasys commersonnii*) and Shad (*Pomatomus saltatrix*) stocks have Collapsed while Dusky Kob (*Argyrosomus japonicus*) is in a critical condition with SB/R at <5% of pristine (Winker *et al.* 2015) (see Box 43). Recovery of linefish species stocks such as **Spotted Grunter** and **Dusky Kob** will be crucial for the emerging small-scale commercial fishing sector, 85% of whose fishers primarily harvest linefish to sustain their livelihoods (Hara *et al.* 2008). Iconic endemic seabreams such as **Seventy-four**

(*Polysteganus undulosus*), Red Steenbras (*Petrus rupestris*) and Dageraad (*Chrysoblephus cristiceps*) are considered to be in a critical condition and catch trends have not yet showed recovery since the linefish "State of Emergency" in 2000 (Mann 2007, Parker *et al.* 2016, Kerwath *et al.* 2019). Despite progressively stricter management regulation since 2000, the **Dageraad** (*Chrysoblephus cristiceps*) population in South Africa is now in a critical state of collapse (Parker *et al.* 2016). Recently, an analysis was conducted to standardize the probability of capturing Dageraad along the South African coast (Winker *et al.* 2014, Parker *et al.* 2016). The probability of capture approach is widely used for rare species and is considered to be more defendable than catch rates because the probability approach is less sensitive to management regulations such as catch restrictions by bag limits (Parker *et al.* 2016, Kerwath *et al.* 2019). The trends for the period 1985-2010, indicate an overall contraction in the distribution range of Dageraad over time and show that the capture probability of Dageraad declined from 8% in 1985 to less than 0.1% in 2011 between Cape Point and Tsitsikamma, and from 24% to less than 0.1% along the Eastern Cape and KwaZulu-Natal coast, corresponding to declines of more than 95% across its South African range. A recent study found that annual commercial catches of **Red Steenbras** (*Petrus rupestris*) had declined by 96.9% in the southwest (Cape Point to Tsitsikamma) and by 96.4% in the east (Tsitsikamma to Durban) of South Africa over the period 1985-2011 (Kerwath *et al.* 2019). This declining trend coincided with a reduction in the standardized probability of encounter of 96% in the southwest and 44% in the east (Kerwath *et al.* 2019). Monitoring data indicates that the distribution of Red Steenbras has been greatly reduced and they are now only found in the core area of their historical distribution range (Kerwath *et al.* 2019).

Effective science-based management has supported **recovery** of some linefish species, such as Carpenter (Winker *et al.* 2017a), Hottentot (Kerwath *et al.* 2017a), Slinger (Maggs *et al.* 2017b) and Santer (Maggs *et al.* 2017a) demonstrating that marine fish species can recover if managed effectively. For linefish, it is recommended that stock status assessments are conducted at intervals equivalent to half of each species' maximum lifespan (DAFF 2010). While many species have not yet been assessed, many that have are due for an update. Important linefish species such as Squaretail Kob (*Argyrosomus thorpei*), Yellowbelly Rockcod (*Epinephelus marginatus*) and Galjoen (*Dichistius capensis*) have not had stock assessments done since 1993 (Fennessy 1994a), 1996 (Fennessy 2000a) and 2003 (Attwood 2003) respectively (Table 38). Many species with **outdated stock assessments** are listed as threatened on the IUCN Red List, for example Yellowbelly Rockcod (Vulnerable), White Steenbras (last stock assessment done in 1993 and listed as Endangered), Riverbream *Acanthopagrus vagus* (last stock assessment done in 2001 and listed as Vulnerable) (Table 41, Table 42). Updated stock assessments and long-term abundance datasets play a crucial role in effective species management but also form a critical component of conducting scientifically defensible IUCN Red List assessments.

Stock status is generally mirrored by **IUCN Red List threat status** as assessments are often based on the same data. Approximately 20% of 121 commercially important bony fishes (subsample of 79 bony fish and 42 seabreams) are threatened while 34% are Data Deficient (Figure 100, Table 41, Table 42). Of the 42 seabreams, 15 species are endemic to South Africa while 14 species are endemic to southern Africa (Figure 100, Table 42). Seabreams are known for their complicated life-history traits with most species being slow growing, late maturing, long-lived, sex-changing and often highly resident with some having a level of estuarine dependency. These attributes make most seabreams vulnerable to even moderate levels of exploitation (Comeros-Raynal *et al.* 2016) (Figure 102).

Fishing remains the single greatest pressure on linefish impacting 100% of linefish species of conservation concern (Figure 101). Species such as Geelbek, Carpenter and Silver Kob are targeted throughout their range by commercial, recreational and small-scale linefishers and are also commonly caught as bycatch in the demersal inshore hake trawl fishery (Attwood *et al.* 2011). The cumulative impacts of fishing has resulted in the Collapse of **Geelbek** and **Silver Kob** stocks which are listed as Near Threatened and Vulnerable respectively (Table 38, Table 41). While **Carpenter** has started to show some stock recovery (Winker *et al.* 2017a), it is still considered Near Threatened (Table 42). Initiatives to limit bycatch and promote sustainable fishing practices include appropriate permit conditions (with "move on rules" for Kob), the formulation of a Bycatch Task Team [led by DEFF with participation from the University of Cape Town (UCT) and The World Wide Fund for Nature (WWF-SA)], promoting sustainable seafood choices through initiatives like the WWF-SA led Sustainable Seafood Initiative (SASSI) (see Box 41), implementation of EAF (see Box 42), the Marine Stewardship Council (MSC) certification of the hake trawl fishery, and the Responsible Fisheries Programme and Fisheries Improvement Programmes led by WWF-SA (Greenstone *et al.* 2016, SECIFA 2017). Targeted exploitation of linefish has led to not only species mortality, but also the selective removal of larger specimens with consequent impacts on overall community composition, sex-ratios, size and trophic structure (Blaber *et al.* 2000, Garcia *et al.* 2003).

Box 41. The South African Sustainable Seafood Initiative (SASSI)

The South African Sustainable Seafood Initiative (SASSI) is led by WWF-SA and is aimed at helping consumers make sustainable seafood choices. By doing so consumers can influence the demand for sustainably sourced seafood products.

The WWF-SASSI list is a snapshot in time of the ecological sustainable status of a species and listings are based on a thorough and in-depth review of all available data and publications.

www.wwf.org.za/sassi

Green-listed fish are a consumer's best choice as these species are fished at ecologically sustainable levels and can handle current fishing pressure.

Orange-listed species are of some concern and caution should be exercised before purchasing and /or eating these.

Red-listed species should be avoided at all costs because there are major conservation concerns or because they are regulated as no-sale species.

See Barendse *et al.* 2018 for a review of the role of SASSI in supporting seafood sustainability in South Africa

By far the most severe interventions to mitigate catches by targeted fisheries include the **70% reduction in commercial fishing effort** between 2002 and 2006, implementation of a fishing moratorium on Seventy-Four in 1998 and an attempted moratorium on Red Steenbras. The **Red Steenbras moratorium** implemented in 2012 was later challenged and won in court by members of the recreational fishing community (High Court of South Africa, Case No. 31629/13) and the moratorium was discontinued. Currently management regulations for recreational angling, which can have a greater impact on species such as Red Steenbras and Dageraad (Parker *et al.* 2016, Kerwath *et al.* 2019), appear to have limited effectiveness largely due to poor angler compliance and knowledge of the regulations (Kramer *et al.* 2017). The most significant response to declining linefish stocks has been the **expansion of South Africa's MPA network** (see Chapter 8). Several local studies have shown that linefish within MPAs are more abundant and larger in size on average than in adjacent exploited areas (Buxton and Smale 1989, Bennett and Attwood 1991, Buxton 1993, Attwood *et al.* 1997a, Cowley *et al.* 2002, Götz *et al.* 2008, James *et al.* 2012, Kerwath *et al.* 2013b, Maggs *et al.* 2013, Mann *et al.* 2016). **MPAs** provide important harvesting refugia for fish communities, acting as an insurance

policy against the failure of traditional fisheries management tools (Roberts *et al.* 2005, Eddy *et al.* 2014) while providing potential benefits to adjacent fisheries through larval export and adult emigration, known as spillover (McClanahan and Mangi 2000, Cowley *et al.* 2002, Russ *et al.* 2003, Roberts *et al.* 2005, Goñi *et al.* 2008, Stobart *et al.* 2009, Kerwath *et al.* 2013b, Eddy *et al.* 2014). In this respect some of the recently declared MPAs (see Chapter 8) will provide important protection to many overexploited linefish species such as Slinger and Scotsman in the iSimangaliso MPA, Squaretail Kob in the uThukela MPA, Seventy-four, Geelbek and Dusky Kob spawning aggregations in the Aliwal Shoal MPA, Red Steenbras, Dageraad, Seventy-Four and Black Musselcracker in the Amathole MPA, White Steenbras and Dusky Kob in the Addo MPA, Carpenter in the Agulhas Banks MPA, etc. However, this is only on condition that large areas of good habitat are effectively managed as no-take zones in these MPAs (Edgar *et al.* 2014).

Box 42. Bycatch management and the Ecosystem Approach to Fisheries (EAF)

Concern has been expressed about the diversity and volume of the bycatch in several of South Africa's fisheries (Fennessy and Groeneveld 1997, Nel *et al.* 2007, Attwood *et al.* 2011, Rollinson *et al.* 2017), particularly the trawl fisheries (Sauer *et al.* 2003, Walmsley *et al.* 2007a, 2007b, Reed *et al.* 2017). The impacts of bycatch on species and the environment differs between fisheries and depends on the type of fishing gear used and habitat in which the fishing occurs (Hall *et al.* 2000). Bycatch in many fisheries is managed by a total allowable catch limit for specific species but these limits do not exist for all bycatch species as many of them do not have commercial value and are not assessed through stock assessments. Apart from being economically wasteful, bycatch has the potential to affect biodiversity and ecosystem functioning (Alverson *et al.* 1994, Hall *et al.* 2000). Issues compounding the impacts of bycatch include a lack in reporting of bycatch and discards and poor data quality when reporting does occur (Alverson *et al.* 1994, Walmsley *et al.* 2007a). As such, fisheries management has progressed from being primarily concerned with the target species to considering the entire ecosystem in which the target species exists (Bellido *et al.* 2011). South Africa together with many other counties ratified the Reykjavik Declaration in 2002 which led to the development of the Ecosystem Approach to Fisheries Management (EAF).



Cape Cormorants (*Phalacrocorax capensis*) are often caught as incidental bycatch in offshore fisheries.

The EAF is an extension of conventional fisheries management in which the impacts of fishing on, and the interactions of the fishery with the surrounding ecosystem are considered (Garcia *et al.* 2003). Through the application of the EAF, bycatch is currently recognised as one of the biggest issues facing global fisheries management. The EAF has elevated the fundamental importance of assessing and managing fisheries bycatch (Garcia *et al.* 2003, Roux *et al.* 2015b). While using traditional stock assessments are not feasible to assess all bycatch (because of data scarcity and the sheer taxonomic diversity of bycatch), risk-based approaches have been applied to assess bycatch populations (Nel *et al.* 2007, McCully *et al.* 2013).

Other **pressures** on linefish include freshwater flow modification and pollution (11-33 % of species affected) and climate change, which affects 11-23 % of species of special concern (Figure 100).

Pollution in the form of agricultural runoff, industrial waste and untreated effluent affects linefish species which use estuaries, bays and the coastal zone due to the high level of retention in these areas (see Chapter 4). Estuaries and the adjacent near-shore and surf zone serve as vital spawning and nursery grounds for many important linefish species (Table 41 and Table 42). Direct and indirect pollution of southern African estuaries is on the increase with 25% and 20% of estuaries in the Western Cape under very high and high pollution pressure respectively (van Niekerk *et al.* 2017). However, very little published information is available on the impact of pollutants on fish species or assemblages (Mzimela *et al.* 2003, Nel *et al.* 2015).

Estuarine pollution has led to fish kills in many estuaries around South Africa (Forbes and Demetriades 2008, van Niekerk *et al.* 2017). A recent study by (Ojemaye and Petrik 2019) found perfluoroalkyl compounds (PFAs) and several **pharmaceuticals** and personal care products (PPCPs) in Snoek, Panga and Hottentot tissue sampled in the Kalk Bay Harbour. Similarly, Polycyclic aromatic hydrocarbons (PAH), organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) have been detected in fish sampled at Durban Bay and the uMngeni and Isipingo estuaries at concentrations that pose potential chronic and **carcinogenic health risks** to human consumers (and by implication to other organisms) (Newman *et al.* 2015). These chemical concentrations are strongly linked to anthropogenic activities, including sewage discharge (CSIR 2017, Petrik *et al.* 2017). There is an urgent need for the adequate regulation of the use and disposal of synthetic chemicals that persist in the aquatic and/or marine environment in South Africa, to prevent any impacts on the sustainability of our marine environment, livelihoods and human lives (Ojemaye and Petrik 2019). **Maintaining and restoring water quality** in estuaries and the coastal zone requires reducing and/or recycling waste water, compliance with Department of Water and Sanitation (DWS) and DEFF waste water (and industrial waste) discharge policies, innovative engineering solutions to storm water management and improved agricultural practises (e.g. prudent application of agricultural fertilisers and pesticides).

Hydrological regime change is a major pressure on linefish species inhabiting marine and estuarine environments (see Chapter 4). **Freshwater input** into estuaries and the adjacent sea is essential for transporting freshwater, nutrients and sediment from the terrestrial environment to the marine environment (De Lecea *et al.* 2013a, 2016, Scharler *et al.* 2016). Reduced freshwater inputs can reduce the spatial extent of important unconsolidated sediment habitats, e.g. mud habitats (van Ballegooyen *et al.* 2007), many of which are important for maintaining ecological processes. For example, the endemic and Endangered White Steenbras (*Lithognathus lithognathus*) spawns on submarine fluvial fans, a localised habitat of limited extent, associated with mixed mud and sand banks deposited by rivers in the southeast Cape coast (Bennett 1993a). Sediment provides turbidity and a refuge for fish which is a key component of estuarine, coastal and offshore nursery areas (Lamberth *et al.* 2009). Freshwater flow into estuaries and the surf-zone influences not only the salinity but also its biochemical properties, including the introduction of catchment olfactory cues. Fishes have a highly developed sense of smell and olfactory cues of freshwater or estuarine origin act as a guide to marine larvae and 0+ juveniles that are attempting to locate estuarine nursery areas (James *et al.* 2008b, Lamberth *et al.* 2009). Increased frequency of estuary mouth closures and associated conditions due to reduced freshwater flow can also disrupt lifecycles and **estuarine-marine connectivity** and deprive fish of the important nursery function of estuaries, consequently impacting fisheries through altered catch composition and **decreased economic returns of fisheries** (Whitfield 1998, Lamberth and Turpie 2003, Lamberth *et al.* 2009). While the National Water Act of 1998 requires the implementation of Resource Directed Measures (RDM) which aim to determine the 'Ecological Reserve' (water quantity

and quality required for the protection of the basic needs of aquatic systems), the promulgation and implementation of these recommended freshwater allocations has generally been lacking. Research is needed to better understand the freshwater flow requirements of fluvially-dependant coastal ecosystems of the major river systems (e.g. Orange, Breede, Mzimvubu and uThukela), and particularly regarding minimum flows during drought periods. The National Environmental Management: Integrated Coastal Management Act (ICMA Act No. 24 of 2008), which aims to support the considerable value, function and services provided by coastal and marine ecosystems (including estuaries), calls for the implementation of Estuary Management Plans (EMPs). To date, many of South Africa's estuaries do not have EMPs and it is essential that management authorities are resourced with sufficient capacity and funding to implement and enforce EMPs and the ICMA Act.

The impacts of **climate change** are likely to place additional stress on exploited linefish species (see Chapter 6 for more detail). Water temperature and salinity are the primary determinants influencing the biogeography of fishes, particularly tropical species in southern Africa (Harrison and Whitfield 2006). Climate change affects both these variables and has the potential to affect major aspects of **linefish physiology** such as their salinity and temperature tolerances, their ability to occupy important spawning and nursery habitats such as estuaries, and ultimately their distribution (James *et al.* 2008c). The impacts of climate change on linefish is largely dependent on their life history and behaviour. Species with slow growth rates, and those reliant on more stable physico-chemical conditions, are likely to be less resilient to climate driven changes (Potts *et al.* 2015). Species less able to respond to changes in climate are likely to decrease in abundance and this may ultimately result in localized extinctions.

Warming conditions will likely see **range expansion** and increased abundance of tropical fish species particularly along the east coast of South Africa (Lloyd 2012). Recent research has shown the southward shift in distribution of West Coast Dusky Kob *Argyrosomus coronus* and consequent hybridization of West Coast Dusky Kob and congener Silver Kob in response to three decades of ocean warming along the Angola-Benguela Frontal Zone (Potts *et al.* 2014). While **hybridisation** in fish can promote rapid adaptation and facilitate evolution in response to the pressures from new environments and climate change (Hoffmann and Sgro 2011, Stemshorn *et al.* 2011), impacts on the productivity of the resource, on coastal fisheries and local communities heavily dependent on this resource is inevitable, with winners and losers depending on the direction of the distribution shift (Potts *et al.* 2014). Changing temperatures may also influence the **reproductive scope** of species dependent on temperature cues for reproduction (Potts *et al.* 2015). For example in a review of the spawning temperatures of the resident Blacktail *Diplodus sargus* complex, (Potts *et al.* 2013) found that populations of this complex did not spawn when exposed to temperatures above 20 °C, regardless of the ambient temperature range. Ocean acidification is another issue associated with climate change that is likely to result in **changes in fish metabolic function, growth and reproduction** (Pörtner *et al.* 2004) with supporting preliminary research for Dusky Kob (James and Potts 2017). Climate change is predicted to alter precipitation patterns which will affect the quality, rate, magnitude and timing of **freshwater delivery** to estuaries and surf-zones and will potentially exacerbate human modifications of these flows, impacting catches of species such as Slinger and Squaretail Kob (Lamberth *et al.* 2009). The impacts of climate change on coastal fish species is still poorly understood in the southern African context (Potts *et al.* 2015). While a few monitoring programmes are currently ongoing (Bennett and Attwood 1991, James *et al.* 2012, Mann *et al.* 2016), increasing such monitoring programmes will aid in better understanding changes in fish distributions. Improving fisheries management could offset

many of the predicted negative impacts of climate change (Gaines *et al.* 2018). Flexible institutional arrangements that allow rapid responses and international collaboration may determine the success or failure of coastal fisheries management in a changing climate. A holistic approach that addresses both the uncertainty around the impacts of climate change and the development of adaptation and mitigation strategies is necessary.

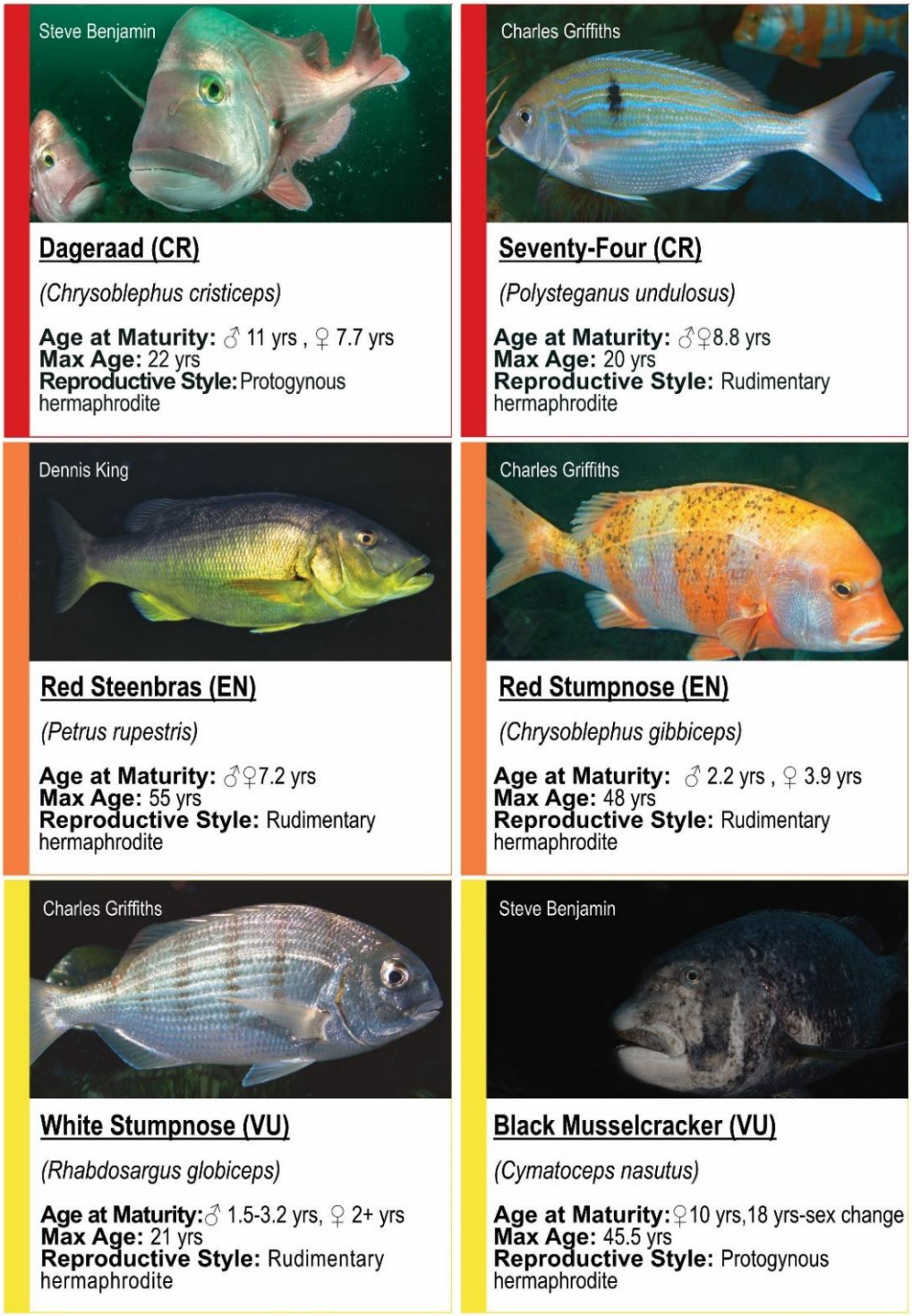


Figure 102. Iconic endemic seabreams (Family: Sparidae), their IUCN Red List status and some of their life history characteristics as reported in (Mann 2013b) and (Andrews *et al.* 2018)

Box 43. Threat status of Dusky Kob (*Argyrosomus japonicus*)

Argyrosomus japonicus is historically one of the most important species in the recreational, commercial and subsistence fisheries (Griffiths 1996) and has a number of vulnerable life-history traits including estuarine dependence, spawning migrations, predictable aggregations, large size, high age at maturity, longevity (generation length 24 years), juvenile residency and high catchability (Griffiths 1996, Childs 2013). There is little doubt that Dusky Kob is in a critical state. A per-recruit stock assessment conducted by (Griffiths 1997a) suggested that the spawner biomass per recruit (SB/R) had collapsed to 1.1-4.5% of pristine spawning biomass, suggesting that the stock status was already well below the threshold reference point of 25% unfished spawning biomass during the mid-1990s. A more recent per-recruit assessment conducted along the Eastern Cape coast suggested that the stock has not improved with spawning biomass levels still estimated between 1 and 3% of unfished levels (Winker *et al.* 2015). The critical stock status of Dusky Kob is associated with long-term declines in catch rates of competitive shore angling and recreational fisheries for the past 30 years. In KZN, an 80% decrease in total catch was recorded in the shore angling fishery between 1994-96 and 2008-09 (Dunlop 2011). Similar large declines have been recorded in the Eastern Cape and Transkei (Pradervand and Govender 2003, Pradervand 2004). Considerable catches of large Dusky Kob continue to be made by recreational and commercial boats at night on spawning aggregations in Kwazulu-Natal, but these are not formally recorded.

Given these declines, an overall decline of between 70 and 80% of the population is suspected to have taken place between 1995 and 2019 (one generation) (Mann *et al.* 1997, 2002b, Pradervand and Baird 2002, Pradervand 2004, Pradervand *et al.* 2007, Dunlop 2011). South Africa's current weak economy and high unemployment rate means that a greater number of people are turning to fishing as an employer of last resort. Fishing pressure combined with a breakdown of fishing regulation capacity and increased illegal gillnetting in estuaries (Mann *et al.* 2002b, Beckley *et al.* 2008, Childs 2013, Winker *et al.* 2015) declining freshwater flows, degrading estuarine environments (Childs *et al.* 2015), changing environment (including climate change) and habitat degradation are all highly likely to result in ongoing declines over the next 48 years (two generations).



A large Dusky Kob is released by a researcher.

Furthermore, recent analysis showed evidence of multiple genetic bottlenecks for this species resulting in low and declining effective population size (Mirimin *et al.* 2016). Globally, there are several populations of this species, but those in Australia and South Africa are genetically quite distinct (Barnes 2015) and are likely to represent two different species. This, combined with the per-recruit stock status assessments for *A. japonicus* (Griffiths 1997a, Winker *et al.* 2015) which show that this stock was collapsed in 1997 and has not recovered since, indicates little chance of local population recovery. This places *A. japonicus* in the **Critically Endangered** category under the A4 criterion with more than 80% decline over a three -generation time period including both past and predicted future decline.

In particular, no-take zones within critical nursery areas, such as the Great Fish estuary, and the use of these habitats by Dusky Kob, should be better reflected in the management arrangements for this fishery species (Cowley *et al.* 2008). No-take Estuarine Protected Areas in important turbid estuarine nursery habitats would afford juveniles protection and prevent growth over-fishing owing to high site fidelity within estuaries (Childs 2013). No-take MEPAs (joint Marine and Estuarine Protected Areas) in important turbid estuaries and their adjacent surf-zones (e.g. Sundays, Gamtoos and Breede Estuaries) would afford protection to all life-history stages (juveniles, sub-adult and adults) of Dusky Kob given the low connectivity and high residency and affinity to estuaries and adjacent surf-zones (Childs 2013). In addtion to the implementation of the (ministerially approved) prohibition on fishing at night in all estuaries in South Africa, other more stringent measures should be considered to improve protection of Dusky Kob if this stock is to recover. These measures include the prohibition of ski-boat nightfishing during spawning season, and amended slot (minimum and maximum sizes) and bag limits to protect important estuarine and associated surf-zone habitats and spawning aggregations on inshore reefs and pinnacles in KZN and Transkei (Connell 2009, Mann 2012).

Cartilaginous linefish

South Africa has one of the world's most diverse cartilaginous fish (chondrichthyans) assemblages (sharks, skates, rays, and chimeras), representing 15% of known species (Compagno 1999, Ebert and van Hees 2015). Of the **185 species** (109 sharks, 68 skates and rays and 8 chimaeras) occurring in South Africa, 15 (8%) are endemic (Compagno 2002a, 2002b). This diversity is only slightly lower when compared to the southern African region (Namibia, South Africa, and Mozambique) which has 204 species (117 sharks, 79 skates and rays and 8 chimaera) (Ebert and van Hees 2015).

In South Africa, an estimated 54% (99) of species are targeted or caught as bycatch in 16 commercial fisheries, the bather protection program of the KwaZulu-Natal (shark nets and drum lines) and South Africa's recreational fishery (DAFF 2013b, da Silva *et al.* 2015). Chondrichthyan fisheries are widely accepted as being unsustainable due to species life-history strategies (slow growth, low natural mortality rates and low fecundity) that render them inherently vulnerable to overexploitation (Stevens *et al.* 2000, Cailliet *et al.* 2005, Field *et al.* 2009). As fish stocks around the world have declined, the demand for chondrichthyans has increased steeply (Clarke *et al.* 2006, da Silva and Bürgener 2007). Sharks are harvested for their meat, fins, skin, cartilage, liver (for oil and squalene) and teeth (Vannuccini 1999). However, while there is limited **consumption of shark meat** in South Africa, shark products are exported to other continents like Australia, North America and Asia (da Silva and Bürgener 2007). Commercial fisheries which catch sharks in significant numbers are the demersal shark longline fishery (see Chapter 4 for more detail), large pelagic tuna longline fishery, commercial linefishery and the demersal inshore and deep-sea trawl fisheries (DAFF 2013b, da Silva *et al.* 2015).

Stock assessments suggest that Smoothhound (*Mustelus mustelus*), Soupfin (*Galeorhinus galeus*) and Blue Sharks (*Prionace glauca*) are Overexploited, Collapsed and Optimally Exploited respectively (da Silva *et al.* 2015, 2018) (Table 38). Blue and Mako Sharks are targeted in the large pelagic tuna longline fishery, and shark landings are managed according to a precautionary upper catch limit of 2000 tonnes dressed weight per annum (da Silva *et al.* 2015) with many other chondrichthyans such as requiem sharks (Order: Carcharhiniformes), Hammerheads (*Sphyrna spp*.) and Thresher Sharks (*Alopias spp*.) caught, but poorly identified and reported in catches (Jordaan *et al.* 2018). South Africa is a member of several **regional fisheries management organisations** (RFMOs) (DAFF 2013b, ICCAT 2018, IOTC 2018). To date RFMOs have had limited impact on shark management and conservation in South Africa, however most have implemented a prohibition on shark finning (defined as slicing off a shark's fins and discarding the body at sea) (Tolotti *et al.* 2015). The commercial linefishery is prohibited from landing chondrichthyans listed on the TOPS list, and the four decommercialised species (*Poroderma pantherinum*, *P. africanum*, *Triakis megalopterus* and *Carcharias taurus*) (da Silva *et al.* 2015). Most of the chondrichthyan catches in the demersal inshore and deep-sea trawl are discarded at sea and landed catches are not reported to species level (da Silva *et al.* 2015). The recreational fishery catches at least 39 chondrichthyan species (da Silva *et al.* 2015), including TOPS listed species. Legally, one individual of each shark species can be retained per day with a limit of 10 sharks in total and these may not be sold (da Silva *et al.* 2015). Many of the chondrichthyans caught by the recreational sector are released alive, but post-release mortality is unknown and expected to be high for some species like Hammerhead Sharks (Gallagher *et al.* 2014). Chondrichthyans are also caught in the beach-seine and gill net fisheries, crustacean trawl fishery, small pelagic and midwater trawl fisheries and the hake longline fishery, but in lesser numbers when compared to the above fisheries (DAFF 2013b, da Silva *et al.* 2015).

Chondrichthyans are one of the most threatened vertebrate groups in the world, with **25% considered threatened with extinction due to global overfishing** (Dulvy *et al.* 2014). Based on global Red List assessments of 189 southern African chondrichthyans, 29% are considered Threatened, 16.9% are Near Threatened, 25.4% are Least Concern and 28.6% are Data Deficient (Ebert and van Hees 2015). National Red List assessments have only been completed for 26 (14%) of the 185 chondrichthyans in South Africa, including two endemics (Figure 100, Table 43). Two of these species (7%) are considered threatened, namely the Soupfin (Endangered) and the Shortfin Mako Shark (Vulnerable), while 42% are considered Least Concern (Figure 100, Table 43). The remaining species (50%) are Data Deficient (Figure 100, Table 43), which is similar to the estimate of 46% for chondrichthyans globally (Dulvy *et al.* 2014), but higher compared to southern Africa's chondrichthyans for which global assessments have been completed (28.6%) (Ebert and van Hees 2015). The high percentage of Data Deficient species is of concern and is due to limited information being available on the biology, life-history, stock structure, catch rates and bycatch levels of most species, which has also contributed to the inability to implement species stock assessments and effective management plans (da Silva *et al.* 2015, 2018).

Of particular concern is the Soupfin Shark population which is impacted by heavy fishing pressure as a result of being caught in several commercial fisheries and consequently exhibiting a steep population decline (da Silva *et al.* 2018). There is currently heavy fishing pressure on Shortfin Mako, requiem sharks (which include Tiger, Blacktip, Spinner, Dusky and Zambezi Sharks) unidentified skates and Smoothhound Sharks (DAFF 2016). Blue Sharks seem to be the only chondrichthyan being caught at optimal levels (DAFF 2016) (Table 38). However, most of these **stock assessments are out of date** and urgently require updating. Twenty-one regional IUCN assessments with population trend analyses were completed in 2018 as part of a workshop organised by the **IUCN Shark Specialist Group** and will be available in 2019/2020 (da Silva *et al.* 2018) , but more focus is needed to initiate new and update existing stock assessments.

The main pressure on chondrichthyans in South Africa is from overfishing, either as **targeted catch or bycatch** (da Silva *et al.* 2015, 2018). This is also reflected in the national species assessments with 94 % of species of special concern impacted by fishing (Figure 101). Illegal, unregulated and unreported fisheries are a growing concern in South Africa e.g. increasingly gillnets are being used in coastal areas such as False Bay and in estuaries, impacting a range of teleost and cartilaginous fishes (da Silva *et al.* 2015). An emerging topic is the potential ecosystem and socio-economic impact of two shark-eating orcas (*Orcinus orca*). They have been recorded preying on at least three shark species, namely, Broadnose Sevengill (*Notorynchus cepedianus*), White (*Carcharodon carcharias*), and Bronze Whaler Sharks (*Carcharhinus brachyurus*) (Engelbrecht *et al.* 2019). As a consequence, sharks not directly impacted have exhibited flight responses and associated abandonment of well-known aggregation sites, negatively impacting shark tourism and altering ecosystem structure (Engelbrecht *et al.* 2019, Hammerschlag *et al.* 2019, Pfaff *et al.* 2019b).

Box 44. Species caught in the Kwazulu-Natal bather protective shark nets

The bather protection programme along the KwaZulu-Natal (KZN) coast has been running since 1952 and extends from Mzamba to Richards Bay. It uses a combination of shark nets and drumlines to reduce local shark numbers, which in turn reduces the risk of encounters between people and sharks (Cliff and Dudley 2011). Target species are Bull (*Carcharhinus leucas*), Tiger (*Galeocerdo cuvier*) and White Sharks (*Carcharodon carcharias*), but many other shark species, turtles (e.g. *Caretta caretta, Chelonia mydas, Dermochelys coriacea, Eretmochelys imbricata* and *Lepidochelys olivacea*), cetaceans (e.g. *Delphinus delphis, Sousa chinensis, Sousa plumbea* and *Tursiops aduncus*) are caught incidentally (Cliff and Dudley 2011).



Turtles like this Critically Endangered Hawksbill turtle (*E. imbricata*) are caught in bather protection shark nets.

Due to concerns around the incidental bycatch, some shark nets have been replaced with more selective drumlines (Cliff and Dudley 2011). In 2014 there were 22.4 km of shark nets and 79 drumlines deployed along the KZN coast (Dicken *et al.* 2018), with plans to reduce the number of nets, but increase the number of drumlines. This sector has a long history of providing valuable scientific monitoring data, but has also contributed to population declines of various marine species (Dudley and Simpfendorfer 2006, Atkins *et al.* 2013). Declining shark populations, incidental capture of species of concern / threatened species and growing public pressure to remove the nets and drumlines has resulted in the KZN Sharks Board and other institutions investigating alternatives to lethal shark control measures. These include development of an electric shark repellent cable (von Blerk, KZN Sharks Board, pers. comm) and a magnetic barrier (O'Connell *et al.* 2018) to deter sharks from beaches.

Non-consumptive recreational activities impact 13% of chondrichthyans of national conservation concern (Figure 101). **Shark diving and viewing tourism** is a large and growing industry in South Africa (Gallagher and Hammerschlag 2011). Several coastal (White, Ragged-tooth, Tiger, Broadnose Sevengill, Blacktip and Bull Sharks) and pelagic (Blue and Mako Sharks) species are the focus of charter businesses who offer close encounters with these animals, often using chum to attract them (Kock and Johnson 2006, Dicken and Hosking 2009). White Shark cage diving is well regulated by the Department of Environment, Forestry and Fisheries through the TOPS Regulations, 2017 (Government Notice No. 40876), the NEMBA (Act No. 10 of 2004) and permit conditions. However, regulations for other species still need to be developed to ensure sustainability. To date, only one study has been published on the impacts of chumming on shark behaviour in South Africa (Laroche *et al.* 2007), but more studies are currently underway. While it has been demonstrated that shark tourism is economically important in South Africa (Hara *et al.* 2003, Dicken and Hosking 2009, Towner *et al.* 2013), more research is needed on the socio-economic and educational value of this industry.

The high proportions of threatened and Data Deficient chondrichthyans, coupled with population declines reported for several species, highlights the need for corrective action in the form of **improved management** informed by sound research on exploited species. South Africa was a pioneer in shark conservation as the first country in the world to protect the White Shark (*Carcharodon carcharias*) under the precautionary principle (Compagno 1991). In 2004, South Africa banned the practice of

shark finning (cutting off the sharks' valuable fins and discarding the rest of the carcass at sea) (DAFF 2013b). However, arguably the most important response to date has been the formalisation and implementation of the **National Plan of Action for Sharks South Africa** (NPOA-Sharks South Africa) by the former Department of Agriculture, Foresty and Fisheries in 2013 (DAFF 2013b). The NPOA-Sharks South Africa provides a detailed strategy for South Africa to achieve economically and ecologically sustainable shark fisheries by providing a state of knowledge on chondrichthyan biodiversity, identification of fisheries which harvest sharks and identification of knowledge gaps and effective management regulations. Issues and actions are classified into high, medium and low priorities.

A substantial amount of progress has been achieved towards the goal of sustainable shark fisheries through the implementation of the NPOA-Sharks South Africa (da Silva *et al.* 2018). Limited information on basic biology (growth and reproductive rates), catch rates and discards, coupled with poor species identification are major limitations to understanding fishery impacts and conducting stock assessments (da Silva *et al.* 2015). In response, DAFF has commissioned and supported research on commercially exploited species, developed and distributed a species identification guide for the 100 chondrichthyans caught in commercial shark fisheries and updated permit conditions for all fisheries that harvest sharks (Bitalo *et al.* 2015, da Silva *et al.* 2015, 2018, Kuguru *et al.* 2018). While **observer coverage** has improved for the large pelagic longline and midwater trawl fisheries, observer coverage and associated independent monitoring of catches and discards is lacking across most fisheries (da Silva *et al.* 2018). Several management actions have been implemented in five fisheries (pelagic longline, demersal shark, recreational, demersal inshore trawl and beach-seine) which catch sharks (da Silva *et al.* 2018). Most notably, the prohibition of **CITES** Appendix II species (Box 45) and Dusky and Sevengill Sharks in the large pelagic longline and demersal shark longline fisheries, the prohibition on use of fish aggregating devices to reduce bycatch, and in the recreational fishery a limit of one individual of each shark species may be retained per day (da Silva *et al.* 2018). Furthermore, a slot (size) limit of 70 – 130 cm for Smoothhound and Soupfin Sharks is in the process of being implemented, which will make a significant contribution to improving the sustainability of fisheries which harvest these sharks (da Silva *et al.* 2018).

In 2015, the DAFF gazetted a **Shark Biodiversity Management Plan** (SBMP) with the aim of achieving favourable conservation status for chondrichthyans in South Africa across ecological, cultural and socio-economic objectives (DEA 2015b). However, since being gazetted, the SBMP has had limited success due in part to insufficient support and coordination. Another stumbling block has been the lack of integration of SBMP objectives with that of the NPOA Sharks South Africa, resulting in confusion with the overarching objectives of the SBMP. One of the successes of the SBMP has been the addition of seven chondrichthyan species under the TOPS regulations. However, the implementation of these regulations needs to be improved with increased awareness among affected users and the enforcement of regulations. To ensure that South Africa's rich Chondrichthyan diversity is adequately conserved and sustainably managed there are several priority actions that are required.

Box 45. Cartilaginous fish listed on CITES



A Mako Shark gliding through the open ocean

Each year, between 63 million and 273 million sharks are caught in the world's commercial fisheries (Dent and Clarke 2015). Unsustainable fishing, driven by an increased demand for shark fins and meat, has led to the worldwide decline in shark populations (Jabado 2014). CITES currently lists four South African chondrichthyans under Appendix I (all of which are sawfishes) and 19 under Appendix II. Two species of sawfish (Appendix I), the Largetooth Sawfish (*Pristis pristis*) and Green Sawfish (*Pristis zijsron*), are considered locally extinct in South Africa, with the last sighting of these once common KwaZulu-Natal (KZN) species, 20 years ago (Kyne *et al.* 2013, Everett *et al.* 2015a). In 2013, five commercially traded species - Oceanic Whitetip (*Carcharhinus longimanus*), Porbeagle (*Lamna nasus*), and Great (*Sphyrna mokarran*), Scalloped (*Sphyrna lewini*), and Smooth Hammerhead Sharks (*Sphyrna zygaena*) - and two species of manta ray were listed under Appendix II. In 2015, CITES parties added the Bigeye (*Alopias superciliosus*), Common (*Alopias vulpinus*) and Pelagic Thresher Sharks (*Alopias pelagicus*); Silky Sharks (*Carcharhinus falciformis*), and all *Mobula* ray species were added to Appendix II. The listing of these species has encouraged action by parties for the protection of these threatened and highly migratory species.

Shortfin Mako (*Isurus oxyrinchus*), Longfin Mako (*Isurus paucus*) and the Giant Guitar Shark (*Rhynchobatus djiddensis*) have been proposed for listing in Appendix II at CITES CoP18. The main pressure on these species is fishing. The meat of Shortfin Mako Sharks is considered of high value and used for human consumption across the world (Fields *et al.* 2018). This species is also exploited internationally for its fins, which are traded in large volumes, specifically destined for Hong Kong (Rigby *et al.* 2019). Guitar Sharks are increasingly targeted due to their high value fins and are replacing sawfish as the most highly valued species for the international shark fin trade (Jabado *et al.* 2018).

The **taxonomic expertise** in South Africa needs to be improved to facilitate species assessments (Ebert and van Hees 2015). Research funding and scientific capacity to work on less charismatic and commercially exploited species needs to be adequately sourced (Ebert and van Hees 2015, da Silva *et al.* 2018). Research on the role of chondrichthyans as prey and as predator, are needed to understand what the loss of these species means for marine ecosystems. The **collection of catch, discard and effort data** across fisheries needs to be improved, in part by implementing independent observer and monitoring programmes (da Silva *et al.* 2018). A holistic and **centralised management strategy** is required to assess the impact and streamline management actions across multiple fisheries which harvest sharks (da Silva *et al.* 2018). More species and resource assessments are urgently needed to understand the state of chondrichthyan biodiversity. Finally, **improved regulatory frameworks** for sharks and enforcement of existing regulations is required to ensure the sustainable use of chondrichthyans in South Africa (da Silva *et al.* 2015, 2018).

Table 41. IUCN Red List status of nationally assessed South African linefish (bony fish, excluding seabreams – see Table 6) with year assessed and associated listing on the South African list of Threatened or Protected Species (TOPS). Estuarine associated or dependent species are indicated with (*), NE= Near Endemic, E= Endemic

Family	Scientific name	Common name	National Assessment	Global Assessment	TOPS
Albulidae	*Albula oligolepis*	Bone Fish, Smallscale Bonefish	Data Deficient (2015)	Data Deficient (2011)	Not listed
Ariidae	*Galeichthys ater* NE	Black Seacatfish, Black Seabarbel	Least Concern (2015)	Not Assessed	Not listed
Ariidae	**Galeichthys feliceps* NE	White Seacatfish, White Seabarbel	Least Concern (2015)	Not Assessed	Not listed
Carangidae	*Caranx heberi*	Blacktip Kingfish, Yellowtail Kingfish	Data Deficient (2015)	Least Concern (2015)	Not listed
Carangidae	**Caranx ignobilis*	Giant Kingfish, Giant Trevally	Data Deficient (2016)	Least Concern (2015)	Not listed
Carangidae	**Caranx papuensis*	Brassy Kingfish, Greenspot Kingfish	Data Deficient (2015)	Least Concern (2015)	Not listed
Carangidae	**Caranx sexfasciatus*	Bigeye Kingfish, Bigeye Trevally	Data Deficient (2015)	Least Concern (2009)	Not listed
Carangidae	**Lichia amia*	Garrick, Leervis	Vulnerable (2019)	Least Concern (2014)	Not listed
Carangidae	*Scomberoides commersonnianus*	Largemouth Queenfish	Data Deficient (2015)	Least Concern (2015)	Not listed
Carangidae	*Seriola dumerili*	Greater Amberjack, Greater Yellowtail	Data Deficient (2015)	Least Concern (2007)	Not listed
Carangidae	*Seriola lalandi*	Cape Yellowtail, Geelstert	Least Concern (2015)	Least Concern (2015)	Not listed
Carangidae	*Seriola rivoliana*	Longfin Amberjack, Longfin Yellowtail	Least Concern (2015)	Least Concern (2012)	Not listed
Carangidae	*Trachinotus africanus*	Southern Pompano, African Pompano	Data Deficient (2016)	Not Assessed	Not listed
Carangidae	*Trachinotus botla*	Largespot Pompano	Least Concern (2015)	Not Assessed	Not listed
Cheilodactylidae	*Chirodactylus grandis* NE	Bank Steenbras	Least Concern (2015)	Not Assessed	Not listed
Cheilodactylidae	*Chirodactylus jessicalenorum* E	Natal Fingerfin	Least Concern (2015)	Least Concern (2009)	Not listed
Coryphaenidae	*Coryphaena hippurus*	Dorado, Dolphinfish	Least Concern (2015)	Least Concern (2010)	Not listed
Dichistiidae	*Dichistius capensis* NE	Galjoen, Damba	Near Threatened (2016)	Not Assessed	Not listed
Dichistiidae	*Dichistius multifasciatus* NE	Banded galjoen	Near Threatened (2016)	Not Assessed	Not listed
Dinopercidae	*Dinoperca petersi*	Cave Bass, Lantern Fish	Least Concern (2016)	Not Assessed	Not listed
Elopidae	**Elops machnata*	Springer, Ladyfish	Data Deficient (2016)	Least Concern (2016)	Not listed
Epinephelidae	*Epinephelus albomarginatus* NE	White-edged Rockcod	Vulnerable (2019)	Vulnerable (2016)	Not listed
Epinephelidae	**Epinephelus andersoni* NE	Catface Rockcod	Near Threatened (2019)	Near Threatened (2016)	Not listed
Epinephelidae	*Epinephelus lanceolatus*	Brindle Bass, Giant Grouper	Vulnerable (2019)	Data Deficient (2016)	Vulnerable
Epinephelidae	**Epinephelus malabaricus*	Malabar Rockcod	Data Deficient (2017)	Least Concern (2016)	Not listed
Epinephelidae	*Epinephelus marginatus*	Yellowbelly Rockcod	Vulnerable (2019)	Vulnerable (2016)	Not listed
Epinephelidae	*Epinephelus rivulatus*	Halfmoon Rockcod	Least Concern (2019)	Least Concern (2017)	Not listed
Epinephelidae	*Epinephelus tukula*	Potato Bass, Aartappel-baars	Least Concern (2017)	Least Concern (2016)	Protected
Gempylidae	*Thyrsites atun*	Snoek, Cape Snoek	Least Concern (2015)	Not Assessed	Not listed
Haemulidae	*Plectorhinchus chubbi*	Dusky Rubberlip	Data Deficient (2016)	Not Assessed	Not listed
Haemulidae	*Plectorhinchus flavomaculatus*	Lemonfish	Data Deficient (2015)	Not Assessed	Not listed
Haemulidae	*Plectorhinchus playfairi*	Whitebarred Rubberlip	Data Deficient (2015)	Not Assessed	Not listed
Haemulidae	**Pomadasys commersonnii*	Spotted Grunter	Vulnerable (2019)	Not Assessed	Not listed
Haemulidae	*Pomadasys furcatus*	Grey Grunter, Banded Grunter	Least Concern (2015)	Not Assessed	Not listed

Family	Scientific name	Common name	National Assessment	Global Assessment	TOPS
Haemulidae	**Pomadasys kaakan*	Javelin Grunter	Data Deficient (2015)	Not Assessed	Not listed
Haemulidae	**Pomadasys olivaceus*	Piggy, Pinky, Varkie	Least Concern (2015)	Not Assessed	Not listed
Istiophoridae	*Istiompax indica*	Black Marlin	Data Deficient (2016)	Data Deficient (2009)	Not listed
Istiophoridae	*Istiophorus platypterus*	Sailfish, Indo-Pacific Sailfish	Least Concern (2015))	Least Concern (2010)	Not listed
Istiophoridae	*Kajikia audax*	Striped Marlin	Near Threatened (2016)	Near Threatened (2011)	Not listed
Istiophoridae	*Makaira nigricans*	Blue Marlin	Vulnerable (2016)	Vulnerable (2010)	Not listed
Kyphosidae	*Neoscorpis lithophilus*	Stonebream, Stinker, Stinkvis	Least Concern (2015)	Not Assessed	Not listed
Lethrinidae	*Lethrinus crocineus*	Yellowfin Emperor	Data Deficient (2015)	Not Assessed	Not listed
Lethrinidae	*Lethrinus nebulosus*	Blue Emperor	Data Deficient (2016)	Least Concern (2015)	Not listed
Lutjanidae	*Aprion virescens*	Green Jobfish, Kaakap	Data Deficient (2016)	Least Concern (2015)	Not listed
Lutjanidae	**Lutjanus argentimaculatus*	River Snapper, Rock Salmon	Data Deficient (2016)	Least Concern (2015)	Not listed
Lutjanidae	*Lutjanus rivulatus*	Speckled Snapper, Blubberlip Snapper	Data Deficient (2016)	Least Concern (2015)	Not listed
Lutjanidae	*Lutjanus sanguineus*	Blood Snapper, Humphead Snapper	Data Deficient (2015)	Not Assessed	Not listed
Lutjanidae	*Lutjanus sebae*	Emperor Snapper	Data Deficient (2015)	Least Concern (2015)	Not listed
Lutjanidae	*Paracaesio xanthura*	Protea Bream	Least Concern (2015)	Least Concern (2015)	Not listed
Lutjanidae	*Pristipomoides filamentosus*	Rosy Jobfish, Crimson Jobfish	Data Deficient (2015)	Least Concern (2015)	Not listed
Megalopidae	**Megalops cyprinoides*	Oxeye Tarpon, Indo-Pacific Tarpon	Data Deficient (2015)	Data Deficient (2016)	Not listed
Merlucciidae	*Merluccius capensis*	Shallow-water hake	Least Concern (2015)	Least Concern (2012)	Not listed
Mugilidae	**Liza richardsonii* [NE]	Harder, Southern Mullet, Bokkoms	Least Concern (2015)	Not Assessed	Not listed
Mugilidae	**Liza tricuspidens* [NE]	Striped Mullet	Least Concern (2015)	Not Assessed	Not listed
Mugilidae	**Mugil cephalus*	Flathead Mullet	Least Concern (2015)	Least Concern (2016)	Not listed
Oplegnathidae	*Oplegnathus conwayi* [E]	Cape Knifejaw	Least Concern (2019)	Not Assessed	Not listed
Oplegnathidae	*Oplegnathus robinsoni* [NE]	Natal Knifejaw	Data Deficient (2015)	Not Assessed	Not listed
Platycephalidae	**Platycephalus indicus*	Sand Gurnard	Data Deficient (2015)	Data Deficient (2009)	Not listed
Pomatomidae	**Pomatomus saltatrix*	Elf, Shad	Vulnerable (2019)	Vulnerable (2014)	Not listed
Rachycentridae	*Rachycentron canadum*	Prodigal Son	Least Concern (2019)	Least Concern (2012)	Not listed
Sciaenidae	*Argyrosomus inodorus* [NE]	Silverkob, Kabeljou	Vulnerable (2019)	Vulnerable (2019 draft)	Not listed
Sciaenidae	**Argyrosomus japonicus*	Dusky Kob, Kabeljou	Critically Endangered (2019)	Endangered (2019 draft)	Not listed
Sciaenidae	*Argyrosomus thorpei* [NE]	Squaretail Kob	Vulnerable (2019)	Endangered (2019 draft)	Not listed
Sciaenidae	*Atractoscion aequidens*	Geelbek	Vulnerable (2019)	Vulnerable (2019 draft)	Not listed
Sciaenidae	**Johnius dorsalis*	Small Kob, Mini-kob	Least Concern (2019)	Least Concern (2019 draft)	Not listed
Sciaenidae	**Otolithes ruber*	Snapper Kob	Least Concern (2015)	Least Concern (2019 draft)	Not listed
Sciaenidae	*Umbrina robinsoni*	Belman, Baardman	Near Threatened (2015)	Near Threatened (2019 draft)	Not listed
Scombridae	*Acanthocybium solandri*	Wahoo	Least Concern (2015)	Least Concern (2010)	Not listed
Scombridae	*Euthynnus affinis*	Eastern Little Tuna, Mackerel Tuna	Least Concern (2015)	Least Concern (2009)	Not listed
Scombridae	*Katsuwonus pelamis*	Skipjack Tuna, Bonito	Least Concern (2016)	Least Concern (2010)	Not listed

Family	Scientific name	Common name	National Assessment	Global Assessment	TOPS
Scombridae	*Scomber japonicus*	Chub Mackerel	Least Concern (2015)	Least Concern (2009)	Not listed
Scombridae	*Scomberomorus commerson*	King Mackerel	Least Concern (2017)	Near Threatened (2009)	Not listed
Scombridae	*Scomberomorus plurilineatus*	Queen Mackerel	Least Concern (2015)	Data Deficient (2009)	Not listed
Scombridae	*Thunnus alalunga*	Albacore, Longfin Tuna	Near Threatened (2016)	Near Threatened (2011)	Not listed
Scombridae	*Thunnus albacares*	Yellowfin Tuna, Geelvin Tuna	Near Threatened (2016)	Near Threatened (2011)	Not listed
Scombridae	*Thunnus obesus*	Bigeye Tuna	Vulnerable (2015)	Vulnerable (2011)	Not listed
Sphyraenidae	**Sphyraena barracuda*	Great Barracuda	Data Deficient (2015)	Least Concern (2013)	Not listed
Sphyraenidae	**Sphyraena jello*	Pickhandle Barracuda, Sea Pike	Data Deficient (2015)	Not Assessed	Not listed
Xiphiidae	*Xiphias gladius*	Swordfish	Data Deficient (2019)	Least Concern (2011)	Not listed

Table 42. IUCN Red List status of globally assessed South African seabreams (of the family Sparidae) with year assessed. Estuarine associated or dependent species are indicated with (*), NE= Near Endemic, E= Endemic, P= Listed as Protected on the South African list of Threatened or Protected Species (TOPS)

Species name	Common name	Global Assessment
**Acanthopagrus berda*	Picnic Seabream	Least Concern (2016)
Acanthopagrus catenula	Bridled Seabream	Data Deficient (2009)
**Acanthopagrus vagus* NE	Riverbream	Vulnerable (2009)
Argyrops filamentosus	Soldierbream	Least Concern (2009)
Argyrops spinifer	King Soldierbream	Least Concern (2009)
Argyrozona argyrozona E	Carpenter	Near Threatened (2009)
Boopsoidea inornata E	Fransmadam	Least Concern (2009)
Cheimerius nufar	Santer	Data Deficient (2009)
Chrysoblephus anglicus E	Englishman	Near Threatened (2009)
Chrysoblephus cristiceps E	Dageraad	Critically Endangered (2009)
Chrysoblephus gibbiceps E	Red Stumpnose	Endangered (2009)
Chrysoblephus laticeps E	Roman	Near Threatened (2009)
Chrysoblephus lophus NE	False Red Stumpnose	Least Concern (2009)
Chrysoblephus puniceus NE	Slinger	Least Concern (2009)
Crenidens crenidens	Karanteen Seabream	Least Concern (2009)
Cymatoceps nasutus E	Black Musselcracker	Vulnerable (2009)
**Diplodus capensis* NE	Blacktail	Least Concern (2009)
Diplodus cervinus	Zebra Seabream	Least Concern (2009)
**Diplodus hottentotus*	Zebra	Least Concern (2009)
Gymnocrotaphus curvidens	Janbruin	Least Concern (2009)
Lithognathus aureti NE	West Coast Steenbras	Near Threatened (2009)
**Lithognathus lithognathus* E	White Steenbras	Endangered (2009)
**Lithognathus mormyrus*	Sand Steenbras	Least Concern (2009)
Pachymetopon aeneum E	Blue Hottentot	Least Concern (2009)
Pachymetopon blochii E	Hottentot	Least Concern (2009)
Pachymetopon grande E	Bronze Bream	Near Threatened (2009)
Pagellus natalensis	Sand Soldier	Least Concern (2009)
Petrus rupestris E	Red Steenbras	Endangered (2009)
Polyamblyodon germanum NE	German Seabream	Least Concern (2009)
Polyamblyodon gibbosum	Knife-back Seabream	Least Concern (2009)
Polysteganus coeruleopunctatus	Blueskin	Data Deficient (2009)
Polysteganus praeorbitalis NE	Scotsman	Vulnerable (2009)
Polysteganus undulosus E; P	Seventy-four	Critically Endangered (2009)
Porcostoma dentata NE	Dane	Least Concern (2009)
Pterogymnus laniarius E	Panga	Least Concern (2009)
**Rhabdosargus globiceps* NE	White Stumpnose	Vulnerable (2009)
**Rhabdosargus holubi* NE	Cape Stumpnose	Least Concern (2009)
**Rhabdosargus sarba*	Natal Stumpnose	Least Concern (2009)
**Rhabdosargus thorpei* NE	Bigeye Stumpnose	Least Concern (2009)
**Sarpa salpa*	Karanteen	Least Concern (2009)
Sparodon durbanensis E	White Musselcracker	Near Threatened (2009)
Spondyliosoma emarginatum E	Steentjie	Least Concern (2009)

Table 43. IUCN Red List status of South African cartilaginous fish with year assessed and associated listing on the South African list of Threatened or Protected Species (TOPS). Estuarine associated or dependent species are indicated with (*), NE= Near Endemic, E= Endemic

Family	Scientific name	Common name	National Assessment	Global Assessment	TOPS
Callorhinchidae	*Callorhinchus capensis* NE	Elephant Fish, St Joseph Shark	Least Concern (2015)	Least Concern (2006)	Not listed
Carcharhinidae	*Carcharhinus brachyurus*	Copper Shark, Bronze Whaler	Data Deficient (2015)	Near Threatened (2003)	Not listed
Carcharhinidae	**Carcharhinus leucas*	Zambezi Shark, Bull Shark	Data Deficient (2017)	Near Threatened (2005)	Not listed
Carcharhinidae	*Carcharhinus limbatus*	Blacktip Shark	Least Concern (2016)	Near Threatened (2005)	Not listed
Carcharhinidae	*Carcharhinus obscurus*	Dusky Shark	Data Deficient (2016)	Vulnerable (2007)	Not listed
Odontaspididae	*Carcharias taurus*	Spotted Ragged-tooth Shark,	Data Deficient (2017)	Vulnerable (2005)	Vulnerable
Lamnidae	*Carcharodon carcharias*	Great White Shark	Least Concern (2016)	Vulnerable (2005)	Vulnerable
Dasyatidae	**Dasyatis chrysonota*	Blue Stingray, Blou Pylstert	Data Deficient (2017)	Least Concern (2008)	Not listed
Carcharhinidae	*Galeocerdo cuvier*	Tiger Shark	Least Concern (2015)	Near Threatened (2005)	Protected
Triakidae	*Galeorhinus galeus*	Soupfin Shark, Vaalhaai	Endangered (2015)	Vunerable (2006)	Not listed
Gymnuridae	**Gymnura natalensis* NE	Diamond Ray	Least Concern (2015)	Data Deficient (2006)	Not listed
Dasyatidae	*Himantura leoparda*	Leopard Stingray, Reticulate Whipray	Data Deficient (2016)	Vulnerable (2015)	Not listed
Lamnidae	*Isurus oxyrinchus*	Mako Shark, Shortfin Mako	Vulnerable (2016)	Endangered (2019)	Not listed
Dasyatidae	*Maculabatis gerrardi*	Whitespotted Whipray	Data Deficient (2015)	Vulnerable (2004)	Not listed
Triakidae	*Mustelus mustelus*	Blackspotted Smoothhound, Spierhaai	Data Deficient (2017)	Vunerable (2004)	Not listed
Myliobatidae	**Myliobatis aquila*	Eagle Ray	Least Concern (2016)	Data Deficient (2005)	Not listed
Hexanchidae	*Notorynchus cepedianus*	Cowshark, Broadnosed Sevengill	Least Concern (2017)	Data Deficient (2005)	Not listed
Scyliorhinidae	*Poroderma africanum* E	Pjama Shark, Striped Catshark	Least Concern (2015)	Near Threatened (2005)	Protected
Scyliorhinidae	*Poroderma pantherinum* E	Leopard Catshark	Least Concern (2015)	Data Deficient (2004)	Protected
Carcharhinidae	*Prionace glauca*	Blue Shark	Least Concern (2015)	Near Threatened (2005)	Not listed
Rhinobatidae	**Rhinobatos annulatus* NE	Lesser Guitarfish, Lesser Sandshark	Least Concern (2016)	Least Concern (2006)	Not listed
Carcharhinidae	*Rhizoprionodon acutus*	Milk Shark	Data Deficient (2015)	Least Concern (2003)	Not listed
Rhinidae	*Rhynchobatus djiddensis*	Giant Guitarfish, Giant Sandshark	Data Deficient (2016)	Vulnerable (2006)	Vulnerable
Sphyrnidae	*Sphyrna lewini*	Scalloped Hammerhead	Data Deficient (2016)	Endangered (2007)	Endangered
Sphyrnidae	*Sphyrna zygaena*	Smooth Hammerhead	Data Deficient (2016)	Vulnerable (2005)	Not listed
Triakidae	*Triakis megalopterus* NE	Spotted Gullyshark	Data Deficient (2016)	Near Threatened (2005)	Not listed

9.3.5 Marine Reptiles

South Africa is home **to 5 of the world's 7 turtle species** and provides breeding grounds for two of these species, namely the southwest Indian Ocean subpopulations of Loggerhead (*Caretta caretta*) and Leatherback Turtles (*Dermochelys coriacea*) (Hughes 1974a, 1974b, 1993, 1996a, 1996b, Luschi *et al.* 2006). Additionally, several offshore ecosystems are important feeding and developmental areas for Hawksbill (*Eretmochelys imbricata*) and Green Turtles (*Chelonia mydas*) (Bourjea *et al.* 2008). Four of the 5 turtle species found in South Africa were assessed and found to be threatened; two of these were assessed both regionally and globally while three were assessed at the global scale only (Table 44). Loggerhead and Leatherback Turtles were assessed as Near Threatened and Critically Endangered respectively for the southwest Indian region (Wallace *et al.* 2013, Nel and Casale 2015), while Hawksbill, Green and Olive Ridley Turtles (*Lepidochelys olivacea*) were assessed globally as Critically Endangered (Mortimer and Donnelly 2008), Endangered (Seminoff 2004) and Vulnerable (Abreu-Grobois and Plotkin 2008) respectively. Based on a meta-analysis of pressures at the global scale, fishing remains the greatest pressure on marine turtles affecting 100% of these turtles of special concern, followed by residential and commercial development in the form of tourism and recreational areas (60%), pollution in the form of solid waste (40%), human intrusion and disturbance through recreational activities (40%) and climate change and temperature extremes (20%) (Figure 101). Some of these pressures may be less relevant at the regional and national level but due to the migratory lifestyle of turtles, global and regional pressures may very well impact the animals occurring in South Africa.

Fishing impacts range from **incidental bycatch, entanglement** in fishing gear, competition for resources due to overfishing of nearshore pelagic resources and the direct utilization of turtles or eggs for human use (Wallace *et al.* 2011, Nel *et al.* 2012). Turtle interactions with a number of fisheries exist in the SA EEZ, the most important being with longlining operations (Bourjea *et al.* 2008, Grantham *et al.* 2008, Petersen *et al.* 2008b, Harris *et al.* 2018), the prawn trawl fishery (Bourjea *et al.* 2008, Harris *et al.* 2018), and gillnetting in the form of bather protective shark nets (Harris *et al.* 2018). The shallow-water prawn trawl fishery was predicted to have the most significant impact on Loggerhead turtles due to spatial overlap with Loggerhead feeding and breeding activity (de Wet 2012). Shallow-water trawling effort was already very low in 2003 and has since decreased to near zero with very little current impact (S Fennessy, Oceanographic Research Institute, pers. comm).

Available data suggest that mean annual catch of sea turtles in **bather protective shark nets** off KZN were 60.7 animals per year for the period 1981-2008 (Brazier *et al.* 2012) with total mortality ranging between 53.2 and 70.6 % (Brazier *et al.* 2012) with much greater impact on neritic species such as Loggerheads (Brazier *et al.* 2012, Harris *et al.* 2018). The impacts of bather protective sharknets on turtles are considered much lower compared to the impacts of longlining (Brazier *et al.* 2012). The South African longline fishery is estimated to catch between 190 and 560 sea turtles per year (Petersen *et al.* 2008b) with Loggerheads constituting 60% of the turtle catch per year, Leatherbacks constituting 33.8%, and Hawksbill and Green Turtles constituting the remainder (Petersen *et al.* 2008b).

Given their oceanic lifestyle and the size of its South African nesting population (<100 females nesting per annum), **Leatherbacks are considered eight times more vulnerable to the impacts of longlining when compared to Loggerheads** (Hughes 1996a, Brazier *et al.* 2012, Nel *et al.* 2013, Harris *et al.* 2018) with longlining hypothesized to be responsible for the suppressed growth of the Leatherback

population (Nel *et al.* 2013). Between 7600 and 120 700 turtles are incidentally caught as bycatch per annum in pelagic longlines operating in the Benguela Large Marine Ecosystem (Honig *et al.* 2008). A much lower number of approximately 3500 turtles was estimated for the IOTC region but the latter estimate was hampered by poor bycatch reporting and data quality (Nel *et al.* 2012). Regional bycatch estimates from the International Commission for the Conservation of Atlantic Tunas (ICCAT) suggest that between 18 708 and 25 731 turtles (across all species) interacted with pelagic longline fishing gear within the region in 2014 although these values are thought to be underestimates (Gray and Diaz 2017). Global estimates suggest that between 180 000 and 260 000 turtles are caught each year (Lewison *et al.* 2004). These estimates are considered highly unsustainable given the longevity, late maturation and low reproductive rates of turtles (Heppell *et al.* 1999).

Given the transboundary nature of turtles, regional approaches and **coordinated international action is key to managing pressures** (Crowder 2000, Bourjea *et al.* 2008, Harris *et al.* 2018). Turtle mortality has been documented in other fisheries such as the purse seine and pelagic trawl in other parts of the world (Magnuson *et al.* 1990, Pandav *et al.* 1997, Silvani *et al.* 1999, Zeeberg *et al.* 2006) but the level of mortality caused by these fisheries in South Africa is poorly understood (Honig *et al.* 2008). While artisanal fisheries are not a significant pressure on sea turtles in SA, this activity in northwest and southwest Madagascar is suspected to be the largest contributor to turtle mortality in the southwest Indian Ocean, estimated to catch 12 030 animals (Green, Loggerhead, Hawksbill and Olive Ridley) per year (de Wet 2012).

In order to better understand the impacts of fishery bycatch on turtles, increased quantitative data of turtle bycatch across fisheries sectors at national, regional and global scale is required. As bycatch monitoring relies on onboard observers or fisher logbooks, trained fisheries observers are vital for quantifying bycatch on both local and foreign vessels. While working groups aimed at addressing issues around turtle bycatch have been established at the regional level (ICCAT and the Indian Ocean Tuna Commission (IOTC)) its effectiveness has been hampered by the lack of quantitative turtle bycatch data. Research which can highlight turtle-fisheries interactions and pilot **strategies for the reduction of bycatch** e.g. time-area closures, deeper sets, reduced soak time, move-on rules, gear restrictions (the use of circle hooks) and bycatch reduction devices (such as Turtle Excluder Devices) should be promoted.

The **direct harvesting of turtles and eggs** occurs commonly in several African countries (such as Madagascar, Maldives, Mozambique and Tanzania) (Costa *et al.* 2007, Lilette 2007, Bourjea *et al.* 2008) and is often fuelled by complex and compounding cultural, socio-economic and political drivers (Bourjea *et al.* 2008). Issues related to livelihoods, resource access and governance need to be addressed in order to decrease turtle and egg harvesting at the regional level. In the South African context, although there has been subsistence harvesting of nesting Leatherback and Loggerhead turtles and their eggs in the past, harvesting of these species ceased with the onset of active conservation and the proclamation of the iSimangaliso and Maputaland Marine Protected Areas (McAllister *et al.* 1965, Hughes 1996a, 1996b, Bourjea *et al.* 2008, Nel *et al.* 2013). Responses to turtle harvesting and trade has included for example the Memorandum of Understanding (MoU) on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA) which came into effect on 1 September 2001. The MoU was established under the auspices of the Convention of Migratory Species of Wild Animals and is aimed at addressing issues related to illegal take and trade of marine turtles through reducing pressures, conserving critical habitat, exchanging scientific data, increasing public awareness and participation, promoting regional

cooperation, and seeking resources for implementation. Additionally, Loggerhead, Green, Leatherback, Hawksbill and Olive Ridley Turtles have been listed on Appendix I of CITES in a bid to restrict international commercial trade of these species (Box 46).

While turtles are migratory, they aggregate off beaches in northern KZN during their nesting season during which time they are particularly vulnerable to coastal pressures and threats. **Residential and commercial development** is an ongoing pressure on turtles and globally beaches are being lost to coastal development and coastal squeeze (the result of coastal development on the terrestrial side and sea level rise on the sea-ward side) (Schlacher *et al.* 2007) which reduces habitat quality and increases habitat fragmentation. South Africa has maintained one the world's most **extensive coastal and marine conservation programmes** (since 1963) for turtles, protecting both nesting and non-nesting sea turtle species in a series of MPAs (Nel *et al.* 2013). Loggerhead Turtles have been shown to benefit (showing population growth) from coastal MPAs while Leatherback Turtle populations within MPAs along the KZN coast have not yet shown signs of growth, but have remained stable (Nel *et al.* 2013).

In addition to coastal squeeze, **climate change** is also predicted to intensify the strength of storms (Slott *et al.* 2006), and these together are predicted to drive increased beach erosion (Bird 2011) and increase the risk of tidal inundation (Foley *et al.* 2006, Xavier *et al.* 2006). Cumulative impacts of coastal development and climate are predicted to result in the future **loss of functional beaches** (Schlacher *et al.* 2007) which are critical nesting habitat for turtles, however this is not a significant threats to sea turtles in SA as turtle nesting populations are protected within the iSimangaliso World Heritage Site where coastal development is minimal. Like many other reptiles, most if not all sea turtles seem to use temperature-dependent sex determination (TSD). TSD has been demonstrated for Loggerhead, Green, Leatherback and Olive Ridley Turtles (Standora and Spotila 1985). The sex of turtle hatchlings is determined by the nest temperature and a warming of 2 °C could potentially result in a large sex ratio shift (Wilkinson 2000, Sheppard 2006) towards females, although some populations may be resilient to warming if female biases remain within levels where population success is not impaired (Poloczanska *et al.* 2009, Tomillo *et al.* 2015). Alteration of wind patterns and ocean currents will affect juvenile and adults in the open ocean (Poloczanska *et al.* 2009). Indirectly, climate change is likely to impact turtles through **changes in food availability**. Although the migratory nature of turtles may increase their resilience to climate change, such resilience is however likely to be compromised by the cumulative impacts of other pressures such as coastal development, pollution and fisheries (Poloczanska *et al.* 2009). South Africa has a **well-established protected area network**, with 5% of South Africa's oceans now being protected by 41 MPAs. South Africa's MPAs network, together with the implementation of the Integrated Coastal Management Act (2008) and Marine Spatial Planning Act (2019), puts South Africa in a favourable position to tackle ever increasing pressures on turtles during their beach nesting and oceanic phases.

Turtles are prone to **ingesting marine debris** (Derraik 2002, Schuyler *et al.* 2012), particularly plastic, mistaking it for food. Some of the impacts of plastic pollution on turtles include reduced ability to absorb nutrients (McCauley and Bjorndal 1999) and absorption of toxins (Bjorndal 1997) which could have negative effects on growth rates, fecundity and survivorship (Hoarau *et al.* 2014). Mortality generally occurs when the digestive tract is obstructed (Lazar and Gračan 2011) but large quantities of debris can remain in the gut for months and pass through the digestive tract without causing mortality (Lutz 1990). Out of 74 Loggerhead Turtles sampled (for the period January 2007 to January 2013) in the southwest Indian Ocean (off Reunion Island and Madagascar), debris was found in 51.4%

of gut or faecal samples with plastics accounting for 96.2% of the total debris found (Hoarau *et al.* 2014). Recent research off the South African coast has shown that plastic ingestion amongst post-hatchling Loggerhead Turtles (the life stage most vulnerable to plastic ingestion), has significantly increased between the 1960's and 2015 (in terms of quantity and diversity) and led to mortality in 28-41 % of stranded turtles examined (Ryan *et al.* 2016). Plastic is described as the most widely reported debris item ingested by all sea turtles based on a meta-analysis of 37 studies published on the ingestion of debris by sea turtles (Schuyler *et al.* 2012).

The toxicological effects of **contaminants** on marine turtles are poorly understood (Finlayson *et al.* 2016) but metals and metalloids, associated with marine debris, have been found in marine turtle eggs sampled off the northern KZN coast (du Preez *et al.* 2018) and can have toxic effects especially on early life stages (Roe *et al.* 2011). Despite international attempts to reduce marine pollution (e.g. the 1972 Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter; the 1978 Protocol to the International Convention for the Prevention of Pollution from Ships (MARPOL) (Lentz 1987, Ninaber 1997), marine debris is an ongoing concern globally and nationally. In order to assess population scale impacts from debris ingestion, a greater understanding of the distribution of debris, as well as the long and short-term impacts of ingested debris is required. Further research and modelling of debris in both the nearshore and oceanic environment, in addition to research on the lethal and sub-lethal impacts of various types of debris loading will provide more accurate and precise estimates of what is available to sea turtles, the likelihood of encounter rate, and ultimately the risks associated with anthropogenic marine debris ingestion. **Plastic pollution** needs to be mitigated rapidly through global improvements in waste management. Effective measures are required to prevent the disposal of plastics into the oceans through reduction, re-use and recycling. Appropriate local legislation associated with educational programs for schools and professional users of the ocean are necessary to promote changes in plastic disposal practices.

Based on its overlap with key turtle migratory corridors, the risk associated with the widespread **hydrocarbon industry**, is considered moderate relative to for example longline fishing. The hydrocarbon industry however has the potential to undermine more than 50 years of turtle conservation efforts should there be any oil-associated accident (Nel *et al.* 2013, Harris *et al.* 2018). In this regard, effective ocean zonation and management is advocated to achieve economic, ecological and social objective. The inclusion of migratory species such as turtles in Environmental Impact Assessments is essential, especially when economic gains could potentially result is severe ecological losses both nationally and/or regionally.

Box 46. Marine turtles listed on CITES

CITES lists 5 turtle species under Appendix I, these are the Loggerhead, Green, Leatherback, Hawksbill and Olive Ridley Turtle. Turtles are impacted by human consumption of eggs, meat and other products.



A scuba diver admires a Green Turtle in iSimangaliso (left) and a Loggerhead Turtle nests on the beach in KwaZulu-Natal (right).

Table 44. IUCN Red List status of reptiles with occurrence in South Africa with year assessed and associated listing on the South African list of Threatened or Protected Species (TOPS). Breeding in SA is indicated by (*), GA= Globally Assessed, RA= Regionally Assessed

Family	Scientific Name	Common name	IUCN Red List status	TOPS
Cheloniidae	Eretmochelys imbricata	Hawksbill Turtle	Critically Endangered (2008) GA	Critically Endangered
Cheloniidae	Chelonia mydas	Green Turtle	Endangered (2004) GA	Endangered
Elapidae	Hydrophis platurus	Yellow-bellied Sea Snake	Least Concern (2009) GA	Not listed
Cheloniidae	*Caretta caretta: Southwest Indian Ocean subpopulation	Loggerhead Turtle	Near Threatened (2015) RA	Endangered
Dermochelyidae	*Dermochelys coriacea: Southwest Indian Ocean subpopulation	Leatherback Turtle	Critically Endangered (2013) RA	Critically Endangered
Cheloniidae	Lepidochelys olivacea	Olive Ridley Turtle	Vulnerable (2008) GA	Vulnerable

Note: The only other South African marine reptile assessed is the Yellow-Bellied Sea Snake (*Hydrophis platurus*) for which populations are widespread and not declining. The species was therefore assessed as Least Concern.

9.3.6 Corals

The Maputaland reefs in the Delagoa Ecoregion of KwaZulu-Natal are the southernmost shallow-water coral reefs on the east African coast and are where the vast majority of zooxenthellate corals occur in South Africa (Riegl *et al.* 1995, Schleyer 2000, Porter *et al.* 2013, Schleyer and Porter 2018). These reefs are not true accretive coral reefs, due to their high-latitude position and marginal nature, yet zooxenthellate soft and hard corals thrive, and dominate the benthic communities (Porter and Schleyer 2019). Despite the high-latitude location, the reefs are characterised by relatively **high levels of coral diversity** (Schleyer and Celliers 2003b). Although soft corals are dominant in terms of reef cover, hard corals contribute most to regional coral diversity (Schleyer and Porter 2018, Porter and Schleyer 2019). At least **39 species of soft corals and 93 species of hard corals** have been recorded on the shallow reefs of Maputaland (Celliers and Schleyer 2008). The reefs are protected within the **iSimangaliso Marine Protected Area**, a World Heritage Site. The marine protected areas of iSimangaliso and Aliwal Shoal are well located in relation to shallow coral diversity hotspots in the region. In addition to formal protected areas, all hard and soft corals from the orders Scleractinia and Alcyonacea respectively, are protected by the Marine Living Resources Act. The NEMBA also protects all hard coral species from the order Scleractinia. Approximately 164 hard coral species with occurrence in South Africa are listed on CITES (Box 47).

Despite the protected status, there are several pressures and threats to corals in the region. Climate change in the form of **ocean warming and acidification** (see Chapter 6 for more detail) is probably the most ubiquitous, although so far the reefs have been only negligibly affected by coral bleaching (Porter *et al.* 2016). First records of **bleaching** were in 1998, with most severe levels occurring in 2000, when 12% of the living cover bleached (Celliers and Schleyer 2002). Three major global bleaching events have occurred thus far, the most recent being in 2015, which resulted in 9.4% of the coral cover bleaching at Sodwana Bay, Maputaland (Porter *et al.* 2016). Although bleaching in the region has been recorded several times, it has only resulted in negligible mortalities limited to hard corals (Celliers and

Schleyer 2002, Sebastián *et al.* 2009, Porter *et al.* 2016). The effects of ocean acidification on local corals remain somewhat of an enigma.

Despite being a significant distance from heavy industry, within a mature Marine Protected Area and lying adjacent to land that is formally protected, there is growing evidence to suggest that **pollutants** from anti-malarial spraying, agriculture and forestry may be exerting pressure on wetlands and coral reefs (Humphries 2013, Porter *et al.* 2018). Some of the highest levels globally, of a range of organochlorine pesticides, have been measured in soft corals and sponges from the region (Porter *et al.* 2018). These pesticides appear to be leaching from wetlands through the dunes and onto coral reefs. However, the effects of these pesticides on corals are unknown. Furthermore, the reefs lie adjacent to an international shipping lane that connects the ports of Durban and Richards Bay with the rest of the east African coast and the Middle East, and thus the threat of an oil spill or ship running aground is possible (Sink *et al.* 2012a).

The coral reefs are also internationally renowned for their spectacular diving. This has resulted in another pressure in the form of disturbance from **divers and boats (noise pollution), and structural breakages** to some species of hard corals from divers (Schleyer and Tomalin 2000). The dive industry expanded in the 1980s with 20 070 dives being recorded in 1987, and reached peak levels in the 90s when 118 389 dives were recorded in 1996 (Schleyer and Celliers 2003b). Since then, the number of dives has approximated 65 000 per year and has largely been constrained by the economic climate (Porter 2017). (Schleyer and Tomalin 2000), recommended the implementation of a diver carrying capacity and the inclusion of diver-related damage into a risk assessment of the coral communities for their sustainable conservation management. The heavy diving pressure is however focused on the Central Reef Complex, which is facilitated by approximately 10 000 launches annually, for both diving and sport fishing purposes (Porter 2017).

In addition to structural damage and breakage of hard corals caused by divers, storms may also cause similar damage. The frequency and veracity of storm events are predicted to increase with global warming, with tropical cyclones predicted to move further south down the Mozambique Channel (Webster *et al.* 2005). While the reefs lie outside of the tropical cyclone belt, they may nevertheless be more frequently affected by cyclone generated swell (Schleyer *et al.* 2018).

The **offtake of pelagic gamefish by recreational fishers** is considered another pressure in the region (Floros 2010, Currie *et al.* 2012, Sink *et al.* 2012a). A reduction in predatory fish reduces top-down pressures and can in theory have effects on lower trophic levels which may indirectly affect corals (Stallings 2008). Bottom fishing is not a pressure and neither is anchoring, as the two activities are illegal in the park and are adhered to.

Increases in the levels of the aforementioned pressures are known to decrease coral resilience which can in turn lead to increases in the prevalence of **coral diseases and outbreaks of crown of thorns starfish** (Jackson *et al.* 2001, Harvell *et al.* 2002, Szmant 2002, Bruno *et al.* 2007, Babcock *et al.* 2016). Disease prevalence and diversity has been investigated in the region and the prevalence in hard coral colonies is low, at approximately 4% of colonies, with seven types of disease being recorded (Séré *et al.* 2012, 2015). Crown of thorns starfish have also been recorded, as far back as the early 1970s by (Heydorn 1972). However, only minor outbreaks having been recorded on Two-mile Reef, particularly between 1994 and 1999 (Schleyer 1998). The aggregations of the starfish were apparently for purposes of breeding rather than to feed on corals, as they dispersed once winter began (Schleyer 1998). Nevertheless, the outbreak caused a severe but patchy reduction in hard coral cover (Schleyer

1998, Celliers and Schleyer 2006). Alien species have not been reported to be a pressure to corals yet, but should be considered a potential threat.

Box 47. Corals listed on CITES



***Acropora* plate corals in Sodwana Bay.**

Due to the difficulties in identifying individual coral species, majority of the Scleractinia order (stony corals) have been listed on CITES Appendix II. There is a total of 1822 Scleractinia species listed on Appendix II and of these, 164 species occur within South African waters (checklist.cites.org). According to the CITES trade database, South Africa has had little to no impact on the trade in stony corals and is unlikely to pose a significant threat as majority of the corals listed occur in deeper waters within Marine Protected Areas - e.g. in the iSimangaliso Wetland Park in KwaZulu-Natal. Stony corals with occurrence in South Africa are however traded elsewhere in the world, mainly as live corals for the international aquarium trade and as dead skeletons for use as home decoration and curios (Thornhill 2012). The most common genera collected for the international aquarium trade include *Euphyllia, Goniopora, Catalaphyllia, Trachyphyllia, and Heliofungia*, of which only *Goniopora* occurs in South African waters (Wabnitz *et al.* 2003).

This current assessment of corals is limited to being based on the IUCN global assessments for hard coral species with distributions in South Africa (Figure 100, Table 46). Of the 95 hard species listed to occur in South Africa by the IUCN, 9 are listed as Vulnerable and 30 as Near Threatened (Figure 100, Table 46). While relevant at a global level, this is less relevant in a national context. Of concern is the fact that these **assessments are out of data** with the last Red List assessment conducted in 2008 and South Africa was not able to contribute to these assessments. Regional level IUCN assessments of coral species' threat status have not yet been undertaken, but the process of assessing corals for the Western Indian Ocean (WIO) region is expected to commence in 2020 (D. Obura, Coastal Oceans Research and Development-Indian Ocean, pers. comm.). However, based on the above local pressures, several coral groups or priority species reaffirm the IUCN-based assessment, or further emerge as priority taxa at a national level.

As far a climate change is concerned, all species of hard and soft corals remain a **priority group** and should be considered vulnerable to either global warming, ocean acidification or both (Table 45). However, several genera of hard coral, in particular *Montipora* and *Acropora*, seem to be particularly susceptible to thermal stress in the region (Table 45). No published information is available on the effects of ocean acidification on local corals but research is underway at the Oceanographic Research Institute. Soft corals in particular are threatened by organochlorine pesticides as this group bioaccumulates chemicals, and many of the species are thought to live for decades and possibly centuries. Structurally complex hard corals, especially various species of *Acropora* are priority species in terms of diver damage and cyclone threats. Patches of *Acropora austera* in particular, have been shown to play important roles as fish nursery areas besides providing key reef framework building

functions (Floros and Schleyer 2017). *Anomastrea irregularis* occurs prominently in the intertidal zone and outside of much of the iSimangaliso Wetland Park (Smit and Glassom 2017), and therefore can be considered a priority species due to its vulnerability to coastal development such as concrete tidal pools, pipelines and any structures and practices that alter intertidal sand inundation dynamics.

Table 45. Some priority taxa according to key local pressures and threats

Priority taxa and species	Pressure/Threat	Key references
Hard corals in particular *Stylophora* spp; *Montipora* spp., *Acropora* spp. *Favia* spp., *Pocillopora* spp., & *Alveopora* spp.	Global warming	(Sebastián *et al.* 2009, Porter *et al.* 2016)
Hard and soft corals	Ocean acidification	(Anthony *et al.* 2008, Fabricius *et al.* 2011)
Soft corals especially long lived taxa such as *Sinularia* spp., *Lobophytum* spp. & *Sarcophyton* spp.	Organochlorine pesticides	(Porter *et al.* 2018)
Hard corals, particularly structurally complex species such as *Acropora austera*, *A. hyacinsus*, *A. clathrata*, *A. branchi*, *Tubastrea micranthus*, but also *Porites* spp. bommies	Structural damage from divers & tropical cyclones	(Schleyer and Tomalin 2000, Webster *et al.* 2005, Celliers and Schleyer 2008, Schleyer *et al.* 2018)
Anomastrea irregularis	Coastal developments e.g. concrete tidal pools	(Goble *et al.* 2014)

Priority actions for addressing climate change impacts specifically on corals were recently provided by (Porter *et al.* 2016) and are summarized in Chapter 6.

Table 46. IUCN Red List status of hard corals with South African distribution with year assessed and associated listing on the South African list of Threatened or Protected Species (TOPS).

Family	Scientific Name	Common name	Global Assessment	TOPS
Acroporidae	*Acropora branchi*	Polyped Hard Coral	Data Deficient (2008)	Protected
Acroporidae	*Acropora forskali*	Staghorn Coral	Data Deficient (2008)	Protected
Acroporidae	*Acropora inermis*	Staghorn Coral	Data Deficient (2008)	Protected
Acroporidae	*Acropora variabilis*	Staghorn Coral	Data Deficient (2008)	Protected
Acroporidae	*Acropora abrotanoides*	Polyped Hard Coral	Least Concern (2008)	Protected
Acroporidae	*Acropora clathrata*	Polyped Hard Coral	Least Concern (2008)	Protected
Acroporidae	*Acropora cytherea*	Hard Coral	Least Concern (2008)	Protected
Acroporidae	*Acropora gemmifera*	Staghorn Coral	Least Concern (2008)	Protected
Acroporidae	*Acropora latistella*	Staghorn Coral	Least Concern (2008)	Protected
Acroporidae	*Acropora microphthalma*	Staghorn Coral	Least Concern (2008)	Protected
Acroporidae	*Acropora valida*	Staghorn Coral	Least Concern (2008)	Protected
Acroporidae	*Anacropora forbesi*	Hard Coral	Least Concern (2008)	Protected
Acroporidae	*Montipora aequituberculata*	Pore Coral	Least Concern (2008)	Protected
Acroporidae	*Montipora danae*	Pore Coral	Least Concern (2008)	Protected
Acroporidae	*Montipora monasteriata*	Pore Coral	Least Concern (2008)	Protected
Acroporidae	*Montipora tuberculosa*	Pore Coral	Least Concern (2008)	Protected
Acroporidae	*Montipora verrucosa*	Pore Coral	Least Concern (2008)	Protected
Acroporidae	*Acropora appressa*	Polyped Hard Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora austera*	Polyped Hard Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora digitifera*	Staghorn Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora divaricata*	Staghorn Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora florida*	Branch Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora formosa*	Staghorn Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora glauca*	Staghorn Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora humilis*	Finger Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora hyacinthus*	Brush Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora millepora*	Fluro Scale Cushion Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora monticulosa*	Staghorn Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora nana*	Staghorn Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora nasuta*	Small Staghorn Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora secale*	Staghorn Coral	Near Threatened (2008)	Protected
Acroporidae	*Isopora palifera*	Catch Bowl Coral	Near Threatened (2008)	Protected
Acroporidae	*Acropora anthocercis*	Polyped hard coral	Vulnerable (2008)	Protected
Acroporidae	*Acropora horrida*	Staghorn Coral	Vulnerable (2008)	Protected
Acroporidae	*Acropora retusa*	Staghorn Coral	Vulnerable (2008)	Protected
Acroporidae	*Acropora verweyi*	Staghorn Coral	Vulnerable (2008)	Protected
Acroporidae	*Acropora willisae*	Staghorn Coral	Vulnerable (2008)	Protected
Agariciidae	*Coeloseris mayeri*	Tombstone Coral	Least Concern (2008)	Protected
Agariciidae	*Gardineroseris planulata*	Gardeners Coral	Least Concern (2008)	Protected
Agariciidae	*Leptoseris explanata*	Porcelain Coral	Least Concern (2008)	Protected
Agariciidae	*Leptoseris scabra*	Porcelain Coral	Least Concern (2008)	Protected
Agariciidae	*Leptoseris solida*	Porcelain Coral	Least Concern (2008)	Protected
Agariciidae	*Pachyseris speciosa*	Serpent Coral	Least Concern (2008)	Protected
Agariciidae	*Pavona clavus*	Leaf Coral	Least Concern (2008)	Protected
Agariciidae	*Pavona duerdeni*	Leaf Coral	Least Concern (2008)	Protected
Caryophylliidae	*Heterocyathus alternatus*	Coral	Least Concern (2008)	Protected
Dendrophylliidae	*Turbinaria mesenterina*	Disc Coral	Vulnerable (2008)	Protected
Faviidae	*Echinopora gemmacea*	Hedgehog Coral	Least Concern (2008)	Protected
Faviidae	*Echinopora hirsutissima*	Hedgehog Coral	Least Concern (2008)	Protected
Faviidae	*Favia favus*	Head Coral	Least Concern (2008)	Protected
Faviidae	*Favia pallida*	Head Coral	Least Concern (2008)	Protected
Faviidae	*Favia rotumana*	Head Coral	Least Concern (2008)	Protected
Faviidae	*Favia speciosa*	Head Coral	Least Concern (2008)	Protected
Faviidae	*Goniastrea edwardsi*	Brain Coral	Least Concern (2008)	Protected
Faviidae	*Goniastrea pectinata*	Lesser Star Coral	Least Concern (2008)	Protected

Family	Scientific Name	Common name	Global Assessment	TOPS
Faviidae	*Goniastrea retiformis*	Lesser Star Coral	Least Concern (2008)	Protected
Faviidae	*Leptastrea purpurea*	Crust Coral	Least Concern (2008)	Protected
Faviidae	*Platygyra daedalea*	Brain Coral	Least Concern (2008)	Protected
Faviidae	*Plesiastrea versipora*	Small Knob Coral	Least Concern (2008)	Protected
Faviidae	*Favia matthaii*	Head Coral	Near Threatened (2008)	Protected
Faviidae	*Favia stelligera*	Head Coral	Near Threatened (2008)	Protected
Faviidae	*Favites abdita*	Larger Star Coral	Near Threatened (2008)	Protected
Faviidae	*Favites flexuosa*	Larger Star Coral	Near Threatened (2008)	Protected
Faviidae	*Favites halicora*	Larger Star Coral	Near Threatened (2008)	Protected
Faviidae	*Goniastrea columella*	Hard Coral	Near Threatened (2008)	Protected
Faviidae	*Goniastrea peresi*	Star Coral	Near Threatened (2008)	Protected
Faviidae	*Montastrea annuligera*	False Knob Coral	Near Threatened (2008)	Protected
Faviidae	*Oulophyllia crispa*	Intermediate Valley Coral	Near Threatened (2008)	Protected
Faviidae	*Platygyra crosslandi*	Lesser Valley Coral	Near Threatened (2008)	Protected
Fungiidae	*Fungia costulata*	Mushroom Coral	Least Concern (2008)	Protected
Fungiidae	*Fungia cyclolites*	Mushroom Coral	Least Concern (2008)	Protected
Fungiidae	*Fungia sinensis*	Mushroom Coral	Least Concern (2008)	Protected
Helioporidae	*Heliopora coerulea*	Blue Coral	Vulnerable (2008)	Not listed
Merulinidae	*Hydnophora exesa*	Hard Coral	Near Threatened (2008)	Protected
Merulinidae	*Hydnophora microconos*	Hard Coral	Near Threatened (2008)	Protected
Milleporidae	*Millepora exaesa*	Firecoral	Least Concern (2008)	Not listed
Milleporidae	*Millepora platyphylla*	Firecoral	Least Concern (2008)	Not listed
Milleporidae	*Millepora tenera*	Firecoral	Least Concern (2008)	Not listed
Mussidae	*Acanthastrea echinata*	Atlantic Hard Coral	Least Concern (2008)	Protected
Mussidae	*Blastomussa merleti*	Cup Coral	Least Concern (2008)	Protected
Mussidae	*Symphyllia valenciennesii*	Sinuous Cup Coral	Least Concern (2008)	Protected
Pectiniidae	*Echinophyllia aspera*	Flat Lettuce Coral	Least Concern (2008)	Protected
Pectiniidae	*Mycedium umbra*	Coral	Least Concern (2008)	Protected
Pocilloporidae	*Stylophora subseriata*	Hood Coral	Least Concern (2008)	Protected
Pocilloporidae	*Pocillopora eydouxi*	Cauliflower Coral	Near Threatened (2008)	Protected
Poritidae	*Goniopora djiboutiensis*	Anemone Coral	Least Concern (2008)	Protected
Poritidae	*Porites lichen*	Hump Coral	Least Concern (2008)	Protected
Poritidae	*Porites lutea*	Hump Coral	Least Concern (2008)	Protected
Poritidae	*Porites solida*	Hump Coral	Least Concern (2008)	Protected
Poritidae	*Alveopora spongiosa*	Net Coral, Hard Coral	Near Threatened (2008)	Protected
Poritidae	*Alveopora allingi*	Net Coral, Hard Coral	Vulnerable (2008)	Protected
Siderastreidae	*Coscinaraea monile*	Wrinkle Coral	Least Concern (2008)	Protected
Siderastreidae	*Psammocora haimeana*	Pitten Petaloid Coral	Least Concern (2008)	Protected
Siderastreidae	*Anomastraea irregularis*	Pillow Coral	Vulnerable (2008)	Protected
Tubiporidae	*Tubipora musica*	Organ Pipe Coral	Near Threatened (2008)	Not listed

9.4 Species assessment limitations in this environment

One of the key limitations of this species threat status analysis is the fact that only four (birds, mammals, reptiles and seabreams) of the seven groups were comprehensively assessed either at national, regional or global scale. **Gaps in taxonomic knowledge** and taxonomic uncertainties are major constraints to species assessments in the marine realm, particularly for marine invertebrates and this limits our ability to conduct comprehensive status assessments of taxonomic groups. A systematic process of detailed **integrated taxonomic studies** on priority groups, including field collections and DNA barcoding, is essential for the enhancement of national species datasets. It is also crucial to build and maintain South African taxonomic knowledge and expertise, especially for understudied groups. Limited occurrence data, a lack of abundance and long-term population trend data, and insufficient knowledge of species life histories and ecology also limit our understanding of marine species threat status and threatened species may go undetected.

Addressing knowledge gaps can guide management to help secure the benefits from marine species. Data quality limits assessment especially for fisheries species (which is the case for many sharks, skates and rays), which are often lumped when reported on catch returns due to identification challenges at sea. Increased reliable data for stock assessments collected over the long term, more and increased frequency of stock assessments (especially for economically important species) and building fisheries science expertise is essential. Due to the variability in fisheries data, and the computational capacity to standardise data, the status of most fish stocks remains unknown, particularly within multispecies fisheries. Nevertheless, progress has been made with developing novel techniques for fisheries data standardisation (Winker *et al.* 2018). Due to limited comprehensive species group assessments and a lack of temporal monitoring data for marine species, using the **Red List Index (RLI)** to track trends in status is not yet possible. There is a bias in assessments towards vertebrates, and these cannot act as a surrogate for invertebrate species diversity and status. To date, very few national assessments have been conducted for **marine invertebrate species** due to inadequate taxonomic knowledge, limited distribution data, a lack of systematic surveys and limited capacity to advance species redlisting. New datasets through increasing foundational biodiversity research and citizen science species atlas efforts are underway but this work requires further investment to consolidate, address key gaps and analyse trends. Building on previous efforts, an updated national strategy to coordinate and prioritise marine species assessments is required. Greater local collaboration in regional and international redlisting initiatives may also help increase local capacity in this regard.

9.5 Protection level for species

Although there has been limited work to assess species protection levels in the marine environment, there have been species analyses that provide some insights into the protection levels of marine species. Lombard *et al.* (2004) undertook a preliminary assessment of **coastal species representation** in South Africa's MPAs using data for 803 seaweed species (Bolton and Stegenga 2002, Bolton *et al.* 2004), 2524 intertidal invertebrates (Emanuel *et al.* 1992, Awad *et al.* 2002) and the species ranges of 1239 fish (Turpie *et al.* 2000). Noting the limitations of these data sets which were assigned into 50-100 km long coastal strips, Lombard *et al.* (2004) found that approximately 90% of coastal seaweeds and invertebrates in the data set may occur in MPAs and that as many as 98% of fish species were assigned to coastal strips that include MPAs. They noted two key problems; (1) the absence of point data meant that it was assumed that species occurred across entire strips and (2) presence in an MPA may not provide protection as a viable proportion of a population may not be included and protection may not actually exist in many MPAs zoned to accommodate fishing activities.

Solano-Fernandez *et al.* (2012) used relative abundance data for 700 **fish species** sampled by four different fish sampling methods to estimate the extent to which protected areas represent the marine fish diversity of South Africa, and to examine the degree of redundancy in the network of protected areas. This approach is more accurate than previous coastal efforts that were inferring continuous distributions of fish between their known distribution limits (Turpie *et al.* 2000). Solano-Fernandez *et al.* (2012) based their study on point data from a broader set of distribution data. They found that only 49% of fish taxa were represented in the 14 MPAs that were sampled with fishes from deeper water (beyond 80 m) being mostly unprotected. For species caught from the shore, 73% of 164 species were present in MPAs and 73% of 106 estuarine taxa sampled by seine net were represented in protected areas. Of the 153 fish species caught by boat angling, 65% occurred in MPAs. Only 27% of a total of 121 species sampled by demersal trawling were included in MPAs highlighting the need to increase

offshore protection. Fish that occur in the offshore trawl grounds of the west and south coast, the fishes of uThukela Bank (caught by crustacean trawl fisheries) and fishes of the estuaries in southern and central KwaZulu-Natal were identified as most in need of protection. Redundancy in the MPA network was low, with fish species most commonly being represented in only one MPA or absent.

With the significant increase in the Marine Protected Area Network declared in 2019 (see Chapter 8), protection level of **marine species is projected to improve**. A recent study combined seven standardized fisheries datasets (covering the -50m to shelf edge of the Southern Benguela and Agulhas ecoregions) to evaluate the distribution of ichthyofaunal communities within MPAs including those gazetted for public comment in 2016 (Government Gazette No 39646. 3 Feburary 2016) (Logan 2018). The results suggested that the planned expansion of MPAs would advance the representation of fish from the previously assessed 19% (Solano-Fernandez *et al.* 2012) to 35% and fish species representation from 27% (Solano-Fernandez *et al.* 2012) to more than 50% (Logan 2018). Logan (2018) noted that only 8% of grid cells sampled deeper than 50 m were found within the proposed MPAs and this suggests that improved data resolution is needed. There is an opportunity to investigate this more fully by including fish data from the visual survey records provided by recent tow camera, Remotely Operated Vehicle and Baited Remote Underwater Video methods (see Box 13).

In future, the marine species assessment includes in the NBA may include an **official indicator on the protection level of marine species** based on the recently developed species protection assessment methods (Skowno *et al.* 2019b). These methods include a measure of population persistence in the assessment of terrestrial and freshwater species and a measure of effectiveness of protected areas to mitigate threats that cause species decline. Further work will be needed to align this type of assessment with fisheries and other biodiversity assessment work.

10. THE GENETIC PERSPECTIVE ON MARINE BIODIVERSITY

Chapter citation: da Silva J, van Vuuren B. 2019. Chapter 10: The genetic perspective on marine biodiversity. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



Cuddle jou kaleljou! Dusky Kob is experiencing a population bottleneck because of overfishing

Chapter Summary

The maintenance of genetic diversity is important for retaining evolutionary potential and the ability of species or populations to adapt to change. Risks to genetic diversity include genetic erosion through overfishing and reduced population sizes, loss of connectivity, hybridization and inbreeding and the disruption of co-adapted gene complex and disease epidemiology through translocations. South Africa has increasingly invested in genetic research and has established a relatively strong baseline understanding of spatial patterns, particularly inshore. There is evidence in South Africa of fisheries impacts on the genetic diversity of some fished species such as Cape Hakes, Kingklip and Dusky Kob. There is an absence of temporal genetic datasets, as well as a lack of genetic diversity indicators and thresholds, against which data can be compared. To assist future genetic monitoring programmes and studies, a genetic monitoring framework is required that outlines a strategic approach to prioritise species for monitoring, identifies appropriate genetic markers and metrics, and specifies the frequency of monitoring.

10.1 Introduction

Genetic diversity is the basis of the diversity of life on Earth. It is responsible for maintaining biological variation and evolutionary processes (Frankel 1974, Lande and Shannon 1996, Frankham 2005, Hughes *et al.* 2008, Bijlsma and Loeschcke 2012). Intraspecific genetic diversity, in particular, represents a species' **evolutionary potential** to evolve and adapt within a changing environment. As such, it drives the process of speciation and plays a pivotal role in ecosystem structure and function (Hughes *et al.* 2008, Whitham *et al.* 2008). Many species are equipped with sufficient evolutionary resilience, or genetic diversity, to overcome rapid environmental change (Hughes *et al.* 2008); however, others are not, as is evident by the rapid loss of biodiversity reported globally (WHO 2005). Most of these instances of decline are typically documented in cultivated species or species that are heavily exploited. For wild species, few data exist on the actual changes in the magnitude and distribution of genetic diversity and even fewer in the vast and inaccessible marine realm (WHO 2005). This realization has prompted the conservation of genetic diversity as an explicit goal of various national and international agreements. In particular, the Convention on Biological Diversity (CBD) and its member nations explicitly agreed to 'promote the conservation of genetic diversity' (UNEP 2003) and sought 'to achieve, by 2010, a significant reduction in the current rate of biodiversity loss at the global, regional and national levels' (UNEP 2003). Despite this commitment, implementation of the conservation and monitoring of genetic diversity has lagged behind implementation for other levels of biodiversity (Laikre 2010, Laikre *et al.* 2016).

The **lag in the assessment and monitoring of genetic diversity** has generally been attributed to the lack of appropriate indicators and thresholds (Walpole *et al.* 2009, Laikre 2010, Tittensor *et al.* 2014, Laikre *et al.* 2016). Although there are examples of conservation genetic studies that have utilised genetic parameters, such as allelic richness (i.e. allelic diversity) and heterozygosity to monitor changes in the genetic composition of species over time, there has been no consistent and comparable approach among them. This inconsistency is with respect to the number of sampling periods, sampling intervals, the type and number of genetic markers used, and the number of individuals sampled. Consequently, it has been difficult to identify simple and direct indicators sensitive enough to detect genetic erosion (i.e. loss of genetic diversity), resulting in genetic biodiversity indicators being largely overlooked until recently.

With the release of the Aichi Biodiversity Targets in 2010, there is a renewed emphasis on the conservation of genetic diversity. **Aichi Target 13** makes specific mention of minimizing genetic erosion and safeguarding genetic diversity, which implies that genetic diversity should be monitored over time in a given population. This temporal dimension is key, as some studies claim to monitor genetic diversity when in fact they are actually 'assessing' genetic diversity at a single point in time (Schwartz *et al.* 2007). For example, using genetic data from a single year or pooled data from multiple years to provide a single-point estimate of a population's diversity and structure (Baker *et al.* 2000, Hua Yue *et al.* 2004, Cannas *et al.* 2016).

South Africa possesses an exceptionally rich marine environment, with a wide diversity of ecosystems and more than 13 000 species, of which 26 to 33% are estimated to be endemic (see Chapter 1). This diversity represents an enormously valuable resource, not only in terms of GDP (e.g., fisheries, tourism) and direct benefits (e.g., food, recreation, transport) (see Chapter 2), but also for the overall intrinsic value of this diversity. This diversity is largely attributable to the confluence of the Indian, Atlantic and Southern oceans, which has created one of the most dynamic and variable oceanographic regimes in the world (Branch and Branch 2018). This has provided South Africa with a unique geographic advantage in terms of understanding the **historical and contemporary processes** that shape marine biodiversity, including anthropogenic impacts on genetic and genomic variation.

Within the past two decades, a strong baseline understanding of the spatial genetic patterns in various coastal species and offshore commercially exploited fish stocks, such as Hake and Kingklip, has been established (von der Heyden *et al.* 2007, 2009, 2010, Henriques *et al.* 2017, Nielsen *et al.* 2017, Mertens *et al.* 2018). This has relied on mitochondrial DNA and to a lesser extent nuclear data such as microsatellite markers (von der Heyden 2009, Teske *et al.* 2011, Wright *et al.* 2015). More recently, research has focussed on epigenetics (Baldanzi *et al.* 2017), as well as genome wide scanning of various species (e.g. ongoing work on Coelacanth, Knysna Sand Goby, Sardine) to identify intraspecific, genome-wide variability and structure. Given the heterogeneous marine environment of South Africa that spans ecological gradients (e.g. temperature, primary productivity, oxygen and salinity), such work is likely to provide crucial insights into **population connectivity and signals of local adaptation**. In doing so, areas of evolutionary importance, persistence and resilience can be identified, which could greatly inform marine spatial planning.

Genetic and genomic data are currently not incorporated into marine spatial planning. Wright *et al.* (2015) show that there is a need to improve genetic connectivity within South Africa's marine protected area network. Failure to do so may reduce the ability of species and their populations to respond to change and leave some unique populations of some species vulnerable. These authors note that South Africa's **MPA network** currently excludes some sites that have been identified as being of evolutionary importance (e.g., many populations and localities along the South African West Coast). The recent proclamation of new MPAs does provide a modest increase in west coast protection but further progress is needed. This is critical to ensure the protection of unique evolutionary patterns and long-term persistence and/or resilience of South Africa's marine biodiversity.

Considering that the available genetic research on marine species in South Africa has focused on commercial or threatened taxa, there is also a need to improve understanding of the basic genetic composition of the general marine environment. **Genetic surveys** using techniques such as DNA barcoding could greatly assist with this. The SeaKeys Project is one example of where this has proven very successful (see Box 48). The genetic reference library resulting from this work (which is

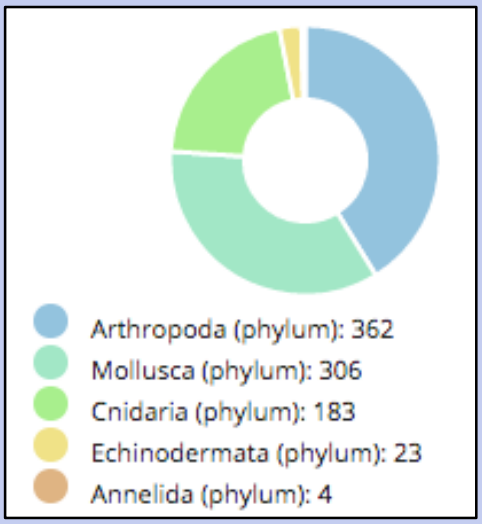
accompanied by detailed locality data and images to aide in the identification and taxonomy of specimens) will prove instrumental in incorporating other molecular surveying and monitoring techniques, such as **environmental DNA** (eDNA: DNA from sloughed skin cells, scales, secretions and other matter from organisms present in a sample of water, soil or sediment). This sampling technique has been shown to reliably and non-invasively detect rare, elusive and difficult-to-study marine species, such as threatened whales, sharks and dolphins (Pikitch 2018). Moreover, it can be used to explore diversity beyond just taxon identifications, specifically intra- and inter-specific genetic diversity (Stat *et al.* 2017). In South Africa, eDNA is still in its infancy, with only a few studies currently underway that incorporate eDNA to survey biodiversity (Box 49) (Ramond *et al.* 2015, Wilcox and Cowan 2016, Segobola *et al.* 2018). Considering South Africa's exceptional biodiversity and the urgent need to protect it, while also understanding the limited financial resources available to do so, it is almost certain that eDNA will become an important tool in species and ecosystem conservation within the country. However, this technique is only as powerful as the genetic reference library used to underpin it. In addition to genetic surveys and assessments of species genetic diversity, research focused on temporally monitoring changes in genetic diversity of threatened, exploited and/or farmed species needs to commence and is of the utmost importance. As such, the remainder of this chapter will focus on genetic monitoring.

Box 48. Improving our understanding of the basic genetic composition of the marine environment
The SeaKeys Project

By Jannes Landschoff and Jessica da Silva

In 2014, the SeaKeys Project (funded by the National Research Foundation's Foundational Biodiversity Information Programme [NRF-FBIP]) was initiated to help identify and address key gaps in South African foundational marine biodiversity knowledge. One goal of SeaKeys was the generation of a mitochondrial DNA barcode library on the Barcode of Life Database (BOLD) for South African marine invertebrates using the cytochrome c oxidase subunit 1 (CO1).

The SeaKeys BOLD Database (SEAKY) was compiled by several South African institutions, namely, Iziko South African Museum, University of Cape Town, University of KwaZulu-Natal, SAIAB, and Stellenbosch University. To date, SEAKY contains 1629 specimen records listing 374 species. In about half of the cases, specimen records were however uploaded although sequencing was not successful. Accounting for these "empty" records, the dataset therefore currently consists of 878 barcode sequences (high quality, no data flags, >500 basepairs), representing 280 species placed in 262 Barcoding Index Numbers (BINs).



Barcodes within SEAKY can be classified into two categories. Records in Category 1 targeted a specific taxonomic group of marine invertebrates through a student project. These groups comprise nudibranchs (MSc. thesis by Jessica Toms, 82 barcodes, 51 species), Scleractinian hard corals (PhD thesis by Brent Chiazzari (in prep.), 183 barcodes, 50 species), and hermit crabs (PhD thesis by Jannes Landschoff, 192 barcodes, 55 species). The SEAKY dataset is therefore heavily biased towards only these three taxonomic groups, together adding 457 barcodes and 156 species (both >50% of the SEAKY dataset, respectively). The remaining records in Category 2 originate from untargeted taxon sampling predominantly through the Charles L. Griffiths' working group at UCT, who provided 90% of the species in this category. The majority of species in Category 2 are conspicuous shore species that were easily accessible during excursions into the intertidal zone. Together this explains why the SEAKY database only comprises 5 Phyla.

Records of Category 1 are analysed and mostly published (see respective theses by students, and also Landschoff and Gouws (2018), Chiazzari *et al.* (2019), whereas barcodes in Category 2 remain entirely unanalysed. One finding of compiling the SEAKY database is that barcoding projects can be highly valuable when linked to specific research questions. For example, the CO1 barcodes have helped to identify 3 new species of hermit crabs, with probably at least 12 more species potentially new to science (Landschoff 2018). The CO1 barcodes contributing towards published research clearly strengthens the dataset. Over time, this builds an accurate library for future DNA-based identifications. For the case of hermit crabs Landschoff and Gouws (2018) however speculate that the existing barcodes with validated morphological identifications represent only 50% of the South African fauna. This shows that it takes years of genetically integrated taxonomic research to build a comprehensive barcoding dataset within such a diverse and taxonomically understudied country like South Africa.

Instead of subjective and untargeted taxon sampling of a wide range of marine invertebrate groups, the focus of DNA barcoding in South Africa should probably lie on groups in which traditional taxonomic expertise is present or in which it is being developed. Broader international collaborations may also help address these challenges.

Box 49. Monitoring the marine environment using eDNA

By Sophie von der Heyden

Although there are more than 12 000 recognised species within South Africa's marine environment, including a high level of endemics, most of the country's marine diversity remains unexplored, particularly for smaller and cryptic taxonomic groups (Griffiths *et al.* 2010; see Chapter 1). Current species description efforts are unlikely to significantly contribute towards plugging the biodiversity knowledge gap, which is a challenge in the light of anthropogenic pressures that have impacts on coastal and offshore marine populations. In order to monitor and better understand changes, as well as quantify anthropogenic impacts on the distribution of marine species, eDNA approaches are being developed to provide better species distribution data that can support spatial planning and biodiversity planning in South Africa. The main projects at present are focussing on mapping the distribution of coastal fishes, as well as community genetics (which includes all eukaryotic organisms) across 48 sites along the 3 650 km of South African coastline. Through repeat sampling that incorporates diverse coastal marine ecosystems including rocky and sandy shores, mangrove, seagrass and coral systems the aim is to identify patterns of biodiversity, as well as to construct networks that provide insights into the links between different marine ecosystems in South Africa. This data can be used to identify taxa that are able to utilise multiple ecosystems, as well as taxa restricted to specific areas or systems, for example. Importantly, this provides a baseline for more targeted monitoring of marine biodiversity and opens the possibility of tracking species and community shifts and invasive species, as well as linking anthropogenic impacts to changes in local diversity. These data can also be mapped and incorporated into marine spatial planning by identifying areas for protection or sustainable utilisation. Finally, the use of eDNA holds great promise for supporting marine biomonitoring in South Africa and should be extended to support ongoing efforts in mapping offshore pelagic and benthic habitats.

10.2 What to monitor?

Although it would be ideal if there were sufficient resources to comprehensively monitor South Africa's diversity, this is unrealistic. A more **realistic approach** is to establish a standard set of criteria with which to 'grade' or score potential candidates for genetic monitoring; and in doing so, create a priority list of species to monitor. Such an approach should strive to span the key pressures on genetic diversity in the marine environment, such as fisheries, aquaculture, coastal development and fragmentation (see Chapter 4). Until a strategic score sheet is developed, national and international biodiversity targets and threats can be examined to gain insight into potential genetic monitoring priorities. South Africa's National Environmental Management: Biodiversity Act of 2004 (NEMBA) requires the monitoring and protection of 'species that are threatened or in need of protection to ensure their survival in the wild'. Moreover, Aichi Biodiversity Target 13 highlights the need to maintain genetic diversity of wild relatives of cultivated and domesticated animals. As such, as a starting point, it is recommended that genetic monitoring is implemented on the following categories:

- *In situ* (wild) populations of highly threatened and or severely overexploited taxa. High **priority taxa** include the Dusky Kob (*Argyrosomus japonicus*), Sparids, Abalone and West Coast Rock Lobster.
- *Ex situ* populations of highly threatened (such as current efforts on the African Penguin) and or severely overexploited taxa
- Species that are farmed in **mariculture** and their wild relatives

10.2.1 In situ monitoring of wild populations of threatened taxa

Threatened taxa, as designated by the IUCN Red List (Vulnerable, Endangered, Critically Endangered), refers to species that are at heightened risk of extinction. The management of these taxa is fundamentally dependent on monitoring to follow trends in species recovery or decline and, in doing so, evaluate and inform conservation strategies. The inclusion of genetic data in monitoring and in

marine species assessments is vital, as species with **low genetic diversity** are at higher risk of extinction due to increased inbreeding and genetic drift, which causes a decrease in effective population size (Crow and Kimura 1970, Frankel and Soulé 1981, Shaffer 1990, Frankham 1996, Spielman *et al.* 2004, Allendorf and Luikart 2007, Palstra and Ruzzante 2008). An evaluation of existing IUCN criteria for assigning threat status found that the criteria typically fail to identify species with low genetic diversity (Willoughby *et al.* 2015). This can be detrimental as there may be a critical threshold of genetic diversity below which species cannot recover. Even if the critical threshold has not been reached, a species with low genetic diversity may risk extinction long after its population size has recovered because such diversity can only be restored slowly, through the accumulation of mutations over many generations (Willoughby *et al.* 2015). Consequently, failure to monitor the genetic diversity of a species could result in premature downgrading in its threat status (Taylor *et al.* 2017). Monitoring of genetic diversity is therefore especially important for threatened and severely overexploited taxa in South Africa, such as many fisheries species [e.g. Seventy-four Seabream (*Polysteganus undulosus*), Dusky Kob (*Argyrosomus japonicus*), West Coast Rock Lobster (*Jasus lalandii*), Abalone (*Haliotus midae*), and Red Steenbras (*Petrus rupestris*)] which remain unassessed for genetic diversity.

10.2.2 Impacts on marine genetic integrity driven by over-exploitation

Globally, there is increasing evidence for the impact of overfishing on the genetic integrity of exploited marine species, including a **loss of genetic diversity in natural fish stocks** (Pinsky and Palumbi 2014, Mirimin *et al.* 2016) and marine reptiles (Rodríguez-Zárate *et al.* 2013). This is not only confined to commercially or recreationally targeted or bycatch species, but has also been shown in fishes collected for the aquarium trade (Madduppa *et al.* 2018). Depleting genetic variation is of high concern, because ultimately it can erode the potential for species to adapt to future change, thereby increasing extinction risk. Even though many marine species have large population sizes, including large effective population sizes, over-exploitation as a driver of changes in measures of genetic diversity, population structure and adaptability remains troubling. In South Africa, disentangling the effects of over-exploitation from other factors, such as habitat loss or climate change, has not yet received much attention for marine species, mainly because there is a lack of pre-exploitation material that can be used to characterise genetic parameters prior to exploitation and which contemporary samples can be compared to. Furthermore, some species also show patterns of genetic chaotic patchiness that point to complex spatio-temporal patterns influenced by seasonal changes in the environment (von der Heyden 2009, Teske *et al.* 2011, Henriques *et al.* 2016). However, some attempts have been made to model genetic population dynamics through time using molecular markers for the Cape Hakes (*Merluccius capensis* and *M. paradoxus*) and Kingklip (*Genypterys capensis*), three species that greatly contribute towards the demersal fishing industry of South Africa.

For the **Cape Hakes**, Henriques *et al.* (2016) provide evidence of a loss of genetic diversity over 15-50 generations, coinciding with increased fishing pressures in the 1970s and 1980s. This may have contributed towards lower levels of contemporary genetic diversity for both species. For **Kingklip** and **Dusky Kob**, fishing pressure has also been invoked as an explanation for lower levels of current genetic diversity than historical measures (Henriques *et al.* 2017) and the presence of genetic bottlenecks (Mirimin *et al.* 2016). All of these species share several life history characteristics, including being relatively slow-growing and long-lived, that may make them more susceptible to loss of genetic diversity compared to faster growing and maturing species in the region. Genetic studies were also used to estimate the population size of the **Great White Shark** *Carcharodon carcharias* in South Africa. Although listed on CITES, the IUCN Red List and being a protected species in South Africa since 1991,

genetic estimates showed a decline in population size of over 50% in recent years (Andreotti *et al.* 2016), placing the future of one of South Africa's iconic marine species in doubt. However, more emphasis should be placed not only on understanding the impacts of over-exploitation, but also habitat loss and other anthropogenically driven processes, as well as climate change on offshore and coastal marine species in South Africa.

With regard to **South African fisheries**, the incorporation of **genetic monitoring** into existing monitoring programmes could be accomplished if additional resources are secured. Tissue samples from specimens, which are sub-sampled as part of the catch monitoring programs, could be genetically analysed to estimate population demography and diversity. Combined with standard assessments, this genetic characterisation could provide further insight into population genetic thresholds that have bearing on long-term sustainable exploitation. Such information would prove invaluable for species such as the Endangered Red Steenbras (*P. rupestris*). Much like the examples above, this species is particularly long-lived (up to 55 years: Andrews *et al.* 2018). In 2012, a commercial fishing moratorium was imposed on *P. rupestris* due to a collapse in the fishery (Mann *et al.* 2014). Although pre-collapse genetic data is not available, monitoring the recovery of this species genetically and demographically would be imperative before the moratorium could be repealed. Genetic assessments using mtDNA and microsatellite markers are currently underway (G. Gouws, SAIAB, pers. comm.).

10.2.3 Ex situ populations of threatened taxa

Although *in situ* conservation of species is considered the most appropriate or preferred way of conserving biodiversity, *ex situ* conservation measures are sometimes needed to support the maintenance and recovery of viable populations. In South Africa, the core objectives of biodiversity conservation programs and supporting policy and legislation are primarily achieved via zoological and botanical gardens, arboreta, aquaria, biobanks, and captive breeding programs. These *ex situ* measures represent important sources for future population supplementation programs and the reintroduction of species. As insurance policies against extinction in the wild, it is essential to (i) minimise genetic threats to *ex situ* resources, while (ii) maximising their representation in wild populations. Assessments of the genetic value of *ex situ* biodiversity resources are increasingly common. **Coordinated monitoring plans**, informed by knowledge of both captive pedigrees and standing levels of variation in wild populations, are required to ensure these resources remain relevant into the future. To date, there have been no studies in South Africa monitoring genetic variation in captive breeding populations, however a study focusing on a marine species reports current levels of genetic variation in a captive population. Labuschagne *et al.* (2016) report current levels of microsatellite genetic variation in captive African Penguins (*Spheniscus demersus*) from zoo and aquarium facilities in South Africa. The study concluded that the *ex situ* population of African Penguins is at risk of losing diversity in the future and the results establish valuable baseline knowledge for future monitoring (see Box 50).

Box 50. Genetic variation in the African Penguin (*Spheniscus demersus*)

By Jacqueline Bishop and Jessica da Silva

Spheniscus demersus is endemic to southern Africa, breeding mainly on islands off the coasts of South Africa and Namibia. The species is currently listed as 'Endangered' (BirdLife International 2018b) and continues to decline, with approximately 15000 reported in 2018 (DEA unpublished data) (see Chapter 9 for more detail). Due to intensive exploitation of guano resources and egg collection in the early 20th century, followed by more recent population declines attributed to food prey shortages, environmental fluctuations, oil spills, and competition with commercial, the species has declined by over 95% of its historic population size. It has been speculated that avian influenza might also be a contributing factor to their decline. However, to date, there has been no direct detection of the virus; only signs of antibodies, which may or may not indicate previous exposure (Parsons *et al.* 2016). In South Africa, just eight colonies support 87% of the country's population and a number of established *ex situ* breeding programs are intended to provide population supplementation and possible restoration into the future. Given that *ex situ* populations of the African penguin are derived from a small number of founders, management informed by the risks of negative genetic changes (e.g. founder effects, inbreeding depression and genetic adaptations to captivity) is vital. Managing *ex situ* penguins in the absence of a genetic strategy will undoubtedly reduce their conservation value significantly. A recent study established important baseline estimates of neutral genetic variation in *ex situ* African penguins. This study provides an initial framework for future monitoring of *ex situ* population resources that is required to ensure their continued value to regional conservation efforts.

Labuschagne *et al.* (2016) genotyped 1 119 penguins from South African zoo and aquarium facilities at 12 microsatellite loci. While estimates of allelic diversity (mean N_A = 5) and heterozygosity (mean H_O = 0.58) were both moderate, the authors conclude that based on differences between first- and second-generation captive birds the *ex situ* population of African penguins is at risk of losing neutral genetic variation in the future. To increase the *ex situ* effective population size, and thereby reduce the rate of genetic drift, management will need to include exchange of birds between captive facilities in the management plans. More importantly, comparison of these findings with levels of *in situ* population variation is central to the design of an effective captive breeding program for the species.

10.2.4 Mariculture

South Africa has a growing mariculture sector and was highlighted in Operation Phakisa due to its high growth potential, but currently low contribution to the seafood supply chain. Mariculture species in South Africa are dominated by invertebrates, particularly Abalone *Haliotis midae*, European Mussel *Mytilus galloprovincialis* and Pacific Oysters *Crassostrea gigas*, although some finfish farming, including Kob *Argyrosomus* spp, and Yellowtail *Seriola lalandii* is occurring at small, exploratory scales. In addition, some seaweeds species including *Ulva* spp. and *Gracilaria* spp. are also commercially grown. From a genetic perspective, the danger of mariculture lies primarily in the **mixing of genetic lineages** between commercially farmed and natural populations. However, both *M. galloprovincialis* and *C. gigas* are already invasive and naturalised in South Africa, with extensive populations along the coastline, but currently there is no evidence of hybridisation with native species. For Abalone, genetically structured populations were recovered for both mitochondrial (Evans *et al.* 2004) and nuclear markers (microsatellites, SNPs, see Bester-van der Merwe *et al.* 2011), highlighting that the provenance of mariculture populations should be carefully considered. Further, Rhode *et al.* (2012) showed similar levels of genetic diversity for natural and cultured populations of *H. midae*, although cultured populations were genetically distinct from wild abalone, potentially as a result of selective pressures during the selection process of individuals, with strains selected to the environment of each mariculture facility. Both Rhode *et al.* (2012) and Bester-van der Merwe *et al.* (2011) highlight the need for **maintaining genetically diverse natural populations** to support the mariculture industry. They recommend provisions that commercially grown Abalone are not released, accidentally or otherwise, into natural systems, as the latter poses a serious risk to the genetic integrity of an already vulnerable stock. However, it is our understanding that current abalone ranching operations do

release cultivated abalone into the wild. With the current plans for expanding mariculture and ranching around South Africa, any new venture needs to ascertain the levels of genetic structure and diversity of species of interest, in order to minimise genetic pollution of naturally occurring populations. Moreover, ongoing genetic monitoring is required for these species to maintain the genetic integrity of wild populations and prevent genetic erosion for the species.

10.3 Monitoring marine diversity at a national level

Although single species are typically the focus of genetic monitoring studies, the ability to track genetic diversity across species for a given taxonomic group at a landscape or ecosystem level could greatly inform biodiversity planning at a national scale. **Phylogenetic diversity** (PD), for example, has been used to identify regions of high genetic diversity (PD) in the South African marine environment, which could be translated into priority areas for conservation (intertidal **chitons**: (Volkmann *et al.* 2014), sparids: Henriques *et al.* unpubl.). Through the assessment of additional taxonomic groups, patterns of PD may emerge, which would further strengthen the importance of these recommended priority areas to include as MPAs.

Another metric, **evolutionary distinctiveness** (ED) could also be used to measure and monitor genetic diversity at a national scale. Indeed, it has even been applied at a global scale. Using ED to examine genetic diversity within a large radiation of chondrichthyan fishes (sharks, rays and chimaeras), Stein *et al.* (2018) identified 21 countries possessing the highest richness, endemism and evolutionary distinctness of threatened chondrichthyan species. The authors recommended that these countries be targets for conservation prioritization. South Africa was ranked among the top seven.

Additional metrics, such as **evolutionarily distinct and globally endangered** (EDGE) and **phylogenetic endemism** (PE) could also add great value to landscape level assessments of genetic diversity. EDGE is used to identify regions with unique, but threatened taxa, and PE regions that are spatially restricted, but have highly divergent species. A recent study utilised all four metrics (PD, ED, EDGE, PE) to examine patterns of genetic diversity across South Africa for terrestrial reptiles (Tolley and Šmíd 2019). Similar studies focusing on marine taxa would be of great value. The main requirement for all of these studies and metrics is that a comprehensive phylogeny exists for a given taxonomic group.

None of the studies mentioned above temporally monitor genetic diversity. They are all spatial assessments conducted at a large scale; however, a **temporal dimension** can easily be applied by incorporating new pressure data and protected area network layers as they become available (e.g. every 5 years).

10.4 The way forward: the future of genetic monitoring within South Africa's marine environment

The overall paucity of genetic monitoring datasets should not deter attempts at establishing genetic monitoring programs. If anything, it should strengthen our pursuit in recognising and utilising which tools are currently available and identifying tools that are needed and yet to be developed.

The various population genetic assessments already published may provide a baseline of genetic diversity, upon which future short- and long-term genetic monitoring studies could be based. In some instances, reorganizing datasets might even allow initial short-term monitoring studies to be conducted without the addition of extra samples. Additionally, museums and other natural history collections have long been recognized and utilized as sources of **historic genetic material** (Roy *et al.*

1994, Bouzat *et al.* 1998, Ross *et al.* 2006, Martínez-Cruz *et al.* 2007, Wandeler *et al.* 2007, Ugelvig *et al.* 2011, Banhos *et al.* 2016). Furthermore, comprehensive tools exist that can aid researchers in the planning and design of genetic monitoring studies. For example, ConGRESS (Conservation Genetic Resources for Effective Species Survival) is an online platform with a variety of free tools that can assist reserachers and decision makers in designing conservation and population genetic projects (e.g., Conservation Genetic Resources for Effective Species Survival: http://www.congressgenetics.eu/; Hoban *et al.* 2013. For a more comprehensive report on each of these, refer to da Silva *et al.* 2019).

With the advent of new molecular techniques, such as **Next Generation Sequencing**, it is becoming easier and more practical to monitor genetic diversity within species. Because NGS allows one to sequence multiple regions across the genome, fewer samples are needed to acquire a wide breadth of the genetic diversity available within populations or species, which is a key benefit for studying marine taxa that are difficult to access (Xiong *et al.* 2016, Arulandhu *et al.* 2017). Although Sanger sequencing is still considered the "gold standard" in seafood surveillance (e.g., Cawthorn *et al.* 2012, Di Pinto *et al.* 2013, Xiong *et al.* 2016, Tinacci *et al.* 2018), NGS has proven instrumental in the identification of multispecies seafood products (Giusti *et al.* 2017) and may even prove effective in identifying whether certified stocks have been substituted by uncertified stocks of the same species (Barendse *et al.* 2019). When coupled with eDNA, NGS has proven extremely effective in the early detection and monitoring of marine invasive species (Ardura *et al.* 2015, Carugati *et al.* 2015, Simmons *et al.* 2015, Zaiko *et al.* 2018), as well as the monitoring of rare, threatened and difficult-to-study/detect species (Parsons *et al.* 2016, Bakker *et al.* 2017, Weltz *et al.* 2017, Boussarie *et al.* 2018, Pikitch 2018). By being able to survey entire biological communities through a single water sample, these techniques could also assist in amassing phylogenies on specific taxonomic groups for national-level monitoring.

Of the utmost importance is the development of a **national genetic diversity monitoring framework** to ensure that comparable long-term datasets can be established and used to better inform biodiversity management. This framework should outline how genetic diversity can be monitored at all levels (national, ecosystem and species) and should be designed to strategically track key pressures on genetic diversity and monitor key areas and species.

11. KEY FINDINGS, PRIORITY ACTIONS AND KNOWLEDGE GAPS

Chapter 11: Sink KJ, Harris LR, van der Bank MG, Franken M, Skowno A, Driver A, Atkinson LJ, Fairweather TP, Kerwath S, Majiedt PA, Robinson T, Pfaff M, Rikhotso W, Smith C, van Niekerk L. 2019. Chapter 11: Key findings, priority actions and knowledge gaps. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds). 2019. *South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm*. South African National Biodiversity Institute, Pretoria. South Africa. http://hdl.handle.net/20.500.12143/6372



We need people to work together for co-operative governance for healthy marine ecosystems and species

Chapter Summary

This chapter distils the key findings and associated priority actions with links to existing policy, plans and frameworks. The links between the NBA, the National Biodiversity Strategy and Action Plan (NBSAP) and the National Biodiversity Framework (NBF) are explained. Twenty one key findings were compiled from previous chapters and cross realm analyses from the NBA including the Coast report. Key priority actions related to these findings were drawn from a review of progress against the NBA 2011 priority actions and expert workshops. Priority actions span the knowledge-action continuum and cover a wide range of actions to improve ecosystem and species status and avoid further ecosystem degradation and impacts on priority species. A key biodiversity response has been the first marine Critical Biodiversity Area (CBA) map that can inform Marine Spatial Planning, environmental authorisations and future protected area expansion. The overlay of South Africa's Ecologically or Biologically Significant Marine Areas (EBSAs) shows that 16 of South Africa's 18 EBSAs receive some protection. Ten priority actions were identified to improve the state of marine biodiversity in South Africa. Building on the limitations identified in this assessment, key gaps and research priorities were also identified. Additional priority actions to address these knowledge gaps and research priorities for future improvements in assessments were detailed. These span foundational biodiversity research at the ecosystem, species and genetic level; research to improve the understanding of key pressures and ecosystem condition; monitoring priorities and research to inform strategies to communicate biodiversity benefits and mobilise better management of marine biodiversity.

The Top 10 Priority Actions to Improve the State of Marine Biodiversity are:

A. **Apply the Coastal and Marine Critical Biodiversity Area Map** in Marine Spatial Planning and Environmental Impact Assessments to mitigate pressures in priority areas.

B. **Develop and implement effective fisheries management plans** to secure food and job security and reduce ecosystem impacts of fisheries.

C. **Strengthen MPA financing and governance** to enhance MPA protection and the equitable flow of benefits from South Africa's MPA network.

D. **Effectively communicate the value of South Africa's marine biodiversity** through improved co-ordinated messaging that articulates benefits, in order to build support for marine conservation, mainstream biodiversity into key production sectors and mobilise people to sustainably use marine biodiversity.

E. **Ensure sufficient quantity and quality of freshwater flows** to marine ecosystems

F. **Prevent new marine invasions** through response planning, ring-fenced resources and rapid action.

G. **Restore marine biodiversity assets** to strengthen climate resilience and sustain key benefits

H. **Enhance co-operative governance** for improved, co-ordinated compliance and marine biodiversity management.

I. **Modernise and integrate data collection, storage and access** to improve marine biodiversity, fisheries, and climate data for better assessment, analysis, and monitoring, and to improve compliance with and evaluation of management actions.

J. **Catalyse research to address critical knowledge gaps** that limit the assessment of marine biodiversity and decision-making for a sustainable oceans economy.

11.1 Introduction

The NBA is a **collaborative effort to synthesise the best available science** on South Africa's biodiversity covering ecosystems, species and genes; pressures and ecosystem condition, benefits and existing responses to inform decisions in a range of sectors. The aim of this chapter is to summarise the results from previous chapters and broader cross-realm analyses (Skowno *et al.* 2019a) and to distil key recommendations for the way forward. This chapter also aims to identify knowledge gaps and limitations of the NBA 2018 marine assessment. To do this, 21 key findings of the NBA 2018 Marine Realm are presented, including highlighting the benefits that biodiversity assets and ecological infrastructure provide for people and reviewing the status of marine ecosystems and species in South Africa, and the pressures acting on them. Given these findings, 10 priority actions are identified to improve the management of marine biodiversity. These priority actions are related to the National Biodiversity Strategy and Action Plan (NBSAP); the National Biodiversity Framework (NBF); spatial prioritisation tools, such as spatial biodiversity plans and the National Protected Areas Expansion Strategy (NPAES); and other policy and legislation for managing the marine environment and its resources. They are also linked to priorities that emerged through the broader cross-realm analyses from the NBA 2018 (Skowno *et al.* 2019a). Ultimately, all priority actions relate to the three-way action plan for biodiversity, as described in the National Biodiversity Framework i.e. to avoid further loss of biodiversity and ensure sustainable use, to protect biodiversity, and to restore ecosystems and promote recovery of species or resources (Figure 103).

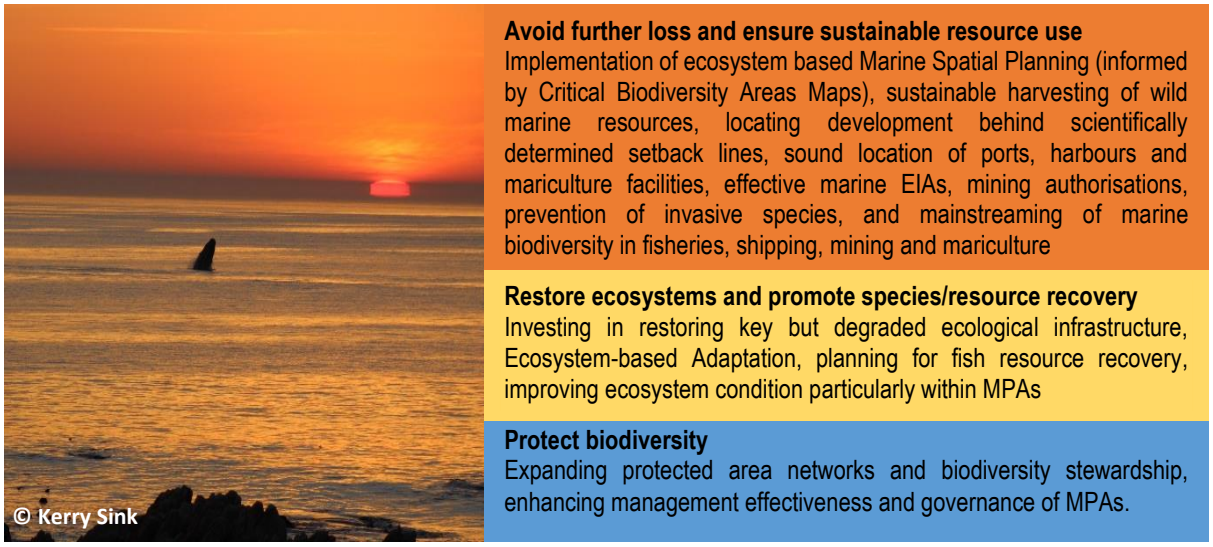


Figure 103: The three-way action plan for biodiversity, adapted to give marine examples.

The limitations to the marine assessment are also presented in this chapter with a view to determining additional priority actions to address these knowledge gaps. As such, the NBA helps to distil a number of key research priorities that if addressed will improve the knowledge base to assess and manage marine biodiversity in South Africa. Addressing these research priorities can strengthen future iterations of the NBA and improve marine biodiversity management in South Africa. In this chapter, the existing policy and legislation tools and their relationships to one another are described below, this is followed by the NBA 2018 Marine findings, Priority actions, knowledge gaps and research priorities, linking to the policy and legislation tools.

11.1.1 The NBSAP-NBF-NBA relationship informs priority actions

South Africa has a well-developed suite of policy and legislation for the management, conservation and sustainable use of biodiversity, including two overarching national tools: the NBSAP and NBF. These documents, developed through thorough stakeholder consultation, set out **South Africa's strategic objectives** for managing and conserving biodiversity and are the primary reference points for related priority actions. The NBA both informs the development of the NBSAP and NBF, and supports their implementation.

An **NBSAP** is a requirement that all contracting parties to the Convention on Biological Diversity (CBD) are obliged to fulfil. South Africa's first NBSAP was completed in 2005, and the second in 2015, in both cases drawing on the preceding NBA. The NBSAP 2015-2025 sets out an integrated and coherent national strategy for the conservation, management and sustainable use of the country's biodiversity to ensure equitable benefits to the people of the country. It outlines how South Africa will fulfil the objectives of the CBD and contribute to the global sustainable development agenda. It also provides a framework for the integration of biodiversity considerations into national development plans and a wide range of other sectoral strategies, placing wise management and protection of biodiversity at the heart of the sustainable development agenda. The NBSAP identifies six Strategic Objectives, under each of which are key outcomes, activities (designated as high, medium and low priority), and medium to long-term targets, which are described in detail.

The **NBF** is developed as a requirement of the Biodiversity Act, and published by the Minister of Environment, Forestry and Fisheries, with the purpose of coordinating and aligning the efforts of the many organisations and individuals involved in conserving and managing South Africa's biodiversity in support of sustainable development. The first NBF was developed in 2008 and the second in 2017. The NBF is a short to medium-term coordination tool that shows the alignment between the strategic objectives and outcomes identified in the NBSAP and other key national strategies, frameworks and systems that currently guide the work of the biodiversity sector, building on the consultative processes through which all of these other products were developed. This is complemented by an overview of national policy and legislation and international commitments relevant to the biodiversity sector, and a description of national level coordination mechanisms and communities of practice through which sector representatives can coordinate their work and exchange information and experiences. The NBF also identifies a set of interventions or 'acceleration measures' that can unlock or fast-track implementation of the NBSAP, and indicates the relative roles of the many agencies involved in implementing these activities.[7]

The **NBA relates to the NBSAP and NBF** in two main ways: 1) the NBA informs the *development* of the NBSAP and NBF, by providing a strong scientific foundation on the pressures on biodiversity and how they are impacting on its status, and thus directing the key focus for society's interventions; 2) the NBA supports the *implementation* of the NBSAP and NBF, by providing science-based evidence that helps to ensure effective action in the right places. In brief, the NBA provides the science that informs

[7] The background information in the above two paragraphs is directly from the NBSAP and NBF documents.

the strategic objectives and priority actions of the NBSAP and NBF. Together, the NBSAP, NBF and NBA provide three key anchors for the work of the biodiversity sector (Figure 104).

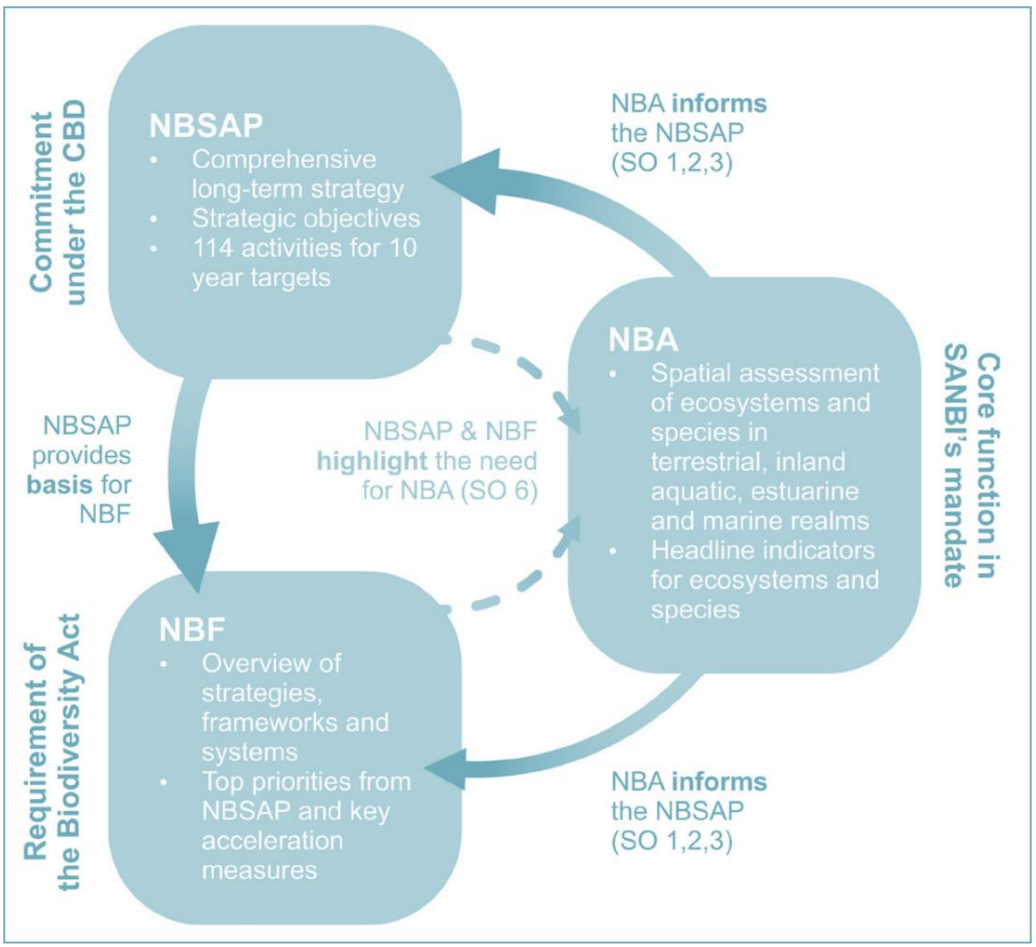


Figure 104. The NBSAP, NBF and NBA together provide key anchors for the work of the biodiversity sector. The NBA synthesises best available science to inform the development and implementation of the NBSAP and NBF.

The NBA directly supports the implementation of **Strategic Objectives** 1, 2 and 3 of the NBSAP and NBF and also has direct links with Strategic Objective 6 (Table 47). Strategic Objective 4 is supported through the NBA efforts to increasingly identify and communicate the benefits of biodiversity and key actions in support of Strategic Objective 5. Strategic Objective 1 focuses on managing biodiversity assets, and includes outcomes related to the protected area network and management of species of special concern. Strategic Objective 2 focuses on maintaining and restoring ecological infrastructure, including key ecological infrastructure features highlighted in the NBA. Strategic Objective 3 includes the science-based planning and decision making tools that the NBA is major contributor to, including maps of threatened ecosystems which are a key input into spatial planning and environmental authorisations. The NBA headline indicators of threat status and protection level are key indicators as to whether interventions are making progress towards achieving the Outcomes for these Strategic Objectives. Several of the Outcomes and activities in Strategic Objective 6 directly strengthen the NBA – in other words, if relevant foundational datasets are continually being updated through research and monitoring programmes and such data are available, then the indicators in the NBA can be calculated more regularly and with a higher confidence of accuracy.

Because of the two-way relationship in which the NBA informs the development of the NBSAP and NBF and supports their implementation, there is no perfect **sequence** for the production of these three key documents. In practice, the **NBA, NBSAP and NBF** have been produced in that order to date, with the exception of the current NBA which has been produced in parallel with the current NBF. The timing of the NBA 2018 means that it is particularly well placed to support the implementation of the NBSAP 2015 – 2025 and the NBF 2017 – 2022. Links between the NBA 2018 priority actions and the strategic objectives of the NBSAP and the NBF are noted below.

Table 47. Strategic Objectives and Outcomes in the NBSAP and NBF. Most have direct or indirect links to the NBA.

Strategic Objectives	Outcomes
1. Management of biodiversity assets and their contribution to the economy, rural development, job ceation and social well-being is enhanced	1.1. The network of **protected areas and conservation areas** includes a representative sample of ecosystems and species, and is coherent and effectively managed. 1.2. **Species of special concern** are sustainably managed. 1.3. The **biodiversity economy** is expanded, strengthened and transformed to be more inclusive of the rural poor. 1.4. Biodiversity conservation supports the **land reform agenda and socio-economic opportunities** for communal landowners.
2. Investment in ecological infrastructure enhances resilience and ensures benefits to society	2.1. Restore, maintain and secure important **ecological infrastructure** in a way that contributes to rural development, long-term job creation and livelihoods. 2.2. **Ecosystem-based adaptation** is shown to achieve multiple benefits in the context of sustainable development.
3. Biodiversity considerations are mainstreamed into policies, strategies and practices of a range of sectors	3.1. Effective **science-based tools inform planning and decision making.** 3.2. Embed biodiversity considerations into **national, provincial and municipal development-planning and monitoring.** **3.3.** Strengthen and streamline development **authorisations and decision making.** 3.4. **Compliance** with authorisations and permits is monitored and enforced. 3.5. Appropriate allocation of resources in key sectors and spheres of government facilitates **effective management** of biodiversity, especially in biodiversity priority areas. 3.6. **Biodiversity considerations are integrated** into the development and implementation of policy, legislative and other tools.
4. People are mobilised to adopt practices that sustain the long-term benefits of biodiversity	4.1 People's **awareness of the value of biodiversity** is enhanced through more effective coordination and messaging. 4.2 **People are mobilised** to conserve and sustainably use biodiversity.
5. Conservation and management of biodiversity is improved through the **development of an equitable and suitably skilled workforce**	5.1. Macro-level **conditions enabled for skills planning, development and evaluation** of the sector as a whole. 5.2. An **improved skills development system** incorporates the needs of the biodiversity sector. 5.3. **Partnerships are developed and institutions are capacitated** to deliver on their mandates towards improved service delivery.
6. Effective knowledge foundations, including indigenous knowledge and citizen science, support the management, conservation and sustainable use of biodiversity	6.1 Relevant **foundational data sets** on species and ecosystems are in place and well-monitored and available to the public in a useful format. 6.2 The **status of species and ecosystems** is regularly monitored and assessed and communicated. 6.3 **Geographic priority areas** for the management, conservation and restoration of biodiversity assets and ecological infrastructure are identified based on best available science. 6.4 Management-relevant and policy-relevant **research and analysis is undertaken** through collaboration between scientists and practitioners. 6.5 **Knowledge base is accessible** and presented in a way that **informs decision making.**

11.1.2 Spatial biodiversity priorities for managing and conserving marine biodiversity

South Africa's biodiversity is not evenly distributed across the seascape and when this is combined with limited resources for action, it means that it is essential to prioritise spatially. An important

feature of South Africa's biodiversity-related action to the pressures on biodiversity has been spatial planning to identify priority areas in the seascape for intervention.

This is particularly important for the implementation of Strategic Objectives 1 (Management of biodiversity assets), 2 (Investment in ecological infrastructure) and 3 (Biodiversity considerations are mainstreamed) of the NBSAP and NBF which otherwise run the risk of being spread too thin geographically to be effective. The production of many spatial planning tools at the national and sub-national level relies heavily on the spatial data layers and datasets that are compiled and collated for the NBA. Efforts to strengthen foundational data for the NBA thus also supports the development of high-quality spatial biodiversity plans.

The NBA provides an initial portfolio of spatial priorities by highlighting the location of the most threatened ecosystems and species. However, it is not only threatened biodiversity that needs attention; often there are strategic gains to be made from focusing on areas that are still in good ecological condition and where there are relatively easy opportunities for protection or effective management. Complementing the NBA, which provides a *spatial assessment* of biodiversity, South Africa has several established *spatial prioritisation tools* for informing the work of the biodiversity sector (each discussed in more detail below). Principle among these are

(1) the **National Protected Area Expansion Strategy** (NPAES),

(2) **Spatial biodiversity plans**, which provide maps of Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs), together called **CBA Maps**.

(3) **Ecologically or Biologically Significant Marine Areas** (EBSAs)

Together these tools provide a comprehensive set of biodiversity priority areas that collectively meet biodiversity targets for ecosystems, species and ecological processes. Increasingly, critical ecological infrastructure assets are also included in this set of biodiversity priority areas. Maps of biodiversity priority areas directly support the implementation of the NBSAP and NBF, especially Strategic Objectives 1, 2 and 3 (Table 47).

The National Protected Area Expansion Strategy

Expansion of Marine Protected Areas (MPA) network stimulated by the Operation Phakisa initiation. Exceptional progress has been made, with 20 new MPAs approved in 2018 and promulgated in 2019. This major event is the culmination of many years of collaborative cross-sectoral work.

The **NPAES** identifies geographic priority areas for expansion of the protected area network, with a focus on under-protected ecosystems. It draws on provincial protected area expansion strategies and provides the primary reference point for consolidating existing protected areas and establishing new ones. The NPAES 2008 was highly effective in ensuring that protected area expansion in the decade that followed resulted in increased protection for previously under-protected ecosystem types, with dramatically increased protection levels especially in the marine realm. The NPAES 2016 built further on this, and is essential for the effective implementation of Strategic Objective 1 of the NBSAP and NBF. The recent implementation of the Phakisa MPA Network (see Chapter 8) represents very significant progress in the expansion of MPAs, with almost all priority areas identified I the NPAES 2016 now included in proclaimed MPAs.

Critical Biodiversity Area (CBA) Maps

Maps of CBAs and ESAs, referred to as **CBA maps**, are produced by all provincial conservation authorities, marine planners and some metropolitan municipalities and are based on the principles of systematic biodiversity planning. They are a form of strategic planning for the natural environment, identifying a set of geographic areas that provide a spatial plan for ecological sustainability at the landscape and seascape scale. A CBA Map comprises **five map categories**: Protected Areas (PAs), Critical Biodiversity Areas (CBAs), Ecological Support Areas (ESAs), Other Natural Areas (ONAs) and areas where there is No Natural habitat Remaining (NNR). A simplified version of South Africa's CBA Maps is given in (Figure 105). Guidelines published by SANBI (SANBI 2017) encourage consistency between the CBAs prepared by different agencies.

Protected areas, CBAs and ESAs together form a network of natural and semi-natural areas that enable ecologically functional seascapes and landscapes in the long term, designed to be spatially efficient and to avoid conflict with non-compatible land and ocean uses wherever possible. CBAs should be kept in a natural or near natural state to support ecological sustainability of the landscape and seascape. ESAs do not need to be entirely natural, but should be kept at least semi-natural so that they retain their ecological processes. These natural and semi-natural areas can co-exist in a matrix of multiple uses, including urban development, agriculture, fisheries, plantation forestry, mining and others. Land-based CBA Maps have been produced for over a decade, while the first map of CBAs and ESAs for the coast and ocean has recently been completed (Figure 105).

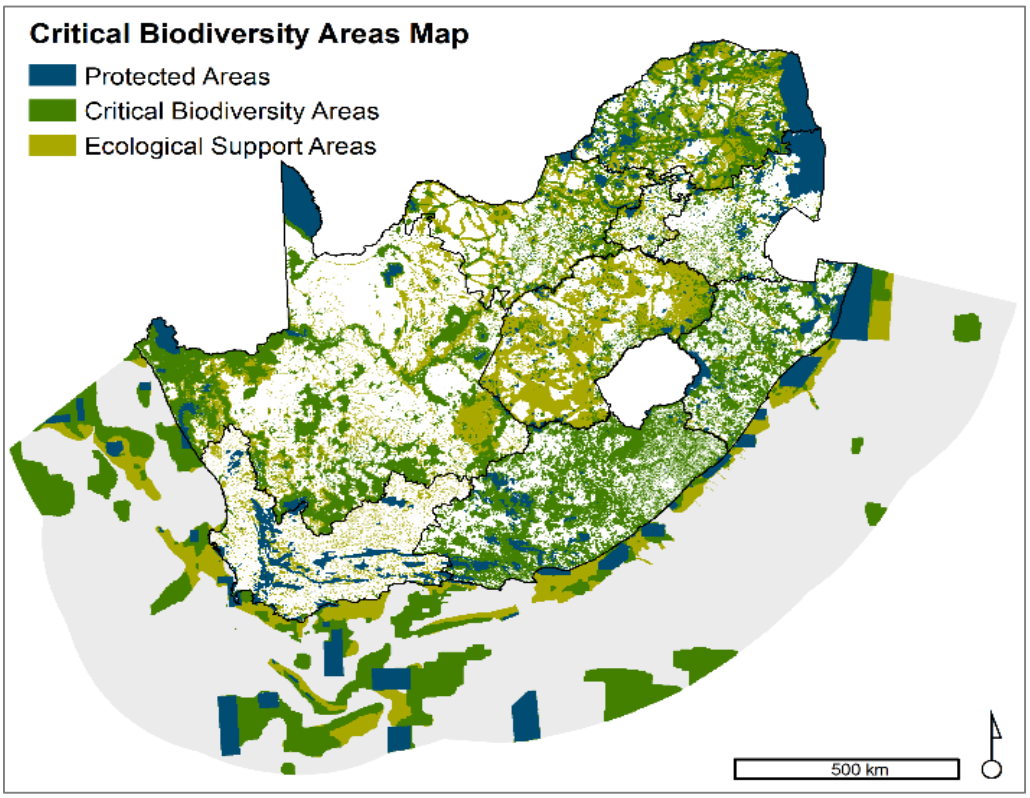


Figure 105. Critical Biodiversity Areas (CBA) maps, prepared at provincial or municipal scale, cover the whole of South Africa's landmass. A preliminary marine and coastal CBA map (developed in early 2019) now compliments this map. Together these maps provide key inputs to local and strategic decision making processes.

CBA Maps are the biodiversity sector's input into decisions on appropriate land and sea uses. There are two main ways that CBA Maps should be used: to inform spatial planning that shows the desired

future uses of the land or ocean (often in the form of Spatial Development Frameworks produced by municipalities); and in decision- making in response to development applications (such as environmental authorisations). CBA Maps are essential for the effective implementation of Strategic Objective 3 of the NBSAP and NBF.

CBA Maps have been steadily advancing for all the provinces since 2002 (Skowno et al. 2019a), building on South Africa's strong and internationally recognised history in Systematic Conservation Planning (Botts et al. 2019). However, notable gap has been the absence of CBAs and ESAs in the marine realm (and in fact, prior to the promulgation of the new MPAs, even protected areas were largely absent in the offshore component of the marine realm). Recently, however, a first national Coastal and Marine Spatial Biodiversity Plan (Harris and Sink 2019) was produced including a Coastal and Marine CBA Map based on data layers from the NBA 2018. An initial accompanying set of sea-use guidelines was also developed. Work is currently underway to strengthen and advance this product, with strong focus on edge-matching and cross-realm integration in the coastal zone, particularly building on existing efforts both on land and in the sea and revising the Technical Guidelines for CBA Maps (SANBI 2017) to provide better guidance for identifying CBAs and ESAs in estuarine, coastal and marine systems. Additional tools, such as DEFF's recently developed Land Use Screening Tool, further enhance spatial planning and decision making (See Box 51).

Ecologically or Biologically Significant Marine Areas (EBSA)

In the marine realm, South Africa has a network of **EBSAs**[8] that were adopted by the CBD in 2014 at the 12th Convention of Parties. Initially, EBSAs were conceptualised to be a tool by which MPAs might be identified and established in the high seas; however, their value within national jurisdiction, and for helping countries to achieve their Aichi targets, soon became apparent. Through a series of regional workshops, EBSAs were identified by evaluating sites against seven criteria (Figure 106), and were delineated within country EEZs, in the high seas, and in transboundary (country-country, or country-high seas) areas.



Figure 106. The seven criteria used to delineate EBSAs.

Currently, 279 sites have been identified globally and, subject to the endorsement of current updates to South Africa's EBSA network, there are 18 within national jurisdiction (Figure 107). Although EBSAs are not legally binding, the CBD encouraged countries to co-operate regionally, and implement

[8] https://www.cbd.int/ebsa

improved conservation and protection measures within EBSAs to secure the special biodiversity features for which they were identified. To achieve this, the Benguela Current Commission (BCC) and its member states (South Africa, Namibia and Angola), in cooperation with GIZ on behalf of the German government, have been working on a regional Marine Spatial Management and Governance Programme (MARISMA; 2014-2020). The intent was to **refine existing EBSAs**, identify **new EBSAs**, assess their **status and management requirements**, and incorporate these into **Marine Spatial Planning** (MSP) processes in each country to achieve sustainable ocean use in the Benguela Current. In South Africa, the MARISMA Project has drawn heavily on the maps and assessments produced for the NBA 2018. In terms of EBSA management and proposed inputs into the emerging national MSP processes, it is likely that EBSAs will comprise two zones: a conservation zone, and an impact management zone. The management objectives of these two zones align strongly with those of CBAs and ESAs respectively; therefore, the Coastal and Marine CBA Map forms the basis of the EBSA zoning. The careful and deliberate alignment of coastal and marine biodiversity priorities, underpinned by the same data and systematic planning and assessment processes, means that there is a single, coherent, science-based "ask" from the biodiversity sector in the multi-sectoral MSP negotiations.

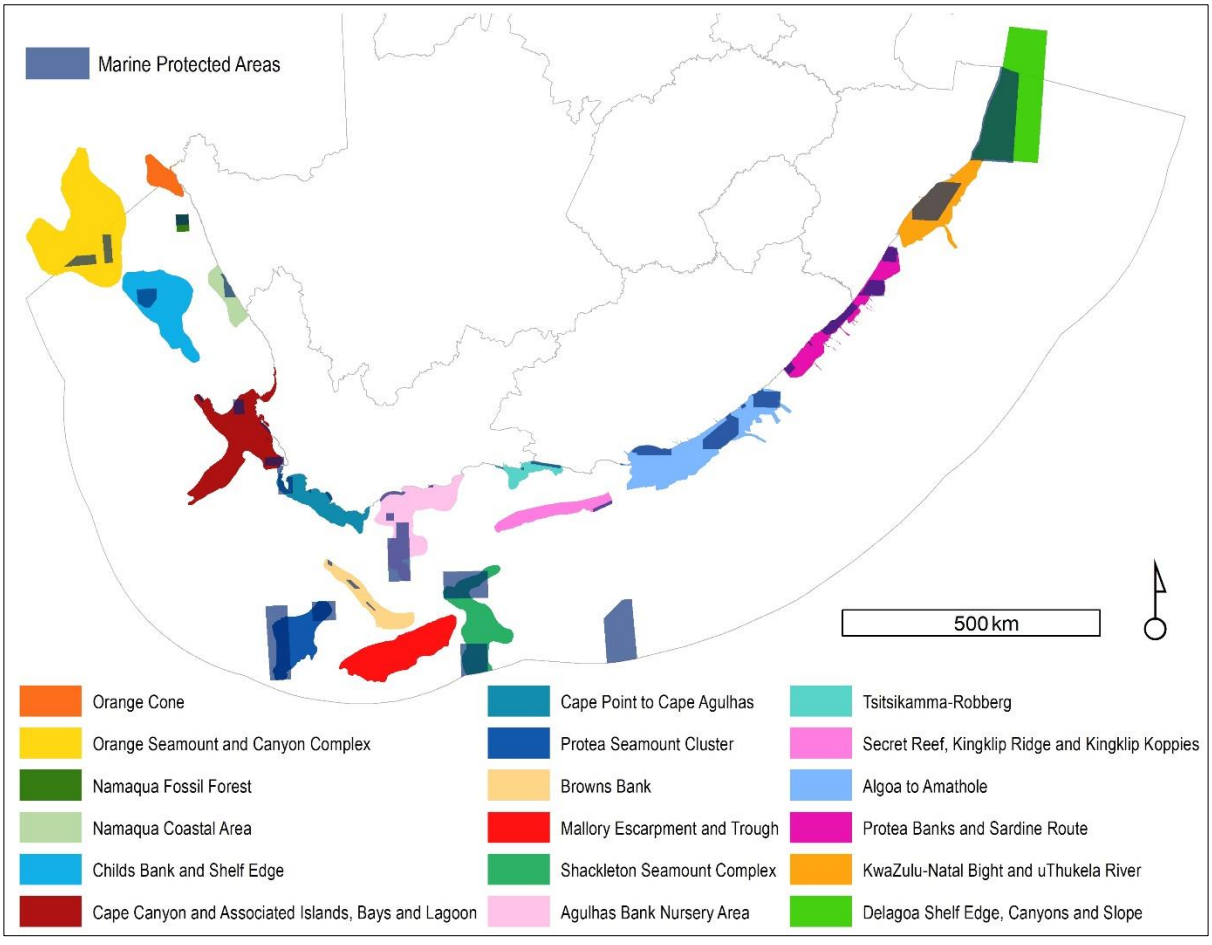


Figure 107. South Africa's proposed revisions to the Ecologically and Biologically Significant Marine Areas (EBSAs) with the expanded MPA network showing that 16 of these 18 EBSAs receive some protection. The Orange Cone and Mallory Trough are the only two EBSAs within national jurisdiction that currently lack any form of protection. The Agulhas Front MPA is also within an EBSA that extends into the high seas.

11.2 Key Findings from NBA 2018

There are 21 key findings from the NBA 2018 marine report that are listed with short headings here and described in detail below.

1. South Africa's exceptional marine biodiversity is globally recognised
2. Marine biodiversity provides a wide array of benefits to South Africans
3. Advances in marine ecosystem mapping supports assessment, planning and management
4. Pressures impact all levels of marine biodiversity
5. Key pressures on marine biodiversity have been identified and mapped
6. Pressure distribution is uneven with hotspots in bays, bights and the shelf edge
7. Ports and harbours are drivers of cumulative impacts and degradation
8. Marine invasive species are increasing despite limited survey effort
9. Climate change worsens pressure impacts, decreasing resilience of people and biodiversity
10. Half of South Africa's marine ecosystem types are threatened
11. Bays, islands, muds and rocky shelves are most threatened
12. Need for further cross-realm integration in shore assessments highlighted
13. Marine ecosystem protection advanced from less than 0.5% in 2018 to 5.4% in 2019
14. Protected area expansion provides first protection for 51 ecosystem types
15. Seven priority marine ecosystem types are threatened and Not Protected
16. Stock status is known for less than 10% of harvested species: 39% are overfished
17. Abalone and West Coast Rock Lobster are in crisis with escalating poaching
18. Approximately 18% of marine species are threatened
19. Marine species are most Data Deficient
20. Knowledge gaps limit the assessment of genetic biodiversity
21. A New Coastal and Marine CBA Map paves the way for improved spatial management

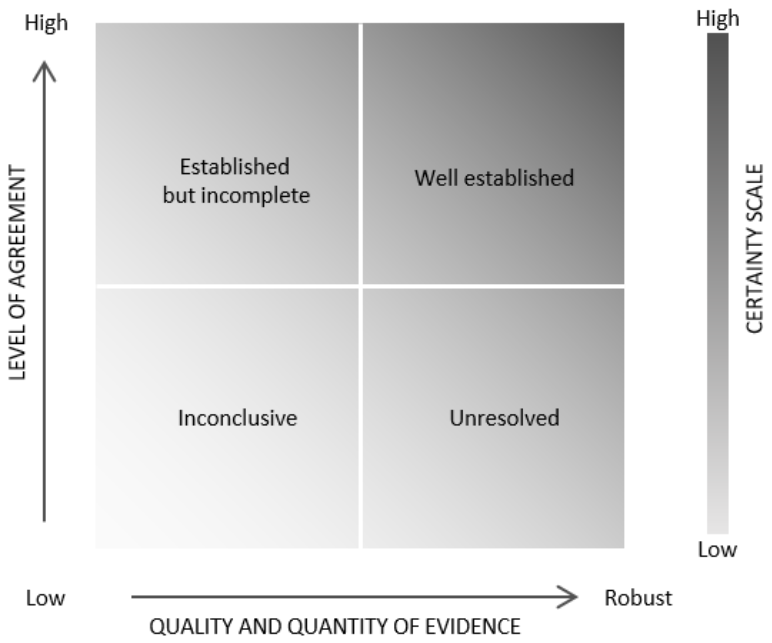


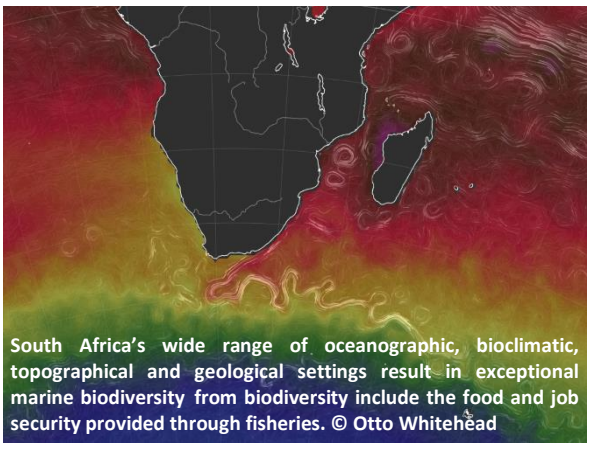
Figure 108. Qualitative measures of certainty based on the level of agreement and supporting evidence.

A **qualitative measure of certainty** is assigned to each finding based on the level of agreement among experts and the quality and quantity of evidence. This was based on the model used by the International Panel for Biodiversity and Ecosystem Services (IPBES) which considers the quantity and quality of evidence, certainty and level of agreement (Figure 108) (Skowno *et al.* 2019a). For the findings in this report, there is high agreement among experts for all findings, but there is a range in the quality and quantity of supporting evidence. Thus, the findings are given as either Established but incomplete or Well established. The priority actions developed in this chapter aim to address these findings.

Key Findings in Detail

1. South Africa's exceptional marine biodiversity is globally recognised

South Africa is globally recognised for its marine biodiversity and high levels of endemism (*established but incomplete*). South Africa's wide range of oceanographic, bioclimatic, topographical and geological settings have not only resulted in high species diversity and endemism, but also high ecosystem diversity. South Africa's marine ecosystems support more than 13 000 species with estimates of marine endemism for different groups ranging between 26 and 33%. South Africa is reported as having the third highest marine endemism after New Zealand (51%) and Antarctica (45%). The highest marine endemicity has consistently been reported for the warm temperate Agulhas ecoregion on the south coast which lies entirely within South Africa's territory and is geographically very isolated from other warm temperate regions. See Chapter 1


South Africa's wide range of oceanographic, bioclimatic, topographical and geological settings result in exceptional marine biodiversity from biodiversity include the food and job security provided through fisheries. © Otto Whitehead

2. *Marine biodiversity provides a wide array of benefits to South Africans*



Benefits from biodiversity include the food and job security provided through fisheries. © Jaco Barendse

South Africa's exceptional marine biodiversity provides a wide array of benefits to the economy, society and human wellbeing *(established but incomplete).*

Marine biodiversity is central to South Africa's national objectives of increased economic growth and job creation. Tangible benefits include the direct harvesting of food and medicinal resources, and the recreational, tourism and educational benefits. Less tangible benefits include the spiritual and cultural values of South Africa's oceans and coasts, also taking into account the likely role of marine resources in modern human evolution. Naturally functioning ecosystems that generate or deliver valuable services to people and thereby enhance human wellbeing are referred to as ecological infrastructure, the nature-based equivalent to built infrastructure. Beaches, reefs and kelp forests are marine ecosystems of limited extent that provide disproportionate benefits. The continued supply of these benefits relies on healthy ecosystems and well managed species. Maintaining the health of marine biodiversity at the ecosystem species and genetic levels helps humans adapt to climate change. The continued supply of the many marine biodiversity benefits relies on healthy ecosystems and well managed species.

See Chapter 2

3. *Advances in marine ecosystem mapping supports assessment, planning and management*

Increased investment in research has improved ecosystem classification and mapping to support effective spatial assessment, planning and management *(established but incomplete).*

A revised Marine Ecosystem Classification and Map showcasing South Africa's 150 marine ecosystem types in six marine ecoregions was produced. Key advances in the map of marine ecosystems included very fine-scale shore mapping with alignment between marine, terrestrial and estuarine realms in the coastal zone; the inclusion of kelp forests, bays, fluvial fans and stromatolite shores as distinct ecosystem types and the introduction of finer depth strata across shelves and on the slope. This was a result of a major effort to collate and increase relevant historic and current data sets to improve ecosystem classification and mapping. Marine ecosystem types that are coastal (including all shore types, ecosystem types on the inner shelf and all river influenced ecosystem types) were identified to produce the first ecologically determined map and assessment of coastal ecosystem types for South Africa. The development of an integrated map of ecosystems for all of South Africa's territory, including the terrestrial, marine and other aquatic ecosystem types in both mainland South Africa and the territory in the Southern Ocean is one of the major achievements of the NBA 2018.

See Chapter 3 and 11

4. *Pressures impact all levels of marine biodiversity*

Pressures are impacting marine biodiversity at all levels: ecosystems, species and genes (*well established*).

There is evidence that pressures on marine biodiversity exert impacts at the ecosystem, species and genetic levels. These impacts are most clearly demonstrated for fishing, the most established marine activity with the longest history in South Africa's oceans. Ecosystem effects from fishing range from impacts on the seabed, declines in target species and other species caught as bycatch or incidentally, and trophic changes with impacts on behaviour and population dynamics of marine predators. These ecosystem changes also impact on species. For example, seabirds are affected by food availability and there is perceived competition between fishers and marine predators. At the species level, dramatic declines in target and other species have been attributed to fishing. Despite limited genetic research, there is evidence of impacts on some fished species including hakes, Kingklip and kobs.

See Chapters 4, 8, 9 and 10

5. *Key pressures on marine biodiversity have been identified and mapped*

Fishing, reduced freshwater flow, pollution, coastal development, mariculture and mining are key marine pressures (*well established*).

Marine ecosystems and species face pressures from an increasing range, extent and intensity of human activities, threatening the societal benefits from marine biodiversity. These pressures include 22 recognised fisheries sectors, petroleum activities, mining, shipping, freshwater flow reduction, coastal development, ports and harbours, mariculture, and pollution. The extent and intensity of pressures, and the impacted components of biodiversity, all warrant consideration in determining key pressures. Coastal development, mining, trawling and mariculture have the highest impact scores among the 31 pressures on marine ecosystem types included in this assessment although. Fishing and shipping are pressures with the greatest extent. Emerging pressures of greatest concern include land-sourced pollution (e.g. plastic pollution and chemical runoff), increased underwater noise and desalination impacts. High levels of organochlorine pesticide accumulation in corals in the iSimangaliso were recently reported along with evidence that microplastics are no ubiquitous across the South African coastline. Fishing is the greatest cause of biodiversity degradation in the offshore environment whereas both coastal development and fishing are the greatest pressures on inshore ecosystems. A meta-analysis of the key pressures impacting on species of conservation concern revealed that fishing remains the greatest pressure on marine species. Key additional pressures include pollution (plastics, underwater noise, waste water and effluent) and freshwater flow reduction.

See Chapters 4 and 9

6. Pressure distribution is uneven with hotspots in bays, bights and the shelf edge

The distribution of pressures is uneven with pressure hotspots in bays, bights and the shelf edge (*well established*).

Pressures are unevenly distributed across the seascape with some areas experiencing high concentrations of pressures. A key pattern that emerged during the NBA 2018 marine assessment was the high cumulative pressures in bays and this is linked to the development of ports and harbours. These pressure hotspots require strategic planning and focused management. Other high pressure areas include the area offshore of the Orange River, the shelf edge on the west and south coast, large portions of the Cape inner and middle shelf, the Agulhas Bank and the KwaZulu-Natal Bight. The new Coastal and Marine Critical Biodiversity Area Map can support and inform Marine Spatial Planning in pressure hotspots.

See Chapter 4

7. Ports and harbours are drivers of cumulative impacts and degradation.

Ports and harbours are key drivers of cumulative impacts and ecological degradation by providing points of access to the sea, increasing coastal development, changing local shoreline orientation, and being pressure hotspots (*well established*).

South Africa's coast is generally exposed to high wave energy; therefore, artificially constructed ports and harbours are necessary transport infrastructure, but are also key drivers of impacts to biodiversity. The development of ports and harbours and associate effects include the impacts of construction, concentration of pressures due to increased access, the introduction of alien and invasive species and the impacts of dredge disposal. As such port and harbours are drivers of significant cumulative pressures that require careful spatial planning and effective management. The highest cumulative pressure mapped in the NBA 2018 marine assessment was recorded in Saldanha Bay with all bays facing high cumulative pressures. Further, ports and harbours have high risks of biological invasions from ship fouling and ballast water, pollution from various chemicals and waste, and disasters such as oil spills. The main points of introduction and refugia for marine alien and invasive species are ports, harbours and marinas; which is where most introduced species (62 taxa) have been recorded. In addition, harbour breakwaters interrupt the natural flow of sand in longshore currents in the surf and inner shelf around the country and contribute to the loss of sand on beaches. If not appropriately located and managed, the natural sand movement corridors ("sand rivers") that once supplied beaches with sand, can be cut off from their sand-bank reserves that beaches need during periods of heightened erosion. For these reasons, the location of ports and harbours should be carefully planned.

See Chapters 4 and 5 and NBA 2018 Coast

8. Marine invasive species are increasing despite limited survey effort

Marine invasive species are increasing in South Africa with 96 alien species and 55 invasive species reported, d**espite limited survey effort** (*established but incomplete*).

In 2011, the NBA reported that the known number of marine alien species had expanded from 17 in 1992 to 84, only 8 of which were considered as invasive. Based on recent research, the number of

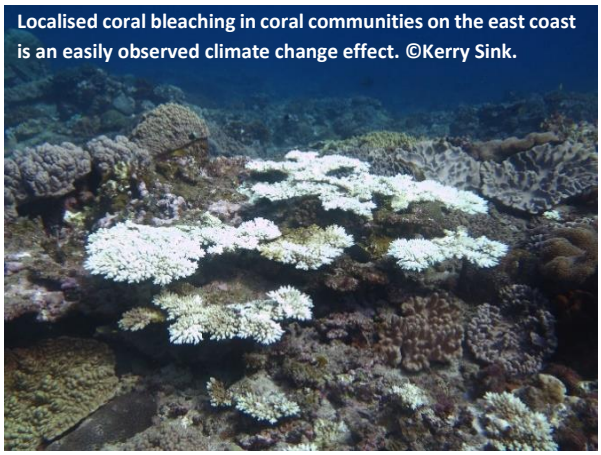
marine alien species has been amended to 96 including 55 that are considered to be invasive. Rocky shores are the most invaded broad ecosystem group, with most invasions in the Southern Benguela ecoregion. Crustaceans and molluscs are the taxonomic groups most often recorded as invasive. The main points of introduction and refugia for marine alien and invasive species are ports, harbours and marinas; which is where most introduced species (62) have been recorded. The main vectors of accidental introductions remain ship fouling and ballast water. Recreational boating has also been identified as a significant contributor to the intra-regional spread of invasive species, and the expanding aquarium trade is an emerging vector of introduction. Gaps in taxonomic knowledge, capacity and opportunities for systematic surveys limit the ability to detect and understand marine introductions and invasions in South Africa. The impacts of marine invasive species on global ocean economies and ecosystems signal the risks to South Africa's ocean economy, biodiversity and coastal communities.

See Chapters 4 and 5

9. *Climate change worsens pressure impacts, decreasing resilience of people and biodiversity*

Climate change exacerbates impacts of pressures on marine ecosystems and species, decreasing resilience and threatening coastal communities and livelihoods *(established but incomplete)*.

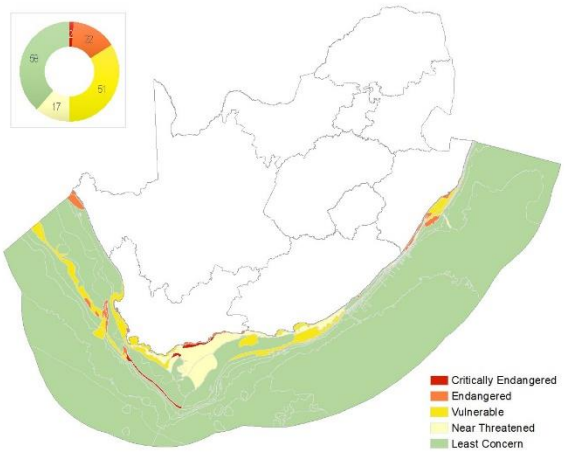
South Africa has experienced significant oceanographic changes over the past few decades. Parts of the Agulhas Current have warmed more rapidly than 90% of the world's oceans, while upwelling on the west and south coasts has increased due to intensified winds, leading to inshore cooling. These shifts are accompanied by increases in sea level, changes in ocean currents (which affect regional climate, energy transfer, and species dispersal), wave height, ocean acidification, low oxygen events and increasingly frequent storms. Such changes are already having marked impacts across a wide variety of South Africa's marine taxa including sponges, kelp, fish, seabirds, molluscs, corals, crustaceans and foraminifera. Resulting shifts in species distribution, abundance, physiology and behaviour are causing changes in community composition, hybridisation, and the spread of alien species. Coastal fisheries most at risk in the short to medium term include those for small pelagics, linefish, netfish and West Coast Rock Lobster. Marine tourism may also be impacted. The complexity and variability of South Africa's marine systems, aggravated by anthropogenic stressors (including historical overexploitation of some marine resources), make future impacts difficult to predict. However, there is high certainty that impacts on biodiversity, ecosystem function, food security and economically valuable industries will continue to intensify.



Localised coral bleaching in coral communities on the east coast is an easily observed climate change effect. ©Kerry Sink.

See Chapter 6

10. Half of South Africa's marine ecosystem types are threatened



A first assessment of marine ecosystems using IUCN Red List Criteria found that half of South Africa's marine ecosystem types are threatened (*established but incomplete*).

A systematic assessment of South Africa's 150 marine ecosystem types using a method aligned to that of the International Union for Conservation of Nature (IUCN) Red List of Ecosystems found that 50% are threatened. By area this equates to only 5% of the ocean space around South Africa, reflecting that many smaller ecosystem types are threatened, with larger deep ocean ecosystem types under less threat. More inshore and shelf ecosystem types are threatened than those of the slope and abyss. Only two ecosystem types (1% of types) are Critically Endangered; the Agulhas Muddy Mid Shelf and Browns Bank Rocky Shelf Edge. A further 22 types are Endangered (15%) and 51 types are Vulnerable (34%). The 2018 results are not directly comparable to the 2011 NBA results because of changes to the ecosystem maps and pressure data, and also differences in assessment methods. To improve this assessment, better data on ecosystem condition is needed, while further international collaboration is required to determine the appropriate spatial scale for ecosystem red listing and to refine thresholds for national assessments.

See Chapter 7

11. Bays, islands, muds and rocky shelves most threatened

The most threatened broad ecosystem groups include bays, islands, muddy ecosystem types and rocky ecosystems on the shelf (*established but incomplete*).

To provide an overview of patterns in ecosystem threat status, ecosystems were grouped into several broad types. Bays, muddy ecosystem types and rocky ecosystems on the inner shelf and shelf edge experience amplified levels of threat due to cumulative pressures. The cold temperate Southern Benguela ecoregion has more threatened ecosystem types than the warm temperate Agulhas ecoregion, while the subtropical Natal and Delagoa ecoregions have the least threatened ecosystems. Areas where pressures are concentrated, such as bays, are priorities for management interventions.

See Chapter 7

12. Need for further cross-realm integration in shore assessments highlighted

Assessment of shores needs to improve in resolution and account for cross realm connections (*established but incomplete*).

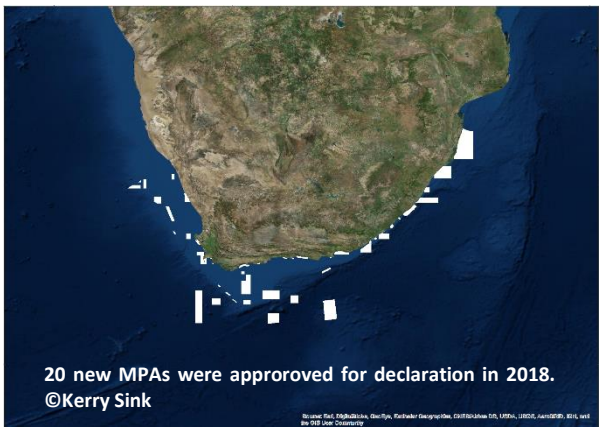
Although there has been excellent progress in mapping and alignment of ecosystems in the land-sea interface, a number of limitations were recognised in the mapping and assessment of shore ecosystems. In terms of ecosystem classification and mapping, the classification of mixed shores needs

research attention and emerging new wave exposure data sets can improve mapping of rocky shore ecosystem types. Mismatches in the scale of ecosystem and pressure mapping limit the assessment of seashore and higher resolution and finer scale analyses may be needed. Considering the large extent of the terrestrial and marine realms, the current resolution of the assessments is generally appropriate except for the highly linear and small seashore ecosystem types. Coastal development impacts may have been underestimated and improved updated data on recreational, subsistence and small scale fishing; invasive species and sea level rise is needed. Although there is evidence of beaches losing sand and eroding due to a legacy of poor management of connected beach, dune and estuarine systems; a lack of national scale data and a limited spatial understanding of degradation due to disruption of sediment movement corridors prevented consideration of these pressures in this assessment.

As such, the ecosystem threat status of seashore ecosystem types, particularly sandy shores, is probably underestimated. In some places, South Africa is losing beaches as they erode to bedrock, and some beaches are inaccessible during spring high tides because waves submerge the whole beach up to the seawalls. Climate-change impacts exacerbating these impacts, with increased frequencies and intensities of extreme storms eroding beaches further, and sea-level rise interacting with seawalls defending inappropriately located development, causing gradual inundation and loss of beaches through coastal squeeze. Losing beaches has the potential to impact tourism, especially because beach visiting is one of the most popular tourist activities, and favoured urban beaches are most at risk of habitat loss given that their resilience is undermined by inappropriate coastal development. Impacts on biodiversity include habitat loss and local extinctions of species, which is concerning because two-thirds of South Africa's beach macrofauna is endemic to southern Africa. Finally, the cross realm connections should be considered in the assessment of adjacent coastal ecosystem types where poor ecological condition could influence the status of adjacent linked coastal ecosystem types. See the coast report for more detail Iterative improvements in cross-realm integration can improve the assessment of shores.

See Chapter 3, 7 and the cross-realm Coast Technical Report (Harris *et al.* 2019)

13. Marine ecosystem protection advanced from less than 0.5% in 2018 to 5.4% in 2019



20 new MPAs were approroved for declaration in 2018. ©Kerry Sink

In 2019, the South African government declared 20 new MPAs advancing marine ecosystem protection from less than 0.5% in 2018 to 5.4% in 2019 *(well established)*.

South Africa's number of MPAs increased from 26 in 2018 to 42 in 2019, inclusive of the Prince Edward Islands MPA in the Southern Ocean and noting that some MPAs were expanded or merged and expanded in the new network. With this, protection of the marine environment around mainland South Africa increased from less than 0.5% (approximately 4 900 km^2) in 2018 to 5.4 % (57 900 km^2) in 2019 with the addition of approximately 53 000 km^2 of protected area estate. This expanded MPA network is helping to sustain

South Africa's emerging ocean economy, protect marine ecosystems, rebuild fish stocks and support climate resilience.

See Chapter 8

14. Protected area expansion provides first protection for 51 ecosystem types

South Africa's MPA expansion provided the first protection for 51 previously Not Protected ecosystem types reducing the number of ecosystem types within this category from 47% to 13% (*well established*).

The proclamation of 20 new MPAs in 2019 significantly improved marine ecosystem protection levels with 51 types receiving their first protection. Most of the ecosystem types that are Not Protected are located in the deeper offshore environment, particularly on the slope, with most of the slope and abyssal ecosystem types still Poorly Protected. Thirteen previously Not Protected and 4 Moderately Protected ecosystem types advanced to Well Protected, an improvement from 20% to 31% of ecosystem types in this category, and 87% of the 150 marine ecosystem types now have at least some representation in the MPA network. The MPA expansion translates into higher levels of protection for the marine realm than for any other realm in terms of ecosystem type representation. The placement of these new MPAs not only resulted in a marked improvement in ecosystem protection levels for many ecosystem types but also contributed to better representation of all ecoregions in the MPA network. A total of 41 marine ecosystem types were downgraded from Well Protected to Moderately Protected because although 20% of the extent of these ecosystem types are protected, insufficient area is in good ecosystem condition within MPAs due to legal and illegal fishing, flow reduction, waste water discharge and historical cumulative pressures.

See Chapter 8

15. Seven priority marine ecosystem types are threatened and Not Protected

There are 7 priority marine ecosystem types that are both threatened and not protected (*well established*).

Although South Africa has significantly improved ocean protection, there are still seven threatened but unprotected ecosystem types that need protection. The highest priority are the Endangered ecosystems: two muddy ecosystem types on the shelf off the Orange River and a reef complex in the mid-shelf of the KwaZulu-Natal Bight. Reef mosaic and deep coral habitats in the trawl grounds of the Agulhas ecoregion are Vulnerable and need protection. In the Southern Benguela ecoregion, St Helena Bay, a unique ecosystem type that faces cumulative pressures as well as the slope component of the Cape Canyon need representation in South Africa's MPA Network. This assessment identified priority ecosystem types for improved protection through MPA expansion and by improving condition in existing and new MPAs.

See Chapter 8

16. Stock status is known for less than 10% of harvested species: 39% are overfished

Updated stock assessments are available for less than 10% of South Africa's harvested marine species and more than a third (39%) of the assessed resources are Overexploited or Collapsed *(established but incomplete).*


Dageraad is one of South Africa's Collapsed Linefish stocks and is a Critically Endangered species. © Denham Parker.

South Africa's oceans provide a high diversity of marine resources with more than 770 marine species that are harvested. Updated stock status is available for only 54 stocks covering at least 42 species. Of these, 39% stocks are Overexploited or Collapsed. Effective science-based management has supported recovery of Deep Water Hake *Merluccius paradoxus* and some linefish species, such as Carpenter *Argyrozona argyrozona*. The recovery of Red Steenbras *Petrus rupestris* and Dageraad *Chrysoblephus cristiceps* should be prioritised. Improved data collection and data management systems and strategic focused research to address critical knowledge gaps can help streamline and update stock assessments.

See Chapter 9

17. Abalone and West Coast Rock Lobster are in crisis with escalating poaching

Abalone and West Coast Rock Lobster resources are severely overexploited with escalating poaching preventing recovery of these valuable resources (well established).


Abalone stocks are in crisis. ©Steve Benjamin.

High value inshore resources are in crisis with illegal and unregulated fishing contributing to the drastic declines in stocks of Abalone *Haliotis midae* and West Coast Rock Lobster *Jasus lalandii*. Illegal Abalone trade is estimated to be almost double the volume of legally caught abalone or that produced by aquaculture operations. Resource recovery plans need to be implemented and fishing quotas need to be allocated in line with scientific recommendations that account for the realities of resource abundance

See Chapter 9

18. Approximately 18% of marine species are threatened

limited effort in assessing marine species threat status in South Africa, 376 species have been assessed using IUCN criteria, of which approximately 18% are considered threatened.


The African Penguin is one of South Africa's Endangered seabirds. © Peter Chadwick

To date, 376 South African marine species have been assessed by a combination of national, regional and global assessments using the IUCN redlisting approach. Of these, 70 taxa were assessed to be threatened. While this is a relatively high percentage, it may not be truly representative of actual threat patterns because the selection of taxa for redlisting assessment was biased towards taxa that were perceived to be under threat. Seabirds**,** endemic sparids and marine reptiles are particularly threatened. Fishing remains the greatest driver of extinction risk in marine species. Climate change, underwater noise, alien species, problematic native species and plastic pollution constitute significant threats to marine mammals, birds and reptiles. Poor catchment management resulting in freshwater flow reduction and reduced estuarine function is increasing the extinction risk of many commercially important estuarine-dependent fish species.

See Chapter 9

19. Marine species are most data deficient

Marine species have the highest levels of data deficiency across all realms (*well established*).

Thirty-four percent (34%) of 121 commercially important bony fish and 50% of 26 cartilaginous fish were assessed as Data Deficient. The high level of data deficiency for fish is due to knowledge gaps in life history, lack of long-term fisheries catch and effort data, impaired data integrity and challenges in data management. The lack of IUCN assessments for marine invertebrates is due to inadequate taxonomic knowledge, limited distribution data, a lack of systematic surveys and limited capacity to advance species' redlisting. Knowledge gaps in taxonomy, long-term population trends and life history limit our understanding of marine species' status and threatened species may be undetected.

See Chapter 9

20. Knowledge gaps limit the assessment of genetic biodiversity

A lack of knowledge and techniques limits our ability to assess the risks to the genetic component of marine biodiversity *(well established).*

The maintenance of genetic diversity is important for retaining evolutionary potential and the ability of species or populations to adapt to change. Risks to genetic diversity include genetic erosion through overfishing and reduced population sizes, loss of connectivity, hybridization and inbreeding and the disruption of co-adapted gene complexes and disease epidemiology through translocations. South Africa has increasingly invested in genetic research and is establishing a baseline understanding of spatial patterns, particularly inshore. There is evidence in South Africa of fisheries impacts on the genetic diversity of some fished species such as Cape Hakes *Merluccius* spp., Kingklip *Genypterus*

capensis and Dusky Kob *Argyrosomus japonicus*. There is an absence of temporal genetic data sets and a lack of genetic diversity indicators and thresholds against which the state of genetic diversity can be assessed. A genetic monitoring framework is required that outlines a strategic approach to prioritise species for monitoring, identifies appropriate genetic markers and metrics, and specifies the frequency of monitoring. High priority resource species, overexploited and threatened taxa, endemic species, species identified as being especially sensitive to climate change and species farmed in mariculture are priorities for genetic monitoring. Spatial patterns in genetic biodiversity need to be taken into account in marine spatial planning and protected area design.



Kingklip are a high value resource species with fisheries impacts on genetic diversity. ©SAEON

See Chapter 10

21. A New Coastal and Marine CBA Map paves the way for improved spatial management

The new Map of Coastal and Marine Critical Biodiversity Areas (CBA Map) strategically identifies priorities to inform Marine Spatial Planning, protected area expansion, restoration efforts and environmental authorisations in support of a sustainable oceans economy *(established, incomplete).*

South Africa is now positioned to secure key marine and coastal biodiversity and ecological infrastructure as a national asset. This is imperative because so many South Africans depend on marine ecosystems and species for food, livelihoods, recreation and spiritual needs. Current decisions and future actions to secure these biodiversity assets and benefits, particularly from our ecological infrastructure, are also crucial to enhance our adaptive capacity and resilience to climate change. Well planned and informed management and decision making for the ocean can contribute to strengthening food and job security, protection from extreme weather and events and more resilient ecosystems and human communities.

This Chapter

11.3 Priority Actions to address the key findings of the NBA 2018

Progress on Priority Actions since NBA 2011

As a key step in developing priority actions for the NBA 2018, progress against the NBA 2011 priority actions, of which there were 63 nested in 9 categories was reviewed by authors and then further reviewed at a workshop (Annexure 6). The main workshop aim was to distil and prioritise key actions to address the findings from the marine NBA 2018.

Ten Marine Priority Actions from NBA 2018

In response to the findings above, the top 10 priority actions for managing and restoring marine biodiversity in South Africa were identified. This was done by considering progress against previously identified priorities, detailing priority actions per key finding and by considering the strategic objectives of the NBSAP and NBF. These were compared with previous priorities, considered in terms of current versus previous relevance, and then refined with consideration of the NBF and NBSAP priorities shown in Table 47 and with input from SANBI's policy division. These ten key priorities are listed below with further details per action provided overleaf. For ease of reference these are assigned letters A to J although it is important to recognise that these actions are considered to carry equal importance.

The top 10 Priority actions to improve the State of Marine Biodiversity in South Africa are:

A. **Apply the Coastal and Marine Critical Biodiversity Area Map** in Marine Spatial Planning and Environmental Impact Assessments to mitigate pressures in priority areas.

B. **Develop and implement effective fisheries management plans** to secure food and job security and reduce ecosystem impacts of fisheries.

C. **Strengthen MPA financing and governance** to enhance MPA protection and the equitable flow of benefits from South Africa's MPA network.

D. Effectively communicate the value of South Africa's marine biodiversity through improved co-ordinated messaging that articulates benefits, in order to build support for marine conservation, mainstream biodiversity into key production sectors and mobilise people to sustainably use marine biodiversity.

E. **Ensure sufficient quantity and quality of freshwater flows** to marine ecosystems

F. **Prevent new marine invasions** through response planning, ring-fenced resources and rapid action.

G. **Restore marine biodiversity assets** to strengthen climate resilience and sustain key benefits

H. **Enhance co-operative governance** for improved, co-ordinated compliance and marine biodiversity management.

I. **Modernise and integrate data collection, storage and access** to improve marine biodiversity, fisheries, and climate data for better assessment, analysis, and monitoring, and to improve compliance with and evaluation of management actions.

J. **Catalyse research to address critical knowledge gaps** that limit the assessment of marine biodiversity and decision-making for a sustainable oceans economy.

A. Apply the Coastal and Marine Critical Biodiversity Area Map

A. Apply the Coastal and Marine Critical Biodiversity Area Map in Marine Spatial Planning and Environmental Impact Assessments to mitigate pressures in priority areas.

What is a CBA Map?

A Critical Biodiversity Area Map (CBA Map) presents a spatial plan for the natural environment, designed to inform planning and decision making in support of sustainable development. The map comprises three main priority areas: Protected Areas (PAs), Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) that are jointly "important for the persistence of a viable representative sample of all ecosystem types and species as well as the long-term ecological functioning of the landscape or seascape as a whole" (SANBI 2017).

Application of the recently developed first national Coastal and Marine Spatial Biodiversity Plan (Critical Biodiversity Area Map (Figure 105) and associated land- and sea-use guidelines) can strengthen Marine Spatial Planning and the environmental authorisation process. CBA maps are a form of strategic planning for the natural environment, identifying a set of geographic areas that provide a spatial plan for ecological sustainability at the seascape and landscape scale (SANBI 2017). They are designed to be spatially efficient and to avoid conflict with non-compatible land and ocean uses wherever possible, and therefore align with the goal of growing South Africa's marine economy. The new Coastal and Marine CBA map (Harris and Sink 2019) includes Protected Areas, CBAs and Ecological Support Areas (ESAs) which together form a network of natural and semi-natural areas that can help maintain the ecological functionality of the ocean and coast. The use of CBA maps in Marine Spatial Planning will help maintain the benefits from biodiversity in the long term. In the terrestrial realm, CBA maps have been guiding land use planning for many years (Botts *et al.* 2019). CBA maps directly support the implementation of the NBSAP and NBF, especially Strategic Objectives 1, 2 and 3 (see Table 47).

South Africa's first national Coastal and Marine CBA map can and will be iteratively improved to reflected updated knowledge. The next iteration will also better incorporate key ecological infrastructure for fisheries and coastal ecosystem services drawing from current work that is underway to support such improvements. Other priorities for future improvements in the CBA Map include (1) consideration of fine scale areas of strategic importance for the petroleum sector to improve conflict avoidance; (2) incorporation of species distributions and movement; (3) finer scale coastal integration and (4) incorporation of genetic information and . Application of the newly compiled guidelines for CBA and ESA identification for estuaries is a priority. This will be incorporated as part of the fine-scale coastal integration. See the NBA Coast Report for additional detail.

Additional tools such as DEFF's recently developed Environmental Screening Tool (see Box 51), further enhances planning and decision making. It is important that sensitive marine ecosystems and species are identified and included in the Screening Tool. This will ensure that the correct environmental authorization requirements (including the requirements for specialist assessments) will be detailed in the screening report.

Box 51. Environmental Authorisation Screening Tool

By Faheima Daniels, SANBI

The Department of Environment, Forestry and Fisheries have developed a Web Based National Environmental Screening Tool to support improvements in environmental authorisations. The use of the Screening Tool in the environmental authorisation process is mandatory as of 05 October 2019. This has the potential to strengthen Environmental Impact Assessments by ensuring that the appropriate available spatial information is considered and that sensitivities are flagged. The screening report (generated by the Screening Tool), lists the requirements for developers and gives details of assessment requirements by prescribing "assessment and reporting protocols". Submission of the screening report is a compulsory part of the environmental authorisation process, so that the competent authority has a record of what the assessment requirements are. Furthermore, the competent authority has a record of the sensitivities at the site and can evaluate whether or not the environmental assessment practitioner has followed the correct protocol to sufficiently inform the decision making process. The use of the Screening Tool will ensure standardisation in the assessment process and allows for transparency and a better informed decision making process for competent authorities.

The marine environmental authorisation process could be further strengthened by ensuring that the greatest drivers of change and impact on marine biodiversity are included in the listed activities in terms of the National Environmental Management Act (No. 107 of 1998) as contained in Gazette numbers 983, 984 and 985. A key recommendation is the development of marine guidelines to improve Environmental Impact Assessments in an ocean environment.

NBA 2018 KEY MESSAGE C1

Areas where pressures are concentrated are priorities for spatial planning

The spatial distribution of pressures on biodiversity across the landscape and seascape is uneven. Pressure hotspots, where many different pressures converge, require strategic spatial planning and focussed management

Skowno et al. 2019.

Among coastal marine ecosystems, escalating pressures on bays require special focus with regard to future developments and utilisation to ensure a sustainable future and viable oceans economy. This requires urgent action to achieve a more integrated and well-coordinated approach to knowledge sharing and decision making through multi-stakeholder frameworks. Scientific working groups and task teams that identify multi- or trans-disciplinary research priorities in priority areas are key for guiding management interventions and policy development. A major knowledge gap in this regard is an understanding how different socio-ecosystem components respond to cumulative pressures and how multiple pressures compound and interact.

B. Develop and implement fisheries management plans for all sectors

B. Develop and implement effective fisheries management plans to secure food and job security and reduce ecosystem impacts of fisheries.

Many of the challenges and concerns raised during this assessment can be addressed through the development and implementation of fisheries management plans, framed under the Ecosystem Approach to Fisheries management (EAF). This includes the recreational fishery which is a priority for management action. Fishery management plans should have clear objectives that holistically address sustainable use of resources, social and economic considerations, governance, and the need to reduce biodiversity impacts of each fishery. Biodiversity impacts include impacts to the seabed, overexploitation of target species, unsustainable impacts on other species (bycatch and incidental) and the broader ecosystem. Such clear, comprehensive management plans will help track performance in the implementation of EAF.

Fishery Management Plans need to define Limit Reference Points for all target and important by-catch species and develop detailed species-specific recovery plans. When these Limit Reference Points are reached, species-specific recovery plans should be implemented. Improvements in the collection of relevant biological, catch and effort data (including fisheries independent data through observer programmes) should be a major focus in most fishery management plans including the expansive multi-species small-scale fishing sector. Reliable data is essential to improve the confidence of stock assessments and the ability to develop prudent management measures.



Recreational fishing requires management (see Box 18). Technological advancements are a feature of many fisheries including recreational fisheries. Recently, drone fishing is allowing shore anglers to reach beyond casting limits.

The implementation of these plans would require regular review to assess progress and to identify emerging threats. The former Department of Agriculture Forestry and Fisheries (DAFF) conducted initial Ecological Risk Assessments (ERAs) for almost all the commercial fisheries in order to identify and prioritize threats and to develop corresponding action plans. These ERAs may be useful as a starting point for fishery management plans and provides a practical means of tracking performance in the implementation of EAF management.

Critical data gaps that limit the undertaking of regular and consistent stock and IUCN threat status assessments should be identified and addressed. Threatened species including sharks, seabirds, and turtles and species of which the populations have collapsed largely due to overfishing, including seabreams and kobs, should be prioritised in management planning and implementation. South African fisheries science is excellent and science based management recommendations have been developed but require urgent implementation. A coordinated approach to improve monitoring and compliance and help reduce poaching (Illegal Unregulated and Unreported fishing), including through multi-disciplinary efforts to address the underlying complex socio-economic drivers, is critical for the recovery of severely Overexploited resources such as Abalone and West Coast Rock Lobster. South Africa's recreational fishery urgently needs management and research attention with the key priorities including updated effort data, reconsideration of bag and size limits and improved monitoring and compliance. Explore the application of FishPath to across fisheries to identify most appropriate monitoring, assessment and management given constraints (Dowling *et al.* 2016). Advancing fishing technologies such as drone fishing require consideration in management efforts. All fishery management plans should consider the impacts of climate change and should seek to build resilient fisheries and ecosystems.

West Coast Rock Lobster Legal Challenge by Mathan Theart, SANBI

In the matter of WWF South Africa v Minister of Agriculture, Forestry and Fisheries and others, delivered on 26 September 2018, the High Court found that the Total Allowable Catch (TAC) for West Coast Rock Lobster (WCRL) was determined by the Department of Agriculture, Forestry and Fisheries (DAFF) in an irrational manner and therefore set aside that determination. In that matter, DAFF had determined a TAC for WCRL almost three times the TAC recommended by a multi-stakeholder scientific working group advising DAFF. The recommendation, in turn, was made on the basis of the best available scientific evidence, which indicated that WCRL is a resource that is critically depleted and that there is a "substantial probability that the [WCRL] resource abundance will decrease further" should the TAC not be dramatically reduced from the previous year's determination. The Court found that the best available scientific evidence was largely disregarded by DAFF. In its view, the decision not to reduce the TAC to the levels recommended by the scientific working group was taken in violation of multiple key principles of environmental law, most notably the principle that a risk-averse and cautious approach should be applied in environmental decision-making. The Court explained that that principle means that lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. The Court laid down two key pre-requisites for applying the risk-averse and cautious approach: the proposed activity should pose a threat of serious or irreversible environmental damage and there should be scientific uncertainty as to the environmental damage. The Court found that the two prerequisites had been met since the depletion of WCRL constituted serious and irreversible environmental damage, and that there may have been some uncertainty as to whether harvesting above the level recommended by the scientific working group would "as a fact" cause serious environmental damage.

C. Strengthen MPA financing and governance

C. Strengthen MPA financing and governance to enhance equitable flow of benefits from South Africa's MPA network.

South Africa has made significant advances in MPA expansion but for protection to be effective there is a need to develop and implement MPA management plans, cultivate innovative MPA financing arrangements, and improve stakeholder liaison and compliance. All of the new MPAs, and some MPAs established before 2019, still require management plans. There is also a need to improve management planning and MPA zonation to help improve ecosystem condition in many well-established MPAs. It is critical to strengthen collaborative efforts and financing to ensure that management authorities are well capacitated and resourced to monitor and enforce MPA management regulations. Improved stakeholder relations are also an essential element for improving compliance and helping South Africa's MPAs deliver more benefits to coastal communities. The NBA 2011 priority actions that were specified to increase the delivery of MPA benefits, including the need for diversified non-consumptive tourism, are still very relevant. The diversification and sustainable expansion of **non-consumptive activities** within Marine Protected Areas, through small enterprise development in local communities, could increase employment opportunities and community beneficiation in line with Strategic Objective 2.1 in the NBF and NBSAP (Table 47). South African MPA management authorities need to build on recent efforts to capacitate MPA staff and ensure that key skills for effective MPA establishment and management are incorporated into the skills planning, development and evaluation responsibilities of the environment and fisheries sectors.

The location, zonation, regulations and benefits of MPAs urgently need to be more effectively communicated. These actions are key elements in Strategic Objective 4 (Mobilising people) of the NBSAP and NBF and link to Strategic Objective 1 (Management of biodiversity assests) and 5 (Developing an equitable and suitable skilled work force to improve biodiversity management) (Table 47). Additional MPAs will need to be established to represent ecosystem types that are Not Protected (particularly those that are also highly threatened) and to advance protection of Poorly Protected ecosystem types towards Well Protected. Improvements in ecosystem condition of bays, kelp forests and shallow rocky shelves within MPAs are important. Although ecosystem types in all of these groups have some level of protection, none of these valuable ecosystem types are currently Well Protected because there is insufficient representation in protected area networks of these ecosystem types that are in natural or near-natural condition. Priority ecosystem types for future protection include the threatened ecosystem types off the Orange River, St Helena Bay and inherently fragile and threatened ecosystem types within the offshore trawl grounds of the south and west coast. These include the Kingklip Koppies and Cape Lower Canyon which are currently Not Protected. The entire lower slope depth zone (1800- 3500 m depth range) is also Not Protected and collaboration with the petroleum and large pelagic fishery is needed to help identify the best areas for protection.

D. Communicate the value of South Africa's marine biodiversity

D. Effectively communicate the value of South Africa's marine biodiversity through improved coordinated messaging that articulates benefits, in order to build support for marine conservation and mobilise people to sustainably use marine biodiversity.

Safeguarding and securing the benefits of marine biodiversity, including the value of marine biodiversity to fisheries, tourism, medicine, cultural heritage, archaeology and bio-discovery is as much a human behavioural challenge as it is a conservation challenge. Increased effort is needed to identify, quantify and communicate the benefits and value of marine biodiversity. This is the core of Strategic Objective 4 of the NBSAP and NBF which emphasises the need to mobilise people to adopt more sustainable practices (Table 47). Improved awareness of the role of marine biodiversity in our everyday lives is needed and better communication of these benefits can help promote more environmentally responsible human behaviour. In this regard, the ongoing collection of data on marine biodiversity benefits, with a focus on jobs and economic value, is a high priority. This is essential for the effective implementation of Strategic Objective 4 of the NBSAP and NBF. Marine biodiversity benefits also require more explicit consideration in biodiversity assessement, emerging Marine Spatial Planning initiatives and Marine Protected Area design to avoid conflict amongst multiple user groups and promote sustainable marine resource use.

E. Improve the quantity and quality of freshwater flows to the sea

E. Ensure sufficient **freshwater flow** to the marine environment and improve water quality in priority areas.

Freshwater flowing from rivers through estuaries into the sea is *not* wasted, and is essential for coastal and marine food production, livelihoods, tourism and future climate resilience. Adequate freshwater and sediment input play a key role in the maintenance of the integrity of marine and coastal ecosystems and important fisheries resources. Through appropriate management, South Africa can maintain the vital freshwater flows that reach the coast. The marine environment needs to be recognised as a receiving environment in the National Water Act to support flow allocation for freshwater flows. This is essential not only for water but also for sediment and nutrient delivery and to address pollution issues in freshwater flows and marine outfalls. Coastal sediment requirements are critical for healthy functional beaches and dunes and offshore muddy habitats that support key fisheries. Sediment delivery to the coast through rivers and estuaries, and movement of sand across land and in the surf and inner shelf has not been well managed in the past. Many beaches and dunes are in a state of erosion, and in some places, beaches are being lost as they erode to bedrock. Beach erosion has the potential to impact tourism and makes South Africa more vulnerable to climate change impacts. The loss of offshore muds is believed to have contributed to the poor catch rates of trawled sole. However, there is still opportunity to invest in protecting and restoring coastal ecological infrastructure through good coastal engineering practices, the implementation of conservative setback lines under the Integrated Coastal Management Act, and by restoring sand delivery to the coast. Other specific actions needed include the combating of illegal sand mining in rivers and estuaries, and improved siting and management of coastal mining activities.

Pollution impacts the health and wellbeing of all life, including humans. Improved pollution management is needed in priority areas to restore the fisheries, regulatory services and recreational values of coastal ecosystems. Addressing the freshwater requirements for coastal and marine systems will improve the condition of marine and other coastal systems and will benefit many of South Africa's important fish species dependent on estuaries and the coastal zone for spawning and nursery function. These actions directly contribute to the implementation of the NBSAP and NBF, especially Strategic Objectives 1 (Management of biodiversity assets), 2 (Investment in ecological infrastructure) and 3 (Mainstreaming of Biodiversity Considerations) (Table 47).

F. Prevent new marine invasions

F. Develop a **marine invasive species response plan** and secure resources for rapid action to prevent invasions.

Increased resources and capacity is needed to enable rapid management action to prevent potential invasive species from becoming established when detected. In order to inform rapid management action, monitoring, early detection and risk assessment is needed. National monitoring of the distribution, spread and population abundance of alien and invasive species can be achieved through a network of broader monitoring initiatives, but a focus on key points of introduction such as ports and harbours is crucial for early detection of potentially invasive alien species. Key gaps in taxonomic and molecular knowledge and capacity that limit South Africa's ability to prevent, detect and manage marine invasives need to be addressed. This priority action is particularly important for the implementation of Strategic Objectives 1 (Management of biodiversity assets) and 3 (Mainstreaming of biodiversity considerations) (Table 47).

G. Restore marine biodiversity assets

G. Restore, maintain and secure marine **ecological infrastructure** to strengthen climate resilience and sustain ecosystem services.

Key ecosystems that play a disproportionate role in climate resilience, including beaches, dunes, kelp forests and mangroves, should be maintained or restored to strengthen climate resilience. Fishing grounds and essential fish habitat, such as spawning and nursery grounds, must be kept healthy in order to sustain the benefits from fisheries in the long term. Such key ecological infrastructure assets are being increasingly recognised and included in maps of Critical Biodiversity Areas and Ecological Support Areas. There is current work underway to support improved mapping of coastal and marine ecological infrastructure and this will be included in the evolving Coastal and Marine CBA map (see Figure 105 and Priority Action A) to help ensure that coastal ecosystem services are fully considered in Marine Spatial Planning. Strategic Fisheries Resource Areas need to be identified, mapped and secured in order to support food and job security in our developing ocean economy. Preliminary analyses indicate that the majority of fisheries catches are caught in less than 10% of the ocean area, therefore these highly productive and important fisheries grounds need to be maintained. The location of expanding and diversifying ocean activities, including alternative energy initiatives, petroleum and seabed mining, should take existing ecosystem services into account and ensure that

the long-term benefits from fisheries and coastal ecological infrastructure are not compromised. Sustainable, adaptive, ecosystem-based management is critical to helping South Africa adjust to future impacts of climate change. These priority actions directly support the implementation of Strategic Objectives 1, 2 and 3 of the NBSAP and NBF and also has direct links with Strategic Objective 6.3 and 6.5 (Table 47).

In March 2019, the United Nations (UN) General Assembly proclaimed 2021–2030 as the Decade on Ecosystem Restoration, "with the aim of supporting and scaling up efforts to prevent, halt and reverse the degradation of ecosystems worldwide and raise awareness of the importance of successful ecosystem restoration" (UN General Assembly 2019). The UN Decade calls for strong commitments and efforts to restore "at least 350 million hectares of degraded landscapes by 2030, realizing up to US$9 trillion in net benefits and alleviating poverty in many rural communities", recognising that this restoration would also contribute to achieving the UN Sustainable Development Goals, 2030 Agenda for Sustainable Development, and many other targets as set out by international conventions and agreements. Restoring the South African coast thus relates directly to this international call for global ecological restoration. "There has never been a more urgent need to restore damaged ecosystems than now.

H. Boost co-operative governance

H. Enhance co-operative governance for **improved, coordinated compliance** and marine biodiversity management. (Strengthen governance **and capacity** for **improved, coordinated compliance** and co-management of marine biodiversity).

NBA 2018 KEY MESSAGE B9

Cooperative governance is essential for healthy landscapes and seascapes

Biodiversity patterns and ecological processes are connected in complex ways that cross realms as well as human-constructed boundaries. At the same time, human activities in a range of different sectors that have separate policies and legislation and are separately managed can impact on the same biodiversity or ecological infrastructure (established but incomplete). To deal with this interconnectedness, cooperative governance and cross-sectoral planning and decision making are essential.

Skowno et al. 2019.

Increased co-ordination, data sharing and collaboration is essential for integrated ocean governance and Integrated Coastal Management. As such, this is highly relevant to every other priority action listed in this report. Improving compliance is a national priority in order to support resource recovery, improvements in species threat status, and better ecosystem condition, and to maintain and increase benefits from marine biodiversity. Alignment of monitoring, surveillance and compliance efforts across relevant environmental management agencies as well as municipal and provincial government will improve efficiency and ensure co-ordination, skills transfer and pooling of resources. Management authorities are well resourced and sufficiently capacitated to achieve their mandates. The exploration of more innovative financing mechanisms and compliance arrangements for the marine environment in general and MPAs in particular (see Priority Action C) is a high priority. Other opportunities to improve compliance include the application of new state-of-the-art technology in

monitoring and enforcement. As indicated in Priority action D above, improved communication is needed to support voluntary compliance.

Improved alignment of management measures and permitting arrangements would help streamline marine biodiversity management. For example, improved alignment between the IUCN Red List and South Africa's List of Threatened and Protected Species (TOPS) under the Biodiversity Act could improve species protection through the coordinated implementation of restricted activities as identified in the Biodiversity Act. There is also scope to advance national coordination and collaboration (Figure 109) in the assessment of marine and coastal biodiversity and this may reduce costs and lead to more streamlined and efficient reporting. In many cases, a single management intervention can make improvements in multiple sectors. For example, actions to improve catchment management (such as removing alien species) can help secure critical freshwater flows to the marine environment which can improve fisheries and help secure coastal tourism assets.

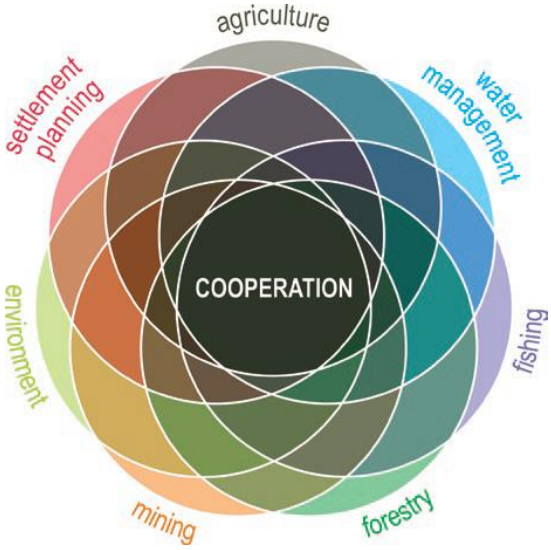


Figure 109. Planning for people, planning for the economy and planning for sustainable environmental resources cannot take place in isolation, but require cooperation across sectors that frequently work in silos. Marine Spatial Planning is being advanced to enhance co-operation between sectors.

Another example is the urgent need for more effective multi-stakeholder engagement in the management of coastal priority areas, such as bays. Increasing pressure through coastal developments and over-utilisation of these important socio-ecological systems has been highlighted during this assessment. Bays are now recognised as priorities for integrated coastal management initiatives and for research to support this work. The formation of multi-stakeholder working groups and task teams are an important step towards more integrated and transparent decision making, as well as improved user buy-in and compliance. A dedicated "Bay" task team is recommended that could inform the Marine Ecosystem Committee (MEC), the National Marine Biodiversity Scientific Working Group and DEFF Working Group 8. Multi- and trans-disciplinary knowledge generation is essential in these processes, based on dedicated research programmes and funding initiatives. Identifying and implementing these critical cross-sector actions is a high priority.

I. Modernise and integrate data collection, storage and access

I. **Modernise and integrate data** collection, storage and access to improve species, specimen, fisheries, ecosystem, oceanographic and climate data for better assessment, analysis, and monitoring of marine biodiversity, and to improve compliance with and evaluation of management actions.

Improved integration and co-ordination in the collation, management and examination of marine biodiversity data is foundational to every other priority action identified in this assessment. Currently, data critical to the assessment, management and conservation of living marine resources is held in outdated, decentralised platforms. Improvements in data quality, data storage and access are needed

to reduce uncertainty and speed of data mining and analyses in order to secure the long term benefits from marine biodiversity. Implementation of coordinated and integrated data systems will drive improvements across the biodiversity value chain by improving foundational knowledge, improving assessment, monitoring and even compliance. South Africa has the opportunity to make information available for education and research to benefit the state and its people. All government-funded research projects should feed their data into such systems (after a reasonable embargo period), ensuring the data from postgraduate degrees are secured and not lost to future generations.

South Africa needs to modernise data management in line with international standards appropriate in an emerging global society that is experiencing the Fourth Industrial Revolution. Improved hardware and information technology support is required to ensure that valuable data sets, that cost millions of rands to collect, are utilised efficiently and for maximum benefit. The application of new technology such as machine learning, automated image recognition, artificial intelligence, which is already commonly used across a large number of industries will accelerate data analysis, streamline data flow and enhance objective, informed, science based advice to decision makers. Making use of near real time data from ships' tracks, fishing gear, video-based monitoring of captured species on deck and during processing will facilitate improved compliance with fisheries and biodiversity regulations.

Data science is a rapidly expanding field; with potential to create new jobs in data and information management and analysis of large data sets. Application of state-of–the–art data storage and processing methodology, combined with improved access options will facilitate the use of available data (long-term catch data, life history data) for IUCN Red List assessments allowing for decreased uncertainty and more comprehensive species assessments. Sufficient human capacity and funding is needed if this is to be achieved in line with Strategic Objective 5 of the NBA and NBF which highlights the need for an equitable and suitably skilled workforce for institutions to deliver on their biodiversity research and management mandates. Open access marine biodiversity data and closer collaboration between South Africa's various biodiversity-related data facilities will reduce costs and improve standards across the value chain.

J. Address critical knowledge gaps

J. Catalyse research to address critical knowledge gaps that limit the assessment of marine biodiversity and decision making for a sustainable oceans economy.

Key limitations in the 2018 assessment include foundational data gaps for ecosystems, species and genes, insufficient data for some pressures and lack of understanding of the impacts of some pressures and interactions among pressures, limited experience regarding the appropriate scale and thresholds for marine ecosystem assessments and challenges in assessing diversity at the species and genetic level. These research priorities are further detailed in Section 11.5 below. This priority action addresses Strategic Objective 6 (Knowledge foundations) of the NBA and NBF (Table 47). Improving foundational knowledge will improve the quality of assessments and reduce uncertainty in results. Building marine assessment capacity and addressing knowledge gaps can support management in securing the benefits from marine species including fisheries, tourism and associated job security and livelihood opportunities. Updated assessments of the benefits of marine biodiversity including updated data on jobs can help support decision making in the marine environment. A business as

usual approach is unlikely to succeed in addressing these critical knowledge gaps timeously. Innovation, greatly increased collaboration and co-ordination, integrated approaches and increased involvement of industry, citizen scientists and the youth are key elements in meeting this challenge. Addressing these knowledge gaps will strengthen future assessments, reduce uncertainty and help direct critical interventions to maintain biodiversity benefits into the future.

These **ten priority actions** can contribute to addressing the key findings of this report particularly in terms of the main marine biodiversity concerns. Implementing these actions will help reduce pressures on threatened species and ecosystems, restore and maintain ecosystem services and increase marine biodiversity benefits.

11.4 Additional priority actions for managing marine biodiversity

Starting with spatial biodiversity priorities, the key marine priorities identified from the entire cross-realm NBA process are summarised (Skowno *et al.* 2019a). These are the general priority actions that support the successful implementation of many of the priority interventions identified through the cross-realm overall NBA process. Ultimately, all of these actions affect South Africa's ability to meet the NBSAP and NBF goals. Six clusters of general priorities were identified:

- Mainstreaming biodiversity priorities into marine production sectors
- Strengthening compliance and enforcement
- Strengthening cross-sectoral and cross-realm planning
- Strengthening evaluation for adaptive management
- Project financing and implementation
- Maintaining and further strengthening capacity

Mainstreaming biodiversity priorities into marine production sectors

Mainstreaming is the incorporation of biodiversity considerations and priorities in the policy, plans and actions of other sectors. Mainstreaming of marine biodiversity into marine production sectors, economic and spatial planning and social behaviour is critical to the improvement of biodiversity status at the ecosystem, species and genetic levels. Implementation of an ecosystem-based approach, which must be science-based and should draw of the findings of this report, is advised for all involved sectors. The implementation will need to be consistent with relevant sectoral legislation and policy, and there are opportunities to strengthen these areas. To achieve this, biodiversity considerations will need to be mainstreamed into policies, strategies and practices of a range of sectors. The key sectors for marine biodiversity mainstreaming in South Africa include mining and energy, mariculture, transport and fisheries. The importance of mainstreaming is reflected in the NBSAP and NBF, as expressed in Objective 3 i.e. Biodiversity considerations are mainstreamed into policies, strategies and practices of a range of sectors.

- Some priorities for mainstreaming in the next five years include
- Supporting **improved environmental impact assessment** for the marine environment
- Updated and improved marine content in the **Mining and Biodiversity Guidelines.**

- Cooperation with the petroleum, mariculture, transport and mining sectors is needed to help **prevent marine invasions.** A risk assessment of pathways to identify those vectors and pathways at most risk of introduction should proceed the development of a strategy to support this work. This should also include a prioritised sampling program with industry collaboration.
- **Strategic Environmental Assessments** with a risk based framework that can help support Marine Spatial Planning
- Preventing harmful interactions of fishing, mining and petroleum sectors with **Vulnerable Marine Ecosystems** (See Chapter 3). The South African hake trawl fishery continues to engage on mitigating adverse environmental impacts and improved management of the fishery through the Marine Stewardship Council (MSC) eco-certification (held by the fishery since 2004). From 2019 the fishery will be assessed against the MSC Fisheries Standard V2.01 which requires the fishery to consider, among other aspects, their impact on potential vulnerable marine ecosystems (VMEs) within the footprint through application of international best practice and scientifically based VME encounter thresholds and move-on rules.

Strengthening compliance and enforcement

The NBF recognises that South Africa has good policy and legislation for biodiversity conservation, but acknowledges that there are implementation challenges. In some cases, there is limited technical capacity to utilise existing policy tools, in others there is limited capacity to enforce legislation or regulations. The NBF highlights the need to monitor and enforce the conditions contained in environmental authorisations and permits, including through strengthening environmental regulatory and compliance frameworks and implementing the National Compliance and Enforcement Strategy for the Environmental Management Inspectorate, which was developed by the former Department of Environmental Affairs in 2014.

Examples of key compliance and enforcement challenges in the marine realm include:

- Social and institutional complexities that complicate marine resource management. Poaching is a major challenge that will need trans-disciplinary action and coordinated compliance efforts to understand and address underlying socio-economic and enforcement challenges.
- Limited capacity and budget in departments to monitor compliance with and enforce relevant environmental laws (e.g. laws prohibiting poaching and governing fishing quotas, the protection of threatened ecosystems, water quality and water abstraction) (Cochrane *et al.* 2015).
- Limited capacity for evaluating EIAs, implementing environmental authorisations, and monitoring compliance with the conditions of environmental authorisations and records of decisions (i.e. the outcome or decision of the relevant authority to grant or deny, with reasons, an environmental authorisation).

Strengthening cross-sectoral and cross-realm planning

South Africa has a well-articulated system of spatial planning governed by the Spatial Planning and Land Use Management Act (Act 16 of 2013) (SPLUMA), which operates across different spatial scales and includes a National Spatial Development Framework (SDF), Provincial SDFs and municipal SDFs. SDFs provide a tool for integrating and reconciling spatial priorities of different sectors, especially in relation to land use, but Marine Spatial Planning is in its infancy. The Marine Spatial Planning Bill (2017) lays the basis for integrated spatial planning between sectors in the marine realm. Spatial biodiversity plans, for example in the form of CBA Maps and maps of FEPAs, provide the biodiversity sector's input into these multi-sector, multi-stakeholder planning processes (see Figure 2). In the marine realm, there are some clear priorities that emerge from the NBA 2018, in which planning across realms and between sectors could be strengthened to improve the state of marine biodiversity, including:

- Improved **strategic resource allocation plans for freshwater flow**, as well as improved catchment and aquifer management planning and implementation, is important for marine and estuarine ecosystem health. These cross-realm efforts will ensure equitable usage of water by various sectors as well as ensure the ecological requirements are met for offshore ecosystems that need freshwater and sediment such as threatened mud ecosystem types and fluvial fans.

- **Cross-realm planning for rehabilitation and restoration efforts**, particularly in pressure hotspots where critical degradation thresholds have not yet been exceeded, is essential. Focussing efforts on improving ecological condition in these areas is more likely to succeed, and improve ecosystem function, thus securing benefits to local communities and society more widely. An example of such a priority area that needs cross-realm initiatives to improve condition includes the Orange River Mouth and adjacent offshore area.

- **Long-term coordinated planning for economically important species** will need to ensure equitable access and benefit sharing, and sustainable ecological offtake limits. A coordinated campaign to address poaching across realms should be explored. Highly threatened species such as seabirds and seabreams will also benefit from more coordinated management and decision making.

- **Long-term, cross-sectoral planning for climate change resilience** will need to be improved, including for vulnerable human communities and specific species and ecosystem types in the coastal zone and further offshore. An example is the need for cross-sectoral management of highly impacted yet ecologically important ecosystem types, such as bays, where coastal and port developments tend to be concentrated and coastal vulnerability to erosion and degradation of infrastructure is a common issue.

- **Marine Protected Areas zonation needs to be improved** to reduce pressure on key marine ecosystems and species. For example, within existing MPAs, coordinated efforts between DEFF, management agencies, scientists and stakeholders are needed to reduce fisheries impacts on Endangered and under-protected species and ecosystem types.

Greater participation of marine experts in cross-realm **learning networks on spatial biodiversity planning** is needed as such planning expands and matures in estuarine and marine environments.

Strengthening evaluation for adaptive management

Interventions that are implemented to manage and conserve biodiversity are often not monitored, which makes adaptive management of the activities near impossible. Given the numerous interventions in place and the complexities of implementation, gauging success, failure or impact of any particular intervention requires a broad evaluation protocol. The protocol should contain a suite of indicators that measure the effectiveness of the interventions against biodiversity objectives such as fisheries management, species and ecosystem conservation, as well as socio-economic objectives (e.g. improving human wellbeing and cost efficiencies). Strengthening capacity for adaptive management needs to be addressed to make progress in this arena. An example of a marine priority action that could significantly advance adaptive management capacity is Priority I which is centred on modernising and integrating data systems for improved knowledge, assessment monitoring and compliance. Improvement of evaluation of protected area effectiveness for mitigating against threats to marine species and ecosystem types is a further example of the need for adaptive management in MPA governance.

Project financing and implementation

Effective planning is crucial to improved biodiversity management but conservation outcomes are often limited by implementation challenges, which are often project specific. Nevertheless, several project level priorities were identified by the broader NBA assessment team. These include restoration projects, critical monitoring projects, protected areas expansion initiatives and efforts to eradicate alien species. Wetland, dunes, beaches and estuaries are critical ecological infrastructure where restoration projects can deliver additional benefits. Investment in innovative initiatives to diversify non-consumptive benefits from MPAs is a further priority. A critical intervention to improve the state of South African seabirds is to eradicate mice from Marion Island (Whitehead *et al.* 2019). Finally, the implementation of key cross-sectoral plans should be prioritised to increase benefits from co-operative governance. Even where cooperative governance is advancing plans, it is the implementation of cross-sectoral plans that is the greatest challenge. Improving project financing and management are key elements in implementation success.

Maintaining and further strengthening capacity

A common theme across the NBA 2018 is that of human capacity. The need to support the building of a capable state is also highlighted in the NBSAP and NBF, with Strategic Objective 5 dedicated to the need for **an equitable and suitably skilled workforce** to improve the management of biodiversity. All of the ten marine priority actions require key capacities to be developed, maintained or increased particularly those in foundational biodiversity science, fisheries stock assessment and marine monitoring initiatives at the genetic, species and ecosystem levels. Priority Actions C (MPA governance), F (invasive management) and I (data integration) rely on upskilling staff and modernising the data management and technological systems that support these areas of work. The enhancement of interventions for the improved management of marine biodiversity cannot take place without the appropriate human capacity and financial resources.

Several indicators could be monitored on a regular basis to inform the human capital development strategy and associated financial resource allocations for the marine biodiversity sector (Box 52).

Marine biodiversity collections in museums and other collection facilities are at risk due to declining capacity and resources to manage these valuable biodiversity assets. There are opportunities to address declining taxonomic expertise by supporting emerging researchers, strengthening collection management, increasing international collaboration and through targeted funding of identified national taxonomic priorities (see Box 53).

Box 52. Potential indicators to evaluate the capacity to undertake priority actions

Indicators to evaluate capacity:

- Number of jobs at various levels of experience that are filled versus those vacant.
- Geographic spread of marine science and collection management capacity across the country, as well as the spread across organisations.
- Number of people with relevant qualifications in national and provincial conservation authorities to address the coastal and marine conservation mandate.
- Scarce skills for the marine biodiversity sector and human capacity development initiatives for those scarce skills – e.g. are Higher Education institutions equipping graduates with the skills needed to support the management of marine biodiversity?
- Taxonomists per number of species (taxonomic focus is skewed, with more taxonomists working on the <4,000 vertebrate species than on the >65,000 invertebrate species; and marine taxonomy lags far behind capacity available for terrestrial species).
- The budgets and staff available for crucial long-term monitoring at specific sites – e.g. water quality, harvested and traded species, introduction pathways of marine invasive species, etc.
- The budgets and staff available to coordinate species and ecosystem mapping, assessment and monitoring, including the ability to coordinate citizen science projects to feed into these assessments.
- Distribution of biodiversity financing across organisations.
- Total expenditure on Marine Protected Areas.
- Budgets ring-fenced for resource management or regulatory functions at the provincial level.

11.5 Knowledge Gaps and Research Priorities

11.5.1 Progress since NBA 2011

The NBA 2011 (Driver *et al.* 2012) identified five main knowledge gaps and research priority areas that would strengthen future NBAs: (i) improving taxonomy capacity for species, (ii) developing a National Ecosystem Classification System, (iii) measuring and mapping ecological condition, (iv) further researching the links between biodiversity and human wellbeing, and (v) improving biodiversity-related monitoring work. A short analysis of the progress to date for these NBA 2011 priorities follows, with an emphasis on marine aspects.

Taxonomy and the uneven distribution of taxonomists across realms and groups

The NBA 2011 raised concerns that the current state of marine taxonomic knowledge limits the understanding of biodiversity pattern and process, ecosystem function, impact assessment and detection of introduced species. This situation remains a significant challenge and the National Strategy for Zoological Taxonomy (2013-2020) made this point clearly in noting that there are more taxonomists working on the <4,000 vertebrate species than on the >65 000 invertebrate species, and that terrestrial taxonomy capacity dwarfs capacity for estuarine and marine species. SANBI recently developed a Marine Taxonomy Working Group to help coordinate the identification of taxonomic priorities and key actions to support progress in this regard. The NBA 2011 also noted that South Africa

lacks basic national marine biodiversity databases and species lists that are available for public dissemination. The SeaKeys project made significant progress in advancing inventories and checklists of species recorded in South Africa along with distribution information (see Box 1). More effort is still needed to advance accessible specimen databases with locality, date of collection, collection method and habitat information. Challenges in the availability of species data persist although there has been considerable effort to improve offshore invertebrate species data (Atkinson and Sink 2018) and South Africa's fish atlasing efforts are increasing data for fish distributions (Solano-Fernandez *et al.* 2012, Logan 2018).

Need to develop an integrated National Ecosystem Classification System

The NBA 2011 made a strong case for the importance of detailed maps of ecosystem types, and the intervening years have seen substantial progress in this regard (Skowno *et al.* 2019a). Many technical improvements have been made informed by newly collated data and technical products e.g. a seamless map of ecosystem types has been produced (Harris *et al.* 2019a). Also see Chapter 3 of this report. Both the NBA 2004 and NBA 2011 recommended inclusion of the Prince Edward Island Ecosystems and this marine and terrestrial sub-Antarctic territory was included for the first time in 2018 (Whitehead *et al.* 2019). A series of realm-specific ecosystem classification committees now operates under the National Ecosystem Classification System, convened by SANBI, ensuring progress continues in this regard. Details on progress in ecosystem classification are reported in Chapter 3. In 2011, key areas identified for improvement of the classification of marine and coastal ecosystems included the need for improved reef, canyon and hard-ground mapping; more systematic biodiversity surveys, and more research to improve our understanding of the drivers of biodiversity patterns and the delimitation of ecologically determined boundaries for habitat mapping. Chapter 3 reports on progress in detail with much better canyon and reef mapping; progress in systematic biodiversity surveys on the southern Benguela shelf (Karenyi 2014, Shah 2018) and the Kwa-Zulu Natal Bight (Franken 2015, Makwela 2017). Patterns in pelagic biodiversity are still poorly known (Roberson *et al.* 2015) and it is a challenge to classify the dynamic three dimensional pelagic environment. The classification of islands was revisited and mapping of reefs, ridges and submarine canyons was substantially improved.

Measuring and mapping ecological condition is crucial to ecosystem assessment.

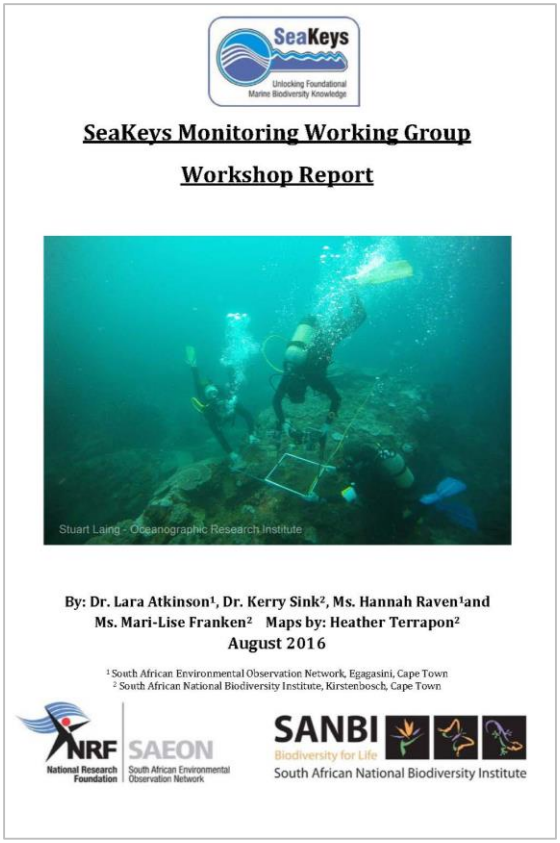
Some progress has been made in ground-truthing ecological condition of reef ecosystems (see Box 28, though substantial efforts are still required to achieve this across all broad ecosystem types. Insufficient progress on ground- truthing condition was made in time to inform the NBA 2018 condition thresholds but current work will form future assessments. Biological and ecological data and indices of condition need to be explored across a range of ecosystem types to compare such assessments of condition with assessments made through cumulative pressure mapping. This area of work remains a key research priority.

Further research on the links between biodiversity and human wellbeing.

Important steps taken on this issue include the DEA-SANBI project 'Making the Case for Biodiversity' that ran from 2010-2015 and helped the biodiversity sector with articulating the benefits of biodiversity, including through powerful case studies. A Compendium of Benefits of Biodiversity (SANBI 2019) was compiled for the NBA 2018, bringing together disparate areas of work on the benefits of biodiversity to demonstrate the substantial work ongoing both in South Africa and

internationally in this arena. In addition, detailed work to identify and articulate the benefits of marine protection (Annexure 1, Annexure 4 and see www.marineprotectedareas.co.za) were undertaken to support work to advance South Africa's MPA network, a priority action identified in both the NSBA 2004 and the NBA 2011. In addition a fact sheet on the benefits of MPAs was developed to support the cabinet submission for the Phakisa Proposed MPA network (see Annexure 2). Chapter 2 of this report makes substantial progress in compiling information on the benefits of marine biodiversity although increasing statistics and economic data, and improving communication about biodiversity benefits is one of the top ten priority actions emerging from the marine component of the NBA 2018.

Biodiversity-related monitoring is essential. In 2011, the limited long-term monitoring of marine ecosystems in South Africa was noted to hamper the understanding of climate variability and change in marine ecosystems and undermine the important ability to separate complex interacting variables driving change in marine ecosystems. There has been limited progress in this area and climate change was still not able to be mapped and included in ecosystem threat assessments. Improved spatial data that reflects the direction of change and information to weight climate change effects in all broad ecosystem groups are needed to incorporate climate change in future spatial assessments of ecosystem threat status. This point remains a major priority going forward as long-term monitoring of biodiversity remains a challenge.


SeaKeys
Unlocking Foundational Marine Biodiversity Knowledge

SeaKeys Monitoring Working Group

Workshop Report

Stuart Laing - Oceanographic Research Institute

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August 2016

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NRF National Research Foundation | SAEON South African Environmental Observation Network

SANBI Biodiversity for Life
South African National Biodiversity Institute

Chapter 6 also reports on some marine monitoring efforts and outlines monitoring progress and priorities from a climate change perspective. The SeaKeys Project (see Box 1 and Box 8) initiated a Marine Monitoring Working Group in 2016 to collate information on marine monitoring efforts in South Africa. The report produced by this SAEON-led working group identified some key spatial and thematic (considering physical data, ecosystem and species coverage) priorities (Atkinson *et al.* 2016). These included spatial gaps on the west coast (especially north of Saldahna Bay); offshore of the area between Mbashe and Port Edward and beyond the shelf edge in general. The need for a national initiative on sandy shores and beaches was highlighted with most efforts focused on rocky shores and shallow reefs to date. Bird monitoring initiatives are providing critical information to assess the status of seabirds and although nesting (female) turtle numbers are monitored, male turtles should be monitored using telemetry and citizen science. There are currently no efforts to track marine phenology (the timing of marine events e.g. arrival of whales, upwelling events, turtle egg-laying season etc.) although there is opportunity to involve citizen scientists in coral bleaching monitoring and in tracking the timing of the sardine run (Atkinson *et al.* 2016). Emerging monitoring priorities from the NBA 2018 are discussed below. These focus on improving knowledge of marine ecosystem degradation and condition, biological invasions and climate change.

11.6 Knowledge gaps and research priorities for strengthening future NBAs

In this section there is a focus on knowledge gaps that have been encountered through the process of developing the NBA 2018. Although the NBA and the data sources available to it have evolved and grown substantially since its first iteration in 2004, a number of important areas that require improvement remain.

Key limitations in the marine assessment include foundational data gaps for ecosystems, species and genes, insufficient data and understanding of the impact of some pressures and interactions between pressures, limited experience regarding the appropriate scale and thresholds for marine ecosystem assessments and challenges in assessing species and genetic diversity. Key areas for improvement of the classification and mapping of marine ecosystems in South Africa relate to the need for additional data coverage, particularly in deep water; a better understanding of benthic-pelagic coupling and pelagic biodiversity patterns. A new national bathymetric data set is a priority that should draw from research, Navy and industry data sets to produce one publicly available bathymetric data set that includes the best available data. An improved understanding of the role of freshwater flow in offshore environments, mapping of fluvial fans and more research to support the mapping and classification of mud habitats is needed. Further data-driven approaches that can integrate large data sets covering multiple ecosystem components collected by multiple methods are encouraged. Further details about these priorities are provided below.

Table 48. Summary analysis of knowledge gaps causing limitations to the NBA 2018 and priority actions for solutions

Knowledge gap causing limitation to the NBA 2018	Research priorities
Spatial and economic data on the **benefits of marine biodiversity** to people is currently very limited and often outdated. There is also a need for further work on marine ecological infrastructure (EI) work to map fisheries EI.	Improved economic data, updated statistics on jobs and spatial data on biodiversity benefits are a priority and will be very valuable for prioritisation and decision- making processes beyond the NBA, and communicating the relevance of biodiversity.
Gaps in **taxonomic knowledge** are substantial, particularly for marine invertebrates and invasive alien species. Taxonomic uncertainties are a major constraint to species assessments and the ability to conduct comprehensive Red List assessments.	A systematic process of detailed taxonomic studies on priority groups, including field collections and DNA barcoding, is essential for the enhancement of national species datasets. It is also crucial to build and maintain South African taxonomic knowledge and expertise, especially for understudied taxonomic groups.
Insufficient knowledge on the impacts of freshwater flow reductions, and ecological **flow requirements** for marine systems	An improved understanding of the role of freshwater flow in offshore environments, mapping of fluvial fans and more research to support the mapping and classification of mud habitats is needed.
Expert driven delineation of ecosystem types leads to bias in ecosystem classification and mapping. Spatial ecosystem classification schemes can greatly benefit from **advances in numerical modelling** of ocean processes that drive ecological processed and spatio-temporal variability of biodiversity patterns. An **integration of model outputs** at relevant scales can help refine biogeographic and ecosystem type boundaries.	High resolution regional numerical models with particle tracking capabilities have recently become available for the Southern African region. They can be used to understand biological processes, such as larval connectivity and retention that can inform Marine Protected area design and other spatial management tools. A numerical wave power model has recently been developed to identify areas of coastal vulnerability based on 20 years of wave data, but its output can be adapted to improve the coastal ecosystem classification scheme for rocky shores, for which wave exposure is an essential variable (see Chapter 3)

Knowledge gap causing limitation to the NBA 2018	Research priorities
There is uncertainty of the impacts of some **pressures** on some ecosystem types and a need to better account for this uncertainty in the assessment of ecological condition.	To counter uncertainty in the assessments of ecosystem degradation and ecosystem threat status, techniques to better estimate and map indicators of ecological condition and pressures on biodiversity at appropriate scales are needed. This should be underpinned by a better understanding of biotic and abiotic degradation. Additional research should be undertaken to assess marine ecosystems at multiple scales and investigate the implications of different criteria and different thresholds of condition and ecosystem size.
Currently the NBA does not take several **emerging pressures** into account, as data are not available. In additional poor data on linefishing was a key limitation of the NBA 2018.	Data and information on the impacts and spatial extent of several emerging pressures is needed. More knowledge on the effects of herbicides, pesticides and pharmaceuticals; the impacts of noise and light pollution on species and the impacts of micro-plastics on biodiversity are needed. Climate change effects needs explicit consideration in assessments.
Limitations linked to the use of **scoring based approaches** in mapping cumulative impacts and challenges in incorporating uncertainty in the assessment.	Investigate approaches to ameliorate the recognised issues associated with expert knowledge. Qualitative process models, quantitative process models and statistical models can be explored. A robust strategy would consider all three modelling approaches, such that models are mutually informative and build upon the strengths and insights provided by each approach. Advancing from qualitative to quantitative methods will require additional expertise and data. (Hemming *et al.* 2017; Martin *et al.* 2012) such as formal elicitation techniques
There are gaps in our ability to understand **thresholds of condition** and there are challenges in measuring the subtler forms of habitat degradation. As a result ecosystem condition may have been under- or overestimated, for example, the impact of pelagic fishing.	Better techniques to estimate and map ecosystem condition at appropriate scales is needed and this should be underpinned by a better understanding of **biotic and abiotic degradation**.
There is **limited experience in the assessment marine ecosystems** using the new IUCN RLE criteria locally but also internationally. South African marine assessments do not define ecosystem collapse and this area needs more research attention.	More effort is needed to assess the influence of **scale** on ecosystem assessment. South Africa needs to develop **conceptual models** for different types of ecosystem types.
Fisheries stock status is not assessed for 90% of the >770 harvested marine taxa. Updated stock assessments and long-term abundance datasets play a crucial role in effective species management but also form a critical component of conducting scientifically defensible IUCN Red List assessments. Uncertainty in stock and species status was a key limitation of the marine component of the NBA 2018. Marine species have the highest levels of data deficiency across all realms meaning that many threatened marine species may be as yet undetected.	Increase **reliable data for stock assessments**. Increase the number of national stock assessments (especially for highly utilised economically important species). The stock assessments must be kept updated through ensuring the development and management of reliable long-term datasets. Building fisheries science expertise is essential. Building marine Red List assessment capacity and addressing knowledge gaps can support management to help secure the benefits from marine species including fisheries and associated food and job security.
There is a bias in species **Red List assessments** towards vertebrates, and these cannot act as a surrogate for invertebrate species diversity and status. Alarming rates of decline being observed from terrestrial invertebrates signals a need to track other groups of invertebrates in South Africa. Marine invertebrates require baseline assessments.	Assessment and monitoring of **invertebrates** need to be prioritised and should include: assessment of full taxonomic groups including marine invertebrates (e.g. Isopods in the genus *Tylos*); marine invertebrates with high levels of potential threat (e.g. cnidarians, intertidal and subtidal resources); and groups with high levels of endemism. *Tylos* are possibly threatened (Brown 2000) with further new concerns about potential effects of light pollution (See Coastal component for details).
The **protection level indicator for species** needs to be tested and refined and applied in the marine realm.	The **species protection index** needs to be applied to species in the marine realm. Two PhD studies are currently underway

Knowledge gap causing limitation to the NBA 2018	Research priorities
	testing the sensitivities of the indicator for a data-rich group (mammals) and a data-poor group (plants), and these will inform future applications for marine taxa.
Limited opportunities for systematic surveys limit the ability to detect and understand **marine introductions and invasions.** There are major gaps in data required to properly measure the indicators developed for the national status report on **biological invasions** (see Chapter 5)	**Coordinated monitoring and spatial data on the abundance and distribution of invasive marine alien species** must be included in ecological condition assessments. More data on the impacts of biological invasions on biodiversity, and the value of management efforts for achieving conservation goals, is needed.
Lack of **monitoring** data to detect changes in species abundance and distribution in response to pressures such as climate change, invasive aliens, biological resource use etc. limits the ability to determine trends in species status via the Red List Index. Citizen science can play a key role in the collection of such monitoring data.	**Coordinated monitoring programmes** that cover a range of taxa and a range of ecosystem types is needed. See section on Monitoring priorities below. It is vital that **existing, established and useful monitoring programmes** receive the support and funding to continue, and **new programmes. Linefish monitoring needs to be re-instated in KwaZulu-Natal, possibly through an observer system.** .
Since anthropogenic **climate change** is escalating at unprecedented rates, understanding, predicting and minimising its impacts in South Africa are major knowledge gaps. The **reliability of models** for predicting climate change impacts is improving, but these rely on input data of high quality and confidence (e.g. species spatial & temporal distribution and weather records). Poor data quality and data gaps lead to low confidence of predictive models, with resulting challenges for decision making.	A **cohesive framework** and indicators to track biodiversity and ecosystem service impacts as a result of climate change, identify critical thresholds or points of non-return and assess the effectiveness of interventions to minimise these impacts, is essential. Ecosystem change data and dedicated species population monitoring over long time frames are needed to detect change and inform predictive models. Ensuring that reliable weather station data is available from across South Africa also remains a priority.
There is insufficient information to track and understand **climate change impacts** on marine biodiversity including their interaction with other pressures and the effectiveness of measures taken to minimise these impacts. In particular, the lack of a long-term monitoring program for South Africa's coral reef communities limits our ability to track and understand the state of these ecosystems and species	South Africa should capitalise on the opportunity provided by our high latitude **coral communities that can serve as a natural laboratory for the study of** these climate sensitive ecosystems. A long-term coordinated monitoring programme with fixed transects at multiple sites is needed with sufficient funding to maintain time series. Further work is needed to detect climate change impacts in other ecosystems and improve our understanding of change for effective adaptation.
There is **insufficient genetic research** to track the status of genetic diversity over time.	There should be testing of metrics to explore the best possible indicators of genetic diversity. A **genetic monitoring framework** is required that outlines how to strategically prioritise taxa for monitoring, identifies appropriate genetic markers and metrics, and provides advice on the frequency of monitoring. The protection of the genetic component of biodiversity needs assessment and genetic and other connectivity data must be incorporated into Marine Spatial Planning.

Research, monitoring and data management priorities emerging from NBA 2018

Research, monitoring and data management priorities have been clustered into research needs, monitoring needs and data management needs (with the understanding that human capacity and funding allocations play a role in each of these - see Skowno *et al.* 2019). Fulfilling these needs clearly supports many other processes that require similar knowledge foundations for managing and conserving biodiversity, spatial planning or reporting. The needs are summarised below and a description of each knowledge gap and its potential solutions or avenues for improvement are included in Table 48.

Research priorities identified from the NBA 2018

Research priorities highlighted in the various technical reports of the NBA 2018 were reported by Skowno *et al.* 2019. It is hoped these will inform formal research strategies such as the National Biodiversity Research & Evidence Strategy (2015-2025); the SANBI Research and Development Strategy 2019-2030; and research strategies of institutions with links to the biodiversity sector. Beyond informing these formal strategies, the information in this section can help to guide research and monitoring project development by providing clear needs linked to national level assessments and planning.

Research priorities for foundational biodiversity information

- Foundational ecosystem information for improved classification of ecosystem types: Ground-truthing ecosystem types remains crucial for ongoing improvement of their descriptions and delineations. For example, the marine realm uses techniques such as remote operated vehicle surveys and seabed sampling (e.g. by grab samples, research trawls and sleds) to collect information on biotic components of ecosystem types; while abiotic data like bathymetry, water turbidity, productivity data and sediments also contribute to ecosystem classification. Marine priorities for strengthening the classification and delineation of ecosystem types are detailed in Chapter 3

- Foundational species information for priority taxonomic groups: Most vertebrate and plant groups have fairly well-established research priorities in South Africa, with ongoing work on mapping and modelling species distributions and active taxonomic research. However, the high levels of Data Deficient taxa for many taxonomic groups illustrate the need for improved data. Life history, population distribution data, and population trend data are required for estuarine and marine taxa, and also for highly utilised species (e.g. linefish, etc.). Foundational data for invertebrates is urgently needed, specifically those with high levels of endemism in South Africa. Initial priorities include work on important marine ecosystem engineers, marine invertebrates that are sensitive to water quality changes and endemic marine invertebrates. South Africa's Marine Taxonomy Working group identified several national priorities (Box 53) to address the critical shortfall in marine taxonomic research and capacity.

- Mapping and assessment of ecological infrastructure: Ecological infrastructure refers to naturally functioning ecosystems that generate or deliver valuable services to people. The mapping of critical ecological infrastructure and the assessment of its status is an important research priority going forward. It is essential to have a clear understanding of which features of the seascape are crucial for delivering services to people, as well as the ecological condition required for them to play this role. Mapping of selected ecological infrastructure features has taken place in some parts of the country, but efforts to date have been piecemeal and methods and approaches remain experimental. Systematic mapping of critical ecological infrastructure could be integrated into or complement CBA Maps to add value to spatial planning and prioritisation exercises.

Box 53. Priority actions identified by South Africa's marine taxonomy working group in 2019. Accurate taxonomy published in the peer reviewed literature can achieve global recognition for South Africa's exceptional marine biodiversity and its talented emerging taxonomists.

1. **Communicate the value** of taxonomic research, collections and collection management to mobilise increased and resources and capacity to address foundational marine biodiversity knowledge. Collections must be recognised as national assets.

2. **Improve the accuracy** of taxonomic components of biodiversity research, environmental impact assessment and natural resource management studies by facilitating, funding and promoting the involvement of taxonomists in such efforts and ensuring that the cost of their contribution is budgeted for in publicly funded projects (e.g. in port surveys, bioregionalisation studies, environmental impact statements, fishery management assessments, etc.). Collection and lodgement of voucher specimens/collections from such projects also requires funding support and allocation, including the costs of initial curation**.**

3. **Increase job opportunities, research funding and provide direction** for taxonomic centres to continue to describe, inventory and assess the marine biota of South Africa. Key taxonomic priorities include cnidarians, sponges, bryozoans, polychaetes, crustaceans, ascidians and elasmobranchs. These priorities were based on available expertise, extent of endemism, economic importance, components of fragile ecosystems, invasive potential, indicators of global change and critical knowledge gaps identified during this assessment.

4. Encourage and support efforts to enhance the development of **modern taxonomic keys**, digital and other guides, and other accessible taxonomic outreach products.

5. Ensure **taxonomic data** is effectively collated, coordinated and managed through effective data management plans, integrated and accessible platforms and by employing or developing well trained, permanent, networked data managers /systems administrators across institutions.

6. Enlist the support of the Department of Science and Innovation and Universities to promote the **inclusion of taxonomy in undergraduate curricula** and the teaching of taxonomy by appropriately trained educators.

7. Establish **targeted PhD scholarships** for students of taxonomy and **mentoring programs** to support early-career researchers to train with local and international taxonomists. Note: the timeframe for this issue is critical as South Africa will have lost most of its remaining taxonomic expertise within 5 years; 10 years is considered too late. There already exist critical gaps with some taxonomic groups where the experts have retired or died.

8. Support increased research and training funding for the development of molecular genetic techniques in the taxonomy of marine organisms – including post-graduate training and developing incentives to partner with industry. South Africa must advance towards **integrated taxonomy**.

9. **Help organisations** that use taxonomic outputs but do not themselves employ taxonomists to support these priorities. For example, Environmental Consultants and MPA management agencies can encourage taxonomists to assist in Environmental Impacts Assessments and MPA surveys and provide key specimens and access to help build taxonomic knowledge.

10. **Attract international experts** to collaborate and develop South African capacity for priority groups.

Research priorities relating to pressures on biodiversity and ecological condition

- Improving ecological condition assessments: Improved assessments of degradation and ecological condition in the marine realm are essential and can be achieved through improved mapping of pressures. For example, better information on the spatial extent and intensity of recreational and commercial linefishing is a high priority. Improved data on the distribution and abundance of

invasive alien species will also enhance ecosystem degradation assessment. Collecting these types of data regularly is a crucial aspect of national monitoring.

In addition to pressure mapping, there is a need to improve data on **ecosystem degradation** and our ability to translate this into information about ecological condition. While the IUCN RLE approach is based on ecosystem degradation, assessments of condition, based on biological data, are still necessary to identify indicators that can be used to ground-truth current ecosystem assessments, to improve the understanding of pressure-state relationships and to inform additional IUCN criteria for future assessments (Korpinen *et al.* 2012, Rodríguez *et al.* 2015, Clark *et al.* 2016). Very few studies have assessed the ability of cumulative impacts to accurately predict ecosystem condition (Halpern *et al.* 2008, Andersen *et al.* 2015, Clark *et al.* 2016), with little consistency observed in the type of indicators used and their response to multiple human pressures. Therefore, future steps should aim to identify a set of ecological indicators for each broad ecosystem type to define reference conditions (Borja *et al.* 2012) and to determine the effect of cumulative impacts on ecosystem processes (IUCN Criterion D), building on current ground-truthing assessments (Box 28) to identify tipping points or thresholds of condition that can relate to ecosystem degradation (Levin *et al.* 2010, Samhouri *et al.* 2010, Rapport *et al.* 2013, Bland *et al.* 2018b).

- Climate change impacts on biodiversity, including through interaction with other pressures: South Africa needs a deliberate, coherent strategy for detecting and tracking climate change impacts on marine biodiversity and this must include genetic, species and ecosystem aspects. Lack of sufficient data on biological responses to climate change and interacting pressures reduces the potential to test modelled projections, and thus determine key thresholds with confidence. Furthermore, the coarse resolution of climate projections makes them biologically less meaningful. It is important to improve the understanding of pressure interactions. Existing datasets (e.g. historic and long-term record sets) could be used to establish improved baselines and track change to date; as well as identify and prioritise gaps for additional data collection. A coordinated and expanded monitoring project is needed to track climate change impacts on South Africa's coral communities in both shallow and deep water.

- Scientific synthesis of multi-disciplinary system-level impacts: In light of increasing pressures on various components of socio-ecological systems and finite funding resources to gather new data, efforts to synthesise existing knowledge across disciplines are essential. Research programmes that focus on scientific synthesis and review of existing literature and data need to be encouraged, and dedicated funding structures developed to support capacity development in this field. This includes the need to collate and archive historical datasets and make meta-data from different disciplines publicly available. Community of Practice initiatives are effective instruments for the synthesis of knowledge through multi- and trans-disciplinary collaboration and facilitate novel insights into complex systems.

- Ecological water requirement studies for estuarine and marine systems: Hydrological regime change is a major pressure on biodiversity in the inland aquatic, estuarine and marine realms. For example, studies are needed on the freshwater flow requirements of the fluvial-dependant coastal ecosystems of the major river systems (e.g. Orange, uThukela, Mzimvubu and Breede), and particularly regarding minimum flows during drought periods. Such research is needed to

inform management actions, for example the objectives of some MPAs can only be achieved when sufficient freshwater flow can be allocated based on scientific recommendations.

- Impacts of emerging pressures on biodiversity: Studies on the impacts of micro-plastics, herbicides, pesticides, pharmaceuticals, noise and light on marine biodiversity are required, as these pressures are poorly understood and have not been incorporated into ecological condition assessments or ecosystem threat status assessments.

Research priorities for improving and growing the suite of indicators for the NBAs

- Effectiveness of intervention measures: Interventions are often implemented, but are often not studied objectively in terms of their effectiveness. For example, studying municipal compliance with waste-water discharge permits and the effect on the environment; tracking whether the delineation of CBAs and ESAs in spatial biodiversity plans has assisted in reducing developments in these areas.

- Incorporation of landscape and seascape level genetic diversity measures into biodiversity assessments: Most current genetic studies are single point estimates that can be useful baselines measures for long-term studies that track genetic diversity over time. The indicators proposed in the NBA 2018 need to be applied to other taxonomic groups and additional metrics need to be tested to further explore the best possible indicators for measuring national-level genetic diversity. A national genetic monitoring framework is required to provide guidance to researchers. Marine research lags in this regard with a need to apply recent genetic metrics to marine taxa. These include phylogenetic diversity, evolutionary distinctiveness, detection of evolutionarily distinct and globally endangered species and indices for phylogenetic endemism.

Monitoring needs identified from the NBA 2018

NBA 2018 KEY MESSAGE: C4

Investment in strategic and collaborative biodiversity monitoring programmes is crucial to inform management and decision-making and for biodiversity assessments

Investment in existing and future strategic and co-operative biodiversity monitoring programmes is essential to strengthen our ability to detect and report on trends, plan accordingly and manage effectively.

Skowno *et al.* 2019

The following should be incorporated into the five-year action plan for the National Biodiversity Monitoring Framework, and the annual plans of research and monitoring institutions:

- Long-term, focussed monitoring of biodiversity at specific sites – including long-term ecological research and observation stations - is required to enable researchers to tease apart the effects of the threats of climate change and biological invasions on specific species populations, and to track these over time to monitor ecosystem functioning.

- Improved fisheries data to report on and regularly update assessments of marine species stock and threat status and assessment of ecosystem degradation and ecosystem threat status.

- Regular monitoring for specific species not only provides information about species distribution and abundance patterns crucial for use in species Red List assessments, but also

gives important feedback to researchers on where to expand searches for species that are only known from a few previous records. Such efforts may also result in new species discoveries.

- There are several other monitoring needs mentioned in the report on The Status of Biological Invasions and their Management in South Africa (Van Wilgen and Wilson 2017); including monitoring rates of alien species introductions and sites of high rates of introductions (e.g. aquaculture facilities, ports and harbours).

- Site-based monitoring of the impacts of various pressures on biodiversity (e.g. mining, port and harbour development, shipping lanes, mariculture) is needed to inform better understanding of these pressures on ecological condition and species populations.

- Structured and resourced national monitoring programmes (including citizen scientists) may help provide opportunity for indigenous knowledge systems to be consulted as part of an inclusive monitoring approach.

- Continued and improved monitoring of water quality and pollution sources in the marine environment is crucial to gain a better understanding of these pressures on marine biodiversity.

- The monitoring of impacts of abstraction and recharge of groundwater on ecosystems and species is urgently required. Groundwater is the main or only source of water for numerous towns or settlements across the country so protecting the capture zone, specifically for municipal supply well-fields, the recharge area, and the integrity of the aquifers, is important.

- Monitoring of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) exports, uptake of export quotas, and implementation of non-detriment findings is required, as is the monitoring of conservation status and utilisation of species listed under the threatened or protected species (TOPS) regulations to determine if the regulations are effective.

It is vital that existing, established and useful monitoring programmes (such as existing long term coral monitoring at iSimangaliso MPA and linefish monitoring at De Hoop MPA) receive the support and funding to continue. A structured nearshore fisheries monitoring program is needed. This should include trained linefish observers. The data from this will feed into annual assessments.

Data management and sharing imperatives

Effective management of national biodiversity data facilitates data sharing across user groups and sectors. The principle of open access (i.e. biodiversity data being freely available) and close collaboration between South Africa's various biodiversity-related data facilities supports research and monitoring, ultimately improves the quality and accuracy of biodiversity assessments, biodiversity planning, and underpins transparent science-based policy advice and decision making.

South Africa has subscribed to open access to biodiversity data for over a decade. The National Biodiversity Information System, currently under development at SANBI, aims to provide users with a

significantly enhanced ability to search seamlessly for relevant and linked information, across institutions (e.g. museums, conservation agencies, citizen science projects) as well as across data types (occurrence records, related ecosystems, publications, images etc.). To do this, SANBI is investing in replicated versions of the data stores of its partners, which are then conditioned and harmonised into a single national instance for each data type, that is fully indexed and search-engine optimised. In addition, new visualisation interfaces and an updated website will provide a superior user experience, making data queries as powerful and easy as possible.

The following goals for improved data management and sharing emerged from the NBA 2018:

- A mechanism is needed to feed information from site-based assessments (such as EIAs) back into national datasets to add to foundational biodiversity information.
- It is important that biodiversity indicators are prepared and released on a more regular basis than the current NBA intervals (5-7 years). Indicator dashboards are being developed to provide users with up-to-date information for improved reporting (towards SDGs for example) and streamlined management and planning.
- Several new indicators are emerging internationally, and will need to be incorporated into NBA data management and sharing processes going forward (e.g. indicators that track the condition of ecosystems, indicators on Key Biodiversity Areas, indicators linked to the status of ecological infrastructure, indicators on genetic diversity, indicators on effectiveness of interventions).

Research to improve communication and mobilise marine biodiversity stewardship

Spatial and economic data on the benefits of marine coastal biodiversity to people are currently very limited. This is an important gap to fill because it is a critical component in **messaging the value of marine** biodiversity to the public and to decision makers, and is a key rationale for safeguarding the underlying biodiversity assets that provide the benefits, e.g., the spawning ad nursery areas and other ecological infrastructure supporting fisheries resources. This is also important for the “super” ecosystems that provide proportionate benefits for their extent of occurrence, which tend to be overlooked as ecosystems (even by scientists in global assessments; see NBA Coast report), and yet play a key role in our tourism economy. More quantitative and updated data on the economic benefits of marine biodiversity will be very valuable for prioritisation and decision-making processes beyond the NBA, and for communicating the relevance and importance of biodiversity. Improved economic data, updated statistics on jobs and spatial data on biodiversity benefits are a priority.

Market research into **biodiversity messaging strategies** have proven successful in terms of how to frame messages to get traction and uptake. Similar research into the methods of communication that best is required to complement communicating the results of the benefits of marine biodiversity to people, noted above. For example, is it more effective to communicate the benefits of biodiversity through experiential methods (e.g., citizen science projects, hands-on outreach programmes), well-designed social media campaigns, or other methods, and what methods are most appropriate for different target audiences? This will inform how best to spend resources on mobilising people to adopt more sustainable use of biodiversity, and improve their contribution to the shared responsibility of maintaining the health, diversity and productivity of marine ecosystems.

12. CONCLUDING REMARKS

The diversity, richness and beauty of South Africa's oceans and coasts are well established. The development of a sustainable oceans economy is being advanced to increase equitable benefits from this environment. Iterative improvements in the assessment of marine biodiversity and systematic spatial biodiversity planning can support a sustainable oceans economy through the identification of strategic priorities to maintain biodiversity assets while supporting job creation, economic imperatives and fisheries sustainability. The priority actions identified in this assessment provide clear steps to help ensure that the health, productivity and resilience of South Africa's oceans are sustained for current and future generations.



The End

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APPENDIX 1: LIST OF MEETINGS HELD FOR DEVELOPMENT OF THIS REPORT

The following meetings were held for the development of this technical report. Meeting reports are available on request.

Meeting date	Venue	Nature of meeting	Participants
23 July 2015	SANBI, Kirstenbosch	Marine Ecosystem Committee Meeting (MEC)	Amanda Driver, Andrew Skowno, Carol Poole, Kerry Sink, Lara Atkinson, Lara van Niekerk, Leslie Powrie, Linda Harris, Maya Pfaff, Natasha Karenyi, Rob Leslie, Stephen Lamberth, Tamsyn Livingstone, Toufiek Samaai
12 November 2015	SANBI, Kirstenbosch	Marine Component Inception Workshop	More than 60 participants
29 August 2016	SANBI, Kirstenbosch	Freshwater dependent coastal and marine ecosystem meeting (MEC subgroup)	Boyd Escott, Carol Poole, Fiona Mackay, Heather Terrapon, Kerry Sink, Lara van Niekerk, Mpho Mmethi, Natasha Karenyi, Stephen Lamberth, Steven Weerts, Steward Bernard, Tamsyn Livingstone, Tommy Bornman
30 August 2016	SANBI, Kirstenbosch	Coastal Think-tank	Amanda Driver, Anisha Dayaram, Boyd Escott, Carol Poole, Fiona Mackay, Heather Terrapon, Jodie Reed, Kerry Sink, Lara van Niekerk, Natasha Karenyi, Ntombovuyo Madlokazi, Prideel Majiedt, Stephen Kirkman, Stephen Holness, Stephen Lamberth, Steven Weerts, Susan Taljaard, Tamsyn Livingstone
13 September 2016	SANBI, Kirstenbosch	Condition Workshop	Amanda Driver, Amanda Lombard, Andrew Skowno, Anthony Bernard, Charles von der Meden, Davit Yemane, Dean Ollis, Hannah Raven, Heather Terrapon, Heidi van Deventer, Jeanne Nel, Kaylee Smit, Kerry Sink, Lara Atkinson, Lara van Niekerk, Laura Blamey, Lynne Shannon Maya Pfaff, Natasha Karenyi, Rob Anderson, Susan Taljaard, Tamsyn Livingstone
15 September 2016	DEA Foreshore	NBA Marine Reference Group Meeting	Alan Boyd, Anthony Bernard, Herman Oosthuizen, John Duncan, Lara Atkinson, Liesl Jansen, Louise Geldenhuys, Megan van der Bank, Maya Pfaff, Millicent Makoala, Pierre de Villiers, Stephen Holness, Stephen Kirkman, Sizo Sibanda, Sven Kerwath, Tamsyn Livingstone, Toufiek Samaai, Robin Adams
23 November 2016	SANBI, Kirstenbosch	Biodiversity Targets Workshop	Andrew Skowno, Ané Oosthuizen, Angus MacDonald, Colin Attwood, Doug Butterworth, Geoff Cowan, Herman Oosthuizen, Jodie Reed, Johann Augustyn, Kaylee Smit, Ken Findlay, Kerry Sink, Lara Atkinson, Laura Blamey, Lauren Williams,

Meeting date	Venue	Nature of meeting	Participants
			Lily Bovim, Lili Ruiters, Lucie Bland, Makgotso Sizakele Sibanda, Mari-Lise Franken, Mbulelo Dopolo, Millicent Makoala, Mike Bergh, Natasha Karenyi, Ntombovuyo Madlokazi, Prideel Majiedt, Ronel Nel, Sean Porter, Siyasanga Miza, Stephen Kirkman, Stephen Holness, Stephen Lamberth, Tammy Robinson, Tamsyn Livingstone, Thivhulawi Nethononda, Tsamaelo Malebu, Zoleka Filander
17 August 2017	SANBI, Kirstenbosch	Marine Ecosystem Committee	Aliya Shah, Amanda Lombard, Andrew Skowno, Anisha Dayaram, Charles von der Meden, Janet Coetzee, Kerry Sink, Lara Atkinson, Lara van Niekerk, Lauren Williams, Linda Harris, Loyiso Dunga, Luther Adams, Mari-Lise Franken, Mariel Bessinger, Mapula Makwela, Maya Pfaff, Myriam Perschke, Sizo Sibanda, Stephen Holness, Stephen Lamberth, Tamsyn Livingstone
30 August 2017	Oceanographic Research Institute, Durban	KZN ecosystem mapping, biogeography, pressures	Fiona Mackay, Jean Harris, Kerry Sink, Lara Atkinson, Mari-Lise Franken, Sean Fennessy, Sean Porter, Tamsyn Livingstone
5 September 2017	SANBI, Kirstenbosch	Deep sea biodiversity pattern and geoscience inputs	Andrew Green, Kerry Sink, Lara Atkinson
14 September 2017	SANBI, Kirstenbosch	Coastal assessment alignment and fluvial fan mapping	Heidi van Deventer, Kerry Sink, Linda van Niekerk, Linda Harris, Stephen Lamberth, Fiona Mackay,
30 October 2017	SANBI, Kirstenbosch	Kelp Condition Workshop	A.J. Smit, Charles von de Meden, Clara Steyn, John Bolton, Kerry Sink, Laura Blamey, Luther Adams, Luther Adams, Maphale Matlala, Mark Rothman, Markel Bessinger, Myriam Perschke, Siyasanga Miza, Kaylee Smit, Loyiso Dunga, Melanie Lück-Vogel, Olona Buswana, Prideel Majiedt, Rob Anderson
20-22 November 2017	SANBI, Kirstenbosch	Pressures Workshop	Andrew Cockcroft, Anthony Bernard, Anè Oosthuizen, George Branch, George Branch, Jodie Reed, Kerry Sink, Lara Atkinson, Linda Harris, Loyiso Dunga, Luther Adams, Maphale Matlala, Mari-Lise Franken, Megan van der Bank, Myriam Perschke, Olona Buswana, Siyasanga Miza, Sizo Sibanda, Stephen Kirkman, Steven Weerts, Prideel Majiedt
24 November 2017	SANBI, Kirstenbosch	Marine Ecosystem Committee	Andrew Skowno, Charles von de Meden, Kerry Sink, Lara Atkinson, Lara van Niekerk, Lauren Williams, Linda Harris, Loyiso Dunga, Luther Adams, Mariel

Meeting date	Venue	Nature of meeting	Participants
			Bessinger, Mari-Lise Franken, Maya Pfaff, Myriam Perschke, Olona Buswana, Prideel Majiedt, Sean Porter, Stephen Holness, Stephen Lamberth, Tamsyn Livingstone, Toufiek Samaai
6 March 2018	SANBI, Kirstenbosch	Kelp meeting	Kerry Sink, Hohn Bolton, Mark Rothman, Loyiso Dunga, Rob Anderson, Laura Blamey
14 May 2018	SANBI, Kirstenbosch	Marine Integrated Ecosystem Mapping Workshop	Kerry Sink, Tamsyn Livingstone, Natasha Karenyi, Linda Harris, Andrew Skowno, Anisha Dayaram, Lara van Niekerk, Stephen Lamberth, Zoleka Filander, Loyiso Dunga, Luther Adams, Mari-Lise Franken
8 November 2018	SANBI, Kirstenbosch	NBA Review Workshop	Alessandro Guerra, Alexis Olds, Andrew Skowno, Anele Zamisa, Anthony Bernard, Asief Royker, Baliso Sinakho, Bikitsha Pila, Carol Simon, Coleen Moloney, David Walker, Dylan Irion, Erin Ross-Marsh, Esethu Madolwana, Funanani Ditinti, Grant van der Heever, Jock Currie, Jodie Reed, Katta Ludynia, Kaylee Smit, Kerry Sink, Kwanele Meva, Lara Atkinson, Lara van Niekerk, Lebo Malefane, Lesley Roos, Lieze Swart, Linda Harris, Lona Nondaka, Luther Adams, Lynne Shannon, Manare Sejeng, Maya Pfaff, Megan van der Bank, Mike Barron, Monica Stassen, Natasha Karenyi, Ntombovuyo Madlokazi, Peter Kowalski, Peter Southwood, Prideel Majiedt, Rabiah Ryklief, Robyn Adams, Seymour Siwa, Shannon Hampton, Sibusisiwe Matiya, Sinazo Maceba, Sinothando Shibe, Siyasanga Miza, Sizo Sibanda, Stephen Holness, Stephen Lamberth, Tabisile Mhlana, Tamsyn Livingstone, Taryn Joshua, Thandeka Mbambo, Tracey Fairweather, William Sonnenberg
21 November 2018	SANBI, Kirstenbosch	Marine Alien Invasive Species Working Group	Adnan Awad, Alexis Olds, Ayaka Peter, Jennifer Olbers, John Wilson, Livhuwani Nnzeru, Lynn Jackson, Megan van der Bank, Ntombovuyo Madlokazi, Prideel Majiedt, Ravi Naicker, Robyn Adams, Sebataolo Rahlao, Shannon Hampton, Sisanda Mayekiso, Siyasanga Miza, Sinothando Shibe
6 December 2018	SANBI, Kirstenbosch	NBA Marine Reference Group Meeting	Alan Boyd, Alison Kock, Anthony Bernard, Kerry Sink, Lara Atkinson, Liesl Janson, Louise Geldenhuys, Maya Pfaff, Megan van der Bank, Pierre de Villiers, Stephen Kirkman, Tanya Haupt, JJ Forgus,

Meeting date	Venue	Nature of meeting	Participants
			Merishka Fester, Ndanduleni Rendani, Sizo Sibanda
10 December 2018	SANBI, Kirstenbosch	Marine Responses Workshop	Carla-Louise Ramjakadh, Daisy Kotsedi, Jock Currie, Kerry Sink, Megan van der Bank, Nketu Lesejane, Nqobile Hlophe, Prideel Majiedt, Robyn Adams, Sizo Sibanda, Siyasanga Miza, Sinothando Shibe, Wiseman Rikhotso
12 March 2019	SANBI, Kirstenbosch	NBA Marine and Prince Edward Islands Technical Meeting	Charles von der Meden, Kerry Sink, Megan van der Bank, Otto Whitehead, Prideel Majiedt, Robyn Adams, Siyasanga Miza, Sizo Sibanda, Stephani van der Merwe, Zoleka Filander
19 March 2019	SANBI, Kirstenbosch	Taxonomy Working group	Albe Bosman, Angus MacDonald, Bahia Brady, Carol Simon, Charles Griffiths, Dylan Clarke, Jannes Landschoff, Kara Jyoti, Keshni Gopal, Kerry Sink, Lara Atkinson, Lauren Fester, Lita Pauw, Mari-Lise Franken, Megan Van Der Bank, Robyn Adams, Siyasanga Miza, Shirley Parker-Nance, Shaun Dayzel, Steven Thembinkosi Dlaza, Theresa Sethusa, Toufiek Samaai
19 July 2019	SANBI, Kirstenbosch	Priority Actions Workshop	Ané Oosthuizen, Anthony Bernard, Bahia Brady, Caitlin Kelly, Craig Smith, Jessica da Silva, Kerry Sink, Lara Atkinson, Mari-Lise Franken, Megan van der Bank, Maya Pfaff, Monica Stassen, Natasha Karenyi, Prideel Majiedt, Robin Adams, Robyn Adams, Shakirah Rylands, Siyasanga Miza, Stephen Kirkman, Sven Kerwath, Tammy Robinson, Tracey Fairweather

APPENDIX 2: LIST OF PRESSURES WITH THE METHOD OF PROCESSING TO CONVERT THE ORIGINAL DATA INTO MAPS OF IMPACT.

Prepared by Stephen Holness (Nelson Mandela University)

Data on the each of the pressures were summarised to 30m grid to facilitate data processing during the spatial assessment. Note that this grid size does not imply that the data should be interpreted or displayed at this scale. For most pressures, pressure values were converted to a 0-100 range using formulas such as p=100*d1/d80, where d1 is the raw pressure value at a site, d80 is the 80th percentile of the pressure values for that entire data set, with resultant values over 100 being assigned a value of 100[9]. This method was required as some of the datasets are extremely skewed and contained some very high values which would have masked the potential impact of moderate levels of pressure. The compilation of the individual pressure layers into this consistent format and range was necessary to allow spatial patterns of intensity of different pressures to be compared and cumulative pressures to be calculated. This appendix provides a short summary for the rationale and processing methods used for each of the pressure impact layers.

Pressure Layer	Source data	Processing methodology
Demersal Inshore and Offshore Trawling	Raw data were received for the period 2008-2016 with start and end positions for each trawl event, alongside data for hours of trawling and total catch in kilograms. The offshore trawl sector was defined as trawl areas deeper than 100m. Catch was recorded as the average annual take in kilograms and effort as hours of trawling.	• The data were cleaned to eliminate likely errors. The points that were removed were tracks on land, tracks over 50km long, tracks where values had been rounded off in the underlying dataset and hence had integer start and end points • A point density was calculated using a 120m grid cell and evaluating all areas within 2.5km of the cell. Values were calculated as a total per square kilometre. • Values were reclassified into 10 quantiles; the lowest intensity quantile (10%) was removed to eliminate remaining very low density and likely error areas. • Values were compared to other datasets such as known trawl footprints. • Two versions of the intensity layer were produced (namely a continuous variable value showing relative intensity and binary trawled area layer giving trawl footprint based on this dataset). • Values were modified using MPA boundaries (where there are trawl exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.

[9] The specific values used in the normalization were n_{80} (80th percentile), n_{90} (90th percentile), and n_{median} (median value). For non-skewed distributions the formaul used a 100*n/n_{max} approach where n_{max} is the maximum value in the dataset. These values are indicated in the table.

Pressure Layer	Source data	Processing methodology
Crustacean Trawling	The NBA 2011 / OMPA crustacean trawl dataset for the period 2001-2005 was combined with more recent data for period 2006-2017. Catch was recorded as the average annual take in kilograms and effort as hours of trawling.	• Existing NBA 2011/OMPA data cleaning retained. • The following analysis was done separately on the NBA 2011 / OMPA crustacean trawl dataset for the period 2001-2005 and the more recent data for period 2006-2017. Results were combined in the final stage. • A point density was calculated using a 120m grid cell and evaluating all areas within 2.5km of the cell. Values were calculated as a total per square kilometre. • We assumed very low effort (under 25hrs) were errors. This eliminated most points that were unlikely (e.g. on land or deep water). • Initial analysis classified the prawn trawl to ten quantiles. This was later revised to a binary footprint layer (trawled / not trawled) due to impacts of industry. • Values were modified using MPA boundaries (where there are trawl exclusions). • Combined footprint from the two datasets used as a prawn trawl impact layer. • The ecosystem map and pressure matrix were applied to produce an impact layer.
Midwater Trawling	Raw data were received for the period 2008-2016 with start and end positions for each trawl event, alongside data for hours of trawling and total catch in kilograms. Catch was recorded as the average annual take in kilograms and effort as hours of trawling.	• Point statistics on effort in hours per square kilometre were calculated (a cell size 0.005° was used, with a 10- cell radius circular search area to determine effort). • We used the 100*n/n80 method to deal with a c=very skewed data distribution. • We removed very low intensity values under 1 which represent any cells with less than 1% of the level of effort of the n80 cell. • The ecosystem map and pressure matrix were applied to produce an impact layer.
Linefishing (commercial and recreational boat-based fishing)	Point data were received for the period 2000-2016. This layer was also used as a proxy for recreational boat-based linefishing, as the patterns of use are similar to that of the commercial sector and data for actual catch by recreational fishermen was not available.	• Linefish data were summarised to centre points of a 5' grid • All values within that grid were added up to give a total kg catch for the grid square. • All points with no catch were allocated a 0 kg catch • A Natural Neighbour Interpolation was done to produce a smoothed continuous surface of estimated catch. • Very low values (under 100kg for the entire period) were excluded. • Values were then reclassified into 10 quantiles. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
Recreational shore-based Fishing	As with recreational boat-based fishing, new data were not available. Therefore, the data from the NBA 2011 was used. The locality data for this activity was estimated to be within 1 km of a beach access point.	• Intensity calculated as days/km^2 for shore ecosystem types that can be accessed • The 100*n/n80 method used to benchmark values against the high intensity of use and deal with isolated very high scores (i.e. the skewed distribution). The values over 100 reclassified as 100. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.

Pressure Layer	Source data	Processing methodology
Demersal Longline Fishing	Point data of start and end positions was received from DAFF for the period 2000-2017, alongside number of hooks per line and the total catch in kilograms.	• Raw point data used for total catch of all species (largely hake and kingklip) • Data presented as annual average over the period 2000 to 2017. • A point density approach was used to add up all catch around an area. A 120m grid was used, with catches within 5000m of each grid cell being aggregated for whole period. Values were calculated in catch / km^2. • Low values of under 1000kg/km^2 removed to deal with scatter of inaccurate points and eliminate very low use areas. • Due to an extremely skewed distribution, a 100* n/n_{70} method was used to deal with high values. The n_{70} value was 19 914 km^2. After the calculation, we reclassified values over 100 as 100. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
Pelagic Longline Fishing	Point data of start and end positions was received from DAFF for the period 2000-2016, alongside number of hooks per line and the total catch in kilograms.	• Base data with line hook numbers (effort) values associated with start and end points • A point density approach was used to add up all effort around an area. A 120m grid was used, with areas within 10 000m of a point being evaluated. • The effort was calculated in hooks/km^2. Low values of under 100 hooks/km^2 were removed to deal with scatter of inaccurate points and very low use areas. • Reclassified into 10 quantiles (given values from 10-100). • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
Tuna Pole Fishing	Point data collated to a coarse 50nm grid was received for the period 2007-2016.	• DAFF pole tuna catch data were collated by Capfish / SANBI • The reporting used very coarse grid squares of 50 nm. • We allocated the total catch records to a centroid for each grid square. Zero values were allocated to all non-fished grids squares. • A natural neighbours interpolation was undertaken for marine areas. • Extremely low values with under 10 000kg catch over the record period were excluded. • A modified 100*n/n_{99} method used to deal with skewed distributions. The n_{99} was 1 004 051. After the calculation values over 100 were reclassified as 100. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
Small Pelagic Fishery	Data were received for the period 2000-2016 and calculated to a 5 min grid by CAPFISH (DAFF/CAPFISH/SANBI)	• A centroid was used for each grid square, with total catch values for the square being allocated to this centroid. A zero value was allocated to non-fished areas. • A natural neighbours interpolation was undertaken for marine areas. • Extremely low values with under 200kg catch over the record period were excluded. • Reclassified into 10 quantiles (given values from 10-100). • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.

Pressure Layer	Source data	Processing methodology
Netfishing: Gillnet Fishing	Spatial distribution of rights per management sector for 2016/17.	• Spatial delineations of management zones for the gillnet sector with TAE (rights allocated) in 2016-17 for each area. Coverage extends from coastline seawards to the 50m depth contour. • Calculated as an intensity Gill net rights/km^2 over the period • A 100* n/n_{max} method used to benchmark values against the highest intensity of use. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
Netfishing: Beach-seine Fishing	Spatial distribution of rights per management sector for 2016/17.	• Spatial delineations of management zones for the beach-seine sector with TAE (rights allocated) in 2016-7 for each area. Coverage extends from coastline seawards to the 10m depth contour. • Calculated as an intensity seine rights/km^2 over the period • A 100*n/nmax method used to benchmark values against the highest intensity of use. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
West Coast Rock Lobster Harvesting	West Coast Rock Lobster harvesting data were collated by for each concession area for the period 2006 to 2016	• Total catch for period for all types of Rock Lobster fishery were aggregated into the spatial delineations of management zones for the catch of West Coast rock lobster. • Coverage extends from coastline seawards to the 20m depth contour. • Calculated as an intensity measured in Total catch/km^2 over the period • A 100*n/n90 method used to deal with skewed distributions, with the n90 being 992.28. We reclassified any resulting values over 100 as 100. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
South Coast Rock Lobster Harvesting	South Coast Rock Lobster harvesting data were collated by for each concession area for the period 2007 to 2016.	• A centroid was developed from the summary grid of total catch. A zero value was allocate to all non-fished grid cells. • A natural neighbours interpolation was undertaken for marine areas. • Extremely low values with under 713kg catch over the record period were excluded. • A 100*n/n_{90} method used to deal with the skewed distribution of values, with n_{90} = 33 420. We reclassified any resulting values over 100 as 100. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
Squid Harvesting	Total catch values for the period 2012 - 2016 were collated and calculated into a 5min grid	• A centroid was developed from the summary grid of total catch for the period. A zero value was allocate to all non- fished grid cells. • A natural neighbours interpolation was undertaken for marine areas. • Extremely low values with under 10000kg catch over the record period were excluded. • Exclude values with under 10000kg catch • Values were reclassified into 10 quantiles (given values from 10-100). • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.

Pressure Layer	Source data	Processing methodology
Abalone Harvesting	The impacts of legal harvesting and poaching were considered in this assessment. Although actual catch data and estimated poaching data were received from DAFF, this data did not reflect the full coverage of Abalone distribution nor adequately represent poaching estimates outside of the legal fishing areas. Therefore, the full distribution of Abalone as reported in the literature was used as the distribution of fishing effort for both legal fishing and poaching. Intensity of legal harvesting and poaching were allocated using expert judgement supported by the literature across the Abalone distribution.	• Single expert-based value used for impacted areas/ecosystems • Modified by pressure matrix and MPAs • Values were modified using MPA boundaries (MPA assessed for effectiveness by expert). • The ecosystem map and pressure matrix were applied to produce an impact layer.
Oyster Harvesting	Average number of oysters collected per year over the period 2000 to 2017 was collated per fishing area.	• Spatial delineations of management zones for the collection of oysters within the Southern Cape and KZN regions. Coverage extends from coastline seawards to the 10m depth contour. • Calculated as a fishing intensity measured in oysters/km^2 over the period • The 100* n/n_{90} method used to deal with skewed distributions, with n_{90} = 2008.16. We reclassified any resulting values over 100 as 100. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
Kelp Harvesting	Kelp harvesting data were collated for the period 2000- 2017 for each concession area. Based on expert input, the area of activity was mapped to the 10m depth bathy.	• The four types of kelp harvesting values were aggregated into a total take in kg. • Values were calculated as an intensity in kg/km^2 over the record period. • The 100*n/n_{90} method was used to deal with skewed distributions, with n_{90} = 29316. We reclassified any resulting values over 100 as 100. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
Subsistence Fishing	NBA 2011 data used as basis (SANBI)	• We calculated harvesters per km of coastline • The 100*n/n_{90} method was used to deal with skewed distributions, with 14.64. We reclassified any resulting values over 100 as 100. • Values were modified using MPA boundaries (where there are activity exclusions). • The ecosystem map and pressure matrix were applied to produce an impact layer.
Shark Control	Point data on shark nets was used, Nets that nets that had been removed were excluded from the dataset.	• Points were buffered by 3500m to align with SANBI expert inputs. • Impacted areas were treated as identical and a value of 100 was coded to produce the sharknets footprint layer. • The ecosystem map and pressure matrix were applied to produce an impact layer.
Sea-based Aquaculture	Data on the footprint of existing sea-based aquaculture was used.	• Sites were buffered by 1km. • These areas are flagged as being within a mariculture impact footprint. A value of 100 was coded to these areas. • The ecosystem map and pressure matrix were applied to produce an impact layer.

Pressure Layer	Source data	Processing methodology
Coastal Development	Data from the NBA 2011 for built up areas was combined with built up areas from new NBA 2018 composite land cover.	• Different development layers combined into a single layer (120m pixels). • A 1000m search radius was used to identify any area that is over 10% developed. • These areas are flagged as being within a coastal development footprint • The ecosystem map and pressure matrix were applied to produce an impact layer.

Coastal Disturbance	NBA 2011 coastal disturbance data based on beach access was used.	• NBA 2011 data used to identify accessible and potentially disturbed areas of coastal ecosystems
		• Disturbed areas were considered to be:
		  ○ Recreational beaches – within 1km.
		  ○ Beach access points – within 1km.
		• The ecosystem map and pressure matrix were applied to produce an impact layer.

Mining	Various SANBI datasets (including NBA2011 data on mine points, mined polygons from industry, the NBA 2018 landcover) were used to identify areas that are mined or within 500m of a mine.	• Different mining layers combined into a single layer (120m pixels). • 500m buffer developed in a raster environment to identify any areas near mines. A value of 100 was coded to these areas. • The ecosystem map and pressure matrix were applied to produce an impact layer.
Petroleum Activities	SANBI collated points on active and dormant oil and gas well points	• Points were buffered by 1km. • Impacted areas were treated as identical and coded into an oil and gas footprint layer. A value of 100 was coded to these areas. • The ecosystem map and pressure matrix were applied to produce an impact layer.
Invasive Species	SANBI dataset on impacted areas as developed by the NBA 2011.	• Impact of invasive alien species mapped by the known distribution of the European mussel Mytilus galloprovincialis and the European shore crab Carcinus maenas (Robinson *et al.* 2005). • Point and linear data on the distribution of invasive alien species were analysed for the presence of these invasive alien species. Areas with both M. galloprovincialis and C. maenas were assigned a value of 100, while areas with M. galloprovincialis were assigned a value of 90. Areas within 1km of harbours and 1km of aquaculture facilities were also coded as 100. • The ecosystem map and pressure matrix were applied to produce an impact layer.
Port and Harbour Activities	Various data sources were combined to develop this layer: – NBA 2011 harbours mapped as part of coastal mapping – Port limits (Transport/SANBI) – Port infrastructure (Transport/SANBI) – Harbour points buffered by 1km (SANBI mapped and verified)	• Point and infrastructure data buffered by 1km. • Port limits were not buffered. • Different port layers combined into a single layer (120m pixels). • The ecosystem map and pressure matrix were applied to produce an impact layer. • Note that the physical infrastructure impacts of a port are covered under coastal development.
Shipping	Data for shipping was extracted from the global dataset published by Halpern *et al.* (2015) and combined with Walbridge (2013).	• Global data were resampled to the SA EEZ. • The values were in SA were rescaled to South African range (0-100). • The $100*n/n_{90}$ method was used to deal with skewed distributions, with n_{90} = 72.29. We reclassified any resulting values over 100 as 100. • Very low values (0-3), were reclassified as 0 • The ecosystem map and pressure matrix were applied to produce an impact layer.

Pressure Layer	Source data	Processing methodology
Waste Water	Point data on current waste water discharge was collated from DEA. DAFF provided point data for aquaculture outfalls. Additional discharge points from NBA 2011 were also included.	• Based on SANBI expert input, a total impact distance of 2500m was calculated. • The values were split into 10 equal distance intervals. Impact was calculated based on Euclidean distance, with 0m distance having a maximum score (100) and 2500m having a score of 0. • The ecosystem map and pressure matrix were applied to produce an impact layer.
Ammunition Dumping	Polygon and point data were received from the Navy National Hydrographics Office.	• We assumed that all sites have a similar overall total use, but differed in terms of precision of data or actual extent. • Values benchmarked against the area of the smallest sites (1km buffered PE ammunition dumping sites). Intensity = 100*(Area of benchmark site in km^2 / Area of individual site in km^2) • The ecosystem map and pressure matrix were applied to produce an impact layer.
Dumping of Dredge Material	Polygon data were received from the Navy National Hydrographics Office.	• Impacted areas treated as identical and coded into a dredge spoil footprint layer. • A value of 100 was coded to these areas. • The ecosystem map and pressure matrix were applied to produce an impact layer.
Freshwater Flow Reduction	Runoff reduction values from Estuary assessment of NBA 2018 were used to develop this layer and the area of influence for this activity assigned to river-influenced ecosystem types from NBA 2018 ecosystem map.	• Runoff reduction coded was into appropriate ecosystems based on location of river mouths. • Runoff could be allocated to smaller systems (primary river influenced systems near the mouths) and to larger broader systems. • Runoff reduction values were calcualted in million m^3/km^2 based on all rivers flowing into each ecosystem in question. • A $100*n/n_{median}$ method was used to deal with skewed distributions, with the n_{median} value being 0.7. We reclassified any resulting values over 100 as 100. • The ecosystem map and pressure matrix were applied to produce an impact layer.