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Birdlife	Birdlife South Africa
DEA	Department of Environmental Affairs (former government department)
DEADP	Western Cape Department of Environmental Affairs and Development Planning
DEFF	Department of Environment, Forestry and Fisheries
DWS	Department of Water and Sanitation
ECPTA	Eastern Cape Parks and Tourism Agency
EKZN Wildlife	Ezemvelo KZN Wildlife
KZN EDTEA	KwaZulu-Natal Economic Development, Tourism and Environmental Affairs
NMU	Nelson Mandela University
ORI	Oceanographic Research Institute
SAEON	South African Environmental Observation Network
SAIAB	South African Institute for Aquatic Biodiversity
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
UWC	University of Western Cape

Contents

Acknowledgements	vi
List of Tables	xii
List of Figures	xv
List of Boxes	xxii
List of Appendices	xxii
List of Annexures (separate supplementary documents)	xxii
List of Acronyms, Abbreviations, Initialisms and Symbols	xxiii
Glossary of Terms	xxv
Executive Summary	xxviii
1. INTRODUCTION AND APPROACH	1
1.1 What is the National Biodiversity Assessment?	1
1.2 Indicators	5
1.3 About the estuarine realm	8
1.4 What is new in the Estuarine Realm?	10
2. BENEFITS OF ESTUARINE BIODIVERSITY	1
Ecosystem Benefits	1
2.1 Introduction	1
2.2 Contribution to livelihoods	3
2.3 Contribution to tourism value	5
2.4 Contribution to property value	6
2.5 Contribution to marine fishery values	7

2.6	Mitigation of climate change damages	8
2.7	Intangible benefits.....	9
2.8	Discussion and conclusions	10
3.	A NEW ECOSYSTEM CLASSIFICATION FOR SOUTH AFRICAN ESTUARIES	12
	Ecosystem Classification.....	12
3.1	Introduction.....	12
3.2	Approach	14
3.3	Defining the ecosystem types	15
3.4	South Africa's estuarine ecosystem-level classification	15
3.5	Estuaries subjected to functional type shifts and causative factors	27
3.6	Conclusions.....	33
4.	EXTENDING THE ESTUARY FUNCTIONAL ZONE TO INCLUDE KEY HABITATS AND PROCESSES	37
4.1	What is the estuarine functional zone?.....	37
4.2	EFZ delineation method	38
4.3	Important habitats in support of estuarine function	45
4.4	Advantages of EFZ delineation	49
4.5	Formalising the estuary delineation.....	50
4.6	Recommendations.....	50
5.	ESTUARINE HABITAT STATUS AND TRENDS	52
5.1	Important Estuarine Habitats	52
5.2	Present Distribution of Estuarine Habitats.....	56
5.3	Species Diversity of Macrophyte Habitats.....	62
5.4	Trends in macrophyte habitat distribution	65
5.5	Habitat conservation and management priorities	74

6.	KEY PRESSURES ON THE ESTUARINE REALM.....	76
6.1	Approach and Methodology.....	77
6.2	Flow modification.....	81
6.3	Pollution.....	84
6.4	Exploitation of fish and invertebrates.....	94
6.5	Land-use and development.....	103
6.6	Estuary mouth manipulation.....	110
6.7	Biological Invasions.....	114
6.8	Emerging pressures.....	131
7.	CONDITION OF SOUTH AFRICA’S ESTUARINE ECOSYSTEMS.....	136
7.1	Condition assessment approach.....	136
7.2	Estuarine condition across biogeographical regions.....	139
7.3	Condition of estuarine ecosystem types.....	145
7.4	Evaluation of condition of abiotic and biotic components.....	148
7.5	Understanding declining condition and estuarine connectivity and inter-estuary recruitment ..	149
7.6	Conclusion.....	150
8.	ECOSYSTEM THREAT STATUS AND ECOSYSTEM PROTECTION LEVEL.....	152
	Ecosystem Threat Status & Protection Levels.....	152
8.1	Ecosystem threat status (Red List of ecosystems).....	152
8.2	Ecosystem protection level.....	166
9.	INDIGENOUS SPECIES ASSESSMENTS.....	175
9.1	Species Diversity in the Estuarine Realm.....	175
9.2	Species Assessment methodology.....	176
9.3	Input Data.....	179

9.4	Species threat status in the estuarine realm.....	180
9.5	Knowledge Gaps	200
10.	HOW VULNERABLE ARE SA ESTUARIES TO CLIMATE CHANGE?.....	203
10.1	Introduction.....	203
10.2	Methods	206
10.3	Key climate change stressors on South African Estuaries	206
10.4	Quantification and mapping of vulnerability	214
10.5	Summary of impact of climate change stressors on critical South African estuarine processes and variables	232
10.6	Synopsis and the Way forward.....	Error! Bookmark not defined.
10.6.2	Conclusion	233
11.	GOVERNMENT’S RESPONSE TO DECLINING CONDITION OF ESTUARINE ECOSYSTEMS.....	234
11.1	Resource and Biodiversity Protection	234
11.2	Management and control of key pressure	241
11.3	Restoration and biodiversity requirements for novel ecosystems	255
11.4	Responses pertaining to Integrated Management Systems	257
11.5	Future-proof estuaries under changing climate conditions	260
11.6	Natural Capital Accounting (NCA) as a complementary reporting system	264
11.7	Monitoring of estuarine resources.....	265
11.8	Recommendations to address ongoing decline in estuary condition.	268
12.	KEY FINDINGS AND RECOMMENDATIONS.....	273
12.1	Key findings and messages	273
12.2	Priority actions.....	279
12.3	Data gaps	281

12.4 Research Priorities	282
1.2 Recommendations for next NBA	284
13. REFERENCES	285
APPENDIX A: Estuary and Micro-system Ecosystem Classification	314
APPENDIX B: Summary of South Africa’s Estuarine Habitat.....	338
APPENDIX C: Estuary Pressure Assesment	344
APPENDIX D: Estuary condition and Biodiversity (Conservation) Priorities.....	354
APPENDIX E: Restoration measures needed to improve estuary condition and productivity.....	359
APPENDIX F: Estuarine Red Listed species	374
APPENDIX I: List of meetings held for development of this report.....	376

LIST OF TABLES

Table 1. Processes utilising the NBA findings, messages and datasets.....	3
Table 2. Links between NBA headline indicators and Aichi Targets and SDGs.	8
Table 3. Whitfield's (1992) typology of South Africa's estuaries.	16
Table 4. Revision of Whitfield's 1992 estuarine classification system.	18
Table 5. Revised South African estuary types, key features and dominant physical processes.	20
Table 6. Number of estuaries in each type across four biogeographical regions and classified into 22 estuary ecosystem types.	26
Table 7. Number of estuaries in each micro-system type across four biogeographical regions and classified into 9 micro-system ecosystem types.	26
Table 8. Estuaries where functional type shifts have occurred.	28
Table 9. Summary of the EFZ areas for estuaries and micro-estuaries.	44
Table 10: Estuarine habitats in the South African estuaries after Adams <i>et al.</i> (1999) with important taxa.	53
Table 11. Area of estuary habitat types (ha) across bioclimatic regions.....	58
Table 12. Habitat area (ha) of the five largest estuaries in each region. Note total area includes habitats not represented in table such as sand/mudbanks and rocks.	59
Table 13. Families and dominant species present in South African estuaries and their relative species richness.	64
Table 14. Past and present cover changes for macrophyte habitats in South African estuaries. Arrows indicate the trajectory of change.	67
Table 15. Intertidal salt marsh area (ha), population trend (↓: decreasing, ↑: increasing, →: stable), pressures and protection status. Estuaries in bold and shaded indicate those where the greatest loss has occurred.....	67
Table 16. Supratidal salt marsh area (ha), habitat trend (↓: decreasing, ↑: increasing, →: stable), pressures and protection status. Estuaries in bold and shaded indicate those where the greatest loss has occurred..	68
Table 17. Changes in the mangrove areas (ha) for the largest stands in the country. Shaded grey indicates increase in area and shaded teal indicates a decrease. Habitat trend ↓: decreasing, ↑: increasing, →: stable.	71

Table 18. Estuaries with the largest areas (ha) of <i>Zostera capensis</i> , habitat trend (↓: decreasing, ↑: increasing, →: stable), pressures and protection status.	73
Table 19. Data references for the six key pressures for South African estuaries.	78
Table 20. Key activities contributing to flow modification pressure in estuaries in South Africa.....	81
Table 21. Estimated freshwater flow abstracted from South African estuaries across biogeographical regions.	82
Table 22. Key activities contributing to pollution pressures in estuaries in South Africa.	85
Table 23. Estimated volumes of wastewater discharged daily into estuaries (or just upstream of estuaries) across various biogeographical regions.....	86
Table 24. Contribution of pollution pressures or combinations thereof, to water quality deterioration in estuaries (ranked as Medium, High and Very High).	89
Table 25. Summary of exploitation of living resources pressures on estuaries.	95
Table 26. Estimated annual landed fish catch (tonnes) in estuaries overall and in each biogeographical region.	96
Table 27. Key activities contributing to land-use and infrastructure development pressure in estuaries. ...	104
Table 28. Summary of percentage land-use changes within the EFZ as proxy for key activities contributing to habitat loss.	107
Table 29. Key activities contributing mouth manipulation pressure on estuaries.....	110
Table 30. Key activities contributing to the introduction of invasive plants in estuaries in South Africa.....	115
Table 31. Estuaries with a high density of terrestrial invasive alien plants.....	117
Table 32. Estuaries supporting aquatic invasive alien plants.	118
Table 33. Key activities contributing to introduced or translocated fish in estuaries in South Africa	122
Table 34. List of introduced fish species in the estuaries of South Africa.....	123
Table 35. List of Extra-limital (translocated) fish species in the estuaries of South Africa.	123
Table 36. Key activities contribution to alien and invasive invertebrates in estuaries in South Africa	128
Table 37. The relationship between loss of ecosystem condition and functionality (modified from Van Niekerk <i>et al.</i> 2013).....	138

Table 38. IUCN criteria and thresholds for the Red listing of ecosystems (Rodríguez <i>et al.</i> 2011).....	155
Table 39. Input data sources for the red list of ecosystem analysis.	157
Table 40. Summary of the assessment outcomes; including the number of ecosystem types per category & proportion of the natural areas remaining per category.	160
Table 41. Summary of ecosystem threat status based on the IUCN Red List of Ecosystems criterion A, B and C.	161
Table 42. Biogeographical summary of ecosystem threat status assessment.	165
Table 43. Protected area estate for the estuaries of South Africa. Condition is indicated as a % of total area in category and extent shown in ha and as a percentage of the total estuarine area.	168
Table 44. Unprotected, poorly protected and moderately protected ecosystem types are collectively referred to as under-protected ecosystems.	169
Table 45. Summary of the input data and ecosystem protection levels.	171
Table 46. Cross tabulation of estuarine ecosystem threat status and protection levels, highlighting those types that are under protected and highly threatened.	174
Table 47. IUCN 3.1. IUCN Red List Categories and Criteria. Version 3.1, summary of criteria that trigger threat status.	178
Table 48. Primary input data used for estuarine species threat status assessments.	179
Table 49. Macrophyte species assessed for this National Biodiversity Assessment.	185
Table 50. Additional macrophyte species of special concern recorded in the Estuary Botanical Database (Adams <i>et al.</i> 2016).	187
Table 51. Summary of changes in estuarine non-passerine waterbird numbers around the coast (Turpie <i>et al.</i> subm).	199
Table 52. Summary of the key physical features of South African estuaries that influence their vulnerability to climate change	208
Table 53. A summary of the impact of climate change stressors on critical South African estuarine processes and variables, which in turn drive a range of key biotic responses. (Large/Small Circle = High/Medium degree of change or vulnerability)	232
Table 54 Key legislation governing estuarine biodiversity protection	235
Table 55 Important Bird and Biodiversity Areas in South Africa	237

Table 56. Summary of legislation governing mitigation, management and control of key pressures in estuaries (including lead agents)	241
Table 57. Status assessment of government's responses to mitigate, manage and control key pressures and associated activities in estuaries (adapted from Taljaard et al. 2019)	253

LIST OF FIGURES

Figure 1. Illustration of the national and international reporting processes and channels into which the NBA is a key informant. Including international conventions signed by the South African Government and voluntary processes.....	2
Figure 2. Steps in assessing ecosystem threat status and ecosystem protection level. Note the link between ecosystem condition and protection level – only natural habitat contributes to protection level targets (e.g. the airport within a large PA would not contribute to protection targets as the natural habitat has been lost).	6
Figure 3. Value of South Africa's harvested estuarine/coastal resources (R/ha/yr). Source: adapted from Turpie <i>et al.</i> (2017a).	4
Figure 4. Contribution of South Africa's estuaries to marine fishery values (R/ha/yr). Source: adapted from Turpie <i>et al.</i> (2017a).	8
Figure 5. The extended typology of South African into nine estuary types and three micro-system types...	19
Figure 6. Estuary distribution across four biogeographical regions in accordance with the Estuarine Classification System shown in maps 1 to 5 (Cool Temperate region depicted in light blue (1), Warm Temperate region depicted in light green (2), Subtropical region depicted in orange (3 & 4), Tropical region depicted in red (5)).	21
Figure 7. Map of the location and biogeographical distribution of micro-systems (< 2ha or 200 m) in length) depicted in maps 1 to 5 (Cool Temperate (1), Warm Temperate (2), Subtropical (3 & 4), Tropical (5)).	25
Figure 8. Integrating the estuarine functional zone into the coastal ecosystem map required extending 'Estuarine Shores' (marked here in white) the full extent of present and historical mouth configurations to the back of surfzone.	41
Figure 9. An example of LiDAR used to refine the 2011 estuary functional zone of the Heuningnes Estuary. Note, high-lying areas surrounded by estuarine habitat such as 's-bends' and 'islands' have been incorporated into the EFZ.....	42

Figure 10. An example of how 5m and 10m LiDAR was used to refine the extent of EFZ at incised locations.	43
Figure 11. Mico-estuary delineation based on a combination of the 5m contour and other coastal features.	44
Figure 12. Habitats that support estuarine functioning – River-Estuary transition areas (marked in turquoise) and fluvially dependent Marine ecosystem types (marked in light brown), have been delineated and embedded in the inland freshwater aquatic and coastal / marine ecosystems realm maps.	46
Figure 13. Mzimvubu River flowing into the sea nourishing the nearshore marine sediment, nutrients and detritus (Source: Darren Hanner)	47
Figure 14. Mzimvubu plume creating a distinct turbidity front (Source: Darren Hanner)	48
Figure 15. Distribution of salt marsh habitat in South African estuaries.	57
Figure 16. Distribution of intertidal salt marsh habitat in South African estuaries.	60
Figure 17. Distribution of supratidal salt marsh habitat in South African estuaries.	60
Figure 18. Distribution of mangrove habitat in South Africa.	61
Figure 19. Species richness in four bioclimatic regions (a) and nine types of estuaries (b) in South Africa. The number of estuaries considered is presented in brackets.	63
Figure 20. a) Mouth closure at Kobonqaba Estuary in July 2010, b) Flooding of mangrove habitat, c) Dead mangroves with clear water line on base in March 2011, d) Colonization by salt marsh habitat in July 2015.	70
Figure 21. uMgeni Bulk Water Supply Scheme on lower uThukela River (Source: F MacKay).	77
Figure 22. Annual flow modification to the estuaries of South Africa.	83
Figure 23. Flow modification pressure on estuaries in South Africa.....	83
Figure 24. Flow modification pressure across the four biogeographical regions in South Africa.....	84
Figure 25. Flow modification pressure on estuarine ecosystem types.	85
Figure 26. Location of industrial and municipal wastewater discharges, as well as estimated daily volumes (m ³ /day).....	87
Figure 27. An illegal discharge at iZimbokodo Estuary mouth. (Source: ORI Estuary Observer Programme). 87	
Figure 28. Pollution pressures on estuaries.	89

Figure 29. Pollution pressure in estuaries across biogeographical regions.	90
Figure 30. Pollution pressure on estuarine types.....	91
Figure 31. Estimated annual fish catches in estuaries across the four biogeographical regions of South Africa (Updated from Van Niekerk et al. 2013).	96
Figure 32. Relative degree of fishing pressures on estuaries between 2018 (top) and 2011 (bottom).	97
Figure 33. Fishing pressure in estuaries across biogeographical regions for 2018 and 2011	98
Figure 34. Fishing pressure on estuarine types.	99
Figure 35. Sand Mining in the iLovu Estuary upper reaches (Source: CoastKZN, ORI).....	105
Figure 36. Land-use and development pressure in estuaries across biogeographical regions.....	108
Figure 37. Land-use development pressure on estuarine types.	109
Figure 38. Spatial distribution of estuaries under land-use and development pressure.....	110
Figure 39. Mouth manipulation pressure on estuaries (updated from Van Niekerk et al. 2015).....	111
Figure 40. Mouth manipulation pressure across the four biogeographical regions.....	112
Figure 41. Mouth manipulation pressure on estuarine ecosystem types.....	113
Figure 42. Location and extent of alien invasive plant coverage in South Africa.....	116
Figure 43. Spatial distribution of alien invasive plant infestations in estuaries.	120
Figure 44. Alien invasive plant pressure in estuaries across biogeographical regions.....	120
Figure 45. Alien invasive plant pressure on estuarine types.....	121
Figure 46. Location and extent of alien and extra-limital fish species in South African estuaries.....	124
Figure 47. Spatial distribution of alien invasive and extralimital fish pressure on estuaries.	125
Figure 48. Alien invasive and extralimital fish pressure in estuaries across biogeographical regions.....	125
Figure 49. Alien invasive and extralimital fish pressure on estuarine types.	126
Figure 50. <i>Magallana gigas</i> in Richards Bay harbour (Source: D Pearton, ORI).	129
Figure 51. <i>Tarebia granifera</i> habitat modification in oHlangeni Estuary (Source: ORI Estuary Observer Programme).....	130

Figure 52. Rapid spread of <i>Tarebia granifera</i> from 2011 to 2019 in KZN estuaries.....	130
Figure 53. Components and weightings of the Estuarine Health Index (DWAF 1999).	137
Figure 54. Bubble plot of South African estuaries arranged from west to east along the coast showing health (% similarity to natural), degree of modification from natural state (A-F) and relative size. (EFZ grouped into six categories: Very Large: > 10 000 ha, Large: 5 000 – 10 000 ha, Medium – Large: 1 000 – 5 000 ha, Medium: 500 -1 000 ha, Small: 100 – 500 ha, Very small: < 50 ha).....	140
Figure 55. Different perspectives arise when the National Health Assessment is presented either as “Percentage estuaries” or “Percentage Estuarine Habitat”. The percentage area analysis highlights the fact that the majority of South African estuarine area is in a degraded state.....	141
Figure 56. Map showing condition of South African estuaries spatial distribution.	144
Figure 57. Ecosystem type condition based on estuarine area.....	145
Figure 58. Deteriorating processes and patterns in South African estuaries summarised as percentage estuaries (top) and normalised by area (bottom).	148
Figure 59. Declining estuarine connectivity illustrated in 100km sections of the South African coastline. .	150
Figure 60. IUCN RLE threat categories, see glossary of terms of definitions. Source: Bland <i>et al.</i> (2017a)..	153
Figure 61. IUCN RLE framework for assessing the risk of ecosystem collapse. Source: Keith <i>et al.</i> (2013)..	153
Figure 62. Process and criteria by which ecosystem threat status is determined.....	158
Figure 63. Ecosystem threat status of South Africa’s estuaries presented as percentage of ecosystems types (a) and percentage area of ecosystems types (b).	160
Figure 64. Map showing the distribution of threatened estuarine ecosystems according to the IUCN Red List of Ecosystems. (size of the dot represents area of the individual estuary). Note: there are many overlaps between points that can obscure the status of smaller estuaries; consult the GIS data viewer via the NBA website for detailed spatial data. Cartographic corrections from Synthesis Report included.	164
Figure 65. Schematic representation of the process followed in determining the estuary ecosystem protection levels.....	169
Figure 66. Estuarine Ecosystem Protection Levels in South Africa by percentage of types (a) and percentage area (b).	172
Figure 67. Schematic representation of estuarine ecosystem protection levels (size of the dot represents area of the individual estuary). Note: there are many overlaps between points that can obscure the status of	

smaller estuaries; consult the GIS data viewer via the NBA website for detailed spatial data. Cartographic corrections from Synthesis Report included.	173
Figure 68. Categories for species red list assessment work, note South Africa uses the IUCN Red List Categories and Criteria, version 3.1 (IUCN, 2012a). National categories of rarity apply to restricted range species that have no anthropogenic pressures.	177
Figure 69. The proportion of indigenous estuarine species assessed to date in each of IUCN Categories of extinction risk: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Data deficient (DD), Least Concern (LC). Only birds were assessed comprehensively.	180
Figure 70. a) <i>Zostera capensis</i> exposed during low tide in the Kobonqaba Estuary (July 2015). b) White Mangrove (<i>Avicennia marina</i>) propagules growing in the <i>Z. capensis</i> beds (Nxaxo Estuary, May 2016), c) Small fish in <i>Z. capensis</i> beds at Keurbooms Estuary (March 2013), d) Healthy <i>Z. capensis</i> with epiphytes in the Kariega Estuary (October 2015).	183
Figure 71. The Sandprawn (<i>Callichirus kraussi</i>) exposed on the sandy sediment surface (Photo: George Branch).	188
Figure 72. The Mud Prawn (<i>Upogebia africana</i>) crawling on a muddy, seagrass habitat (Photo: Alan Whitfield).	189
Figure 73. The River Swimming Crab (<i>Varuna litterata</i>) (Photo: Fiona MacKay).	190
Figure 74. The River Swimming Crab (<i>Varuna litterata</i>) recruitment through uThukela Estuary prior to construction of weir (Photo: Fiona MacKay).	190
Figure 75. Knysna seahorse (<i>Hippocampus capensis</i>) - Endangered B1ab(iii,iv,v)+2ab(iii,iv,v) (Source: David Harasti)	192
Figure 76. Dried seahorses confiscated at roadblock.	193
Figure 77. Estuarine Pipefish (<i>Syngnathus watermeyer</i>) - Critically Endangered C2a(i)b (Source: Fred Fourie)	193
Figure 78. Bot River Klipvis (<i>Clinus spatulatus</i>) - Endangered B1ab(iii)c(ii,iv) +2ab(iii)c(ii,iv)	194
Figure 79. Freshwater mullet (<i>Pseudomyxus capensis</i>) - Vulnerable (A2cde+42cde) (Source: Corne Erasmus, DEFF)	195
Figure 80. Eels in spring flowing into Goulou Estuary at Stilbaai Information Centre (Source: Lara van Niekerk)	196
Figure 81. Changes in abundance at 16 estuaries that have been counted in at least 20 different years (Turpie <i>et al.</i> subm. based on CWAC data).	197

Figure 82. (a) Comparison of number of estuary birds counted for earliest count and the average of most recent 5 counts. (b) Difference in counts from earlier to recent counts $\ln(\text{difference})$. Estuaries and micro-estuaries numbered west to east with important estuaries labelled and delineation in terms of biogeographic zones and sections of coast (S KZN = South coast KwaZulu-Natal, N KZN = north coast KwaZulu-Natal). Note the log scale (Turpie <i>et al.</i> subm.).	198
Figure 83. The number of species in different groups of estuary birds which have increased or decreased since earliest counts. Numbers in darker shade are deemed to be significant changes based on strict criteria (Turpie & Forsythe, subm).	199
Figure 84. Map showing the six coastal regions, relative catchment size and rainfall seasonality for South Africa (Van Niekerk, 2018).	205
Figure 85. Annual mean near-surface temperature ($^{\circ}\text{C}$) change from the median projected for 2036-2065 (top) and 2066-2095 (bottom), relative to present (1976-2005), under conditions of the RCP 4.5 (left) and RCP 8.5 (right) pathway.	211
Figure 86. Annual total rainfall percentage (%) change from the median projected for 2036-2065 (top) and 2066-2095 (bottom), relative to present (1976-2005), under conditions of the RCP 4.5 (left) and RCP 8.5 (right) pathways.	212
Figure 87. Regional summary of changes in ocean circulation patterns and shifts in temperature regimes and the influence on the community structure, abundance and distribution of estuarine species. Vulnerability is indicated as high/medium/low shifts from west to east with potential change a. to f. depicted by moving outward from the coast.	215
Figure 88. Regional summary of the consequences of changes in precipitation on key estuarine processes – mouth state, salinity regime, nutrient inputs, floods and sediment depositional cycles, contaminant behaviour, habitat type and nursery function. Vulnerability is indicated as high/medium/low shifts from west to east with potential change a. to g. depicted by moving outward from the coast.	218
Figure 89. Regional summary of the consequences of sea level rise on key estuarine processes – salinity penetration, tidal flushing and mouth state. Vulnerability is indicated as high/medium/low shifts from west to east with potential change a. to g. depicted by moving outward from the coast.	225
Figure 88. Regional summary of the consequences of increased frequency and intensity of sea storms on estuary mouth state, overwash and marine sediment processes. Vulnerability is indicated as high/medium/low shifts from west to east with potential change a. to d. depicted by moving outward from the coast.	228
Figure 91. Regional summary of the vulnerability to ocean acidification and the possible consequences on calcifying species. Vulnerability is indicated as high/medium/low shifts from west to east with potential change a. to b. depicted by moving outward from the coast.	230

Figure 92. South African Ecologically or Biologically Significant Marine Areas.....	240
Figure 93. A summary of restoration interventions required in estuaries to address decline in condition.	256
Figure 94. Summary of status in government sectorial responses pertaining to implementation of integrated management systems.....	260
Figure 93. Embedding estuarine resilience to climate change by incorporating predicted effects of climate change into current planning and managed approaches (Van Niekerk 2018).....	262
Figure 94. Steps in ecosystem accounting (Source: UNEP 2017).	265
Figure 95. Shallow Water Coastal Marine Infrastructure Initiative (SMCRI) Sentinel and Satellite Sentinel Sites.	267

LIST OF TEXT BOXES

1. Habitat lost and habitat gained. Development drives estuary type change - the case of Richards Bay.
2. South African estuary naming convention.
3. The occurrence of fish kills and pathogens in south african estuaries.
4. Illegal and unsustainable gillnet fishing in estuaries causes collapse of the harder chelon richardsonii resource.
5. Eradication of invasive *Spartina alterniflora* from Great Brak Estuary.
6. The occurrence and distributions of microplastics in south african estuaries.
7. Noise pollution interrupting the dawn chorus of estuarine fish.
8. St Lucia estuarine lake restoration is an ongoing process - not without stress to critical habitat.
9. Langebaan lagoon: ecosystem health and pressures.
10. Definitions of ecosystem threat categories (CR, EN, VU, LT).
11. Fish Species Population Genetics.
12. Sea-Level Rise and coastal squeeze on salt marshes at Knysna.
13. The Quantification Of Blue Carbon In South African Estuaries.
14. Initiating a national coastal monitoring programme.

LIST OF APPENDICES

APPENDIX A: Estuary and Micro-System Ecosystem Classification

APPENDIX B: Summary of South Africa's estuarine habitat

APPENDIX C: Estuary Pressure Assessment

APPENDIX D: Estuary Condition and Biodiversity (Conservation) Priorities

APPENDIX E: Restoration measures needed to improve estuary condition and productivity

APPENDIX E: Estuarine Red Listed Habitat/species

APPENDIX G: List of meetings

LIST OF ANNEXURES (SEPARATE SUPPLEMENTARY DOCUMENTS)

1. NBA National Botanical Database
2. Estuarine Ecosystems map
3. Species information

LIST OF ACRONYMS, ABBREVIATIONS, INITIALISMS AND SYMBOLS

%	Percentage
~	Approximately
< / ≤	less than / less than or equal to
> / ≥	greater than / greater than or equal to
CARA	Conservation of Agricultural Resources Act (43 of 1983)
CBA	Critical Biodiversity Area
CE	Critically Endangered
DAFF	Department of Agriculture, Forestry and Fisheries (former government department)
DALRRD	Department of Agriculture, Land Reform and Rural Development (formed by merging DAFF and Department of Rural Development and Land Reform in June 2019)
DEA	Department of Environmental Affairs (former government department)
DEFF	Department of Environment, Forestry and Fisheries (formed by merging DAFF and DEA in June 2019)
DSI	Department of Science and Innovation (new departmental name in June 2019)
DST	Department of Science and Technology (former government department)
DWS	Department of Water and Sanitation
EFZ	Estuary Functional Zone
EN	Endangered
ha	Hectare
IBA	Important Bird Area
IUCN RLE	International Union for Conservation of Nature Red List of Ecosystems
KZN	Kwa-Zulu Natal
LC	Least concern
m	Metre
MAR	Mean annual run-off
MSL	Mean Sea Level
NBA	National Biodiversity Assessment

NBF	National Biodiversity Framework
NEM:ICM	National Environmental Management: Integrated Coastal Management Act (24 of 2008)
NEM:PAA	National Environmental Management: Protected Areas Act (57 of 2003) / Protected Areas Act
NEM:WA	National Environmental Management: Waste Act (59 of 2008)
NEMA	National Environmental Management Act (107 of 1998)
NEMBA	National Environmental Management: Biodiversity Act (10 of 2004) / Biodiversity Act
NFEPA	National Freshwater Ecosystem Priority Areas
NFEPA	National Freshwater Ecosystem Priority Areas project
NGI	National Geo-spatial Information
SPLUMA	Spatial Planning and Land Use Management Act (16 of 2013)
Stats SA	Statistics South Africa
VU	Vulnerable
x10 ⁶ m ³	Million cubic metres

GLOSSARY OF TERMS

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.

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.

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): An ecosystem type is Critically Endangered when the evidence indicates that it meets any of the criteria A to E for CR. It is then considered to be at an extremely high risk of collapse. Critically Endangered ecosystem: an ecosystem type that has very little of its original extent (measured as area, length or volume) left in natural or near natural condition. 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.

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.

Ecological infrastructure: Ecological infrastructure refers to naturally functioning ecosystems that generate or deliver valuable services to people.

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.

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.

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 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): An ecosystem type is Endangered when the evidence indicates that it meets any of the criteria A to E for EN, and is then considered to be at a very high risk of collapse.

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.

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 or species that has experienced little or no loss of natural habitat or deterioration in condition.

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

Near Threatened (NT): An ecosystem type is Near Threatened when it has been evaluated against the 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 Protected (NP): An ecosystem type that has less than 5% of its biodiversity target included in one or more protected areas

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

Present Ecological State: A set of categories for describing the ecological condition of rivers, wetlands and estuaries, developed by the Department of Water and Sanitation. Assessment of Present Ecological State takes into account a range of factors including flow, inundation, water quality, stream bed condition, introduced instream biota, and riparian

or stream bank condition. The categories range from A (natural or unmodified) through to F (critically or extremely modified), with clear descriptions linked to each category.

Priority estuary: An estuary that is required to meet targets for representing estuarine ecosystems, habitats and estuarine-dependent species, as identified in the National Estuary Biodiversity Plan.

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.

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.

Vulnerable (VU): cross ref - 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.

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

EXECUTIVE SUMMARY

Estuary Realm Profile

South Africa has 290 estuaries and 42 micro-estuaries which have been classified into 22 estuarine ecosystems and 3 micro-estuary types. This represents a high diversity of estuary types stemming from the country's diverse climatic, oceanographic and geological drivers. Four biogeographical regions characterise the South African coast; namely the Cool Temperate (Orange to Ratel), the Warm Temperate (Heuningnes to Mendwana), the Subtropical (Mbashe to St Lucia) and the Tropical (uMgobezeleni to Kosi) (Emanuel *et al.* 1992; Harrison 2002; Turpie *et al.* 2000). Rainfall in these regions varies significantly from less than 100 mm along the arid west coast to about 1 200 mm along the east coast (Davies & Day 1998; Lynch 2004; Schulze & Lynch 2007; Schulze & Maharaj 2007). Accordingly, the estuary classification for South African estuaries recognises that these systems may not necessarily have a 'free connection with the sea' but are 'either permanently or periodically open to the sea' (Day 1980; Heydorn 1989; Whitfield 1992). South Africa's National Biodiversity Assessment of 2018 defines an estuary as 'a partially enclosed permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action, salinity penetration or back-flooding under closed mouth conditions. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area or, when there is little or no fluvial input, an estuary can be isolated from the sea by a sandbar and become fresh or even hypersaline' (modified after Van Niekerk & Turpie 2012; CSIR 1992). A defining feature of this definition is that complex estuarine abiotic processes dominate, i.e. restricted tidal action, mixing of fresh and salt water, increased retention and/or increased water levels under closed mouth conditions.



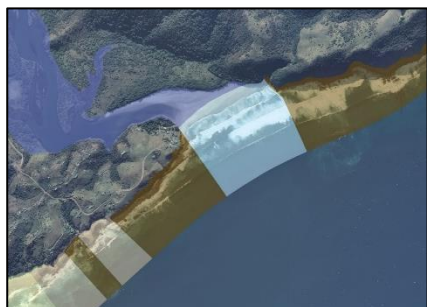
In South Africa there are *circa* 176 estuarine-associated plant species, the majority (56 species) of which are associated with salt marsh habitat. Key estuary habitats in South Africa cover a total area of 103 500 ha, with reeds and sedges (17 500 ha) overall the dominant habitat type. On a bioregional scale, supratidal salt marsh dominates in the cool temperate region (6 300 ha) and warm temperate region (2 400 ha), reeds and sedges in the subtropical region (10 800 ha), and swamp forest in the tropical region (2 000 ha). Estuaries with the largest extent are St Lucia (44 800 ha), Groot Berg (8 000 ha) and Knysna (2 400 ha). The number of macrophyte species per estuary varied from 1 to 54 (recorded at Kosi). Macrophyte species richness in estuaries of the Cool and Warm Temperate region is higher than that in the Subtropical and Tropical region. Macrophyte species are distributed amongst 58 families with the dominant contributors being Cyperaceae (23), Chenopodiaceae (18), Mesembryanthemaceae (14) and Asteraceae (11), whilst 33 other families had only one representative species. Only *Juncus kraussii* and *Phragmites australis* occurred in more than half of South African estuaries. Only 66 plant species occurred in five or more estuaries in the country.

Approximately 50 of the 150 estuarine-associated fish species that regularly occur in estuaries are Southern African endemics of which 20 are exclusively found in South African waters with some species confined to only a few systems. For example, the iconic Knysna seahorse only occurs in three estuaries (Knysna, Swartvlei, Keurbooms), the Bot River Klipvis in two estuaries (Bot/Kleinmond and Klein) and the Estuarine Pipefish in five estuaries (Bushmans, Kariega, Kasouga, East and West Kleinemonde but only confirmed extant in two of these systems). Even important 'bait' invertebrate species Sandprawn (*Callichirus kraussii*), Mud Prawn (*Upogebia africana*) and *Macrobrachium petersii* are southern African endemics, while the freshwater Sand-shrimp (*Palaemon capensis*) is a South African endemic.

Key Findings and Messages

South Africa has 290 estuaries and 42 micro-estuaries which have been classified into 22 estuarine ecosystem types and 3 micro-estuary types. This represents a high diversity of estuary types stemming from our wide array of climatic, oceanographic and geological influences. Some ecosystem types and estuarine species only occur in South Africa, with some species confined to a few systems.

Estuaries are “super” ecosystems. Although they comprise less than 2% of South Africa’s territory, these highly productive ecosystems contribute R4.2 billion per annum to the South African economy. They are focal points for development, tourism and recreation, as well as important for supporting biodiversity, livelihoods and marine fisheries. However, the development in estuaries and their catchments has come at a cost of about R700 million per annum in terms of lost fishery benefits as well as unknown costs to society from the overexploitation of resources and loss of biodiversity. This has reduced the diversity of benefits delivered by estuaries as well as the diversity of beneficiaries enjoying their services. Moving forward, development and resource use needs to be balanced to ensure the equitable sharing of benefits derived from these highly productive systems.



The Estuarine Functional Zone (EFZ) has been expanded to include all estuarine habitats (e.g. swamp forest, estuarine shores) to ensure that all estuarine ecotones are captured in the delineation and considered in estuarine planning, monitoring and management. In addition, interconnected riverine, wetland and marine river-dependent ecosystem types that support estuarine functioning were also identified and embedded in the national map of South Africa ecosystems. The recognition of the connectivity between these

ecosystems is essential for integrated management to secure estuarine ecosystem health and associated benefits.

More than 60% of SA estuaries are relatively healthy, but this amounts to only 22% of total estuarine extent, comprised mostly of small estuaries. However overall, more than 63% of estuarine area is significantly modified with important ecological processes under severe pressure and with resultant reductions in productivity, food security, fisheries livelihood, property values and recreational enjoyment.

The estuarine realm is the most threatened of all realms in South Africa, in terms of both number of ecosystem types and by area. About 86% of the 22 estuary types are threatened with 9% Critically

Endangered, 45% Endangered and 32% Vulnerable. Of total estuarine area, 99% is threatened with 3% Critically Endangered, 74% Endangered and 22% Vulnerable. Multiple interventions are required to avoid further decline in health. These include protection of freshwater inflow, restoration of water quality, reduction in fishing effort and avoidance of mining, infrastructure development and crops in the EFZ.

The decline in conditions stems from multiple escalating pressures managed across a number of key sectors. **A third of South Africa's freshwater flow no longer reaches the coast, with present inflows down from 36 900 to 24 800 million cubic metres per annum.** Twenty percent of estuaries are severely impacted (very high to high pressure) by freshwater flow reduction. **There has been a substantial increase in pollution pressure in estuaries, e.g. 840 million litres of waste water flows daily into estuaries, with deteriorating water quality driving change on regional scales.** Consequently, about 33% of estuaries are under severe pollution pressure. This reduces ecosystem resilience and nursery function, kills invertebrates and fish; and makes estuaries vulnerable to invasive species, parasites, pathogens and disease, threatening human health,



wellbeing and food security. **Over 3 730 t of fish is caught annually in contrast with 3 030t in 2011, with 21% of estuaries subjected to high or very high fishing pressure.** There's been a substantial increase in fishing effort in estuaries in the Subtropical and Tropical bioregions, exacerbated by the effective open-access to resources that arose with the collapse of fisheries compliance in KwaZulu-Natal. Less than 1% of estuaries are not under some fishing pressure as few have "no-take" status. In addition, the integrity of estuarine protected areas is being eroded by both sanctioned and unlawful fishing in these areas. In many instances, fishing effort is now five times higher inside than outside restricted areas, e.g. estuaries in the Dwesa-Cwebe Marine Protected Area (MPA) and Nature Reserve. **Overall, 29% of South African estuaries are subject to severe habitat modification**

pressure from land-use and development. Less than 10% of all estuaries in South Africa are under no pressure from development, most of these being confined to national, provincial or municipal protected areas. Agriculture was responsible for about 10% of land-use change, while urban areas comprise about 4% of change in land-use. Plantations contributed <1% to land-use changes. **Small-scale mining of sand, diamonds and heavy minerals is causing permanent habitat destruction in about 12% of estuaries,** with especially low-value sand



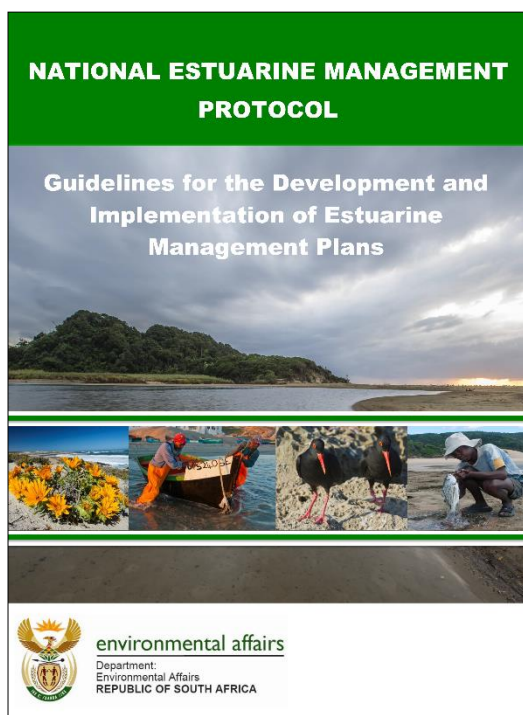
mining impacting on critical habitats, estuary hydrodynamics, sediment structure (grain size) and depleting sediment reservoirs needed to replenish physical habitat after scouring by floods. **The mouths of only 15% of South African estuary are artificially manipulated, but these estuaries represent more than 60% of the total estuarine habitat in the country.** Artificial breaching at low water levels is causing premature closure, reduced marine connectivity and the accumulation of marine sediments in the lower reaches. Artificial breaching is a listed activity that should only be allowed under exceptional circumstances that are guided by a national breaching policy. **Alien, extralimital or translocated fish occur in 25 % of South Africa's estuaries.** There are 22 species recorded to

date with one to nine per system. **A third of estuaries have invasive terrestrial plants occurring within the estuarine functional zone whilst aquatic invasive species heavily infest 8% of estuaries.**

Salt marsh, seagrass and mangrove habitats are under severe pressure, e.g. mangroves no longer occur in 10 estuaries that they previously occurred in, and nearly 30% of salt marsh habitat has been lost. Estuarine-dependent fish species are threatened by overfishing (especially gill-netting), declining water quality, and reduced flows with their concomitant influence on recruitment and marine connectivity. **All exploited estuarine fish are overfished with stocks of the five most important species collapsed. Historically, the latter contributed more than 80% of landed catch biomass. Global and local pressures have seen more than 265 000 waterbirds having been lost from our estuaries, most of which are waders and from larger estuaries.**



Overall, estuaries are under protected in South Africa with only 18% of ecosystem types and 1% of estuarine area well protected. Since 2011 the situation has worsened with a loss of protection caused by removal of no-take restrictions and developing commercial fisheries in Marine protected Areas (MPAs). This said, several under protected ecosystem types can advance to Well Protected solely with improved management of fishing and water quality. For example, 32% of types and 10% of area can be well protected if fishing effort in just 3 estuaries are better controlled – Langebaan, Knysna and Kosi.



South Africa has a strong policy and legislative framework with regards to estuary protection and management. Significant progress has been made in the management of estuaries across a number of sectors. DWS has determined the ecological water requirements of nearly 40% of estuaries, with 37% of these being subject to the “Classification” of freshwater resources. In addition, about 18% of estuaries have Estuary Management Plans in various stages of completion. These noteworthy gains play a critical role in maintaining estuary health and ensuring the benefits that society derives from them.

These measures are also proactive in that they set management objectives for estuarine resources on the strategic level through the engagement of society in the decision making process. Unfortunately, there has been deterioration in the management of extractive use in estuaries.

Urgent need for a 5-year Strategic Estuarine Management Framework

The ongoing decline in estuary condition, high number of threatened estuarine ecosystem types, and low protection levels emphasise the need for strategic interventions across multiple sectors to restore estuarine health and protect benefits to people. **To avoid further compromising of the benefits derived from estuaries a 9-point Strategic Estuarine Management Framework needs to be developed focusing on implementation and compliance across key sectors – including freshwater allocation, fish and other living resource use, water quality management, land-use planning, agriculture and mining.**

Complex ecosystems, such as estuaries, require an integrated approach to address the ongoing decline in condition. To be effective all actions and programmes need to be integrated into one coordinated framework with regular feedback to ensure implementation. Key actions that should be addressed in the **Strategic Estuarine Management Framework** should be:

1. **Increase estuarine protection levels and share the benefits of estuarine protected areas equitably among coastal communities.**

The development of the NBA 2011 National Estuary Biodiversity Plan was the first step towards this. The DEFF, in collaboration with SANBI and DWS, should lead the implementation of the National Estuary Biodiversity Plan (or any revisions that may stem from it). This should include the setting of short- to medium-term targets for Estuarine

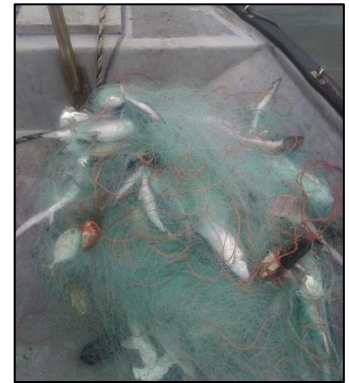


Protected Areas, e.g. 10% of all ecosystem types will be formally protected by 2025. However, the integrity of existing estuarine protected areas (including no-take MPAs) is being compromised by both sanctioned and illegitimate fishing in these areas. Estuaries are first and foremost a national asset providing and sustaining fisheries resources throughout South African coastal waters, not just on a local scale. Over-allocating fishing rights to local fisheries is compromising the benefits to communities on a national scale throughout the coast. This practise has to be reviewed and reversed to ensure an equitable and sustainable sharing of coastal resources by all communities dependent upon them. An additional tool in the biodiversity protection arsenal is the identification of Estuary Critical Biodiversity Areas (CBAs) and Ecological Supporting Areas (ESAs) that are integrated across land and seascapes (project in progress to address this). These need to be embedded in local planning and EIA processes. Salt marsh, seagrass and mangrove habitats require greater protection, with a strategy for especially mangrove protection urgently needed to prevent further loss. Apart from improving the overall health of estuaries, planners and managers also need to include sanctuary areas that are large enough to protect birds and their prey from human disturbance and exploitation.

2. **Complete ecological water requirements and classification of all estuaries within five years and implement flow requirements within two years of their classification.** This process is likely to require a two-tiered approach in which the findings of the NBA 2018 form the basis for allocation on

a national level in the 'classification' of water resources in terms of the National Water Act. While more detailed ecological water requirement studies will be needed for water-stressed catchments or biodiversity priority areas, there is also an urgent need for strategic assessments (such as the National Water Resources Strategy) to take cognisance of estuarine flow requirements which are often substantially higher than the flow requirements of the river entering the estuary. This little recognised fact leads to national- and catchment- scale water resource plans that over-estimate the water resources available for development, thus compromising the ecosystem processes that coastal communities depend upon. **This includes the recognition, determination and allocation of the freshwater requirements of nearshore river-dependent marine ecosystems by DWS in consultation with DEFF.**

3. **Stock or population recovery of fish and invertebrate resources must be facilitated by reducing fishing pressure, increased compliance, ensuring adequate freshwater inflow, decreasing nutrient pollution, managing noise pollution and boating activity.** DEFF is poised to roll out ministerial approved slot limits and the 'night fishing ban' country wide in an effort to facilitate national stock recovery. Efforts are also in progress to restore compliance along the KZN coastline.



4. **A comprehensive 'Pollution Reduction Strategy' is needed for estuaries.** Municipal wastewater treatment works (WWTW) and pump stations are no longer able to cope with high sewage volumes. Even if effluent is treated to legal standards, effluent volumes are too high to remain within the assimilative capacity of estuaries. In response, South Africa's new coastal waters discharge regulations state that no new wastewater discharges will be allowed into estuaries. This regulation needs to be enforced. While existing WWTWs should evaluate options for reuse and recycle or ocean outfalls. In addition, agricultural best practise guidelines needs to be developed, and implemented, by the DALRRD in consultation with DWS and DEFF, to reduce agricultural return flow and other agricultural impacts. Estuaries are being overwhelmed by contaminated stormwater runoff from rapid urbanisation in their environs. Traditional approaches to managing stormwater require urgent re-thinking as technologically innovative guidelines are needed to address this growing pressure. A census of solid waste disposal and collection sites near, or in, estuaries, is required to assess their impact and identify possible mitigation measures. The impact of plastic pollution should be systematically targeted through the



'Source to Sea' initiative and the 'Working for the Coast Programme'. Poor legal compliance and lack of enforcement contributes significantly to deteriorating water quality in estuaries. The recently established DWS Anti-Pollution Task Team is set to deal with the escalating incidents of pollution in rivers. A similar unit must be established in DEFF for the coast and estuaries. Healthy functional estuaries support the cultural, aesthetic, commercial, recreational and subsistence benefits upon which coastal communities depend.

5. **Estuarine Lakes are in crisis requiring urgent management interventions prioritised within an ‘Estuarine Lakes Programme’.**

This group of estuaries has seen extensive infrastructure development in the EFZ, substantial flow reduction, nutrient pollution, overfishing (especially gillnetting) and are subjected to artificial breaching / mouth manipulation. In addition, the lakes are highly vulnerable to climate change. These impacts have reduced their ability to provide key services such as flood regulation, nutrient cycling, nursery habitat, and have compromised recreational and tourism values.



To ensure future climate change resilience, a long-term ‘Estuarine Lakes Programme’ is needed to restore habitat, improve water quantity and quality, reduce pressure on resources and increase protection levels. The Lake St Lucia Estuary Restoration Programme represents the start of such a programme.

6. **Strengthen the National Estuary Management Protocol** to ensure cooperative governance between lead authorities, and to facilitate the development and implementation of Estuary Management Plans. The current focus on enabling local estuary management (e.g. bottom-up approach to land-use), should also be broadened in scope to actively facilitate pro-active strategic resource use managed between national and provincial departments (e.g. top-down approach to regional water and fisheries resource allocation). Mechanisms to ensure that compliance to policy and regulations becomes the norm, need to be investigated, funded and implemented. **Ensure that the legal definition of estuaries in South Africa includes the biophysically defined EFZ (as defined in NBA 2018).** NEMA EIA Regulations (2010) identifies the EFZ as a sensitive area that requires environmental authorisation before a development may proceed. It is important that the more inclusive NBA 2018 delineation be assimilated into the Integrated Coastal Management (ICM) Act and the National Water Act, both of which need to recognise the value of the estuarine ‘floodplain’ and the hazard of (back) flooding to development within this zone. Formal protection and adopting the EFZ as a ‘setback line’ is a key mechanism to halt the creeping decline in habitat condition.

7. **Extractive activities, such as mining, need to be carefully examined to ensure that ecological, social, economic and access issues are addressed in a sustainable manner.**

This is especially the case for mining, in and around estuaries that has disproportionately large ecological impacts with often little economic or social benefits to the diversity of estuarine beneficiaries enjoying their services, e.g. nursery function, coastal protection, tourism. A



A strategic assessment of the spatial extent and associated impacts on of mining on estuaries and the coast is urgently needed, i.e. **‘Mining SEA for South Africa’s estuaries’ that includes an analysis of estuarine and coastal sediment budgets.**

8. **Invest in solutions to restore estuarine ecological infrastructure to strengthen climate resilience and sustain ecosystem services.** There is a pressing need for a '**National Estuary Restoration Programme**' that focuses on degraded and novel systems, with an emphasis on the larger systems of high biodiversity importance and the socially important urban systems. Here an opportunity exists for flagship programmes that could be developed in a collaborative manner between government agencies and civil society.



9. **Implement coordinated long-term monitoring to inform conflict resolution, provide for high-confidence decision making and science-based management pressure hotspots** For example, current ecological flow requirements are mostly done at a low-confidence desktop level due to lack of long-term datasets. While some new data is being collected on larger systems, very little data is being collected on the numerous smaller estuaries. This results in poor decision making and hinders maximising the benefits that flow from estuaries. National-scale field surveys of South African estuaries were last carried out in the early 1980s and 1990s. **Up-to-date field surveys of abiotic (topography, bathymetry and sediment structure) and biotic components (plants, invertebrates, fish and birds) are in urgent need of being repeated in a once-off effort that is comparable with earlier surveys.** For example, DEFF: Fisheries Research should expand the estuary fish and fisheries monitoring programme to the entire coastline. **This includes the monitoring of invasive alien and extralimital plants, invertebrates and fish, and the inclusion of estuaries into national detection and eradication programmes.** **Fund and implement the National Estuary Monitoring Programme initiated by DWS,** this multi-tier, multi-parameter (including biotic and abiotic components) programme is based on current best practice and with sufficient funding, and support from other organs of state, could go a long way in addressing data deficiencies. This may require that the programme be integrated into the DEFF Oceans and Coasts National Water Quality Monitoring Programme. **The NBA 2018 Estuaries Management and Monitoring Register** was developed to foster institutional collaboration and the sharing of management and monitoring resources and



datasets. It enables the cross linking of estuary condition or present ecological state (PES), desired condition or recommended ecological category (REC), management initiatives (Estuary Management Plans and Freshwater allocation) with monitoring activities. This register tracks the various ongoing data collection efforts occurring along the coast in order to optimise resources and ensure that critical issues are

addressed. It also identifies gaps where ongoing pressures are degrading systems that provide critical ecosystem services and/or form part of the core set of priority systems in need of formal protection to achieve biodiversity targets.

10. **Address critical knowledge gaps that limit the assessment of estuarine biodiversity and decision making for a sustainable oceans economy.** Action research is needed on restoration, pollutants (herbicides, pesticides, pharmaceuticals and plastics), noise and light pollution, population genetics, climate change impacts, estuarine connectivity, recruitment studies of fish and invertebrates, invasive species and resource economics.

The United Nations Decade of Ecosystems Restoration 2021-2030 makes restoration and protection of critical ecosystems an imperative at a global scale. This call to arms, aims to scale up the restoration of degraded ecosystems to combat the climate crisis and enhance food security and biodiversity. It also presents a host of funding opportunities through climate finances instruments (e.g. Blue Carbon trading), Ecosystems-based Adaptation (EbA) global funds, and national debt restructuring mechanisms which will be highly supportive of a **South African Strategic Estuarine Management Framework**.



The NBA 2019 assessment is the first step towards the development and funding of an integrative strategic framework aimed at ensuring an equitable sharing of estuarine benefits now and into the future.

1. INTRODUCTION AND APPROACH

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1.1 What is the National Biodiversity Assessment?

This technical report focusses on the state of estuarine biodiversity in South Africa and forms part of the National Biodiversity Assessment (NBA) - 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 seeks to answer the following high-level, policy-relevant questions:

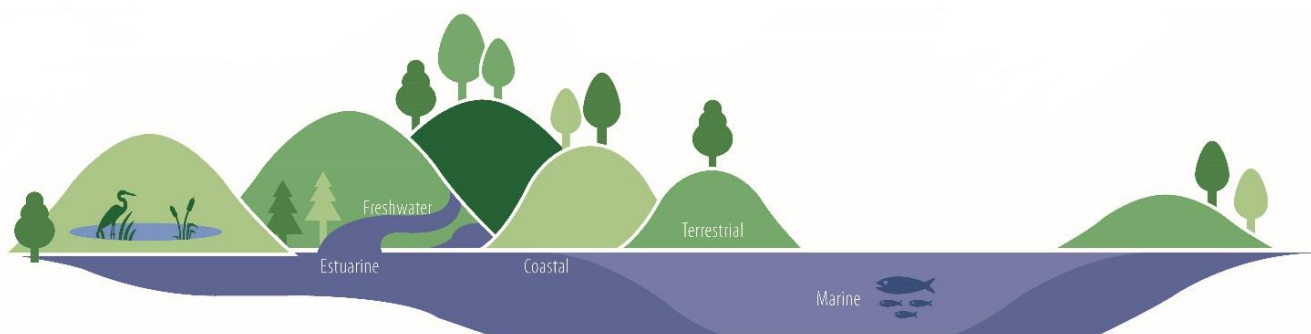
- **Status:** How is South Africa's biodiversity doing at the ecosystem, species and genetic level?
- **Trends:** Are ecosystems, species and genetic diversity doing better or worse?
- Are we **responding** effectively to the challenge of managing and conserving biodiversity?
- How is society **benefiting** from biodiversity?

What is Biodiversity?

According to the Convention on Biological Diversity (CBD), 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 of ecosystems". Ecosystems are defined as a "dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit".



Biodiversity incorporates diversity at the genetic level, species level and ecosystem level; which together form the foundation of ecosystem services. Biological diversity is about more than plants, animals and micro-organisms and their ecosystems – it is about human well-being and our dependence on ecosystem services.



1.1.1 What is the NBA used for?

The NBA is used to inform policy in the biodiversity sector, such as the National Biodiversity Framework (NBF) and the National Protected Area Expansion Strategy (NPAES), as well as informing policies and strategies of a range of other sectors that rely on, or impact on natural resources, such as the water, agriculture and mining sectors (Table 1, Figure 1).

The NBA provides information to help prioritise the often limited resources for managing and conserving our biodiversity – actions can focus on preventing further loss and degradation of ecosystems and ecological infrastructure; on consolidating and expanding the protected area network; and on interventions required to restore areas not in good condition so that they become healthy, functioning systems of benefit to people.

The NBA provides context and information that feeds into strategic planning processes such as strategic environmental assessments and bioregional plans. Figure 1 illustrates the links between the NBA and a range of national and international level monitoring, reporting and assessment processes.

The NBA ensures that the Department of Agriculture, Forestry and Fisheries (DEFF) can produce the national Environment Outlook Report and that DEFF has the necessary biodiversity information to meet our international reporting commitments to the International Convention on Biological Diversity (CBD) and national and regional reporting linked to the Sustainable Development Goals (SDG). Including reporting the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES).

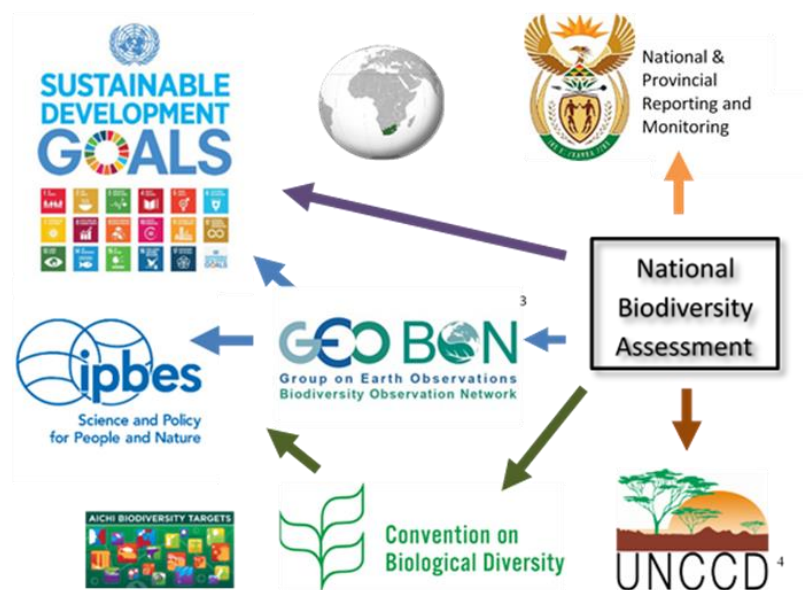


Figure 1. Illustration of the national and international reporting processes and channels into which the NBA is a key informant. Including international conventions signed by the South African Government and voluntary processes.

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.

1.1.1 SANBI's mandate

The National Biodiversity Assessment is the overarching tool for monitoring and reporting on biodiversity in South Africa and provides focus and impetus for measuring several indicators and synthesising them periodically at the national scale. There are several additional reports that provide more detail on certain aspects, including: status reports for invasive alien species, reports on impacts of genetically modified organisms and reports linked to the trade of threatened or protected species. All of these form part of SANBI's mandate to monitor and report regularly on the status of South Africa's biodiversity, in terms of the National Environmental Management: Biodiversity Act (Act 10 of 2004). The NBA has an especially important role to play in supporting the development and implementation of biodiversity policy and legislation in South Africa.

1.1.2 Navigating the NBA

The National Biodiversity Assessment (NBA) 2018 is the third national assessment for South Africa - following the National Spatial Biodiversity Assessment (NSBA 2004) & the National Biodiversity Assessment (NBA 2011). The NSBA 2004 was the first comprehensive national spatial assessment of the state of biodiversity, covering terrestrial, inland aquatic, estuarine, coastal and marine environments. It introduced two new headline indicators for assessing the state of South Africa's biodiversity: Ecosystem Threat Status, and Ecosystem Protection Level. Each iteration of the national assessment has seen advances in information and analyses undertaken.

The NBA is structured as follows: **Technical Reports** were produced for each **realm** (marine, inland aquatic, estuarine and terrestrial), for the coastal zone, for the Prince Edward Island group and the surrounding seas, and for the genetic component of biodiversity. These are presented as separate technical volumes of the NBA 2018. The overall results were summarised and are presented in the **Synthesis Report**. Additional technical reports on specific aspects of the NBA, such as the inland aquatic biodiversity inventory report, the benefits of biodiversity compendium, and the technical report on land cover change are available online.

Table 1. Processes utilising the NBA findings, messages and datasets

PROCESSES	EXAMPLES	FINDING & MESSAGES	DATASETS
National & provincial reporting	National and provincial Environmental Outlook reports (EO) (also known as state of environment reporting) are key national reporting channels that rely on the NBA.	✓	✓
National strategies	The national development indicators linked to the National Development Plan of the Presidency (NDP) National Development Plan, National Biodiversity Framework, National Protected Areas Expansion Strategy are all built partly on the findings of the NBA.	✓	
National policies	National Estuarine Management Protocol.	✓	
Sector strategies	The NBA informs sector specific strategies for sustainable development including the national Coastal Management	✓	

PROCESSES	EXAMPLES	FINDING & MESSAGES	DATASETS
	Programme, National Water Resources Strategy, Mining and Biodiversity Guidelines, Fisheries Climate Change Adaptation and Mitigation Plan (CCAMP).		
International reporting	CBD Country Reports and the National Biodiversity Strategy and Action Plans (NBSAP) rely on the NBA as do the IPBES – Regional Assessments and global Assessments; the UNCCD Land Degradation Neutrality Reports; and the UN SDGs – national reporting processes.	✓	
Biodiversity planning	Bioregional planning & biodiversity sector planning at provincial and municipal scales rely on the NBA for regional context and for updated national scale datasets on ecosystem and species status.	✓	✓
Regional planning	Spatial Development Frameworks (SDF) and Environmental Management Frameworks (EMFs) at local government level.	✓	✓
Protected area planning	Protected Areas Expansion Strategies (PAES) at national and provincial scales.		✓
Strategic Environmental Assessments (SEA)	SEA for large infrastructure programmes such as Square Kilometre Array, national electricity grid, renewable energy infrastructure, shale gas exploration, national gas pipelines.	✓	✓
Environmental Impact Assessments (EIA)	Ecosystem and species status & distribution data; ecosystem condition data; and protection data are used extensively in EIAs both at site level and for regional context. The overall finding provide mostly contextual information for the EIA.	✓	✓
Research	Researchers use both the findings and messaging for context in conservation and biodiversity research, and the datasets are extensively used in ecological research, biogeography, environmental research etc.	✓	✓
Education	The NBA and the technical reports that underpin it are realm specific summaries of biodiversity status that are widely used in tertiary education in biological and environmental sciences in particular.	✓	✓

The NBA is a multi-author and multi-institution effort. The authors of each section and subsection are clearly indicated and acknowledged in all the various volumes 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. Various governance structures were put in place in 2015 to guide the approach taken in the NBA 2018, and ensure that a wide range of experts in each specific biodiversity sector were included in the process:

- Reference groups were set up for each realm consisting of key technical and scientific experts.
- 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.
- A Core Reference Group made up of the leaders of the realms and themes as well as key technical and policy experts.

- An internal SANBI Steering Committee to engage with senior management from the various Divisions and Directorates.
- A Strategic Advisory Committee, which met annually from 2016 to review outputs and provide guidance on key messages that should be highlighted in the NBA Synthesis Report.

1.2 Indicators

1.2.1 Headline indicators: threat status & 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; Geijzenborffer *et al.* 2015). Indicators in general, are a tool to: i) improve general awareness and gain public attention for biodiversity; ii) meet international reporting requirements; monitor conservation actions; and iv) inform policy and decision-making by governments (Nicholson *et al.* 2012; Keith *et al.* 2013; Nicholson *et al.* 2015; Geijzenborffer *et al.* 2015, Keith *et al.* 2015; Tanentzap *et al.* 2017).

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 2012) 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.*, 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 (RSA 2011).

The second indicator, protection level, was developed in South Africa for national reporting (Driver *et al.* 2004) 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 species and it will be reported on for the first time in the 2018 NBA. These headline indicators provide a way of comparing results meaningfully across the different realms, and also 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. 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 Threatened (LC), based on the proportion of each ecosystem type that remains in good ecological condition

relative to a series of thresholds (Figure 2). 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) pre-dated the development of the IUCN RLE and the South African Threatened Ecosystem framework was used (Driver *et al.* 2004), making South Africa one of the pioneers globally of this approach to 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 Protected Areas Act.

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 habitat types, which provides an essential scientific basis for ecosystem-level monitoring, assessment and planning.

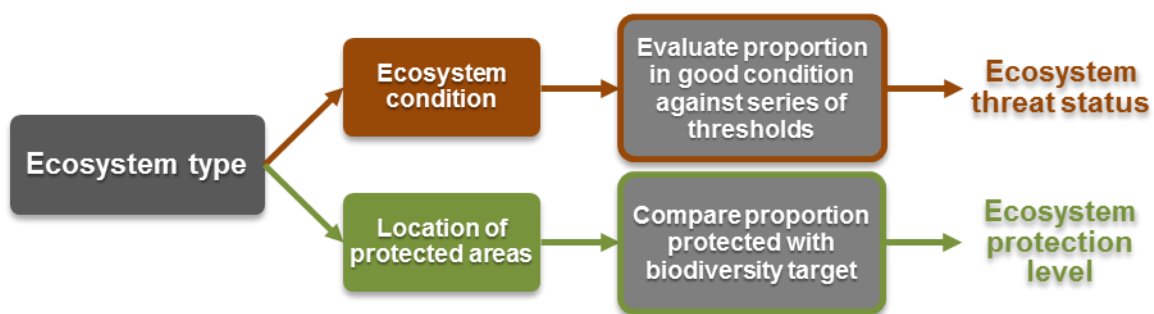


Figure 2. Steps in assessing ecosystem threat status and ecosystem protection level. Note the link between ecosystem condition and protection level – only natural habitat contributes to protection level targets (e.g. the airport within a large PA would not contribute to protection targets as the natural habitat has been lost).

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 2012).

1.2.2 Other indicators

Habitat loss indicators

While a suite of comprehensive and inclusive biodiversity indicators are under development - through initiatives such as biodiversity indicators partnership and Group on Earth Observation: Biodiversity Observation Network (GEOBON) and others - there is a need to report nationally and sub-nationally on rates of natural habitat loss. To fill this gap two simple indicators of terrestrial habitat loss / ecosystem extent have been developed for the NBA 2018. The land cover change data (discussed in Chapter 6), which is available for the first time at a national scale in South Africa, makes it possible to compute the rate of loss of natural habitat to anthropogenic activities between 1990 and 2014 (expressed as percentage of the 1990 extent per year). When this **rate of habitat loss** (RoL) is combined with the extent of natural remaining in 1990 it is possible to estimate the number of **years to ecosystem collapse**¹ (YtC) (supporting criteria for estuarine ecosystem threat status).

Indicators for biological invasions

Van Wilgen and Wilson (2017) provide a framework for reporting on biological invasions at a national level. The framework considers biological invasions in terms of pathways, species (taxa), sites and interventions. Indicators for pathways describe the opportunities available for introduction to and dispersal within South Africa. Indicators for species include the number and status of alien species in the country, the extent and abundance of alien species, and the impacts caused. Indicators for invaded areas include number of alien species, alien species richness relative to indigenous species richness, abundance of invasive species relative to abundance of indigenous species, and the impact of invasions. Indicators for the interventions include an assessment of key inputs, outputs and outcomes. The four high-level indicators of the framework, in turn, align with the pressure, state and response framework. While this data is not readily available for South Africa's estuaries some effort is made in Chapter 6 to quantify this pressure on a national scale.

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.

¹ Ecosystem collapse is a term linked to the IUCN Red List of Ecosystems risk assessment framework (Keith *et al.* 2013b), and occurs when the entire historical extent of an ecosystem type has lost its characteristic biota and ecosystem function, and has been replaced by an anthropogenic landscape (e.g. croplands, urban settlements) or novel ecosystem (Bland *et al.*, 2018; Rowland *et al.* 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.

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

NBA INDICATOR	AICHI TARGET	SUSTAINABLE DEVELOPMENT GOAL	COMMENT
Estuary water quality	5	6.3.2	Measured/modelled estuary water quality condition can be used to report on the proportion of bodies of water (in this case estuaries) with good ambient water quality.
Estuary Condition	5	6.6	Measured/modelled estuary condition can be used to report on the change in the extent of water related ecosystems over time (with a focus on extent and water quantity).
Ecosystem Threat Status	5	15.1	This powerful indicator of threats 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 15.1.2 reporting.
Species Threat Status	12	15.5	Good links between national indicators and the Aichi and SDG indicators.
Ecosystem extent / habitat Loss	5	-	Not adequately 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.

1.3 About the estuarine realm

South Africa has 290 estuaries and 42 micro-estuaries which have been classified into 22 estuarine ecosystems types. This represents a high diversity of estuary types stemming from our diverse climatic, oceanographic and geological drivers. Four biogeographical regions characterise the South African coast; namely the Cool Temperate (Orange to Ratel), the Warm Temperate (Heuningnes to Mendwana), the Subtropical (Mbashe to St Lucia) and the Tropical (uMgobezeleni to Kosi) biogeographical regions (Emanuel *et al.* 1992; Harrison 2002; Turpie *et al.* 2000). Rainfall in these regions vary significantly from less than 100 mm along the arid west coast to about 1200 mm along the east coast (Davies & Day 1998; Lynch 2004; Schulze & Lynch 2007; Schulze & Maharaj 2007). Catchment size thus also varies significantly, ranging from very small (< 1 km²) to very large (> 10 000 km²), with those entering the sea in the arid Cool Temperate region tending to be the largest (Jezewski *et al.* 1984; Reddering & Rust 1990).

In all, annual runoff of South African rivers is highly variable and unpredictable in comparison with larger northern hemisphere systems, fluctuating between floods and extremely low, to zero, freshwater inflow (Dettinger & Diaz 2000; Jones *et al.* 2014). A number of South African estuaries are ground-water dependent systems, i.e. Langebaan, uMgobezeleni, Kosi. The relatively small South African estuaries are wave-dominated, shallow (water depth 2–3 m) and microtidal (<2 m) (Cooper 2001). The ensuing low tidal flows, coupled with comparative low freshwater inflow, results in a limited ability to maintain inlet stability (i.e. open mouth conditions). The effect of strong wave action and high sediment availability is that more than 90% of estuaries have restricted inlets, with more than 75% closing for varying periods of time when a sandbar forms across the mouth (Cooper 2001; Whitfield 1992).

Thus, the estuary classification for South African estuaries recognises that these systems may not necessarily have a ‘free connection with the sea’ but are ‘either permanently or periodically open to the sea’ (Day 1980; Heydorn 1989; Whitfield 1992). South Africa’s National Biodiversity Assessment of 2018 defines an estuary as “a partially enclosed permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action, salinity penetration or back-flooding under closed mouth conditions. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area or, when there is little or no fluvial input, an estuary can be isolated from the sea by a sandbar and become fresh or even hypersaline’ (Van Niekerk & Turpie 2012; CSIR 1992). A defining feature of this definition is that complex estuarine abiotic process dominate, i.e. restricted tidal action, mixing of fresh and salt water, increased retention and/or increase water levels under closed mouth conditions.

In South Africa there are ~ 176 estuarine-associated plant species, the majority (56 species) of which are associated with salt marsh habitat. Key estuarine habitats in South Africa cover a total area of 103 500 ha, with reeds and sedges (17 500 ha) overall the dominant habitat type. On a regional scale, supratidal salt marsh dominates in the cool temperate (6 300 ha) and warm temperate region (2 400 ha), reeds and sedges in the subtropical region (10 800 ha) and swamp forest in the tropical region (2 000 ha).

The estuaries with the largest extent of vegetated area are the St Lucia (44 800 ha), Groot Berg (8 000ha) and Knysna (2 400 ha). The number of macrophyte species per estuary varied from 1 to 54 (recorded at Kosi). Macrophyte species richness in estuaries of the Cool and Warm temperate regions is higher than that in the Subtropical and Tropical regions. Macrophyte species are distributed amongst 58 families and the dominant families are *Cyperaceae* (23), *Chenopodiaceae* (18), *Mesembryanthemaceae* (14) and *Asteraceae* (11), whilst 33 other families were only represented by one species. Only *Juncus kraussii* and *Phragmites australis* occurred in more than half of South African estuaries. Only 66 plant species occurred in five or more estuaries in the country.

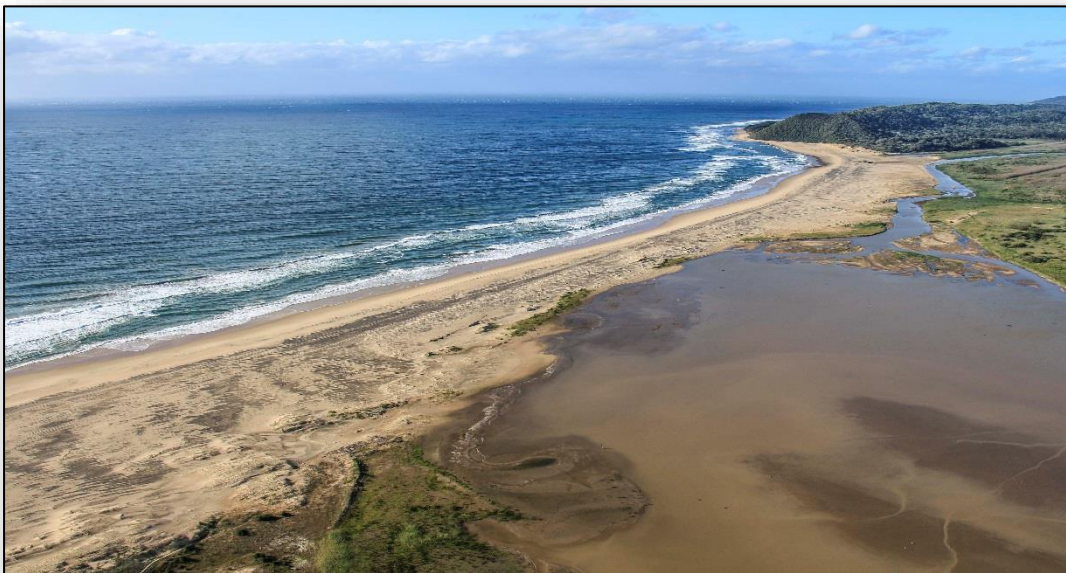
Some estuarine faunal species only occur in South Africa, with some species confined to a few systems. For example the iconic Knysna seahorse (3 estuaries), the Bot Riverklipvis (2 estuaries) and the Estuarine Pipefish (5 estuaries, confirmed in 2). Even important ‘bait’ invertebrate species Sandprawn

(*Callichirus kraussii*), Mud Prawn (*Upogebia africana*) and freshwater prawn *Macrobrachium petersii* are southern African endemics, whilst the Freshwater Sand-shrimp (*Palaemon capensis*) is a South African endemic. There are no entirely estuary-dependent bird species. A total of 35 bird species were considered dependent on estuaries if more than 15% of their regional population was found in coastal lagoons and estuaries (Turpie, Wilson & Van Niekerk *et al.* 2012; Hockey *et al.* 2005).

1.4 What is new in the Estuarine Realm?

A number of key refinements and new initiatives were undertaken as part of the 2018 NBA, including:

- Revising the estuary ecosystem classification of South Africa estuaries to include Langebaan Estuarine Lagoon and the small, arid west coast systems previously omitted, distinguish between the large, sediment rich and small, black water fluvially dominated estuaries, and separate the very small temporarily open system from the large temporarily open estuaries.
- Extending the estuary functional zone (EFZ) to include estuarine habitat and processes that what were previously excluded, e.g. swampforest.
- Aligning and embedding the estuary delineation in the South African national ecosystems, inland aquatic, national vegetation and new coastal maps.
- Spatially mapping key estuarine habitat in 121 estuaries.
- Determining Estuarine Ecosystem Threat status according to the IUCN criteria.
- Calculating Estuarine Ecosystem Protection Levels using spatial data for the first time.
- Developing the NBA Estuary Management and Monitoring register to inform government's responses to pressures on estuaries.



St Lucia Estuarine Lake System © iSimangaliso Wetland Park

2. BENEFITS OF ESTUARINE BIODIVERSITY

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Ecosystem Benefits

- Contribute R4.2 billion per annum to the South African economy.
- Over 70% of this value is manifest in property and tourism values which have continued to increase as a result of increasing development at the coast.
- However, resource use and development has come at a cost of about R700 million per annum in terms of lost fishery benefits, including unknown costs to society due to the overexploitation of resources and loss of biodiversity. This has reduced the diversity of benefits being delivered by estuaries as well as the diversity of beneficiaries enjoying their services.

2.1 Introduction

Estuaries are rich and productive systems that produce a wide range of benefits to society. They derive their richness and productivity from nutrient and sediment inputs received from river and sea water, combined with the relatively sheltered aquatic habitat that they provide. Their characteristic biodiversity assemblages have arisen from the need for biota to cope with their salinity gradients and fluctuations. These unique characteristics make estuaries among the most valuable types of ecosystems on earth.

Understanding the value of conserving estuaries or at least managing them for sustainable use has become vital for managers and policy makers who are increasingly being faced with difficult decisions regarding water extraction and development of surrounding coastal areas. These factors have direct impacts on estuarine systems which can affect their contribution to economic well-being. An understanding of what values are at stake and the factors affecting those values is helpful in weighing up the costs and benefits of management decisions, both for individual systems and at larger scales.

Research into the economic value of estuaries in South Africa started during the 1990s, along with a growing awareness of their role in generating ecosystem services and contributing to local and regional economies. Since then, a number of studies have been carried out on the value of estuaries. Many of the earlier studies focused on single estuaries (e.g. Turpie & Joubert 2001; van Zyl & Leiman 2001; de Wet *et al.* 2005, Turpie *et al.* 2005; Turpie & Joubert 2005) or a small group of estuaries (e.g. Cooper *et al.* 2003; Turpie 2006). These studies focused mainly on recreational use and property values associated with estuaries. Hosking *et al.* (2002) also conducted a contingent valuation study of a number of South African estuaries in order to value users' willingness to pay for water to maintain a stated hypothetical level of biodiversity in these systems, also including on estuary users. Lamberth & Turpie (2003) conducted the first national scale valuation study of estuaries, focusing on fishery-related values, whilst in 2005, Turpie & Savy produced the first estimate of the non-use values of estuaries in South Africa. In 2007, Turpie & Clark (2007) recognised the potential value of incorporating estuary values into conservation planning, and estimated the values of all temperate estuaries in order

to inform the C.A.P.E. estuary conservation plan. Their study was based on existing studies and some additional data collected for the purpose, which included a contingent valuation study to elicit public willingness to pay for estuary conservation, as a measure of estuary existence values, and a study on the property values attributed to estuaries (Maswime 2006).

Napier *et al.* (2009) conducted a comprehensive study of subsistence use of the Knysna Estuary providing estimates of the value of subsistence fishing. In 2014, Turpie & Goss estimated the value of recreational angling on the Breede Estuary. Since then further work has been carried out on some estuaries, including urban estuaries (e.g. Turpie *et al.* 2017b) and a comprehensive valuation study of the St Lucia Estuary (Turpie *et al.* 2014). More recently, as part of the classification of the Berg and Breede-Gouritz Water Management Areas (WMA), Turpie *et al.* (2017c, d) conducted a socio-economic analysis which included the valuation of estuary ecosystem services in these two WMAs, and using locally-sourced and other relevant information, Turpie *et al.* (2017a) valued and mapped the ecosystem services provided by South Africa's terrestrial, freshwater and estuarine habitats.

In this assessment, we review and analyse existing data and provide updated estimates of the value of South Africa's estuaries. As part of the current NBA, a more comprehensive list of estuaries has been generated by estuarine specialists. This list includes estuaries and micro-estuaries that were previously not included in regional and national assessments. As such, this study sought to update previous estimates for estuaries already included on the list and generate values, where possible, for any new estuaries previously not included in any regional or national assessments. A total of 325 estuaries were included in the assessment. Given that this study is based on existing data, some of which is more than a decade old, we recognise that the values presented here should be considered as ballpark estimates. It is recommended that a comprehensive country-wide study on the value of estuaries be conducted in order to accurately update these estimates, and perhaps more importantly, the marginal effects of management changes on estuary values.

The understanding of ecosystem services and benefits and their valuation has advanced considerably over the past couple of decades. Here it is important to distinguish the various concepts. In general, policy makers need to understand how changes in ecosystem extent and condition affect economic outputs and human welfare. The latter two are somewhat but not perfectly related. Thus ecosystem accounting, an extension of the System of National Accounting that is still under development, aims to record how ecosystem changes affect sectoral and national income levels, in measures such as Gross Domestic Product. This is measured in terms of 'exchange values', such as changes in turnover (UN 2017). We also need to understand how this affects human welfare. This is measured as changes in the sum of producer and consumer surplus, which are measures of nett benefits to society. Estimating consumer surplus requires understanding society's willingness to pay for benefits, which requires much more effort to estimate with any confidence. This study focuses on direct contributions to GDP (similar to producer surplus), but also discusses some of the more intangible benefits.

In ecosystem accounting, ecosystem services are defined as the 'contributions that ecosystems make to **benefits** used in economic and other human activity (i.e. **they are contributions that ecosystems**

make to human wellbeing, UN 2017). Of particular relevance is determining how changes in the supply of ecosystem services affect human wellbeing, and to understand this, it is necessary to understand the underlying links between ecosystem structure and function and the supply of ecosystem services as well as their demand. In most cases, estimating these contributions is made very complex by the fact that value is derived from the combination of natural and man-made capital. For example, one would not have the same tourism value without appropriate infrastructure. With all of the above in mind, this chapter discusses the following estuary benefits:

- **Contribution to livelihoods** through provision of **living resources** that are harvested for nutrition, energy and raw material purposes.
- **Contribution to marine fishery values** through provision of **nursery areas** for the maintenance and productivity of marine fish populations.
- **Contribution to the amelioration of climate change damages** through **sequestration of carbon** from the atmosphere.
- **Contribution to recreation, tourism and property values** as a result of ecosystem **attributes** that lend aesthetic beauty and are attractive for recreational activities.
- **Contribution to sense of wellbeing** through the knowledge of their contribution to the continued **existence** of nature and biodiversity.

2.2 Contribution to livelihoods

In South Africa, estuaries provide a wide range of resources that are harvested for the purposes of nutrition and health, energy and raw materials. These include reeds, fish, invertebrates, food and medicinal plants, and in the case of mangrove forests wood for fuel and construction.

The value of estuary resources was calculated using existing estimates from Turpie *et al.* (2017a) inflated to 2018 Rands. Their estimates were in turn based on Lamberth & Turpie (2003), and Turpie & Clark (2007) who used fisheries data (effort, quantities and values of fish and invertebrates harvested from estuaries) collected from large sections of the South African coast to estimate the subsistence use value associated with individual estuaries, recent survey-based estimates of subsistence use for St Lucia (Turpie *et al.* 2014) and updated estimates for the estuaries of the eThekweni Municipality (Turpie *et al.* 2017b).

The value of subsistence harvesting from estuarine habitats was estimated to be about **R64 million per annum**. This does not include indirect contributions to marine fishery values, discussed below. Unsurprisingly, estuaries tend to be more valuable where larger systems coincide with urban areas or dense settlements in traditional or tribal areas of the country, such as northern KwaZulu-Natal (see Figure 3).

Subsistence activities do not occur in all estuaries and are generally related to the size of the estuary as well as its degree of accessibility and enforcement of conservation within protected areas. Indeed, while these livelihood activities can occur on a significant scale in some estuaries, much of the use is thought to be illegal and the degree of sustainability of the harvesting activities unknown. This is

largely because species-specific sustainable yields for most of the resources targeted by subsistence users along the South African coastline are limited. For example, the bulk of subsistence catches of estuary fish are species such as mullet, with a significant bycatch of estuary dependent line fish. While the catches of mullet might be sustainable, the latter are thought to be unsustainable in many cases.

A livelihood study of communities living inside and neighbouring the iSimangaliso Wetland Park in KwaZulu-Natal conducted by Turpie *et al.* (2014) highlights the concern around illegal subsistence activities and the impact it can have on estuarine resources. The study found that fishing as a livelihood occurred on a significant scale in the St Lucia estuary, albeit mostly illegally. Survey data suggested that about 1876 fishers were operating in the St Lucia system in 2012/13, with an overall fishing effort of 111 000 fisher days per year and estimated catches of about 820 tonnes of fish and 100 tonnes of crustaceans (mainly prawns) from the lakes, and another 11 tonnes of fish from the uMfolozi-uMsunduze estuary system. Overall catches were estimated to be worth about R12 million, of which R2.5 million was from prawn harvest (Turpie *et al.* 2014). Evidence suggested that effort and catches had increased markedly over the previous two decades, raising serious concern for the future status of the fisheries resources in the St Lucia estuary.

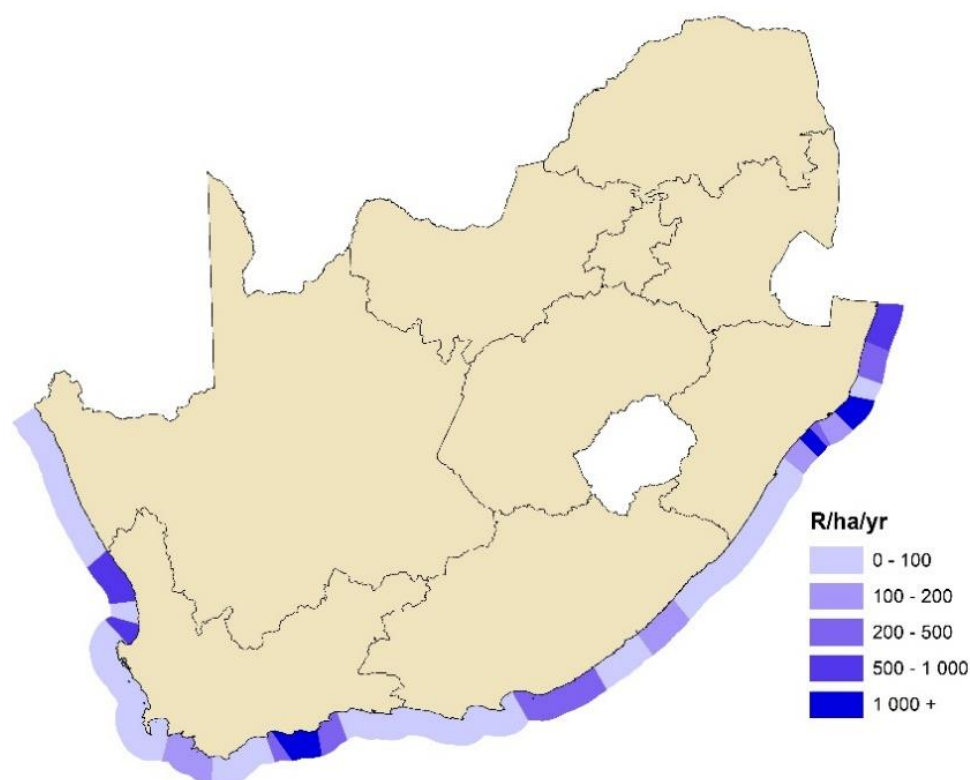


Figure 3. Value of South Africa's harvested estuarine/coastal resources (R/ha/yr). Source: adapted from Turpie *et al.* (2017a).

Furthermore, Turpie *et al.* (2017a) determined that the demand for natural resources exceeded sustainable yields in 47% of municipalities in South Africa. This was slightly lower at 35% for coastal municipalities when all natural resources were considered, yet was as high as 54% for the harvesting of reeds and sedges which is a dominant livelihood activity in coastal areas and in particular in estuaries.

2.3 Contribution to tourism value

Tourism activities are centred on a wide range of attractions, many of which are or are linked to natural environments, in which aquatic ecosystems are often a significant feature. Estuaries in South Africa are popular holiday destinations and offer a host of recreational activities including paddling, bird watching, boating, fishing and swimming. Visitors to estuaries generate expenditure on accommodation, in restaurants and in the retail sector. However, not all tourism expenditure in visiting estuary resorts is attributable to the estuary itself, as there are often multiple attractions associated with the area, such as beaches, villages and surrounding natural areas. To some degree, the tourism value of an estuary is closely tied to the level of development around the estuary, even though individuals assign value to particular estuaries for very different reasons and often in very different proportions. Indeed, tourists that seek a wilderness experience may have a more valuable experience at a less developed than a more developed estuary (i.e. have a higher willingness to pay for the former), but the tourists that enjoy more developed estuaries (because of the variety of things to do, etc.) tend to be more numerous.

Turpie *et al.* (2017a) estimated the tourism value of South Africa's natural ecosystems based on the spatial variation in the density of 237 467 geo-tagged photographs uploaded to Panoramio. Panoramio hosts images that focus on outdoor natural, agricultural and cultural features and landscapes (Panoramio 2015). However, their results were not summarised for estuaries specifically. Turpie *et al.* (2017c; 2017 d) used a similar approach, but to assign values specifically to most estuaries in the Western Cape. In this study, we refined this approach, in that we first estimated that value of tourism in the estuary area based on photo densities, and then we used expert opinion to assign a proportion of value attributed to the estuary, based on the presence of competing tourism assets such as beaches and urban attractions. This was a conservative approach, in that in many cases the small towns have developed in these areas because of the presence of the estuary. Thus in reality, the value is likely to lie between the two estimates. This method updates the estimates of Turpie & Clark (2007), which were generated based on four empirical studies and expert opinion. The approach used in this study gave a better indication of the spread of tourism along the coastline without needing to conduct site-specific tourism surveys. While the values are thought to be slightly conservative in some cases, they are likely an improvement on previous estimates.

Recreation and tourism expenditure attributable to the coastal areas surrounding estuaries was estimated to be in the region of R10.2 billion per annum. Based on our estimates for individual

systems, at least a quarter of this value, or **R2.4 billion per annum**, can be assigned to the estuaries themselves, representing 57% of the total estuary benefits value. Values were highest for the larger, more developed systems such as Knysna, Langebaan, St Lucia, Breede, Gouritz, Groot Berg and Keurbooms estuaries. This value represents just less than 10% of the total nature-based tourism value in South Africa (see Turpie *et al.* 2017a).

2.4 Contribution to property value

While natural ecosystems may generate revenues through domestic and international tourism, they can also manifest in property values, leading to value added in the associated services and financial sectors. This is particularly true for estuaries. People do not only visit pleasant environments, they may also pay a premium to live near them. This is reflected as additional amenity value that is not reflected in tourism expenditure.

Turpie & Clark (2007) estimated the property price premiums and associated contribution to the economy for all temperate estuaries (up to Mdumbi in the Eastern Cape) on the basis of property numbers and interviews with estate agents. Turpie *et al.* (2017c; 2017d) updated the counts and estimates for the estuaries of the Berg and Breede-Gouritz WMAs (most Western Cape estuaries). In estimating the contribution of ecosystem services to property value, Turpie *et al.* (2017a) national study did not distinguish the contribution of estuaries from that of the coast.

Up to now, no estimates have been made of the contribution of estuaries to property values outside of the temperate region. For this assessment, the earlier estimates were inflated to 2018 prices, and a high-level desktop approach was used for the remaining estuaries. Google Earth was used to assign the number of properties with estuary frontage or a good view and the number of properties within walking distance of each estuary. Following this, price data was gathered from property websites and a base price was determined (the average price of house in the area that does not have frontage or views) for each estuary. The same frontage-base and walking distance-base ratios associated with estuaries in the Transkei, previously used by (Turpie & Clark 2007), were applied to the sub-tropical estuaries in the Eastern Cape province from Mdumbi to Port Edward in order to calculate the premium relative to the base price. For the estuaries in KwaZulu-Natal the premium ratios associated with frontage properties and properties within walking distance were assumed to be lower than those used by Turpie & Clark (2007) for temperate estuaries. This is because the estuaries in KwaZulu-Natal are smaller with views and access to the estuary often being limited. Furthermore, while most of the resort towns along the Kwa-Zulu Natal coastline are situated adjacent to estuaries, the estuaries are often very small and less important than the other coastal attractions, such as beaches and deep sea fishing. In these cases, the premium attached to the estuary was estimated to be very small. The aggregate property premium for each estuary was then translated to an annual direct contribution to GDP following the methods in Turpie & Clark (2007).

Estuaries were estimated to add R20 billion to the value of coastal property in South Africa, generating an estimated **R609 million per annum** in terms of direct contribution to GDP. Estuaries in the Western Cape account for about 59% of this value, followed by the Eastern Cape (37%) and KwaZulu-Natal (4%).

2.5 Contribution to marine fishery values

Estuaries play an important role as nursery areas for many fish and invertebrate species that spend the rest of their life cycle in marine or freshwater habitats, including many species harvested for recreational or commercial purposes (Whitfield 1994; Beck *et al.* 2001). Estuaries are very productive systems mostly due to high nutrient inputs, while also providing sheltered habitat and nursery grounds for many organisms which can either be exploited directly in the estuary or later in life in coastal areas (Costanza *et al.* 1997, Cooper *et al.* 2003). Freshwater flow and the frequency and duration of estuary mouth openings are major factors affecting estuarine biota, and particularly the juveniles of marine organisms that use them as nursery grounds (Whitfield 1994; Strydom *et al.* 2003) either directly through habitat availability, or indirectly through their impact on system productivity (Gillsanders & Kingsford 2002). Factors that make estuaries suitable nursery habitats are increased food, higher temperatures, turbid waters and lower salinities, all of which can be changed by alterations in freshwater input. In South Africa, estuaries act as nursery areas for a number of line-fish species throughout the country, as well as for enaeid prawns caught mainly along the KwaZulu-Natal coast (Demetriades & Forbes 1993; Lamberth & Turpie 2003).

Fish diversity and abundance differs between estuaries of different sizes and types, with higher species richness associated with larger and permanently open systems (Lamberth & Turpie 2003), such as the Knysna and Breede estuaries. However, many estuaries have become degraded as nursery habitats because of freshwater starvation and mouth manipulation. Furthermore, the fish stocks themselves have also been depleted through fishing, both legal and illegal.

Lamberth & Turpie (2003) estimated the nursery value of all South African estuaries, based on fishery data, and ascribed values to individual estuaries based on their characteristics. It must be noted there was lack of confidence in the contribution of the St Lucia estuary. Subsequently, Turpie *et al.* (2014) were able to produce a relatively robust estimate of the nursery value of the St Lucia estuary system, based on a comparison of catches in recreational and commercial nearshore fisheries before and at the end of a very long period of estuary closure (2002-2010), and taking changes in fishery regulations and recreational demand into consideration. They found that the fisheries were losing about R31 million per year as a result of the closure of the St Lucia estuary mouth over much of the preceding decade, and this provided evidence of the system's true nursery value. Taking this and the general changes into account, Turpie *et al.* (2017a) published an updated estimate of nursery value, which in 2018 Rands, amounts to about **R960 million per annum**. Values are highest along the south Western Cape and Eastern Cape coast (Figure 4). Given that the capacity of estuaries to replenish marine fishery stocks has been lost due to freshwater starvation and recreational fishing pressure, this value represents only 58% of what it would be if all estuaries were in their natural condition. In other words, fishery values have been reduced by an estimated R695 million as a result of estuary degradation.

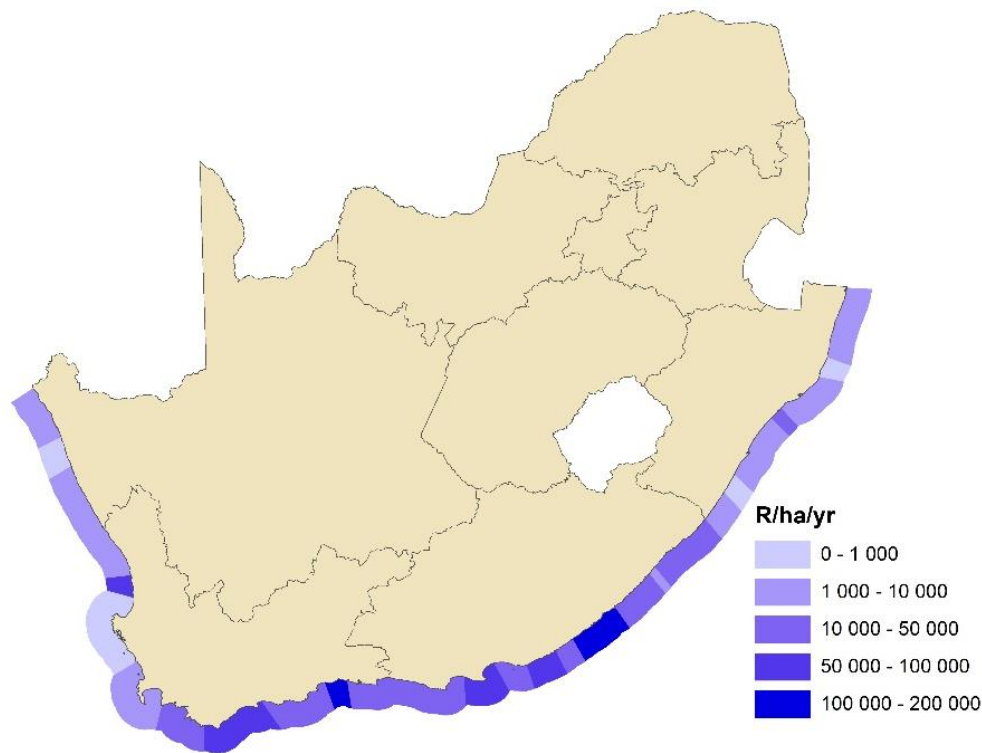


Figure 4. Contribution of South Africa's estuaries to marine fishery values (R/ha/yr).

Source: adapted from Turpie *et al.* (2017a).

2.6 Mitigation of climate change damages

Estuarine habitats such as salt marsh, submerged macrophytes and mangrove forests are highly productive systems that have the capacity to sequester carbon at a rapid rate (Barbier *et al.* 2011; Beaumont *et al.* 2014). The relative carbon storage potential of estuarine habitats is now widely acknowledged and considered significant in the regulation of both local and global climate (Beaumont *et al.* 2014; Sidder 2018). Recent research by Krauss *et al.* (2018) has shown that even upper estuary habitats, such as tidal freshwater forested wetlands and low-salinity marshes, store significant amounts of carbon, in some instances even exceeding those of seagrass and salt marsh ecosystems. In South Africa, the role of estuarine habitats as a source and sink of greenhouse gases is comparatively unknown.

The term 'blue carbon' is used to describe the carbon found in three major coastal and marine ecosystems: mangroves, seagrasses, and salt marshes (Siikamäki *et al.* 2012). These habitats sequester carbon from the atmosphere and lock it into the soil where it can stay for millennia. These habitats are unique in that the carbon that they sequester during photosynthesis is often moved from the short-term carbon cycle (10-100 years) to the long term carbon cycle (1000 years) and is continuously buried as slowly decaying biomass (Barbier *et al.* 2011). However, many of these coastal habitats are

threatened, thereby reducing their capacity to provide ecosystem benefits. Drivers of this degradation include urban and industrial development, aquaculture, agriculture, tourism, forestry, coastal erosion and sea level rise (Beaumont *et al.* 2014). When these habitats are degraded they emit large amounts of CO₂ into the atmosphere contributing to global climate change with impacts on biodiversity, water supply, drought and floods, agriculture and human health. Therefore, restoration or protection of these ecosystems is important for reducing ongoing losses and rebuilding carbon stores, i.e. mitigating or avoiding these damages, respectively.

South African estuaries contain 1 672ha of mangroves, 14 596ha of salt marsh and 2 685ha of submerged macrophytes (Adams 2018). Based on estimates of carbon stocks for blue carbon ecosystems from Siikamäki *et al.* (2012), the total estuarine ecosystem carbon was estimated as 6.7 Tg C, which equates to approximately 24.6 Tg CO₂ (using molecular weight of CO₂/molecular weight of carbon; EPA 2016). Following the approach of Turpie *et al.* (2017a), the avoided social cost of carbon associated with estuarine habitats in South Africa was estimated using a social cost of carbon of US\$31.25 per ton of CO₂ (in 2010 USD; Nordhaus 2017) and the assumption that 3% of this would be borne in Africa (Nordhaus 2017). The cost to South Africa was assumed to be proportional to its GDP contribution to Africa, scaled by level of vulnerability to climate change using the Notre Dame Global Adaptation Initiative (ND-GAIN) vulnerability index. Based on this index, it was estimated that South Africa is likely to bear only 0.35% of the global social cost of each ton of carbon emitted. This suggested that the avoided degradation and loss of South Africa's 6.7 Tg of South Africa's estuary habitats represents avoided damages (or GDP losses) of **R11.8 billion per annum** at a global scale, and South Africa's share of this would be **R42 million per annum**.

2.7 Intangible benefits

Beyond tourism and property values, people often derive value merely from the knowledge that nature exists and that it can be enjoyed by future generations. However, existing values are notoriously difficult or impossible to value fully in monetary terms. Most valuation studies use stated preference methods to determine the existence value of ecosystems. These methods involve questionnaire surveys of the affected population and elicit peoples' willingness to pay (WTP) for the benefit of retaining or acquiring an improvement in an environmental asset or willingness to accept compensation (WTA) for its degradation or loss. Although there has been an estimate of the non-use value of South African biodiversity in general (Turpie 2003), Turpie & Savy (2005) produced the first estimate of the non-use values of estuaries in South Africa, as well as of the Knysna estuary in particular. Following this Turpie & Clark (2007) estimated the existence value for temperate estuaries. However, since these studies there has been limited further research on the non-use values of estuaries. Based on those studies and using Google Earth to assign scenic beauty scores to estuaries previously not scored by Turpie & Clark (2007), the existence value of South Africa's estuaries could be in the order of **R153 million per annum**. Given the lack of any recent stated preference studies, this is a magnitude first-cut estimate. Stated preference valuation methods have advanced considerably, and further research would be strongly recommended.

2.8 Discussion and conclusions

Overall, estuaries are estimated to contribute some **R4.2 billion per annum** to the economy, the majority (~71%) of which is manifest in property and tourism values. This value has arisen as a result of the gradual increasing rate of property development at the coast, which has meant that the potential property and tourism value of estuaries, potentially an enormous sum, has been increasingly realised. It is important to see this in a broader context, however. As estuaries become developed, so certain types of activities are necessarily replaced by others (e.g. enjoying a wilderness experience is replaced by water-skiing), and aggregate tourism values go up, even though for certain individuals, the value of the recreational experience goes down. Urban development and industrial activities may also replace tourism activities. In general, values generated by estuary development can be expected to increase steeply at first, but then more gradually as all potential value is extracted. This provides a strong incentive for development. However, these benefits come at a cost, in that the development and activities themselves impact on the natural environment, hindering its capacity to deliver regulating services that support biodiversity. This is maximised when development and activity are kept to a minimum. There are a number of examples in South Africa where the rapid, largely unplanned and *ad hoc* expansion of coastal settlements (e.g. low-lying developments, land reclamation, roads, bridges, jetties, marinas and harbours) has had negative impacts on the overall health and functioning of estuarine systems. Since they are more difficult to quantify, many of the environmental costs associated with such developments remain unknown.

One example is the supporting function of inshore marine fisheries. It is estimated that almost half (42%) of the capacity of estuaries in South Africa to contribute to marine fishery stocks has been lost. While the nursery value of estuaries represents just 22% of the tangible estuary values estimated here, this proportion would be significantly higher if estuaries were in their natural condition. In this case, traditional line fishers and many lower income recreational fishers have suffered costs at the expense of developments that tend to benefit the wealthier sectors of society. Ecological degradation can have severe environmental, social and economic impacts. In some cases, this can be at least partly reversed through restoration. For example, much of the value of the St Lucia estuary is expected to be restored through a major investment to restore its freshwater inflows following a near-total collapse of the ecosystem and its benefits as a result of environmental mismanagement (Turpie *et al.* 2014). Rehabilitation is expected to lead to recovery of biodiversity and resource stocks, to the benefit of the tourism industry and the poor communities living around the iSimangaliso Wetland Park, as well as society as a whole.

Further studies are required to determine the optimal levels and configuration of development of estuaries at local to national scales that maximise the sum of their values to society. Current development trajectories, coupled with management of catchment inputs to estuaries, are degrading many estuaries and eroded many of their benefits. Future values are also being threatened by planned mining activities and infrastructure developments that will undermine the sense of place of many estuaries for which South Africa stood to derive large future tourism and livelihood benefits in a world where wilderness is becoming increasingly scarce. With better planning that incorporates adequate

zonation, conservation and wilderness areas, and increased investment in restoration, management and monitoring, benefits derived from estuary use could be further enhanced in a way that minimises the trade-offs involved in terms of the regulating and cultural services generated by estuaries and increases overall estuary value. This will require significant strengthening of conservation measures, as well as the active implementation of ecological water requirements and monitoring of estuary system and their benefits.



Langebaan Estuarine Lagoon © Peter Chadwick

3. A NEW ECOSYSTEM CLASSIFICATION FOR SOUTH AFRICAN ESTUARIES

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Ecosystem Classification

- Four Biogeographical regions: Cool Temperate, Warm Temperate, Subtropical and Tropical.
- Nine estuary categories (Estuarine Lake: Estuarine Bay, Estuarine Lagoon, Predominantly Open, Large Temporarily Closed, Small Temporarily Closed, Large Fluvially Dominated, Small Fluvially Dominated, Arid Predominantly Closed).
- 22 estuary ecosystem types and 9 micro-system types.
- 290 estuaries and 42 micro-estuaries.
- Anthropogenic pressures have altered critical estuarine lake processes to the extent that their functionality is changing thus reducing their benefits.

3.1 Introduction

Estuaries are difficult to classify because they vary temporally in shape and size, and also encompass a gradient in conditions from riverine to marine. Human interventions and morphological changes brought about by climate and sea level fluctuations further complicate the process. This paper recognizes an estuary as a partially enclosed permanent water body, either continuously or periodically open to the sea on decadal time scales and extending as far as the upper limit of tidal action, salinity penetration or back-flooding under closed mouth conditions. During high flows or floods an estuary can become a river mouth with no seawater entering the formerly estuarine area or, when there is little or no fluvial input, an estuary can be isolated from the sea by a sandbar and become fresh or even hypersaline (modified from Van Niekerk and Turpie 2012; CSIR 1992).

'Typology' refers to the characterisation of estuary types according to shared key features, whereas 'ecosystem classification' refers to the categorising of estuarine ecosystem types based on their abiotic constituents (e.g. climate, oceanic conditions, substrate, water, and all other non-living elements) and its biotic constituents, consisting of all its living members (Allee *et al.* 2000). Ecosystem classifications are complex, and often hierarchical or nested, whilst typologies tend to be more straightforward, based on general type. The level of classification depends mainly upon the number of criteria selected (e.g. biogeography, geomorphology and biology) and the spatial resolution required (e.g. local, regional or global) (Whitfield & Elliott 2011). The greater the number of criteria and the wider the geographical scope, the more complex the classification becomes. Depending on the task or information required, a balance needs to be established between the number of criteria and the level of detail selected (Whitfield & Elliott 2011)?

Reflecting the high diversity of estuarine types globally, numerous estuary typology and classification schemes exist. These are usually specific to a geographic region (Whitfield & Elliott 2011). Traditionally, estuaries have been typed based on key processes and features such as tidal range, tidal prism, topography, geomorphology, salinity characteristics and ecosystem energetics (Davies 1964; Nichols & Biggs 1985; Kennish 1986). Topographical typologies categorize them as drowned river valleys, fjords, bar-built estuaries and others (Prichard 1952b; Dyer 1997), while morphological typologies base groupings on physical features resulting from the interplay between catchment runoff and sediment loads, tides, waves and other coastal processes (Dalrymple *et al.* 1992). Salinity-based approaches separate them according to the degree of mixing within the water column (Pritchard 1955; Cameron & Prichard 1963) and stratification–circulation typologies using densimetric numbers from the fluid mechanics discipline (Hansen & Rattray 1966; Fischer 1966; Simpson *et al.* 1990). Most of these typologies require extensive in-field time-series and high spatial coverage data.

National or regional ecosystem-level classification schemes need to recognise environmental parameters often not strongly reflected in physical and morphology typologies, such as variations in climate or biogeography, vegetation and other biological aspects (see Whitfield & Elliott 2011 for the evolution of estuary classification). Examples include the comprehensive United States marine and estuarine ecosystem and habitat classification that moves from a biogeographical level to a habitat level at its smallest spatial scale for estuaries and the coast (Allee *et al.* 2000). Regional schemes that explicitly include temporarily closed estuaries, common on the South African coastline, are those of Australia and California. Early Australian schemes identified seven geomorphology-based estuary types across five biogeographical regions under the influence of wave, tide and river energy (Boyd *et al.* 1992; Dalrymple *et al.* 1992; Kench 1999). Linking these to climate and rainfall characteristics allowed for the incorporation of freshwater and evaporation-dominated types (Boyd *et al.* 1992; Heggie *et al.* 1999a, 1999b; Kench 1999). A more recent Australian classification described three intermittently open/closed estuary (IOCE) types based on the duration and frequency of estuary mouth condition and estuary size (large, medium or small) (McSweeney *et al.* 2017). A typology of Californian estuaries distinguished eight closed-mouth states based on berm elevation and tidal exchange where river inflow rather than tidal influence controls mouth opening. This scheme recognised that mouth states prevail over multi-year to multi-decadal time frames (Jacobs *et al.* 2010). Over the past six decades estuary classification studies have thus evolved from relatively simple ‘typology’ schemes (defining estuary types based on a key process or feature), to more complex regional ecosystem-level classification schemes (regional schemes that include elements of climatic/biogeography, estuarine processes, biological responses).

The choice of classification system depends to some extent on its intended purpose. Ecosystem-level classification schemes have a wide range of potential application in research and natural resource management. National and sub-regional ecosystem classifications are useful because they can be applied to the IUCN Red List of Ecosystems (RLE) framework to assess risks and identify vulnerable ecosystems based on a set of criteria and thresholds (Rodríguez *et al.* 2011; Keith *et al.* 2013, 2015; Bland *et al.* 2017a, 2017b; 2018). The RLE requires clearly defined units of assessment (ecosystem types) that can be spatially delineated (Keith *et al.* 2013a). Ecosystem classification is therefore one of the fundamental inputs for such global assessment processes.

South African national-level biodiversity assessments, and national and regional conservations plans also need ecosystem-level classification that details similarities and differences between estuary types and describes their biogeographical occurrence (Turpie & Clark 2007; Van Niekerk *et al.* 2012; Turpie *et al.* 2012). Classification is fundamental to estuary conservation planning to pinpoint important biodiversity areas and initiate the setting of targets for species, habitats and types to ensure that all species and the critical processes they depend on are conserved (Turpie *et al.* 2012; Turpie & Clark 2009). It is also essential for determining estuary flow requirements and water resource allocations where estuary type serves as an indicator of sensitivity to flow modification and declining water quality (Van Niekerk *et al.* 2019a, 2019b). In a data-limited environment such as South Africa, classifications can be used to signify system-specific ecosystem processes and associated biotic characteristics.

The aim of this chapter was to develop an ecosystem-level national classification scheme for South African estuaries that incorporates key processes and patterns in different biogeographic regions and can inform broad-scale assessments of estuary resilience to anthropogenic pressures.

3.2 Approach

A detailed literature review of globally (see Introduction) and locally used estuary typologies was conducted to identify key parameters that support estuary classification at the ecosystem-level. Parameters used most often in estuary typologies included estuary size and geomorphology, catchment features (size and geology), flow and tidal regimes, marine connectivity (mouth state or inlet stability), sediment processes, salinity structure, habitat diversity and biotic composition. In addition, common to most national or global ecosystem-level, classification schemes were biogeographical, ocean processes (wave energy), or climatic elements.

Developing an estuarine ecosystem-level classification scheme for South Africa required a number of steps which involved:

- Revisiting the biogeographic organisation of South African estuaries to ensure that all climatic and oceanic processes are accurately reflected based on emerging research;
- Evaluating exiting typologies and revising, if needed, the high diversity of estuarine processes and responses that occur on the subcontinent; and
- The inclusion and organisation of previously neglected very small outlet types that do not fully function as estuaries, collectively referred to here as micro-systems.

A functional estuarine system, even if very small (>2ha or >200 m in length), was taken as any permanent coastal water body that supports significant estuarine processes or biological activity.

A significant effort was made to ensure all rivers and streams with outlets to the sea were identified and to address systems omitted from historical lists. Datasets consulted included the CSIR NRIO list (1981) and those of Harrison *et al.* (2000), Van Niekerk & Turpie (2012), Whitfield & Baliwe (2013) and

Bate *et al.* (2016). Micro-system types, previously omitted from formal classification schemes, were also identified through the literature and using satellite imagery (Google Earth TM) and aerial photographs from the 1930s to 2000s. Where possible, a distinction was made between natural outlets and artificially created storm water outlets (with the latter ground-truthed by site visits), with a focus on only including naturally occurring features in the landscape. Seven coastal outlets, not previously listed as estuaries, were deemed to be functional estuarine systems based on size, topography and vegetation cover and added to the formal list of estuaries. All larger outlets (> 200 m) were delineated based on the 5m topographical contour (obtained from Department of Rural Development and Land Reform: National Geo-spatial Information) to determine how far they extend inland (Van Niekerk *et al.* 2019; Harris *et al.* 2019). Existing national and bioregional datasets were then scrutinised to establish what information was available on estuary physical features and processes (e.g. size, mean annual runoff, mouth state) and biotic components (plants, invertebrates, fish and birds) to assist with classification (Harrison *et al.* 2000; Van Niekerk & Turpie 2012; Van Niekerk *et al.* 2015; Van Niekerk *et al.* 2019).

Using the collated information, all functional estuaries were evaluated by a panel of national experts in 2009 and again in 2018 (see author list), each expert having between 10 and 35 years' experience in estuarine physical processes, vegetation, invertebrates and / or fish (Van Niekerk *et al.* 2013). The specialists assessed each dataset to identify estuary types that support key ecosystem processes and functions across biotic groups. While published information was given preference, the panel also drew on the authors unpublished field data and personal field observations. The outcome was cross-validated by consulting historical data sources and published literature. Data and field observations were often lacking for very small estuaries and outlets and classification for these systems relied on visual observations and expert judgements. Usually the panel participant's consensus view on a system's classification was adopted, with the few exceptions being resolved by a majority vote.

3.3 Defining the ecosystem types

3.4 South Africa's estuarine ecosystem-level classification

At present, there are a number of typologies or classification systems recognised for estuaries in South Africa, largely based on geomorphological and/or physical characteristics. Early attempts described estuary types fairly loosely and with little scientific backing, e.g. temporarily closed estuaries were referred to as 'lagoons' (Begg 1978), 'blind estuaries' (Day 1981) or 'seasonally open/closed' estuaries (Bennett 1989). Whitfield (1992) typed South Africa's estuaries into five types based on their physiographic (tidal prism, size), hydrographic (mouth state and mixing process) and salinity characteristics (Table 3). A geomorphological system used by Harrison *et al.* (2000) recognised six main types based on mouth condition (open or closed), size and the presence of a sand bar at the mouth (or inlet). More recently, the NBA 2011 assessment (Van Niekerk & Turpie 2012) proposed a typing based on estuary size, mouth state, salinity structure and catchment type. This resulted in 46

ecosystem types which included three estuary size classes (large >100 ha, medium 100 – 10ha and small <10 ha).

Whitfield's (1992) typology of estuaries has been most widely used to describe the estuaries on the subcontinent (Table 3). Most estuaries were classed as temporarily open/closed systems where connection to the sea is governed by a sand bar that builds across the mouth under conditions of low river flow and high wave conditions. Floods cause the mouth to re-open by scouring large volumes of sediment to sea. Permanently open estuary types are controlled by marine and riverine processes that act together to maintain an open mouth. Estuaries categorised as river mouths are dominated by riverine processes because strong outflow inhibits marine intrusion into the mouth area, allowing oligohaline conditions to persist, especially in the upper and middle reaches. Heavy silt loads are a common feature, resulting in shallow estuaries and ebb tidal deltas. Estuarine Bays and Lakes, the two remaining categories, are large open water systems uncommonly represented along the coast. The bays are permanently linked to the sea by deep mouths and have euhaline salinities in the lower and middle reaches whereas the lakes are usually drowned coastal systems filled by reworked sediments and separated from the sea by vegetated sand dunes. Estuarine Lakes can be either permanently or temporarily linked to the sea.

However, Whitfield's (1992) scheme omitted a large number of small estuaries and micro-outlets from its original characterisation. The scheme also primarily covered functional estuary types and ignored regional biogeography. Atypical estuary types, such as coastal lagoons where a river or stream is absent and groundwater provides only a limited freshwater signal, were also not represented. The scheme showed a bias towards estuaries important to fish, and thus largely ignored the small, hypersaline systems along the west coast, which have few fish but are important for plants and birds. Nearly 75% of all estuaries were classified as temporarily open/closed systems, and did not recognize the differences between the more habitat diverse/species-rich larger systems, and the relatively depauperate smaller examples of this type. Finally, the river mouth type encapsulated a diversity of fluvially-dominated estuary types ranging from those being fed by large, sediment rich catchments to clear, smaller catchment, black-water systems with very limited suspended sediments.

Table 3. Whitfield's (1992) typology of South Africa's estuaries.

TYPE	TIDAL PRISM	MIXING PROCESS	AVERAGE SALINITY *
Estuarine Bay	Large ($>10 \times 10^6 \text{ m}^3$)	Tidal	20 – 35
Permanently Open	Moderate ($1-10 \times 10^6 \text{ m}^3$)	Tidal/Riverine	10 - >35
River Mouth	Small ($<1 \times 10^6 \text{ m}^3$)	Riverine	<10
Estuarine Lake	Negligible ($<0.1 \times 10^6 \text{ m}^3$)	Wind	1 - > 35
Temporarily Open / Closed estuaries	Absent	Wind	1 - > 35

* Expressed without units due to the fact that salinity is a ratio or according to a Practical Salinity Scale (seawater ~35).

The above limitations of the Whitfield (1992) estuarine classification necessitated the development of an expanded ecosystem-level classification scheme for South Africa's estuaries, while at the same time allowing for 'crosswalking' of historical studies and assessment. Developing a more comprehensive ecosystem-level classification scheme required three interlinked steps: 1) the formal biogeographic organisation of South African estuaries to reflect regional biotic responses; 2) the refinement of estuary types to reflect the high diversity of small and large estuary types that occur in South Africa; and 3) the inclusion and organisation of previously neglected micro-system types.

3.4.1 A new tropical biogeographic zone

The traditional biogeographic organisation of South African estuaries has included only three regions, viz. subtropical, warm-temperate and cool-temperate (Emanuel *et al.* 1992; Harrison 2002; Turpie *et al.* 2000). However, the tropical distribution of some species recorded in the Kosi and uMgobezeleni estuaries in the north, provides good motivation to subdivide the subtropical region and include a tropical transition zone in the north-east of South Africa. Both of these systems, albeit differing in size, type and function, are unique clear water estuaries on a small section of South African coast, the location also being the higher latitudinal limit of Western Indian Ocean coral reefs (Schleyer *et al.* 2008).

The Kosi Estuary has a uniquely tropical flora amongst South Africa estuaries indicated by presence of the seagrass (*Halodule univervis*) and mangrove species *Lumnitzera racemosa*, *Ceriops tagal* and *Xylocarpus granatum* that are found in no other South African systems (DWS 2016). Recent records of tropical species such as the Snake Sea Cucumber (*Synapta maculate*) and Pen Shell (*Pinna muricata*) (associated with *H. univervis*), in the Kosi Estuary point to a tropical influence on the system's invertebrate fauna (DWS 2016). The *Kosi ichthyofaunal* comprises a particularly wide diversity of fishes, including tropical species not reported from any other South African estuaries (Blaber & Cyrus 1981; DWS 2016). Although the presence of reef habitat at the mouth contributes to this, biogeographic considerations also play a role. Elements of the estuary-associated fish fauna in Kosi appear to reflect the unique (in a South African context) linkages between estuarine habitats, particularly clear water mangroves, and offshore coral reefs. This is evidenced by the abundance and large sizes of several members of the Lutjanidae (snappers) in the Kosi system. This family of fishes includes many species that rely on linkages and strong connectivity between mangroves and coral reef habitats on tropical coastlines elsewhere in the world (e.g. Nagelkerken *et al.* 2000, 2002; Mumby *et al.* 2004).

To the south, St Lucia Estuary supports invertebrate communities common in subtropical estuaries (MacKay *et al.* 2010). The new zone aligns with marine biogeographic patterns evident for floral and faunal groups such as benthic macroalgae (Bolton *et al.* 2004), intertidal invertebrates and microalgae (Sink *et al.* 2005), shelf holothuroideans (Thandar 2015) and agrees with the recent marine biogeographic map that includes the Natal-Delagoa tropical region (Sink *et al.* 2019).

Thus, the updated ecosystem-level classification scheme defined the biogeographical regions as the tropical from Kosi to uMgobezeleni, the subtropical stretches from the St Lucia in KwaZulu-Natal to

the Mbashe Estuary in the Eastern Cape, the warm-temperate from the Mendwana Estuary in the Eastern Cape to the Ratel Estuary near Cape Agulhas, and the cool-temperate from the Uilkraals Estuary to the Orange Estuary on the Northern Cape coast (Emanuel *et al.* 1992; Harrison 2002; Turpie *et al.* 2000).

3.4.2 Revision of South Africa's estuarine types

Improved scientific understanding has resulted in necessary updates to Whitfield's (1992) classification. Adding two new estuary types; Estuarine Lagoon and Arid Predominantly Closed estuaries. Langebaan is an example of an Estuarine Lagoon, while the Buffels, Swartlintjies and Spoeg estuaries in the same region are examples of Arid Predominantly Closed estuaries (Figure 5 and Figure 6, Appendix A). Whitfield's 'river mouth' category was renamed 'Fluvially Dominated' and divided into large and small systems and according to river sediment inputs. The Temporarily Open/Closed Group was also divided by size into Large and Small Temporarily Closed estuaries. The new types are further described in Table 4 and Figure 5, with key features and dominant physical processes that characterise these revised South African estuary types summarised in Table 5. The listing and designation of all systems is provided in Annexure A. Localities around the coast are shown Figure 6.

Table 4. Revision of Whitfield's 1992 estuarine classification system.

1992 CLASSIFICATION	2018 CLASSIFICATION
Estuarine Lake	Estuarine Lake
Estuarine Bay	Estuarine Bay
-	Estuarine Lagoon
Permanently open	Predominantly Open
Temporarily open / closed	Large Temporarily Closed
	Small Temporarily Closed
River mouth	Large Fluvially Dominated
	Small Fluvially Dominated
-	Arid Predominantly Closed

Estuarine Lakes

Estuarine Lakes comprise one or more typically large circular water bodies connected to the sea by a constricted inlet channel (Table 5). Maximum water levels are determined by berm height, mouth state and freshwater input. Marine connectivity varies from almost permanently open to closed on annual scales. Salinities are highly variable, ranging from fresh to hypersaline because of differing freshwater input (surface and ground water), evaporation and the extent of the marine connection. Mixing processes are dominated by wind and, to a lesser extent fluvial inputs, owing to their restricted mouths and relatively large surface areas. Average tidal amplitudes are negligible (15 – 20 cm) when connected to the sea, primarily due to restricted mouth conditions. Sediment processes tend to be stable, with infilling occurring over long time scales and resetting confined to larger flood events.

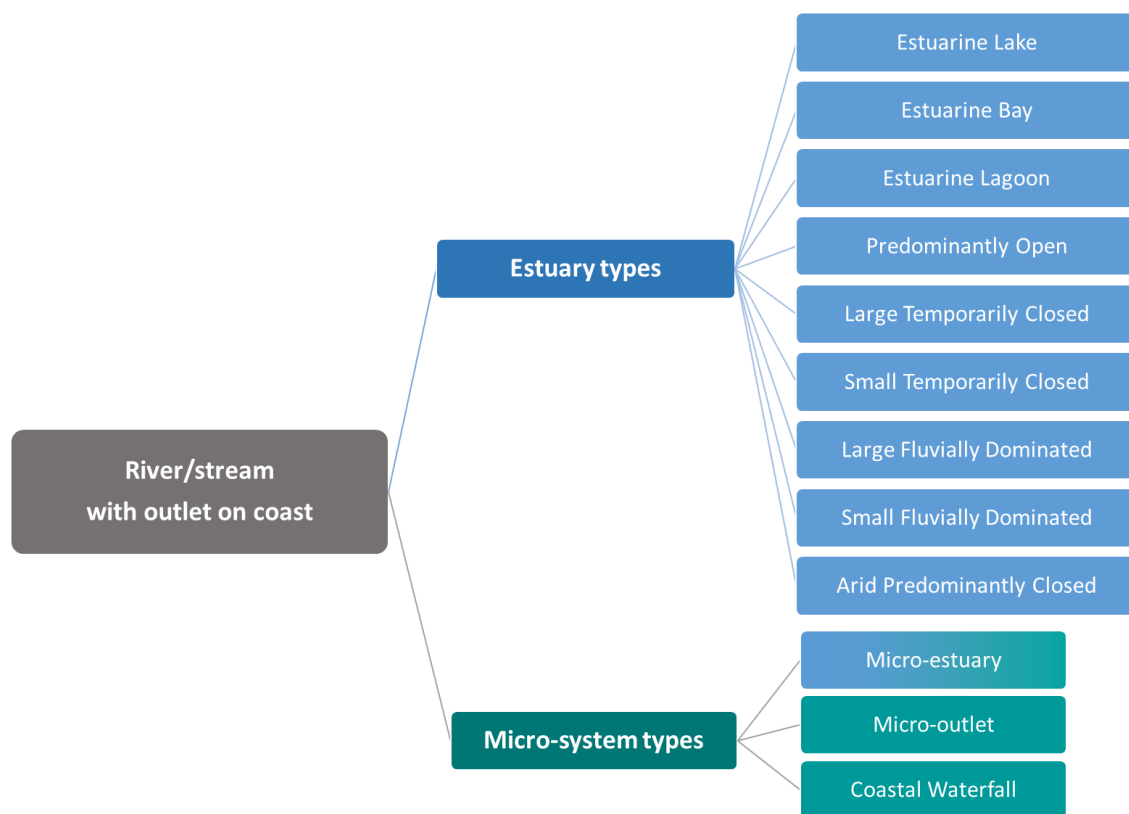


Figure 5. The extended typology of South African into nine estuary types and three micro-system types.

Estuarine Bays

Estuarine Bays are permanently linked to the sea by unrestricted, deep mouths and are dominated by tidal processes, with tidal amplitudes close to those of the sea (Table 5). These are large systems (>1200 ha) with generally round basins where only the upper reaches experience a degree of constriction to tidal flows. As a result of relatively low river inputs they have a predominantly euhaline salinity regime in the lower and mid reaches, with freshwater mixing processes being mostly confined to the restricted upper areas. Sediments are typically marine in origin and grain size distributions are stable. There are two natural occurrences of Estuarine Bays in South Africa (viz. Knysna and Durban Bay (Figure 6).

Estuarine Lagoons

Langebaan Lagoon has many of the characteristics of an estuary (Whitfield 2005), including calm waters that are protected from marine wave action and biota that reflect many of the species usually found in estuaries (Table 5, Figure 6). However, despite groundwater seeps into some areas, it lacks riverine inflow and a normal estuarine salinity gradient (Table 5).

Table 5. Revised South African estuary types, key features and dominant physical processes.

ESTUARINE TYPE	ESTUARINE AREA (HA)	% TIME OPEN TO THE SEA	GEO-MORPHOLOGY	AVERAGE TIDAL RANGE (M) [#]	MAXIMUM WATER LEVEL DETERMINED BY:	TYPICAL SALINITY RANGE	MIXING PROCESS	SEDIMENT STABILITY	MEAN ANNUAL RUNOFF (x 10 ⁶ M ³)
Estuarine Lake	>800	Variable	Circular with constricted inlet channel	0.1- 0.15	Mouth State	0 - 35	Wind/ riverine	Stable	20 - 650*
Estuarine Bay	> 1 000	100	Circular with unrestricted inlet	1.5 - 2.0	Tides	30 - 35 Average: 35	Tidal	Stable	40 - 80
Estuarine Lagoon	> 1 000	100	Circular with unrestricted inlet	1.5 - 2.0	Tides	35 - 36 Average: 35	Tidal	Stable	0*
Predominantly Open	10 – 7 500	90 - 100	Linear with restricted inlet	0.75 - 1.5	Tides/ Mouth State	0 - 40	Tidal/riverine	Mobile (reset by large floods)	10 – 1 790
Large Temporarily Closed	>15	>50	Linear /funnel with highly restricted inlet	0.25 - 0.5	Mouth State	0 - 60	Tidal/ riverine/ wind/seepage	Mobile (breaching and floods)	1 - 280
Small Temporarily Closed	<15	<50	Linear/funnel with highly unrestricted inlet	0.15 - 0.3	Mouth State	0 - 30	Riverine/ wind/seepage	Mobile (breaching and floods)	0.1 - 70
Large Fluvially Dominated	100 - 3 700	>90	Linear with highly restricted inlet	0.5 - 1.0	Mouth State	0 - 10	Riverine	Highly mobile (reset annually)	370 – 10 830
Small Fluvially Dominated	< 15	100	Linear with highly restricted inlet	0.5 - 1.5	Mouth State	0 - 5	Riverine	Highly mobile (reset annually)	20 - 50
Arid Predominantly Closed	10 - 500	<5	Linear/funnel with highly restricted inlet	0 (overwash & breaching)	Mouth State	0 - 200 Average: Hypersaline	Evaporation/ seepage/wind	Stable, but reset on decadal-scales during floods	0.2 - 10

*Langebaan (Estuarine Lagoon), uMgobezeleni and Kosi (Estuarine Lakes) are groundwater dependent systems. [#]Tidal ranges are indicative of what is normally experienced, but some deviations are expected, e.g. after breaching or post-floods.

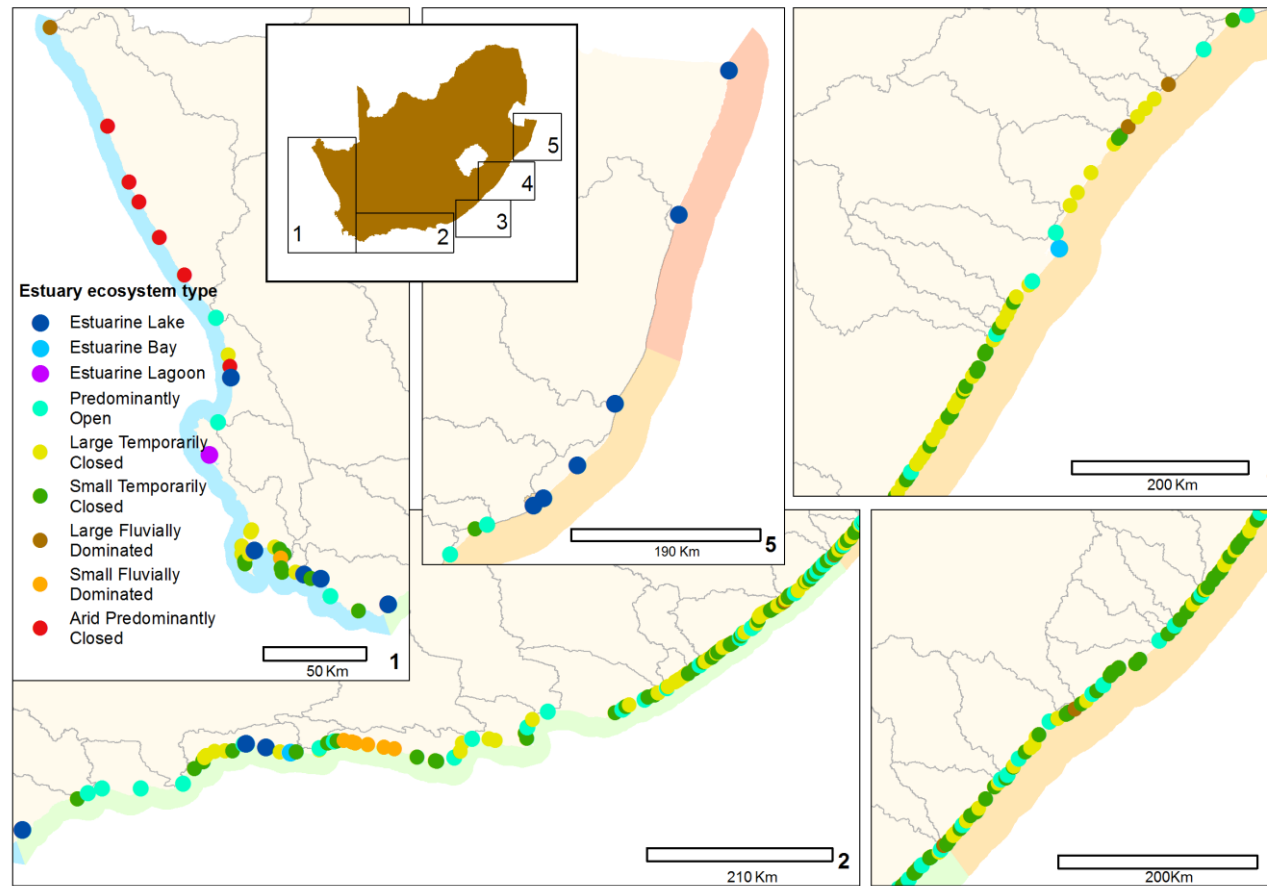


Figure 6. Estuary distribution across four biogeographical regions in accordance with the Estuarine Classification System shown in maps 1 to 5 (Cool Temperate region depicted in light blue (1), Warm Temperate region depicted in light green (2), Subtropical region depicted in orange (3 & 4), Tropical region depicted in red (5)).

Langebaan Lagoon represents a unique coastal ecosystem type (Table 6) and is recognised as an estuary because its ecological functioning includes both freshwater and marine inputs into a semi-enclosed embayment. Estuarine Lagoons, as defined here, are permanently connected to the sea and are therefore marine dominated. Tidal action is the dominant mixing process and sedimentary processes are thus generally stable. Tidal amplitude and water levels are close to those of the sea.

Predominantly Open Estuaries

These estuaries are open to the sea for more than 90% of the time (similar to Whitfield 1992). Some are permanently open owing to perennial river flows or the presence of large tidal prisms (Table 5). Tidal amplitude ranges from 0.75-1.5 m. Predominantly Open estuaries are linear systems in which mixing processes are dominated by both fluvial inputs and tidal action creating vertical and horizontal salinity gradients. Under low flows, hypersalinity can develop in the upper reaches. The degree to which the mouth is restricted depends on the rate and volume of freshwater inflow. Some systems become severely constricted during low flow periods, decreasing the tidal amplitude and increasing the duration of the ebb tidal cycle. Regular flooding results in relatively mobile sediments. These estuaries usually support wetlands, salt marshes, macrophyte beds and marine and estuarine fauna (Whitfield 1992). Surprisingly, their size varies considerably ranging from 10 to 7 500ha, with smaller systems afforded a degree of protection against direct wave action by rocky headlands or subtidal reefs, which assists in maintaining an open mouth.

Large and Small Temporarily Closed Estuaries

The sizeable temporarily open/closed category of Whitfield (1992) was divided into Small and Large Temporarily Closed estuaries using a total habitat area of 15ha (associated with ~10ha of open water area) as the dividing threshold (Table 5 and 6). The division was based on differences in biophysical processes and patterns. Small systems are likely to experience rapid increases and decreases freshwater runoff over a few hours making them strongly event driven. There will be little scouring during breachings, and a semi-closed mouth condition can easily develop owing to a small, perched, outflow channel that restricts tidal amplitude to 10 to 15cm. There is minimal water column area during the open state. Habitat diversity is likely to be low (and without intertidal salt marshes) and species diversity and abundance reduced. Significant differences have been noted between fish assemblages of Small and Large Temporarily Closed estuaries along the southeast coast (e.g. Vorwerk *et al.* 2003; James & Harrison 2017).

Both large and small systems tend to be linear or funnel shaped with highly restricted inlets. Smaller systems especially tend to be 'perched' above normal tidal levels, resulting in little to no open water area during the open mouth low tide state. Water levels are dominated by the state of the mouth, with highest levels of 1 m to 2 m above mean sea level during the closed phase. Tidal ranges are very restricted, varying from 25-50 cm in Large Temporarily Closed estuaries to 15-30 cm in Small Temporarily Closed estuaries. Open phase mixing processes are dominated by fluvial input and partially by tides. When closed, wind and seepage losses through the berm play a key role. Sediment composition is largely stable, resetting mainly during floods. Salinity regimes range from almost fresh to hypersaline, which in large systems can develop during times of low flow or droughts. Small

Temporarily Closed estuaries tend to be fresher in character as they have less connectivity with the sea.

Small and Large Fluvially Dominated Estuaries

Estuaries characterised as river mouths by Whitfield (1992) were divided into two categories, Small and Large Fluvially Dominated systems to distinguish between small (<15 ha), black water dominated, rocky temperate southern coast estuaries, and large, shallow, sediment rich, freshwater dominated systems of the east and west coasts (Table 5 and 6). The larger systems have very high sediment turnover, often develop ebb-tidal deltas, are turbid and can close during periods of low flow, e.g. uThukela and Orange estuaries (Figure 6). Small, sediment-starved, fluvially-dominated systems have unrestricted mouths as they usually occur along rocky shores and receive clear humic-stained water from Table Mountain Sandstone catchments. Large Fluvially Dominated estuaries tend to be constricted and can even periodically close during low flows. Fluvial processes are dominant and salinities are mostly fresh throughout the estuary for more than half the time. During peak flood conditions, outflows can influence salinities for considerable distances offshore.

Arid Predominantly Closed Estuaries

This type comprises six small estuaries (Buffels, Swartlintjies, Spoeg, Groen, Sout (Noord) and Wadrift) located in the Namaqua west coast region (Figure 6, Appendix A). They are linear or funnel shaped and closed on annual to decadal scales. Salinities tend to be high to hypersaline (>35) as a result of low fluvial input and high evaporation rates (Table 5). Thus, mixing processes tend to occur over long time periods and are dominated by the effects of evaporation, winds and seepage. Occasional breaching and over-washing during high sea conditions provide for marine input and connectivity. Sediment processes are generally stable on decadal time scales and are reset by large intermittent flash floods. Water levels are determined by the interplay between sand berm level, evaporation rates and seepage losses. Groundwater and inflows from local fountains replenish these losses and influence the salinity regimes of these estuaries.

Arid conditions promote the growth of unique vegetation such as salt tolerant, succulent *Sarcocornia* spp. and *Salicornia* spp. that can occur kilometers inland making it difficult to distinguish between arid estuarine salt marsh vegetation and upstream Namaqualand riverine vegetation. These vegetated areas can be stable despite open water salinities reaching above 200 (Wooldridge *et al.* 2016). Fish diversity, abundance and community structure relies on 'suicidal' recruitment that is largely a function of connectivity with the sea and the degree of overwash during high seas. Fish survival depends mostly on groundwater inflow maintaining a salinity gradient and at least some areas with hypersalinity not exceeding 40. Safe return to the sea is usually during flood events and depends on a quick breach and fish not suffocating in sediment-laden water backing up against the berm. Invertebrate diversity, abundance and community structure are related to changing salinity gradients including long cycles of hypersalinity. The Swartlintjies, Sout and Groen are hypersaline with a high biomass of brine Shrimp *Artemia* sp. that hatch at salinities above 40 and encyst sinking to the bottom when salinities exceed 150. Cycles of *Artemia* abundance follow salinity regimes that in turn affect the diversity, abundance and occurrence of flamingos and other birds that feed on them.

3.4.3 Micro-system types

There are approximately 400 river and stream outlets along the coastline. They were categorised into two broad categories: fully functional estuaries and micro-systems (Figure 7), with micro-systems generally being permanent or non-permanent coastal water bodies smaller than 2ha in area or less than 200m in length (Appendix A). Historical datasets contain information on outlets not deemed to be functional estuaries (Harrison *et al.* 2000).

Nine small systems previously classified as estuaries were reclassified as micro-systems under the new classification (Table 7) as there are clear indications that they do not support typical estuarine functionality, e.g. the system has limited estuarine biota, with limited or no fish fauna recorded over a number of visits (Magoro 2018). Micro-systems were classified into three categories based on spatial features and field biotic observations:

Micro-estuaries

These are defined as small, permanent coastal water bodies in which mixing of salt and freshwater can periodically occur owing to overwash from the sea or breaching of the mouth. These small systems are likely to support low densities of a limited number of estuarine and marine species.

Micro-outlets

These are very small water bodies (<1ha in area or <50m in length) that are ephemeral in nature (i.e. they can dry out during periods of low flow) or are elevated above mean sea level with a perched outflow channel that does not facilitate mixing of salt and freshwater. It can however act as a limited conduit between the land and the sea during periods of elevated stream outflow.

Coastal waterfalls

This outlet type is represented by water bodies elevated more than 10 m above mean sea level that have no direct channel connection with the sea. Due to their elevation, they do not serve as conduits between the land and the sea. However, the continuous outflow of freshwater into rocky coastal habitats may support unique marine biotic assemblages along the coast.

The localities of designated micro-estuaries, coastal outlets/seeps and coastal waterfalls are shown in Figure 7, including distributions across the revised biogeographical regions. Listing and designation of all systems is provided in Annexure A.

3.4.1 Ecosystem level classification

The final step in the ecosystem classification of South Africa's 290 estuaries is to intersect the four biogeographical zones, namely the Cool Temperate (Orange to Ratel), the Warm Temperate (Heuningnes to Mendwana), the Subtropical (Mbashe to St Lucia) and the Tropical (uMgobezeleni to Kosi) with the nine primary estuary types. This resulted in 22 estuary ecosystem categories for South Africa (Table 6). This represents a high diversity of estuary ecosystem types, which is not unexpected considering the country's diverse climatic, oceanographic and geological drivers.

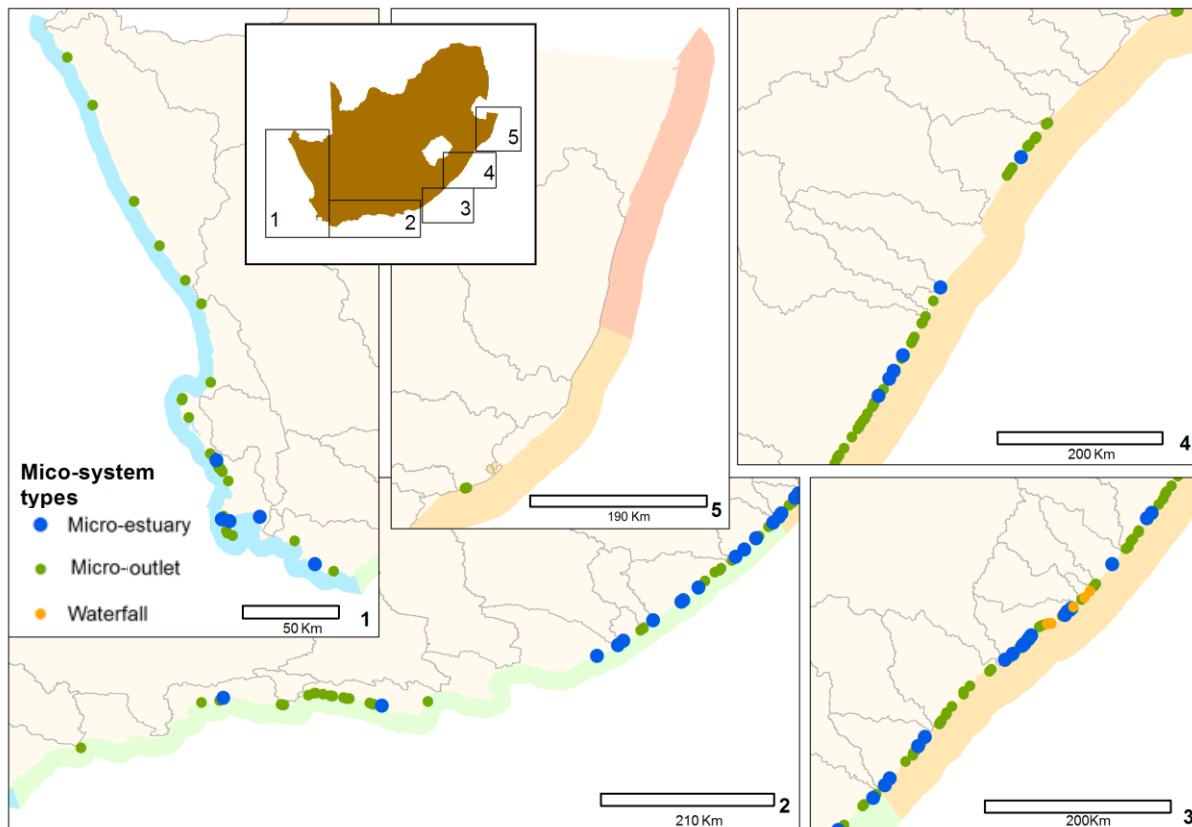


Figure 7. Map of the location and biogeographical distribution of micro-systems (< 2ha or 200 m in length) depicted in maps 1 to 5 (Cool Temperate (1), Warm Temperate (2), Subtropical (3 &4), Tropical (5)).

Overall the Tropical biogeographical region has the least number of estuaries, while the Subtropical (130) and Warm Temperate (124) regions incorporate the highest number of estuaries.

Estuarine Lagoons are the rarest South African estuary type with only one member in the Cool Temperate region, followed by Estuarine Bays with two in the Subtropical and one in the Warm Temperate region, and Arid Predominantly Closed estuaries with six systems confined to the Cool Temperate region. The Large and Small Fluvially Dominated primary type have seven systems each, occurring in three and two biogeographical regions respectively.

The most numerically dominate types are the Small Temporarily Closed (116), Large Temporarily Closed (94), and Predominantly Open (44) that occur across the Cool Temperate, Warm Temperate and Subtropical biogeographical regions. Estuarine Lakes occur in all four biogeographical zones, and while not numerically common, represent the largest surface area of all estuarine types, with Lake St Lucia representing more than half of South Africa's estuarine surface area.

Table 6. Number of estuaries in each type across four biogeographical regions and classified into 22 estuary ecosystem types.

ESTUARY TYPE	BIOGEOGRAPHICAL REGIONS				# ESTUARIES IN TYPE	# ESTUARIES IN ECOSYSTEM TYPES
	Cool Temperate	Warm Temperate	Subtropical	Tropical		
Estuarine Lake	4	3	3	2	12	4
Estuarine Bay		1	1		2	2
Estuarine Lagoon	1				1	1
Predominantly Open	3	25	16		44	3
Large Temporarily Closed	9	40	45		94	3
Small Temporarily Closed	8	48	60		116	3
Large Fluvially Dominated	1	1	5		7	3
Small Fluvially Dominated	1	6			7	2
Arid Predominantly Closed	6				6	1
Total	33	124	130 (131)*	2	289 (290)*	22

From an ecosystem type perspective Cool Temperate Estuarine Lagoons, Cool Temperate Large and Small Fluvially Dominated estuaries, Warm Temperate Estuarine Bays, Warm Temperate Large Fluvially Dominated estuaries, and Subtropical Bays are the rarest types as they each have only one member. Overall, the Subtropical and Warm Temperate Small Temporarily Closed estuary types dominate numerically with 60 and 48 members respectively.

Table 7. Number of estuaries in each micro-system type across four biogeographical regions and classified into 9 micro-system ecosystem types.

MICRO-SYSTEM TYPE	COOL TEMPERATE	WARM TEMPERATE	SUBTROPICAL	TROPICAL	# ESTUARIES IN TYPE	# ECOSYSTEM TYPES
Micro-estuary	5	13	24		42	3
Micro-outlet	26	31	96		153	3
Waterfall outlet			7		7	3
Total	31	44	127		202	9

An additional 202 micro-systems were also allocated to a micro-system ecosystem type, albeit with a very low confidence due to lack of data (Table 7). Of these, only 42 micro-estuaries occurring in the Cool Temperate (5 systems), Warm Temperate (13 systems) and Subtropical (24 systems) biogeographical regions was highlighted in need of further research and assessment. Micro-outlets

and waterfalls were only identified in so far as that they act as a potential conduit for land-sea interactions and should not be targeted for coastal and water resource development to preserve estuarine ecosystem services.

3.5 Estuaries subjected to functional type shifts and causative factors

Estuaries and coastal ecosystems are facing increasing anthropogenic pressures impacting their productivity and ability to provide ecosystem services (Borja *et al.* 2016). The main pressures impacting South African estuaries include flow modification, catchment degradation, coastal development, pollution, exploitation of living and non-living resources, and mouth (inlet) manipulation (Van Niekerk *et al.* 2013). These have altered key defining features or processes (i.e. mouth behaviour, water level fluctuations, mixing processes) in some estuaries to the extent that they no longer function in accordance with their natural type (see Table 8 for summary of estuaries that were subjected to functional shifts).

Type shifts should not be confused with degraded estuaries that still function in a similar way to natural, e.g. iSiphingo Estuary is severely degraded (i.e. undergone a condition shift) as a result of pollution and habitat loss but still maintains its function as a Predominantly Open estuary through a concrete pipe constructed in the sand berm at the mouth.

Estuarine Lakes

The Zeekoei, Heuninges, Richards Bay and iNhlabane systems were once Estuarine Lakes that have all been irreversibly altered through mouth manipulation and development (Table 8). The Zeekoei lake system naturally closed for long periods until the 1940s when the connection between the lakes and main estuary channel was severed by weirs and levees that were constructed to prevent flooding of surrounding urbanised areas whilst maintaining high water levels in the main water bodies. A concrete canal currently connects the lake system to the sea. Although there is no tidal exchange, the system is essentially permanently open but no longer functions as an Estuarine Lake.

Development and agriculture on the Heuningnes Estuary floodplain have contributed to the system's function changing from an Estuarine Lake, that closed periodically, into a Permanently Open Estuary. Over a century ago drains were excavated throughout the floodplain and adjacent wetlands to 'reclaim' land for grazing and dry land agriculture. Since the 1940s sand dunes at the mouth have been manipulated to prevent mouth closure and natural inundation of the estuarine floodplain, much of which is now under farmland. Subsequently, the mouth has closed on only a few occasions. Artificial breaching is then practised to ensure an open mouth. The topography and paleolimnology suggest that in its natural state the estuary would have supported a large open water area that would develop over several years under closed mouth conditions, followed by natural breaching after river flooding and significant sediment scour in the lower reaches.

Table 8. Estuaries where functional type shifts have occurred.

ESTUARY NAME	NATURAL TYPE	FUNCTIONAL TYPE	DRIVER OF CHANGE	COMPROMISED ESTUARINE PROCESSES THAT DEFINED NATURAL ESTUARY TYPE					
				Mouth closure	High water levels	Tidal regime	Salinity gradient	Mixing process	Connectivity (i.e. Floodplain, lakes, catchment)
Zeekoei	Estuarine Lake	Predominantly Open (Canalise)	Mouth manipulation, development	●	●	●	●	●	●
Heuningnes		Predominantly Open	Mouth manipulation, development	●	●		●	●	●
uMhlathuze / Richards Bay		Predominantly Open / Estuarine Bay	Mouth manipulation, development			●	●	●	●
iNhlabane		Small Temporarily Closed	Development, impoundment	●	●	●	●	●	●
Uilkraals	Predominantly Open	Large Temporarily Closed	Flow modification (-)			●	●	●	●
Eerste	Large Temporarily Closed	Predominantly Open	Flow modification (+)	●	●	●	●	●	●
Silvermyn		Small Temporarily Closed	Mouth manipulation, development		●	●	●	●	●
Sout (wes)	Small Temporarily Closed	Predominantly Open (canalise)	Mouth manipulation, development	●	●	●	●	●	●
Baakens		Predominantly Open (canalise)	Development	●	●	●	●	●	●
Papenkuils		Predominantly Open (canalise)	Development	●	●	●	●	●	●

uMhlathuze in its pristine state was an Estuarine Lake that once connected a network of coastal marine lakes to the sea (Weerts *et al.* 2014). The development of a deep-water harbour at Richards Bay in the 1970s and the construction of a 4 km long berm wall divided the lake into a northern harbour section and a southern estuarine sanctuary. The uMhlathuze River to the west was canalised and diverted into the sanctuary and a new marine outlet created by dredging through the coastal berm 5 km south of the natural outlet (Weerts & Cyrus 2002).

The new intertidal habitat and delta of the sanctuary was rapidly colonised by the White Mangrove (*Avicennia marina*) and currently constitutes the largest mangrove habitat in South Africa (Bedin 2001; Adams *et al.* 2016). Invertebrate estuarine communities have become species-rich from increased marine exposure but have lost signature endemic species such as the burrowing Ocypodid Crab (*Paratyloplitax blephariskios*) (MacKay & Cyrus 1998). Currently Richards Bay and uMhlathuze function as an Estuarine Bay and a Predominantly Open system respectively (Appendix A).

TEXT BOX 1: HABITAT LOST AND HABITAT GAINED. DEVELOPMENT DRIVES ESTUARY TYPE CHANGE - THE CASE OF RICHARDS BAY

Pre-development, Richards Bay Estuary was a large (3 100 ha) estuarine lake comprising two main parts; a broad shallow lake (“Umhlathuze Lake”) and a narrow channel to the sea (Millard and Harrison 1954) (Figure 1). The naturally narrow and shallow mouth constrained tidal range to 0.5 - 0.2 m across the lake and restricted mangrove distribution to the system’s lower reaches and the eastern lake shore. Salinities were marine (> 30) in the channel and polyhaline (18 - 30) in the lake (Millard and Harrison 1954). Swamp vegetation (*Phragmites* reeds and *Juncus* rushes) covered most of the lake’s banks, importantly trapping river sediments and preventing siltation and shallowing of the system. Eelgrass beds (*Zostera capensis*) covered extensive areas in the upper and middle channel, where sediments were muddy sand and water was more saline and less turbid than in the lake, which had a muddy bottom. The system’s ecology was driven by its hydrology, the estuarine salinity gradient, the nature of the sediments and the *Zostera* beds, providing habitat for an abundance and diversity of small fishes and crustaceans and a productive detrital food base for the greater system. Richards Bay Estuary was recognised as one of the most productive, diverse and least impacted estuaries in KwaZulu-Natal (Millard and Harrison 1954).

This changed in 1972 with construction of a deep-water port, entailing division of the previously undisturbed system into two sections by the construction of a 4 km long dividing berm (Weerts and Cyrus, 2002). The bay to the north-east was given over to development and has grown into South Africa’s largest port (Port of Richards Bay). The remaining area (approximately 1 200 ha) to the south-west of the berm was designated as a nature sanctuary (uMhlathuze Estuary) following the re-routing and canalisation of the lower uMhlathuze River and cutting of a new estuary mouth (Begg 1978) (Figure 2).



Figure 1. Engineered changes to Richards Bay Estuary to create a deep-water port and an adjacent sanctuary (uMhlathuze Estuary).

These changes had immediate and far reaching impacts. *Zostera* beds were destroyed and fish and crustacean species associated with eelgrass were lost. The widening and deepening of the pre-existing mouth to act as a port entrance channel, and the cutting of a new mouth to serve the sanctuary area, resulted in a significant increase in tidal range in both new basins with consequent tidal exposure of previously shallow subtidal areas. Large areas of shallow subtidal habitat were lost with a concomitant increase in intertidal area. Changes in residence time caused by increased tidal flushing reduced plankton productivity. Nevertheless, connectivity

to the sea allowed continued recruitment of marine spawned biota to both the new port and the sanctuary and an essentially estuarine character and function was retained in both the Port of Richards Bay and uMhlathuze Estuary. Over the years new intertidal sand- and mudflats have been colonised by mangroves and by 2000, mangrove coverage in the estuary had increased from 150 ha to 652 ha (435 %< Adams et al., 2000) (Figure 3).

Natural successional changes have established significant new biological habitat which is now nationally important. uMhlathuze Estuary and Richards Bay now collectively support > 50% of South Africa's national mangrove area. Moreover, efforts to re-establish *Zostera*, transplanted from the St Lucia Estuary, were successful in uMhlathuze Estuary in 1991. By 1998 approximately 5 ha of *Zostera* beds had established in the estuary (Adams et al., 2000). This was < 8% of the area covered prior to port development but this new *Zostera* area supports

a richness of fishes and crustaceans similar to the original *Zostera* beds (Weerts and Cyrus, 2002).

Although highly modified from the original state as an estuarine lake to the extent that they could now be regarded as novel ecosystems, Richards Bay (an estuarine embayment) and uMhlathuze Estuary (a permanently open estuary) are nationally important estuarine biodiversity areas, supporting globally important critical habitats (mangroves and eelgrass) and are important nursery areas supporting fisheries across the wider KwaZulu-Natal coast. For all the present-day value of the permanently open uMhlathuze Estuary and the Richards Bay estuarine embayment, these systems do not offset the loss of the original



Figure 3. uMhlathuze Estuary mangrove forests (Photo F. MacKay ORI)



Figure 2. Dividing Berm. L is Port of Richards Bay. R is uMhlathuze Sanctuary (Photo F. MacKay ORI).

estuarine lake which is critically threatened estuarine habitat in South Africa. The destruction of the near-pristine system for port development is one of many examples of widespread loss of estuarine resources to development in South Africa, but one of very few that illustrate the resilience of estuaries if basic ecological processes are maintained. uMhlathuze Estuary as a permanently open estuary and Richards Bay as an estuarine embayment are highly modified from their natural condition but retain ecological functions that provide various valuable ecosystem goods and services locally and farther afield.

Citation: Weerts, S.P. and MacKay, C.F. 2019, 'Habitat lost and habitat gained. Development drives estuary type change - the case of Richards Bay' in Volume 3: Estuarine Realm. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A

Similarly, a concrete barrage was constructed in 1978 across the estuarine connection for Lake iNhlabane to increase water storage for mining purposes. Prior to 1978 iNhlabane consisted of two interconnected lakes that had a direct connection to the sea through the iNhlabane Estuary. Raising of the water level resulted in the merging of the two lakes into a single bi-lobed freshwater lake and the loss of typical estuarine fish and invertebrate communities (Cyrus & Wepener 1997). The downstream section of this system now functions as a Small Temporarily Closed Estuary.

Predominantly Open estuaries

Excessive flow modifications have fundamentally changed the type and function of these systems. Freshwater abstraction and the presence of dams upstream can cause permanently open estuaries to close, as evident in the Uilkraals Estuary, which was once predominantly open. In 2008 it closed (seemingly permanently) for the first time and is currently experiencing successive artificial breaches and closures. In its natural state the mouth may have closed briefly (days to weeks) during drought conditions but present mouth closures endure for months, changing the system from functioning as a Predominantly Open estuary to that of a Large Temporarily Closed one (Table 8).

Increased mouth closure has led to abnormal brackish to fresh conditions in the Uilkraals caused by inundation levels well above the average high tide, or hypersaline conditions that result from low freshwater inputs and high evaporation. Tidal flushing has been reduced and affects the estuary's capacity to exchange nutrients, remove accumulated salts and maintain the diversity and zonation of species-rich salt marshes (Mucina *et al.* 2003; Adams *et al.* 2010). Maintaining the system's biodiversity is important as it falls within a biogeographic and phylogeographic transition zone between the cool-temperate and warm-temperate regions, with several aquatic macrophytes having phylogeographic breaks and distinct lineages within this zone (Harrison 2002; Teske *et al.* 2011). Closed conditions is also inhibiting fish recruitment and nursery function.

Large Temporarily Closed Estuaries

Excessive regulated inflow can also permanently change an estuary type. Historically, the Eerste Estuary was temporarily closed and seawater intrusion created estuarine conditions up to 2.5 km from the mouth (Brown & Magoba 2009). Currently, inflow from five municipal wastewater treatment works causes the mouth to remain permanently open (Table 8). There is limited tidal influence as seawater penetrates only 500 m into the estuary under specific mouth and river flow conditions (CSIR 2001). Fish surveys conducted before the municipal inflows commenced recorded 3-11 endemic marine and estuarine species (Clark *et al.* 1994). Subsequent surveys have yielded almost mono-specific catches, reduced catch rates, and the size distributions are indicative of a severe deterioration in suitable habitat for indigenous estuary-associated fish species. The invasive freshwater Sharptooth Catfish (*Clarias gariepinus*) is currently caught in high numbers in this once important system.

The placement of development infrastructure such as housing, canals, railway embankments and bridges has impacted the natural hydrology of numerous estuaries. Silvermyn Estuary in Cape Town was once a series of large, shallow, seasonal pans and vleis that formed periodically behind a low barrier dune above the high-water mark (Brown & Magoba 2009). It would have functioned as a Large Temporarily Closed system but in the 1990s, to alleviate flooding of surrounding properties, the

estuary's floodplain was re-engineered using gabions and earth berms reducing its size, thus changing its character to that of a Small Temporarily Closed estuary (Table 8) with limited marine connectivity.

One of the earliest maps of Table Bay, drawn by Barbier in 1786, show that the Sout-Diep system shared a common mouth. The map indicates that the Sout (Wes) was in the same location as at present, with the exception of the lower section which used to join up with the Diep, Liesbeek and Black rivers along the alignment of the present-day Zoarvlei, before flowing out to sea. The system is now artificially separated from the Diep, with the Diep Estuary mouth being located some three kilometres north of its historical position. Between 1930 and 2000 a series of projects were undertaken that resulted in the Sout (Wes) being diverted to the Black River and canalised in its present configuration. Extensive urbanisation of the area surrounding the Sout-Diep Estuary has largely resulted in a complete loss of estuarine function and habitat within this system.

Small Temporarily Closed

Further to the east, records indicate that in the early 1800s, the Small Temporarily Closed Baakens Estuary in Port Elizabeth formed a deep inlet that could be used by small sailing vessels and it was also an important recreational area. The establishment of wool-washing operations and laundries on the banks lead to the water becoming polluted and unusable for recreational activities (thecasualobserver.co.za). Later, more industries were developed nearby and construction rubble was dumped into the estuary during the 1800s. This led to it becoming predominantly open and canalised along much of its length (Table 8). Over many years, almost all the estuarine natural vegetation has been removed, with only small patches of reeds remaining. Although it supports about nine estuary-associated fish species, the prevalence of small sizes, dominance of marine species, and lack of habitat diversity suggests that the fish fauna is severely constrained. This contrasts with the rich diversity of estuary-associated fishes (30 species) found in the nearby large permanently open Swartkops Estuary to the north (James & Harrison 2010).

The development of freeways and an industrial area close to the banks of the Small Temporarily Closed Papenkuils Estuary in Algoa Bay led to the canalisation of its lower reaches and the construction of a concrete bed (Table 8). The estuary receives industrial and domestic effluent that has polluted its water (James & Harrison 2010). It was even known historically as Smelly Creek in the 1800's. The system currently functions as a stormwater and industrial effluent canal. Prior to these developments, typical salt marsh plants such as *Sarcocornia* spp. occurred in the lower reaches, with bird life being prolific and 57 water bird species (especially flamingos) frequenting its banks (Taylor 1964). An estuary transformed into polluted storm water canal such as the Papenkuils Estuary is unlikely to provide any suitable habitat for endemic estuary associated biota (James & Harrison 2010).

3.5.1 Mitigating for functional shifts in estuaries

Overall, where feasible, estuary management plans should ensure that natural estuarine processes in degraded estuaries are restored to ensure the overall resilience of estuarine ecosystems in South Africa. In extreme cases, some estuaries have been so extensively modified that they have completely lost their natural functionality. Science-based management and intervention is needed to improve functionality of these modified estuaries.

Each estuary has its own issues that require remediation. The Zeekoei Estuary needs an improved stormwater infrastructure to enhance its water quality. The mouth of the Heuningnes Estuary should be allowed to close so that breaching at naturally high water levels can scour accumulated sediment.

The Uilkraals Estuary requires restoration of its baseflows to ensure the mouth remains permanently open. Recently accumulated sediment in this system may need to be removed to restore tidal flows to pre-2010 conditions and ensure a permanent connection to the sea. The Eerste Estuary would benefit from the establishment of an artificial wetland and decreased wastewater input to reduce excessive nutrient loading. Artificial manipulation of the Silvermyn mouth and/or meandering outflow channel, by the local authorities and illegal bridge squatters, should be discontinued as the backwater area that forms under closed mouth or meandering channel conditions is the only remaining functional estuarine area in the system. Hydro-carbons and other pollutants enter the uMhlathuze Sanctuary via the obsolete Richards Bay Harbour tidal gates. These gates should be closed off to prevent ongoing contamination of the Sanctuary area. Illegal gillnetting is also negating uMhlathuze regionally important nursery function and should be addressed through increase compliance. Nhlabane Lake needs the partial link between the lake and estuary to be re-established, which in turn needs continuous operation of the present fishway, lowering of the barrage level, and rehabilitation of riparian areas around the lake. There are few options to improve the functioning of the canalised Sout (wes), Baakens, Papenkuils estuaries, apart from ensuring pollution levels are controlled and the water column remains oxygenated.

3.6 Conclusions

Estuary ecosystem types can serve as surrogates for ecosystem processes and enable predictions of biophysical characteristics. Understanding ecological processes and patterns associated with an estuary type facilitates an assessment of its resilience to anthropogenic pressures. This allows for extrapolation in data-limited environments.

For nearly three decades, the characterisation scheme of Whitfield (1992) served as the reference framework to type South African estuaries. This paper revises the characterisation scheme through the development of an ecosystem classification scheme that explicitly incorporates biogeographical zonation, introduces new estuary types and redefines existing types based on size. The revised classification also introduces three micro-system types previously omitted, i.e. permanent or ephemeral coastal water bodies smaller than 2ha in area or less than 200 m in length.

The classification scheme divided the biogeographical regions that characterise the South African coast into four major zones: the Cool Temperate (Orange to Ratel), the Warm Temperate (Heuningnes to Mendwana), the Subtropical (Mbashe to St Lucia) and the Tropical (uMgobezeleni to Kosi), with the latter being a new addition to the estuarine biogeographical provinces.

All rivers or streams with outlets to the sea were categorised broadly as estuaries and micro-systems. For estuaries, Estuarine Lakes, Estuarine Bays and Predominantly Open types were largely retained. New types, previously omitted, are Estuarine Lagoons (e.g. the groundwater-fed Langebaan system) and the Arid, Predominantly Closed estuaries that occur on the west coast (e.g. Groen and Spoeg).

The numerically dominant temporarily open/closed category was subdivided into Small and Large Temporarily Closed estuaries based on size, with a total habitat area of 15ha serving as the threshold separating small from large types. River mouths were renamed 'Fluvially dominated' estuaries and divided into large and small size categories to reflect dissimilar catchment influences, with similar to Temporarily Closed estuaries, a total habitat area of 15ha serving as the threshold separating types. Micro-systems were further divided into micro-estuaries, micro-outlets, and coastal waterfalls based on spatial features and biotic observations in the field.

TEXT BOX 2: SOUTH AFRICAN ESTUARY NAMING CONVENTION

South Africa has less than 300 functional estuaries. Most of them are identified by name. However, there is considerable confusion regarding naming conventions used in past studies. Broad criteria are therefore required to resolve conflicts around estuary names. These could include:

- Estuaries are named after the inflowing river and not the area surrounding the estuary, e.g. Disa versus Hout Bay. The names of a place should only be adopted for estuaries if no river name is known.
- Estuaries should not be named after coastal features or estuary type, e.g. Kosi versus Kosi Bay.
- Where duplication of estuary names occurs, the coastal position in the form of North, South, West or East can be indicated in brackets behind the estuary name in order to distinguish between systems (adopted from NRIO and NBA 2011 lists).
- KwaZulu-Natal is in the process of (re)gazetting all estuary names between Kosi and uMthavuna following extensive community consultation. The revised spelling of most estuary names is largely being adopted in anticipation of this gazetting process in consultation with the provincial authority.
- Where possible, Eastern Cape Conservation Plan names were adopted, with the exception of the exchange between Blue Krans and Freshwater Poort names which were incorrectly allocated by the Plan.
- Whitfield & Baliwe (2013) identified a number of estuaries with isiXhosa names in which the exhalation "h" has been omitted in the anglicized version of the spelling, e.g. Birha not Bira. In these cases the recommended name was listed in brackets. It is recommended that a formal naming process be undertaken to address these discrepancies.
- Along the West Coast, Afrikaans synonyms were adopted in line with the regional spelling and colloquial names. The exception here was the Orange Estuary which retained the English name as it is identified as such in most maps.
- The location of a few systems have also been corrected, e.g. Busha, Silverstroom, Sout (Suid) and Springfontein were incorrectly located in the 2011 NBA and has been corrected for the 2018 NBA.

Citation: Van Niekerk, L., Adams, J.B., James, N., Lamberth, S.J., MacKay, C.F., Turpie, J.K., Rajkaran, A., Weerts, S.P. & Whitfield, A.K., 2019, 'South African estuary naming convention. Volume 3: Estuarine Realm', South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A

Overall, South Africa's 290 estuaries were classified into 22 estuarine ecosystem categories arising from the interplay between four biogeographical zones with nine estuary types. In addition 202 micro-systems were also classified into nine ecosystem types, of which only the micro-estuaries (42 systems) share some functionality with estuaries. This represents a high diversity of estuary types, not unexpected considering the country's diverse climatic, oceanographic and geological drivers.

The variety of estuarine types collectively form an interconnected network of estuarine systems providing resilience to climate fluctuations and the impacts of climate change predicted for the future. Large-scale human activities, especially urbanisation and industrialisation, change ecological processes in estuaries that can permanently alter the functioning of these systems. Impacts are shown in morphological changes that affect estuary hydrodynamics and marine connectivity, chemical characteristics such as salinity, and ultimately large scale biodiversity loss and susceptibility to invasion by non-native species.

South African Estuarine Lakes are large and rare estuarine systems on the subcontinent. However, they are in crisis, with the majority being subjected to alterations in key ecological processes. This group of estuaries has undergone extensive infrastructure development to their functional zones, substantial flow reduction, nutrient pollution, overfishing (especially gillnetting) and manipulation of mouth areas. These combined impacts have reduced their ability to provide key ecological services such as flood regulation, nutrient cycling and nursery habitat provision, and have compromised their value as recreation and tourism venues. To ensure their resilience to future climate changes stressors, a strategic programme is needed to restore habitat, improve water quantity and quality, reduce pressure on natural resources, and increase protection levels.

The revised classification scheme is useful because its ecosystem-level approach provides a holistic and detailed framework that integrates biogeographical factors and the extensive range of biophysical parameters evident in South African estuaries. The classification scheme forms the 'blue print' for South Africa's IUCN Red Listing of estuarine ecosystem types, that allows for the identification of threatened ecosystem types, i.e. 'Critically endangered', 'Endangered', or 'Vulnerable' (Van Niekerk *et al.* 2019). Thus, highlighting ecosystem types in urgent need of management intervention and protection. Determining the condition of estuarine ecosystem types have the added advantage that it can also be used for reporting on United Nations Sustainable Development Goal 14 (Conserve and sustainably use the oceans, seas and marine resources) that specifically highlights coastal ecosystems such as estuaries. Ecosystem types, together with species and habitat targets, are used in setting conservation planning targets to ensure that all life supporting abiotic and biotic processes are captured in a representative protected areas network (Turpie *et al.* 2012). Given that the identified estuary types characterise physical and biotic processes, they can also be used as proxies for predicting sensitivity to anthropogenic pressures such as flow reduction and increased nutrient loading in environmental flow assessment in data-poor environments. Aquatic ecosystem typing is one of the fundamental datasets for extrapolating freshwater flow requirements across a region in low confidence assessments (Van Niekerk *et al.* 2015).

While this study focused on developing a data-driven ecosystem classification system, key datasets were found to be lacking that could facilitate a more detailed assessment. Critical parameters that would have allowed for a more nested or hierarchal classification include information on seasonal salinity regimes, mouth states, water clarity, estuary topography and bathymetry, and sediment structure. In addition, very little information was available on the invertebrate community for most of South Africa estuaries. Overall, data on biological responses is more than 30 years old (e.g. national bird counts date from the 1980s; Underhill & Cooper 1984) and national fish surveys date from the 1990s (e.g. Council for Scientific and Industrial Research unpublished data; Harrison 2000, 2005). While new data are being collected on some of the larger systems, very little information is currently being gathered on the numerous smaller estuaries, especially those in remote areas along the coast. Without a major investment in baseline information from numerous poorly studied South African estuaries it will be difficult to refine this new classification system in the future.



Goukamma Estuary. © Cape Nature.

4. EXTENDING THE ESTUARY FUNCTIONAL ZONE TO INCLUDE KEY HABITATS AND PROCESSES

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Extending the Estuary Functional Zone

Delineation of the Estuarine Functional Zone included the following components:

- Maximum historical extent of all estuarine processes (abiotic and biotic).
- Lateral boundaries: 5m contour, but up to 10 m contour in small incised estuaries with high river inflow.
- Estuarine shores: Maximum meander of estuary channel mapped from the base of the foredune to the seaward extent of the surf zone.
- Upstream boundary: Maximum limit of tidal variation and/or salinity penetration.
- Include marinas and harbour developments in estuaries.
- Include swamp forest and mosaics of estuarine vegetation previously omitted.
- Incorporated contiguous habitat surrounded by estuarine habitat/processes.
- Merged contiguous small freshwater ecosystems (seeps and springs).
- Assimilate flood processes, i.e. flood lines of flood maps.

4.1 What is the estuarine functional zone?

Unlike a rainforest for example, estuaries have little permanent habitat structure as estuarine habitats are constantly forming and eroding at various temporal and spatial scales. Over longer time scales, the total habitat area of the various component estuarine habitat types tends to remain more or less constant. The actual spatial location of the various estuarine habitats is highly likely to change between resetting events (e.g. larger floods on decadal scales).

A fundamental constraint with the assessment and management of estuaries is defining their spatial extent (i.e. the smallest management unit or boundary) (Van Niekerk & Taljaard 2003). The relative ephemeral nature of estuary habitats presents an assessment and planning challenge. Biodiversity protection and the wise use of estuarine resources require not only the protection of estuarine habitat and biota, but also the protection of the physical processes that sustain ecological and evolutionary processes. Thus it is important to define the 'space' within which estuaries function over longer time scales to ensure their present and future health - called the 'Estuarine Functional Zone' (EFZ) (Van Niekerk *et al.* 2012, 2013)).

In South Africa, the EFZ is defined as the area that not only encapsulates the estuary waterbody, but also the supporting physical and biological processes and habitats necessary for estuarine function and health. It includes all dynamic areas influenced by long-term estuarine sedimentary processes, i.e. sediment stored or eroded during floods, changes in channel configuration, aeolian transport

processes, and changes due to coastal storms. It also encompasses all the multiple ecotones of floodplain and estuarine vegetation that contribute detritus (food source) and provide refuge from strong currents during high flow events.

Spatial delineation of the EFZ needs to be standardised, inclusive of all estuarine physical and biological processes and cost-effective to protect estuarine habitats. The EFZ captures the natural, historical estuarine extent and should not be confused with setback/management lines that often exclude developed areas. The EFZ purpose is to identify the 'space' in which estuarine physical and biological functions take place over long timescales (>decades). Development in the EFZ is captured as an aspect of habitat degradation or decline in overall estuary condition. This section further describes the approach followed in delineating the estuaries of South Africa for the NBA 2018.

Traditionally, authors such as Cameron and Pritchard (1963) defined an estuary as a semi-enclosed body of water that has a free connection with the ocean and within which there is a measurable dilution of seawater by freshwater derived from the land. However, this definition does not include reference to the greater estuary ecosystem, i.e. riparian habitats, upper reaches under tidal action or areas back flooded under closed mouth conditions.

A functional zone is defined as a geographic entity where there are common structural and functional characteristics that can be demarcated and quantified by measurement (Dennison & Abal 1999; Pantus & Dennison 2005). Internationally, various approaches are used to determine the lateral boundaries of estuaries. Some methods use the extent of permanently or mean-maximum flooded and waterlogged areas (e.g. Brazilian estuaries and wetlands (Junk *et al.* 2013)). The outer borders of estuaries can also be indicated by the absence of hydromorphic soils and/or hydrophytes and/or specific woody species (e.g. Australian estuaries (Adam 1992)). A more detailed sedimentological approach was used for the Sado Estuary, Portugal (Caeiro *et al.* 2003); fine-fraction particle size, redox potential, and total organic matter, in association with multivariate geostatistical approaches, were used to delineate the estuarine lateral boundary. Whilst a test application based on a range of the above criteria yielded sound results for Cape Estuaries, these approaches are data intensive and not suitable for highly dynamic systems characterised by changes in water level and habitat distribution over long time-scales; typical of small KwaZulu-Natal estuaries (Veldkornet *et al.* 2015).

In addition, ecotones between salt marshes and terrestrial vegetation are important areas of ecosystem functionality (Wasson & Wolfolk 2011). To ensure healthy functional estuaries, such areas need to be in a good condition to prevent invasion by alien plants and to ensure landward migration of saltmarsh vegetation under climate change vectors such as sea-level rise (Wasson *et al.* 2013; Veldkornet *et al.* 2015).

4.2 EFZ delineation method

Lack of long-term (>50-year time series), high resolution (e.g. <10 cm accuracy for x, y and z components) data necessitate the development of delineation criteria based on available spatial data,

observed estuarine physical behaviour and expert judgement. Little information is available on the historical spatial extent of South African estuaries. For example, in the Western and Eastern Cape provinces, significant habitats have been lost due to urban development. In subtropical areas (northern Eastern Cape and KwaZulu-Natal provinces) urban expansion and cultivation have removed estuarine habitat (Veldkornet *et al.* 2015). South African estuaries have undergone significant changes in terms of land use (Van Niekerk & Turpie 2012, 2013). Changes in land cover and land use complicate the identification of boundaries (Masefield *et al.* 2014). Land cover or land-use changes show the loss of natural habitat due to urban sprawl and cultivation in the EFZ (e.g. National Land Cover 2000 (NLC 2000) updated in 2009 (SANBI 2009), some of these changes were already formative and significant > 40 years ago and change detection studies show stability until now (e.g. KZN estuaries; Sheppard & MacKay 2019).

In 2011, the first national scale delineation was undertaken for nearly 300 estuarine systems along the South African coastline (Van Niekerk *et al.* 2012). For each estuary, the EFZ and open water areas were digitized using SPOT 5 imagery (*Satellite Pour l'Observation de la Terre*, "Satellite for observation of Earth") and historical, multi-seasonal and interannual Google Earth imagery which had been available up to 2008. For a large part of the coast the images were relatively cloud free, but where cloudy conditions occurred on SPOT 5 images, Google images were used. Lateral boundaries included all associated wetlands, intertidal mud and sand flats, beaches and foreshore environments that are affected by riverine or tidal flood events (Edgar 2000). The 5m topographical contour, which was obtained from the National Geo-spatial Information (NGI) (a directorate of the national Department of Rural Development and Land Reform (DRDLR)), was used as the boundary to delineate the estuarine functional zone. Where the 5m contour was not available in digital format in 2011, orthophotos (1:10 000) were scanned, georeferenced and the 5m contour was digitised. Where no orthophotos were available in 2011 (13 systems), floodplains were mapped from SPOT 5 imagery using changes in topography and vegetation types as indicators. From the estuarine functional zone delineation, spatial data such as area, length and perimeter (estuary coastline) and distance to the next system could be inferred.

Following a more inclusive approach in 2018, extensive efforts went into addressing subsequent identified deficiencies in the estuary delineation process of the NBA 2011. For example, estuaries are dynamic environments and without a good understanding of changes over time, these ecosystems cannot be assessed and managed appropriately. Thus, where data were available, certain EFZs were mapped to the maximum of the historical extent, but excluding modifications brought about by marina and harbour developments adjacent to estuaries. In addition, Google Earth provides a time-series dataset allowing for the mapping of the ever-changing processes that characterise South African estuaries, e.g. change in mouth configuration and inundations patterns across multiple seasons and between years. To address this, the maximum movement of the estuary mouth (inlet) from any historical image, be it aerial photography or satellite imagery, was incorporated in the EFZs. The EFZs were also extended to incorporate contiguous habitat that is principally surrounded by estuarine habitat or processes (e.g. more than 75% of feature is surrounded), such as 's-bends' and 'islands' of high-lying ground, as they have the potential to be eroded away in future resetting flood events.

Where small slivers of freshwater ecosystems contiguous to estuaries were identified (e.g. seeps and springs), these were also included in the EFZ, if judged not to be a modelling artefact (van Deventer *et al.* 2019). This aspect needs additional work in the future as lateral seeps and springs provide critical input to micro-habitats along the banks of estuaries but are poorly mapped and understood.

Over the last five years, important supporting datasets became readily available in digital format such as the 5m and 10m topographical contours, mapped at a scale of 1:10 000 by DRDLR:NGI (National Geo-spatial Information), and which were used as proxy for height /distance above mean sea level (DRDLR:NGI 2017). In addition, 30 m raster format Shuttle Radar Topography Mapper (SRTM) Digital Elevation Model (DEM) datasets (contoured to the 5m and 10m elevation), while of low spatial resolution, provided another information source that could also be interrogated to resolve uncertainty in the inclusion of riparian areas. The upstream boundaries of estuaries were determined as the limits of tidal variation or salinity penetration, whichever penetrates furthest. This is in line with scientific studies and the administrative definition of a South African estuary (DWAF 2008). Wherever possible, the upstream boundary was derived from the literature, expert judgment or field observations. In a number of systems, no physical data were available and the upper boundary was assumed to be the 5m topographical contour (bearing in mind that the tidal range in South Africa is microtidal (< 2 m) and sand bars at closed estuary mouths can sometimes build up as high as + 4.5m MSL). The upper boundaries were also screened against other spatial delineations, e.g. KwaZulu-Natal Estuaries database (Version 1.00.02) with preference given to data from the larger scale studies. Shapefiles files were converted to Google Earth (KMZ formats) and reviewed by members of the Consortium for Estuarine Research and Management (CERM). In the case of the Kwa-Zulu Natal Province, concerted effort was made to visit the upstream boundaries of the estuaries and verify the extent. In most cases the 5m contour was still used to define the functional zone of the estuary. However, for some small incised estuaries (i.e. 0 m, 5m and 10m contour in close proximity to each other) with relatively high river flow, the 10 m contour or a combination of the 5m and 10m contour, were used as the default to accommodate mapping uncertainty, and flood processes, e.g. inundation levels and lateral scouring of riparian area. Where there was no topographic information, the SRTM 4.1 90 m DEM was used to generate the 5m and 10 m contours above sea level. A comparison of the known upstream boundaries of some incised small systems, e.g. Palmiet, showed disturbing mapping errors in both the DRDLR: NGI contour data and the STRM datasets resulting in an underestimation of the true estuarine extent. Thus, a precautionary approach was used when delineating similar small systems as the incised upper reaches were not accurately represented in the existing datasets.

The estuary mouth was taken as the downstream boundary of an estuary. The highly dynamic nature of this area presents a significant challenge to accessing change in biodiversity and even managing estuaries. To account for this, and to allow for a seamless integration with the Marine and Coastal Realm, the concept of 'Estuarine Shore' (see Figure 8) was introduced to reflect the dynamic nature of the interface between estuaries and the coast (Harris *et al.* 2019).

Estuarine Shores refers to sand berms or bars that form in front of estuaries. They vary substantially in size and shape over decadal scales and can be completely absent during a flood or a near permanent

feature during periods of low flow. An Estuarine Shore was defined as the area from the base of the foredune, or where this line would be if dunes were present, to the back of the surf zone. The alongshore extent was taken as the width of shore that includes the known variability in estuary mouth position based on all available historical imagery for each estuary. The full extent of the Estuarine Shore is encompassed in the EFZ and not considered separate from the functional unit. The surfzone was included to reflect a continuum in estuarine-marine connectivity through estuarine inputs to the surfzone, either as direct flow through an open mouth or in seepage through the berm in a closed system. Accumulations of estuarine fishes in the surfzones adjacent to estuaries are well-documented and highlight the biotic continuum between surfzone and estuarine habitats. Even in the case of closed estuaries, seepage through the berm creates a mixing zone wherein salinity, turbidity, temperature or olfactory signals cue aggregations of larval and juvenile estuarine and estuarine-associated fishes in anticipation of breaching events which will give them access to critical nursery habitats. (Whitfield 1989; Cowley *et al.* 2001; Vivier 2001; Strydom 2003).

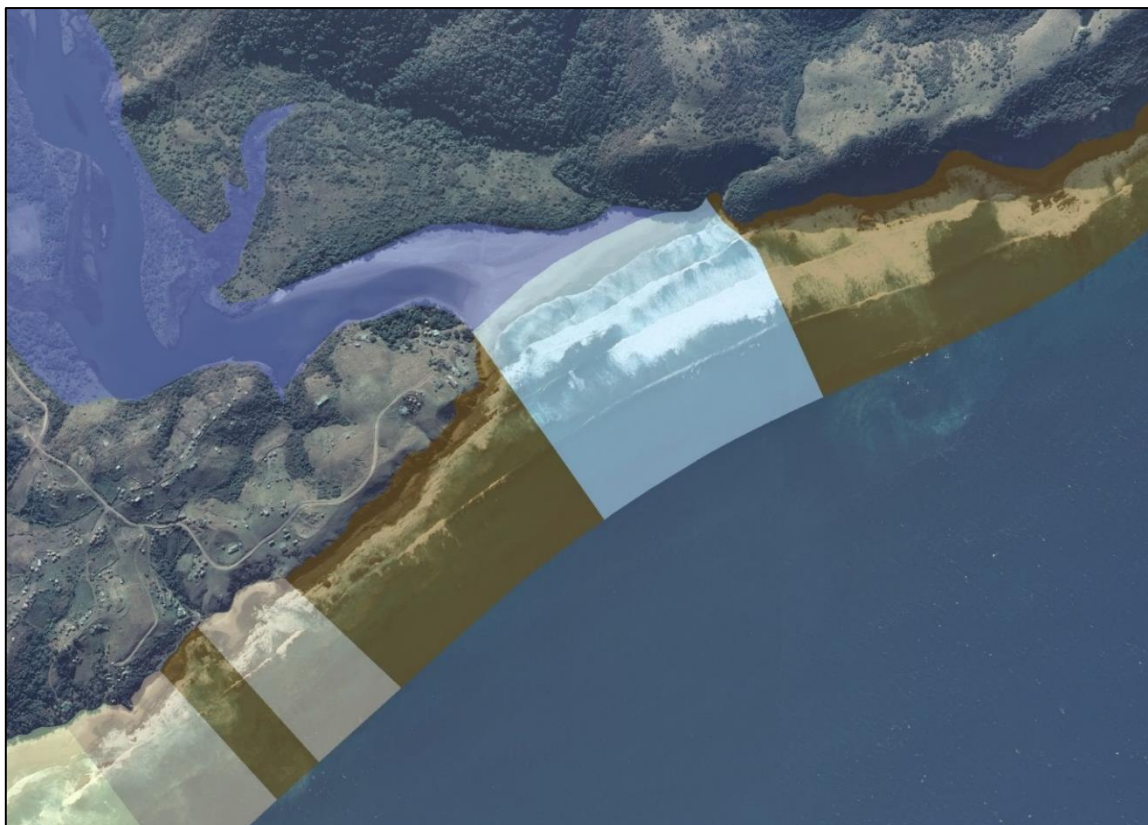


Figure 8. Integrating the estuarine functional zone into the coastal ecosystem map required extending ‘Estuarine Shores’ (marked here in white) the full extent of present and historical mouth configurations to the back of surfzone.

Veldkornet *et al.* (2015) emphasised that critical estuarine habitats, such as salt marsh and swamp forest were excluded from the NBA 2011. In addition, over the last five years significant efforts have gone into updating the National Estuarine Botanical Database with field observations and more detailed mapping (Adams *et al.* 2016). Following a precautionary approach, all estuarine habitat or estuarine-associated habitat previously excluded is now incorporated into the EFZs, including all swamp forest and salt marshes adjacent to estuaries. The EFZs were also extended to incorporate vegetation ecotones that have elements of estuarine habitat, e.g. mosaics of swamp and dune forest.

Light Detection and Radar (LiDAR) data, available for parts of the coast of South Africa, aided an increased vertical spatial accuracy in the mapping of estuarine features of between 5 and 10 cm. However, LiDAR was not consistently corrected to mean sea level and proved less reliable than anticipated. In particular, LiDAR datasets that were geodetically corrected. Significant additional work is required to standardise existing datasets before they can be the sole platform on which EFZ delineation is based. In addition, for some estuaries there was indication that elevation was due to the vegetation canopy rather than the return signal from the ground, thus excluding areas and underestimating what should be part of the EFZ. In most cases where LiDAR was available, a combination of LiDAR and the 5m or 10 m contour data was used and visually screened against historical aerial or Google Earth satellite imagery (Figure 9 and 10).

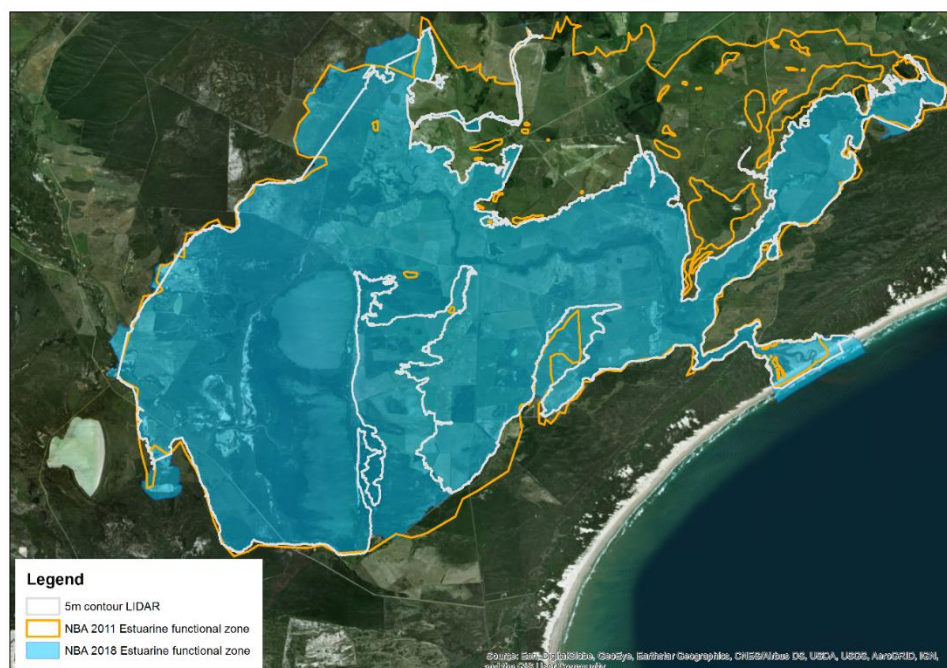


Figure 9. An example of LiDAR used to refine the 2011 estuary functional zone of the Heuningnes Estuary. Note, high-lying areas surrounded by estuarine habitat such as ‘s-bends’ and ‘islands’ have been incorporated into the EFZ.

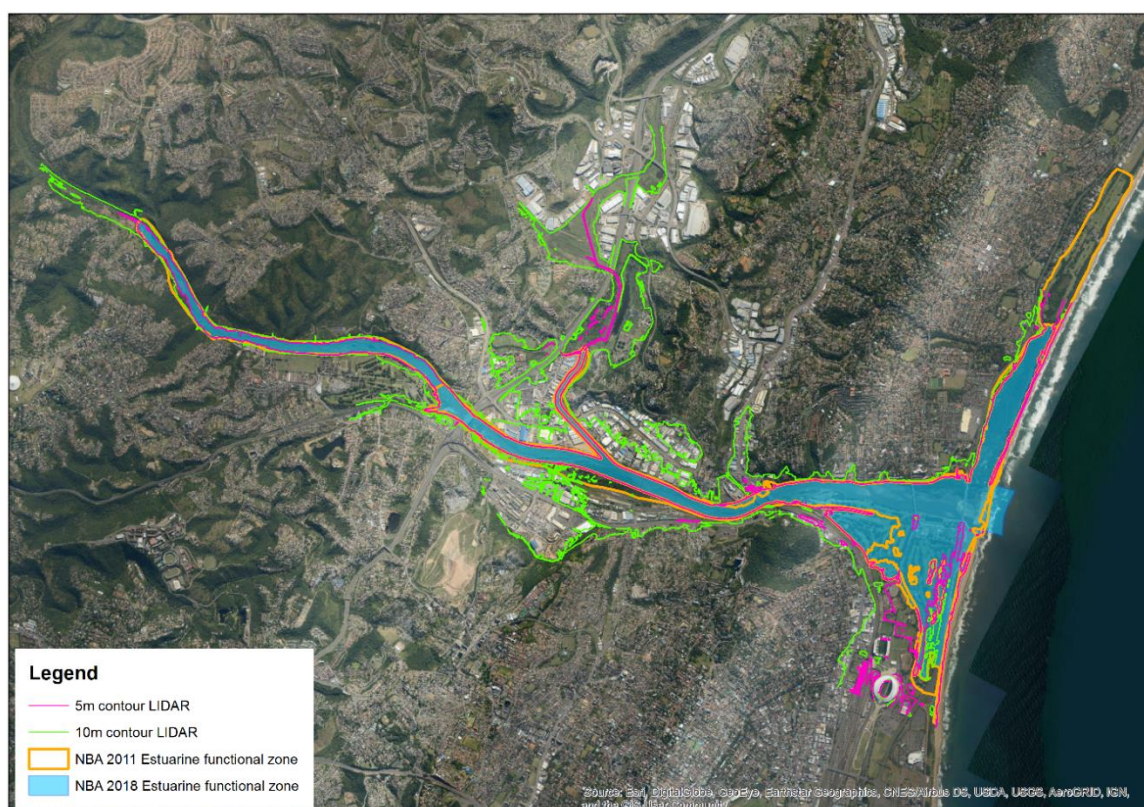


Figure 10. An example of how 5m and 10m LiDAR was used to refine the extent of EFZ at incised locations.

Detailed 1:100-year flood studies and associated spatial datasets have also been conducted on some larger estuaries highlighting inundated areas previously assumed to be elevated. The flood line determination on the Breede and Groot Berg estuaries strongly supported the use of the 5m contour as a baseline in the absence of detailed flood line surveys. The areas previously excluded were incorporated into the EFZ. Engineering studies on the Bulura Estuary indicated that smaller estuaries are also vulnerable to storm surges and that the 5m contour provided a valuable indication of the high water level at which flooding from the sea can be anticipated.

Where micro-systems, including micro-estuaries (< 500m in length), river inlets, ephemeral systems and waterfalls, were only represented as x,y point data in 2011, an effort was also made to map some of these smaller features, i.e. micro-estuaries, in this version of the NBA.

Micro-estuaries were distinguished from outlets and seeps as being those micro-systems that had a permanent waterbody in all available imagery. Estuarine Functional Zones (EFZs) for micro-estuaries were mapped, but not the smaller ephemeral coastal outlets and seeps (Figure 11). The latter are represented only as a point (x,y dataset), and are thus excluded from the integrated national ecosystem classification map.



Figure 11. Micro-estuary delineation based on a combination of the 5m contour and other coastal features.

Based on the above approach, the total extent of the mapped estuarine functional zone in South Africa is 200 730ha, with the inland component estimated at 191 980ha and estuarine shores at 8 750ha (representing 4% of EFZ area). In contrast, the micro-estuaries only covered a total area of 620ha, of which only 130ha (21%) are inland and 490ha were shore and surfzone in nature. More than half of South Africa's estuarine area in the Subtropical region (55%), followed by the Warm Temperate (22%), Cool Temperate 19% and the Tropical biogeographical (4%) regions. In contrast, most of the micro-estuary area occurs in the Warm temperate region (44%), followed by the Subtropical (35%) and the Cool Temperate (21%). No micro-estuaries were identified for the Tropical biogeographical region.

Table 9. Summary of the EFZ areas for estuaries and micro-estuaries.

	LAND (ha)	SHORE (ha)	EFZ (ha)
ESTUARIES			
Cool Temperate Estuary	35 800	1 880	37 680
Warm Temperate Estuary	40 730	3 770	44 500
Subtropical Estuary	107 330	3 060	110 390
Tropical Estuary	8 120	50	8 170
Total area	191 980	8 750	200 730
MICRO-ESTUARY			
Cool Temperate Micro-estuary	30	100	130
Warm Temperate Micro-estuary	50	220	270
Subtropical Micro-estuary	50	170	220
Total area	130	490	620

4.3 Important habitats in support of estuarine function

While mapping and classification creates the impression that the transitions from rivers or wetlands to estuaries are abrupt, in reality it is a continuum with significant overlap in physical processes and biotic responses.

4.3.1 River-Estuary Transition Zone

In addition to the EFZ, the transition zone between rivers and estuaries was also defined as part of the NBA 2018 (Figure 12), as river reaches which during any time of their hydroperiod are subject to only riverine abiotic processes, but host both riverine and estuarine biota (see also Rundle *et al.* 1998). These areas are not influenced by tidal action or back-flooding, and at no stage experience an increase in salinity as a result of tidal penetration. Explicitly, the river-estuary transition zone is immediately upstream but does not include the River-Estuarine-Interface (REI). The latter is defined as the area in an estuary within which salinity ranges from 10 to zero under the influence of the upstream limits of back-flooding or tidal intrusion. These transitions are poorly understood and have not been delineated previously, owing to their dynamic nature over long hydrological cycles. The river transition lengths varying between 0.5 km and 30 km were defined based on sampling data, topography and expert opinion. The steeper the gradient, the shorter the transition zone. Thus, rivers with extensive lowland reaches such as the Breede and the uThukela will have longer transition zones. Ephemeral rivers upstream of estuaries were excluded from this delineation. The extent of the transitional rivers were mapped and included in the national rivers database of the NBA 2018 (Smith-Adao *et al.* 2018).

Estuarine-associated fish and invertebrate assemblages within the freshwater- estuarine transition areas are a mixture of typically estuarine species e.g. moony *Monodactylus falciformis*, those equally adept at completing their entire lifecycle in both habitats e.g. estuarine roundherring *Gilchristella aestuaria*, freshwater species that may have an estuarine phase of their life-history e.g. Freshwater prawns and shrimps *Macrobrachium spp.* and *Palaemon spp.* and catadromous crabs (*Varuna litterata*) and *Anguillidae* eels that are either resident, passing through whilst recruiting to the upper catchment or migrating back as adults to spawn far offshore in the abyssal depths. Typically, estuarine species include but are not limited to, 'facultative catadromous' fish such as Freshwater Mullet (*Pseudomyxus capensis*) that may opportunistically spend most of their life in freshwater but return to spawn in estuaries or the sea (Van Deventer *et al.* 2019).

Benefits of these transition zones include refuge from adverse conditions such as hypersalinity, eutrophication, hypoxia and temperature extremes in the estuarine environment. Similarly, pathogens and parasites that latch onto hosts in estuaries and the sea may be shed through osmotic stress in these transitional freshwater reaches. Fish and invertebrates can also benefit from a greater diversity and abundance of grazing and prey that may be unavailable or limited in the adjacent estuarine habitat. In turn, lower predation levels arise from stenohaline estuarine predators not being able to follow euryhaline prey. Transitional zones also provide extended habitat for euryhaline estuarine and marine species, a function particularly important during low-flow and drought periods when the REI breaks down and / or the estuary may be cut off to the sea. Weirs, impoundments and other instream obstacles in the transition zone may greatly reduce the availability and benefits of this

habitat to estuarine-associated species. This includes a reduction in the transport of detritus and habitat-forming sediments from the transition zone to the estuary downstream. Recruitment of estuarine-associated species will be limited to *G. aestuaria* and similar animals that are able to complete their entire lifecycle in this habitat. Alien and extralimital fish may have a similar impact. Many of these fish are predatory, outcompete their indigenous counterparts and thrive in transitional waters where they can provide an effective barrier to any larval or juvenile fish and invertebrates trying to recruit from downstream.

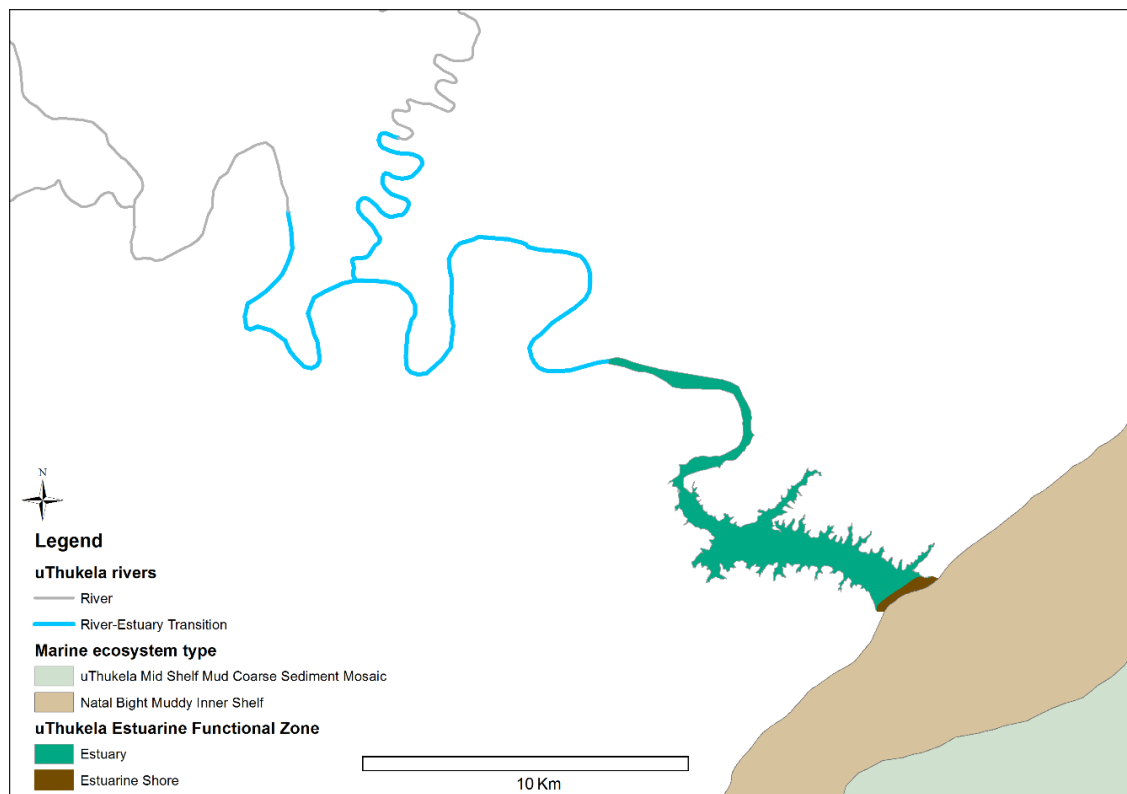


Figure 12. Habitats that support estuarine functioning – River-Estuary transition areas (marked in turquoise) and fluvially dependent Marine ecosystem types (marked in light brown), have been delineated and embedded in the inland freshwater aquatic and coastal / marine ecosystems realm maps.

Whilst these transition zones were not incorporated into the EFZ as they are not subjected to estuarine abiotic processes (i.e. tidal fluctuations), they should be highlighted as estuarine supporting areas in current planning legislation and approaches. This will ensure that future development and resource use, i.e. effluent discharges, water abstraction and infrastructure development, do not disrupt or degrade estuarine connectivity and ultimately, condition. Transition zones are essential supporting habitats to estuarine systems and require proper mapping for the purpose of policy formulation and the protection of these zones. In addition, coastal ecosystems are also poorly understood and mapped for South Africa.

4.3.2 RIVER-INFLUENCED NEARSHORE MARINE ENVIRONMENTS

In addition, river-influenced nearshore marine environments were also identified and mapped (Figure 12). Freshwater flow to the sea transports nutrients, sediment and detritus to the marine environment (Figure 13), generates productive plumes and fronts (salinity, temperature, turbidity) (Figure 14) that serve as temperature and turbid refugia; migration and spawning cues; fish nurseries and spawning habitat and facilitate coastal connectivity (Gillanders & Kingford 2002; Lamberth & Turpie, 2003; Van Ballegooyen *et al.* 2007; Lamberth *et al.* 2009; Porter 2009). Nearshore environments adjoining for example, the Orange, uThukela and uMzimvubu estuaries, that comprise extensive mud zones of terrestrial origin were identified and mapped based on available sediment data. Given that these habitats types support estuarine biota during various life cycles, the health of these ecosystem types are indelibly linked to the health of estuaries in the region.

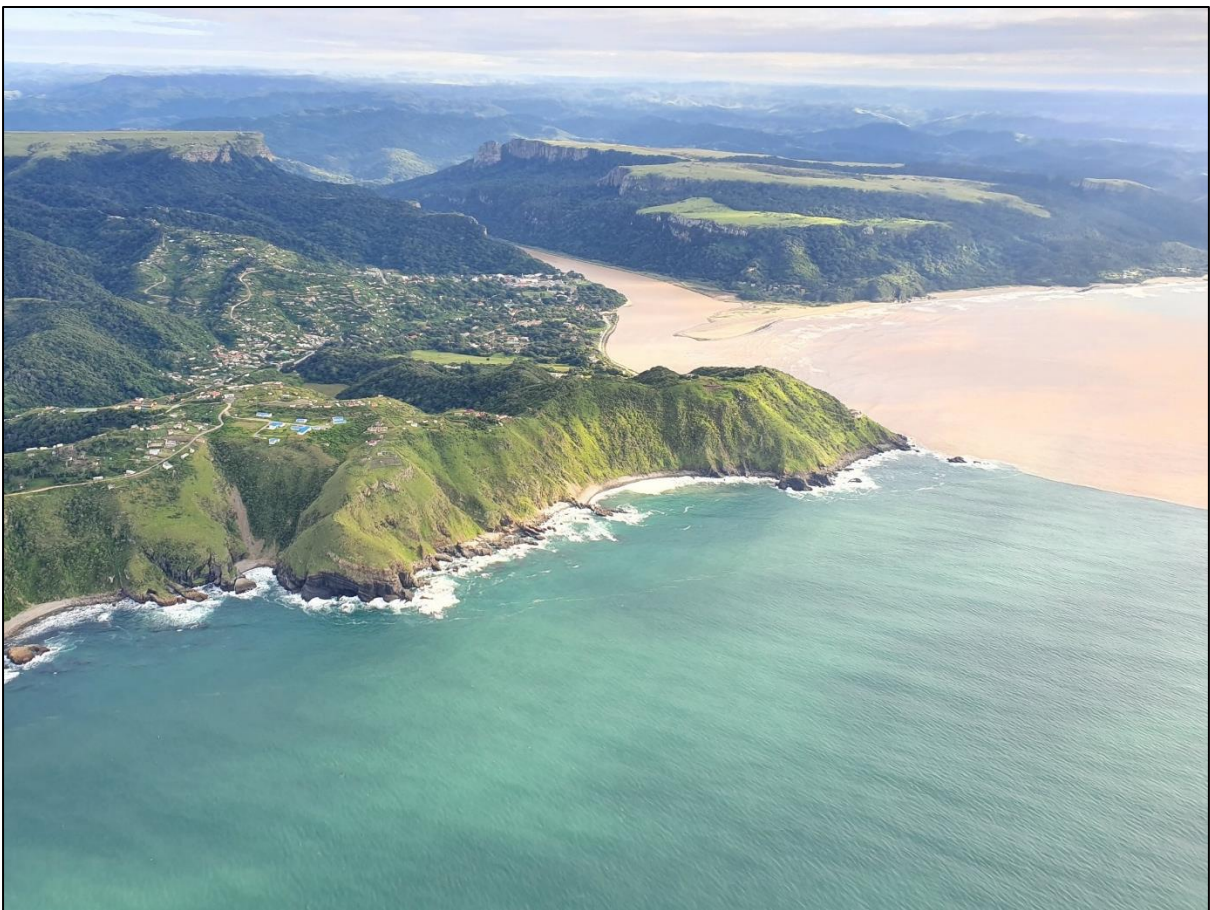


Figure 13. Mzimvubu River flowing into the sea nourishing the nearshore marine sediment, nutrients and detritus (Source: Darren Hanner)

Impacts of freshwater flow reduction extend far offshore. An example is the response to flow patterns measured in catches of commercial line fish documented more than 40 km offshore on the uThukela

Banks (Lamberth *et al.* 2009). The reduction of river flow leads to reduced sediment supply to the coast with implications for beach and subtidal habitats. Reduced sediment input can change beach dynamics, accelerating beach erosion and can even lead to the loss of beach habitat (Harris *et al.* 2010). In the subtidal environment, fluvial inputs provide important sediment inputs for the maintenance of subtidal fluvial fans or deltas outside the mouths of large river systems (Green & MacKay 2016; MacKay *et al.* 2016). Many of these habitats are also important for ecological processes. For example, the endemic and endangered White Steenbras (*Lithognathus lithognathus*) is believed to spawn on subtidal fluvial fans, a localised habitat of limited extent (Bennett 1993).

In turn, these nearshore habitats often support unique biotic communities.

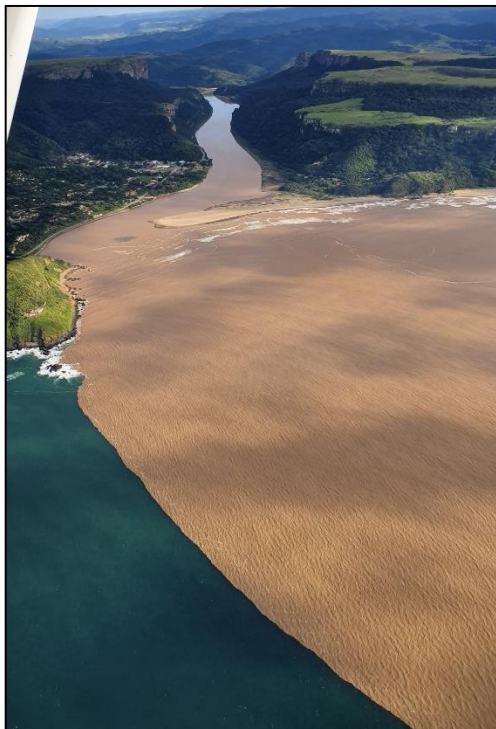


Figure 14. Mzimvubu plume creating a distinct turbidity front (Source: Darren Hanner)

Reduced turbidity can alter predation pressure and the catchability of fish important in nearshore fisheries (Lamberth *et al.* 2009). Altered freshwater flow leads to changes in important environmental cues such as those relevant for spawning, recruitment and migration (Whitfield 1998; Lamberth *et al.* 2009). Catchment derived nutrients are an important component of coastal and marine food webs stimulating phytoplankton production, or trophic systems that rely on primary consumers of particulate organic matter (Untiedt & MacKay 2016; MacKay *et al.* 2016). The impacts of reduced nutrient supplies will travel through coastal and marine ecosystems via food webs. Reduced detritus also impact on marine food webs as river-associated detritus are important food sources for deposit and other particulate feeders, detritivorous fish and invertebrates (Berry *et al.* 1979; Schleyer 1981; Berry & Schleyer 1983; Whitfield 1998; Porter 2009). A KwaZulu-Natal study showed that suspended riverine particulate organic matter (terrestrial, aquatic plant material and plankton) plays an important role in supporting inshore filter-feeder

communities, e.g. Red Bait (*Pyura stolonifera*), Mussels (*Perna perna*), and Oysters (*Striostrea margaritacea* and *Saccostrea cucullata*) (Porter 2009). It was found that up to a third of marine filter-feeder diets consisted of material introduced by rivers.

In short, freshwater flowing into the sea is not wasted!!!! Changes in freshwater flow and associated variations in sediment supply, salinity, turbidity, nutrients and detritus can impact on marine biodiversity and fisheries resources and decrease their socio-economic value. Fisheries resources in South Africa that are vulnerable to reduced freshwater input include linefish and prawns (Lamberth *et al.*, 2009; Demetriades *et al.*, 2000). The ecological needs of South Africa's transitional waters (i.e.

freshwater dependent coastal and marine environment) must be considered in the allocation of freshwater resources to ensure healthy, functioning marine ecosystems that support productive and sustainable fisheries.

4.4 Advantages of EFZ delineation

Using the EFZ as an estuary delineation boundary holds the following biodiversity and planning advantages:

- a) The EFZ encapsulates the most dynamic areas influenced by long-term estuarine sedimentary processes, i.e. sediment stored or eroded during floods, mouth dynamics, changes in channel configuration, aeolian transport processes, and changes due to coastal storms. It allows for natural variability on decadal timescales and thus represents the 'accommodation space' for key physical processes that influence biodiversity along the South African coastline previously not considered in estuary delineation;
- b) The EFZ encompasses all floodplain and estuarine vegetation that contribute detritus (food) and provide refuge during flood events. Most estuarine-associated biota occurs within the EFZ. This is as far as the influence of the sea can be detected on land;
- c) More than 75% of South African estuary mouths close to the sea, with water levels varying between 2.5 and 4.5m msl. The EFZ allows for water-level increases due to 'back-flooding' under closed mouth conditions, wind generated wave action, or exceptionally high tides and coastal storms;
- d) In most cases, the extended EFZ allows for the inclusion of habitat ecotone that represents the transition between terrestrial and coastal ecosystems, e.g. the mosaic of estuarine and terrestrial vegetation;
- e) The extended EFZ also represents 'climate change accommodation space' as it allows for estuaries to retreat under sea level rise scenarios of between +0.5 and +2.0m projected for South Africa in the short to medium term;
- f) An accurate delineation of the high-water mark is not available for the entire South African coastline, the EFZ based on estuarine physical and biotic processes, therefore side steps this administrative quagmire;
- g) Historical flood lines (1:100-year return period) for estuaries were often inaccurately determined under open mouth conditions or for too short a return-period (e.g. 1:20 year return-period), which leads to underestimation of flood heights. In the absence of long-term berm height data (which can vary substantially under different climatic conditions) the 5m contour provides the best protection against natural hazards such as floods and storms;

- h) The EFZ with intact riparian habitats minimises the risk of pollution to estuaries. Septic tanks are sunk about 2 to 3 m into the ground. During closed mouth conditions (and very high tides) density differences between fresh and saltwater causes drainage problems or infrastructure damages if tanks are not above the groundwater table; and
- i) Droughts, water resources development and land-use change in the catchment can lead to changes in mouth behaviour (e.g. change in Uilkraals Estuary type from a Predominantly Open system to Large Temporarily Open as a result of damming and insufficient flow allocation, the Gamtoos Estuary closing in 2017 for the first time in nearly 70 years due to severe drought and no flow allocation causing complications with backflooding of riparian land). Extended EFZs reduce development conflict moving forward.

4.5 Formalising the estuary delineation

In 2010, the EFZ, encapsulating not only the estuary water body but also supporting physical and biological processes and habitats necessary for that estuarine function and health, was listed under the National Environmental Management Act (NEMA), Environmental Impact Assessment (EIA) Regulations (2010). This notice stipulates that estuaries (defined by the spatial delineation of the estuarine functional zone) are 'sensitive areas' that require environmental authorisation before developments within this zone may proceed. These regulations were not backdated but strive to curb inappropriate future development in the EFZ. The spatial demarcation of the EFZs enabled, for the first time, their explicit incorporation into planning and approval processes, such as provincial conservation plans and municipal Integrated Development Plans (IDPs). Importantly, the EFZ increases the 'traditional estuary' considerably, now including habitats such as floodplain areas, previously not considered essential for estuary functioning.

In summary, the delineation of the estuarine functional zones for South African estuaries elevated the status of estuaries from merely a points layer (X,Y dataset) to spatially demarcating the space where most ecosystem functions occur. The promulgation of the EFZ under the NEMA Regulations and its incorporation into regulations under the ICM Act (specifically Chapter 4 of the Act) provide significant protection to estuarine biodiversity.

4.6 Recommendations

At several estuaries, the EFZ goes beyond the 5m contour for one or more of the following reasons. In deeply incised floodplains, where the river/estuary bed may be meters below the mapped floodplain area, tidal action and/or backflooding may be detected further upstream than indicated by the 5m contour on the topographical map. This is an artefact of the mapping process and needs site-specific data to correct. For some narrow, deeply incised estuaries with very large catchments the 1:100 year flood lines may be above the 5m contour (i.e. limited floodplain area in relation to significant flood volume), e.g. uMzimkulu and uThukela that have been known to reach 12 to 15 msl. In such cases it is recommended that a detailed topographical survey be conducted and that the flood line is estimated

following engineering principles to demarcate physically dynamic areas and indicate flood risk on a more local scale. The littoral active zones adjacent to an estuary can stretch beyond the 5m contour, e.g. dune fields next to the Duiwenhoks and Sundays estuaries, and should be incorporated in the EFZ in site specific cases. While the NBA 2018 has directed significant resources towards the refinements of the EFZ there are still uncertainties in the supporting datasets. It is recommended that a concerted effort be made by an experienced team in estuarine physical processes to determine the upper limits of South Africa's estuaries.

In total, 42 micro-estuaries (5 in the Cool Temperate, 13 in the Warm Temperate and 24 in the Subtropical biogeographical regions) were not formally delineated on the 5m contour dataset as it was too coarse a resolution for these small estuarine features. Mapping was done based on a combination of geographical information, vegetation changes and high-resolution mapping done for the ecosystem classification of the coast. Important to note, is that by not delineating these micro-systems as functional estuaries means that they lack adequate protection from future developments. It is recommended that a separate study be undertaken to demarcate these smaller and/or more ephemeral outlets more accurately and integrate them into current planning frameworks. While these micro-systems do not require individual estuary management plans, it is recommended that an overarching guideline document be developed that can control /prevent coastal development on these very small dynamic systems.



Groot Brak Estuary © SAEON

5. ESTUARINE HABITAT STATUS AND TRENDS

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Estuarine Habitat Status & Trends

- Six different macrophyte habitats occur nationally, with reeds, sedges and salt marsh distributed throughout the biogeographic zones, whereas mangroves and swamp forest are restricted to Subtropical and Tropical areas.
- Over 170 estuarine-associated plants have been identified with the greatest diversity at Kosi Estuary. Cyperaceae, Chenopodiaceae and Mesembryanthemaceae spp. are the dominant plant families occurring in South African estuaries.
- Plant biodiversity is greater in the Arid and Cool Temperate regions where extreme conditions promote diversification.
- 30% of supratidal salt marsh has been lost to encroaching development, with some loss of intertidal salt marsh from bridges, causeways and jetties.
- Mangroves no longer occur in ten small Kwa-Zulu Natal estuaries as a result of catchment and mouth disturbance, while in the Eastern Cape province, growing pressures are harvesting, cattle browsing and changes in estuary mouth condition.
- Salt marsh, seagrass and mangrove habitats require great protection. Priority estuaries for protection are Groot Berg, Knysna, Mngazana, uMlalazi, St Lucia and Kosi estuaries. Great Berg Estuary, with its expansive floodplain marshes, is especially unique and must be prioritised for rehabilitation and protection status. Knysna Estuary has important large intertidal salt marsh areas and the most extensive population of the Endangered seagrass *Zostera capensis*.
- Estuarine Lakes support largest areas of submerged macrophytes and require special protection as they have weak resetting mechanisms and represent nutrient sinks.

5.1 Important Estuarine Habitats

Six different macrophyte habitats are recognized in South Africa estuaries (Table 10). The spatial distribution of different macrophyte communities along the length of an estuary is dependent on the salinity created by a continual flow of freshwater into the system. This spatial distribution is of significance as it gives a good indication of the health of the estuary. Estuaries with low freshwater inflow tend to have low macrophyte diversity. Macrophytes fulfil an important ecological function as growth and decomposition influences other biotic and abiotic components. Macrophytes provide physical structure to the littoral zone and serve as a habitat for fauna. Macrophytes also play an important role in terms of nutrient trapping, recycling and as a food source. Data on the area coverage and species composition of macrophyte habitats are used to determine the Estuarine Health Index for South Africa estuaries. It is also used to inform management (Estuary Management Plans) and conservation priorities. The presence or absence of rare and keystone species can be used as indicators of change. It is therefore important to have these data available and regularly updated.

Table 10: Estuarine habitats in the South African estuaries after Adams *et al.* (1999) with important taxa.

HABITAT	DESCRIPTION
SUBMERGED MACROPHYTES  <i>Zostera capensis</i> in the Swartkops Estuary	Plants that are rooted in both soft subtidal and low intertidal substrata and whose leaves and stems are completely submerged for most states of the tide. Submerged macrophytes tend to occur in permanently open estuaries, particularly Eelgrass (<i>Zostera capensis</i>) whereas <i>Ruppia cirrhosa</i> prefers the less saline and sheltered conditions of estuarine lakes and temporarily open/closed estuaries. <i>Stuckenia pectinata</i> (Ribbon Weed, Fennel Pondweed) prefers fresher conditions (salinity below 10) and therefore occurs in closed systems or in the upper reaches of estuaries. Submerged macrophytes are important primary producers in estuaries providing a source of food, refugia and nursery for invertebrates and fish. They play an important role in biogeochemical processes including oxygenating the water column during the growing season through photosynthesis, improving water clarity, nutrient trapping and recycling. The distribution and abundance of submerged macrophytes is threatened by a decline in water quality and smothering from macroalgal blooms and invasive aquatic plants.
SALT MARSH  Salt marsh mosaic in the Swartkops Estuary	A suite of herbaceous vascular plants that are adapted to endure the extremes of salinity, desiccation and tidal flooding characterizes salt marshes. Common genera are <i>Sarcocornia</i>, <i>Salicornia</i>, <i>Triglochin</i>, <i>Limonium</i> and <i>Juncus</i>. Halophytic grasses such as <i>Sporobolus virginicus</i> and <i>Paspalum</i> spp. are common. Salt marsh plants show distinct zonation patterns along tidal inundation and salinity gradients. Zonation is well developed in estuaries with a large tidal range e.g. Berg, Knysna and Swartkops estuaries. Intertidal salt marsh occurs below mean high water spring and supratidal salt marsh above this. <i>Sarcocornia pillansii</i> is common in the supratidal zone and large stands can occur in estuaries such as the Olifants. Salt marsh vegetation stabilizes the sediment protecting the banks of an estuary from eroding away. They are important filters of sediment and pollutants as well as zones of nutrient production and retention.
REEDS AND SEDGES  Reeds in the St Lucia Narrows	Reeds, sedges and rushes are important in the freshwater and brackish zones of estuaries. Because they are often associated with freshwater input they can be used to identify freshwater seepage sites along estuaries. The dominant species are the common reed <i>Phragmites australis</i> and sedges <i>Schoenoplectus</i>, <i>scirpoides</i> and <i>Bolboschoenus maritimus</i>. Like salt marsh, reeds and sedges protect the banks of estuaries from erosion. They also provide an important habitat for birds, invertebrates, fish and food for detritivores. Due to their high productivity <i>Phragmites</i>-dominated marshes are widely used in artificial wetlands for the treatment of polluted water.

HABITAT	DESCRIPTION
MANGROVES  Mangroves at Nxaxo Estuary	Mangroves are trees that establish in the intertidal zone in permanently open estuaries along the east coast of South Africa north of East London where water temperature is usually above 20 °C. The White Mangrove (<i>Avicennia marina</i>) is the most abundant, followed by the Black Mangrove (<i>Bruguiera gymnorhiza</i>), followed by the Red Mangrove (<i>Rhizophora mucronata</i>). Mangrove forests protect the coastline acting as buffers against severe weather. They are extremely productive habitats that are home to a diversity of fish and invertebrate species. Mangroves are also important for filtering and improving water quality. They also have a high recreational, cultural and tourism value. More recently the value of mangrove forests as a carbon sink has been recognized. Mangroves are threatened by overutilization such as the harvesting of mangrove wood for building material, and for removal for aquaculture and slash and burn cultivation. At Kosi Bay mangroves are intensively harvested for the construction and maintenance of traditional fish traps. Harvesting results in stunted growth and coppicing of the trees. Climate change driven sea level rise and temperature changes has the potential to change the distribution range of mangrove species.
SWAMP FOREST  Swamp forest at uMdloti Estuary	Swamp forests are freshwater ecosystems associated with estuaries in the subtropical and tropical regions, including species such as <i>Barringtonia racemosa</i>, <i>Hibiscus tiliaceus</i>, <i>Ficus trichopoda</i> and <i>Syzigium cordatum</i>. In systems with little submerged macrophytes they play an important role in detritus input in the form of leaf litter. This habitat plays an important role in riparian erosion control and flood attenuation.
MACROALGAE  Macroalgal bloom at Zand Estuary	Macroalgae can be free floating or attached to rocks and other substrates. Filamentous macroalgae often form algal mats and increase in response to nutrient enrichment or calm sheltered conditions when the mouth of an estuary is closed. Typical genera include <i>Ulva</i> and <i>Cladophora</i>. Marine genera in estuaries are <i>Codium</i>, <i>Caulerpa</i>, <i>Gracilaria</i> and <i>Polysiphonia</i>. Increased nutrient loads due to agricultural runoff and wastewater input have resulted in increased incidences of macroalgal blooms.

HABITAT	DESCRIPTION
SAND AND MUD BANKS  Intertidal flats at the Nxaxo Estuary	This habitat provides a possible area for microphytobenthos to inhabit.
OPEN WATER AREA  Phytoplankton bloom at Zand Estuary	This is the habitat associated with the water column of an estuary and is measured as water surface area. Serves as a possible habitat for phytoplankton.

Adams *et al.* (2016) presented the total area coverage and species composition of South African estuary habitats associated with different estuary types and bioclimatic regions. The paper published an estuary botanical database summarising data from literature and field studies on the coverage and species composition of macrophyte habitats in the country. The habitat cover worksheet contains each estuary name, coordinates, estuary type, biogeographic zone, habitat area and human pressures such as extent of development. The species worksheet lists the presence of macrophyte species noted during field surveys. Details pertaining to the different vegetation maps was also included such as who mapped the estuary, what aerial photographs were used, and if it was ground truthed.

Since Adams *et al.* (2016), additional ground truthing and vegetation mapping has been completed mainly along the West Coast. Mangrove and salt marsh habitat extent was updated through mapping efforts in Google Earth. Polygons were drawn around these habitats, distinguished by colour, height and position in the estuary. Mapping was carried out by the same person to ensure accuracy. The available vegetation maps were standardized and converted to meet SANBI specifications (available online at www.bgis.com). This resulted in some area changes as older maps were not based on the Estuarine Functional Zone (EFZ) and therefore required adjustment. Different projections have been used and topological errors were corrected (i.e. overlaps or slivers).

Species records have also been updated since 2016 including data for the recently visited estuaries, and incorporating new data sources namely, the Botanical Database of Southern Africa (available online at <http://newposa.sanbi.org/>), which contains records from the National Herbarium in Pretoria

(PRE), the Compton Herbarium in Cape Town (NBG & SAM) and the KwaZulu-Natal Herbarium in Durban (NH). The citizen science websites Ispot (www.ispotnature.org) and Inaturalist (www.inaturalist.org) were also checked. All three of these sources were used in the same manner by searching the coast of South Africa in map view to determine if any additional species had been recorded at any of South Africa's estuaries. The 'Species list' tab of the Botanical Database spreadsheet contain the species name with full authority as columns, divided according to broad macrophyte habitats. Estuary names were presented as rows with the presence of a species in a particular estuary marked as an '*'. Habitats followed the descriptions available in the Vegetation Map of South African (available online: www.bgis.sanbi.org/). The life form of each species was also captured. Additions to the Botanical Database are cumulative and thus the species list for each estuary is a summation of its historical species list.

A revised 2019 estuary botanical database has been produced to encapsulate all the updates and changes since Adams *et al.* (2016). This dataset provides a snapshot in time that will be continually updated as new data are available.

5.2 Present Distribution of Estuarine Habitats

To date 122 estuaries have GIS vegetation maps available, with 41 mapped prior to the EFZ and for some estuaries only particular habitats were mapped such as mangrove distribution. The geodatabase containing these shapefiles are available on request from the Botany Department at Nelson Mandela University. The geodatabase contains the distribution and area covered by the different macrophyte habitats in South African estuaries. The associated metadata provides necessary details pertaining to the method followed.

Trends were similar to those described by Adams *et al.* (2016). Estuary habitat covers a total area of 103 500ha (Table 11). Reeds and sedges (17 530ha) were the dominant habitat type overall. Supratidal salt marsh was dominant in the cool temperate region (6 300ha) and warm temperate region (2 400 ha) and reeds and sedges in the subtropical region (10 800ha). In the cool temperate, warm temperate and subtropical regions, the estuaries with the largest areas were the Berg (7 970 ha), Knysna (2 380 ha) and St Lucia estuaries (44 830ha), respectively (Table 12). Reeds and sedges occur in brackish conditions throughout South Africa. This habitat is increasing as estuaries become nutrient enriched encouraging reed growth. Like submerged macrophytes reeds and sedges are dynamic with dieback occurring in winter and complete removal during flooding events. Over 7000ha of reed habitat has been mapped in the wetlands of St Lucia Estuary. The Berg Estuary in the Western Cape (1910 ha) and uMfolozi in KwaZulu-Natal (1610 ha) have large floodplains representing the second and third largest reed beds in the country. Fifteen more estuaries in the country support over 100ha of reed habitat.

Salt marsh habitat occurs across the biogeographic zones and is the primary constitute of cool and warm temperate estuaries (Figure 15). The large Berg Estuary supports the greatest salt marsh area in the country, however the health of this marsh is threatened by agricultural encroachment, salinization and drying of some of the open pans due to drought. Langebaan and Olifants estuaries on

the West Coast support large salt marsh habitat, with the combined area of inter- and supratidal habitat 1 350ha and 1 010 ha, respectively. Nine estuaries in the country support greater than 100ha of intertidal salt marsh and sixteen estuaries over 100ha of supratidal salt marsh (Figure 16). Aside from Berg and Langebaan, Knysna Estuary has a large intertidal salt marsh (552 ha) (Figure 17). Olifants (910 ha), St Lucia (700 ha), Heuningnes (660 ha), Orange (627 ha) and Langebaan (557 ha) estuaries support over 500ha of supratidal salt marsh habitat.

The Berg Estuary is a unique system worthy of conservation as it has extensive floodplains with high habitat diversity. The largest area is occupied by halophytic floodplain (1 520 ha), open pan (1 160 ha), sedge pan (980 ha) and xeric floodplain (920 ha). It has the largest and most diverse associated saline and freshwater wetlands compared to all other permanently open estuaries in South Africa. These are threatened by drought, reduced freshwater inflow and encroaching agricultural activities. All specialists who have studied this system (McDowell 1993; O’Callaghan 1994; Boucher & Jones 2007) indicated that the estuarine area have been significantly transformed and threatened by anthropogenic disturbance. This estuary with its expansive floodplain marshes is unique nationally and must be prioritised for rehabilitation. No grazing, burning or use by cattle should take place in the surrounding floodplain and marsh habitats. Changes in rainfall patterns and an increase in drought conditions in response to climate change pose a serious threat to the state of the estuary. Disturbance has resulted in a loss of vegetation cover, erosion and barren windswept areas. The situation will be exacerbated by a decrease in flooding and increase in drought conditions due to freshwater abstraction as well as climate change. The macrophyte habitats are dependent on specific salinity and flooding conditions. Monitoring on an annual basis is required to assess the integrity of these habitats.

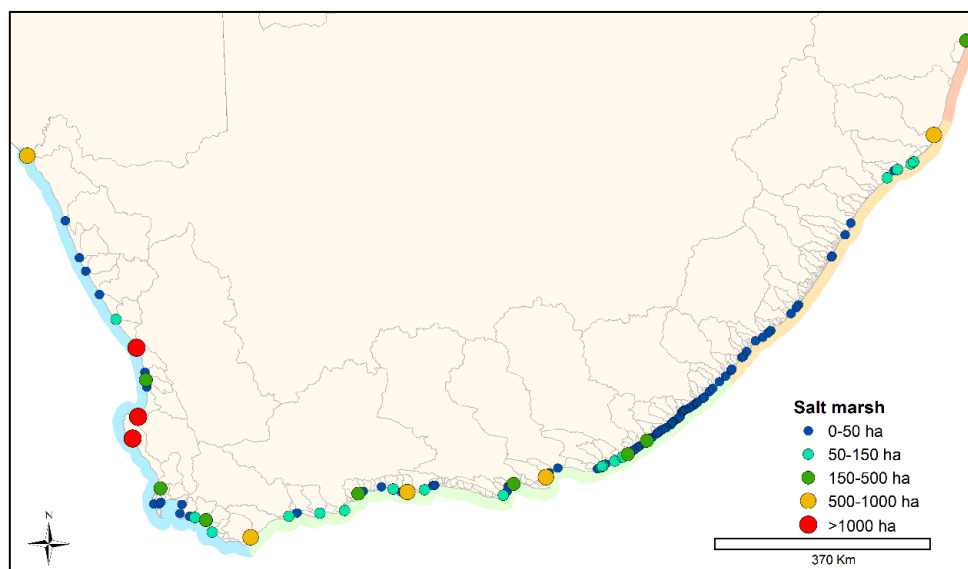


Figure 15. Distribution of salt marsh habitat in South African estuaries.

Table 11. Area of estuary habitat types (ha) across bioclimatic regions.

	COOL TEMPERATE	WARM TEMPERATE	SUBTROPICAL	TROPICAL	TOTAL AREA
Open water	9 541	8 484	37 550	3 447	59 022
Intertidal salt marsh	2 814	1 887	502	58	5 261
Supratidal salt marsh	6 302	2422	837	229	9790
Submerged macrophytes	593	1 051	488	675	2 807
Reeds and sedges	3 831	2 651	10 800	244	17 526
Mangroves	0	25	1 577	71	1 673
Sand/mud banks	897	1 717	1 223	24	3 861
Rocks	11	106	4	0	121
Swamp forest	0	1	2 077	1 286	3 364
Total area (ha)					103 425

Table 12. Habitat area (ha) of the five largest estuaries in each region. Note total area includes habitats not represented in table such as sand/mudbanks and rocks.

ESTUARY	ESTUARY TYPE	OPEN WATER	INTERTIDAL SALT MARSH	SUPRATIDAL SALT MARSH	SUBMERGED MACROPHYTES	REEDS AND SEDGES	MANGROVES	SWAMP FOREST	TOTAL
Cool Temperate									
Groot Berg	Predominantly Open	821.7	1658	3226.2	206.0	1909.90	0	0	7 972.9
Langebaan	Estuarine Bay	4017.1	791.7	556.9	85.8	123.60	0	0	5 584.3
Orange	Large Fluvially dominated	605.4	144.0	626.9	1.0	316.8	0	0	1 829.8
Verlorenvlei	Estuarine Lake	1061.2	0.0	20.9	0.0	518.4	0	0	1 601.73
Klein	Estuarine Lake	703.9	7.9	208.5	202.5	106.9	0	0	1 398.2
Warm Temperate									
Knysna	Estuarine Bay	945.5	551.9	133.0	447.3	37.8	0	0	2 381
Breede	Predominantly Open	1367.8	20.5	29.55	6.00	229.2	0	0	1 789.0
Heuningnes	Predominantly Open	907.9	16.2	660.40	10.2	1154.98	0	0	2 793.0
Swartvlei	Estuarine Lake	630.9	0.0	91.40	219.4	167.1	0	0	1 242.1
Swartkops	Predominantly Open	135.0	209.2	338.15	44.7	4.5	0	0	926.7
Subtropical									
St Lucia	Estuarine Lake	32 533.9	250.0	700.0	431.5	7225.8	209.5	17.4	4 1368.1
iMfolozi/uMsunduze	Large Fluvially dominated	90.0	0.00	0.0	0.0	1607.2	78.2	1 683.1	3 458.5
Richard's Bay	Estuarine Bay	869.0	69.9	0.0	0.0	309.0	171.0	16.0	1 965.9
uMhlathuze	Predominantly Open	679.0	60.0	0.0	28.5	205.0	761.5	0.0	1 824.0
Tropical									
uMgobezeleni	Estuarine Lake	80.0	0	0	22.64	117.0	0	416.7	636.8
Kosi	Estuarine Lake	3367.0	58.0	229.0	652.0	127.0	71.0	869.0	5 396.0

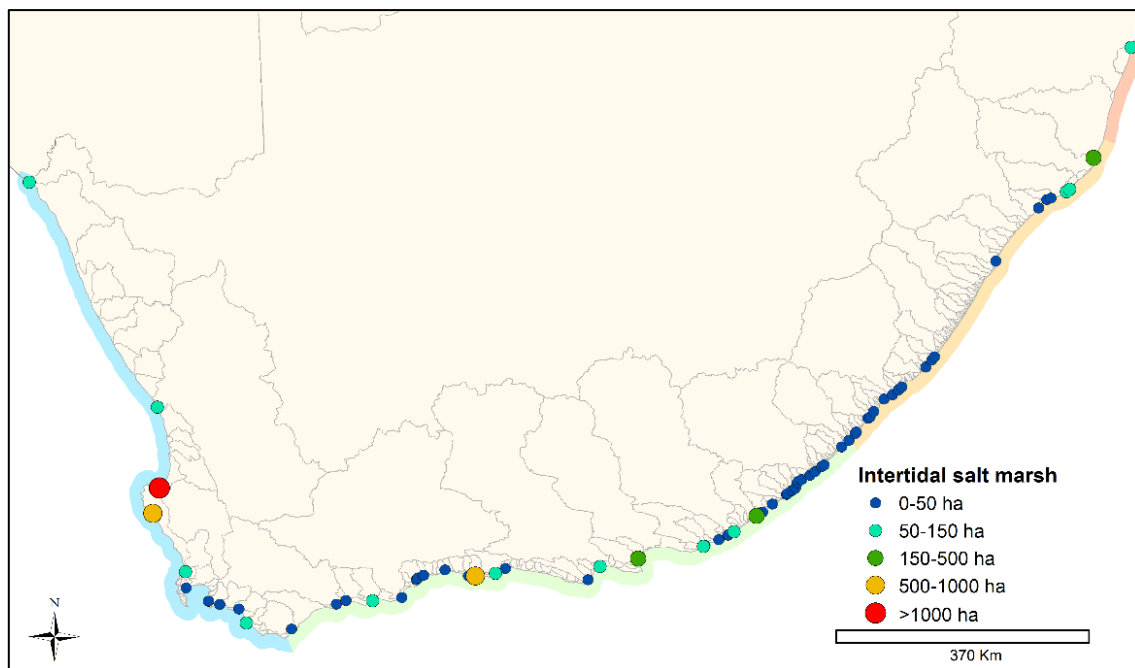


Figure 16. Distribution of intertidal salt marsh habitat in South African estuaries.

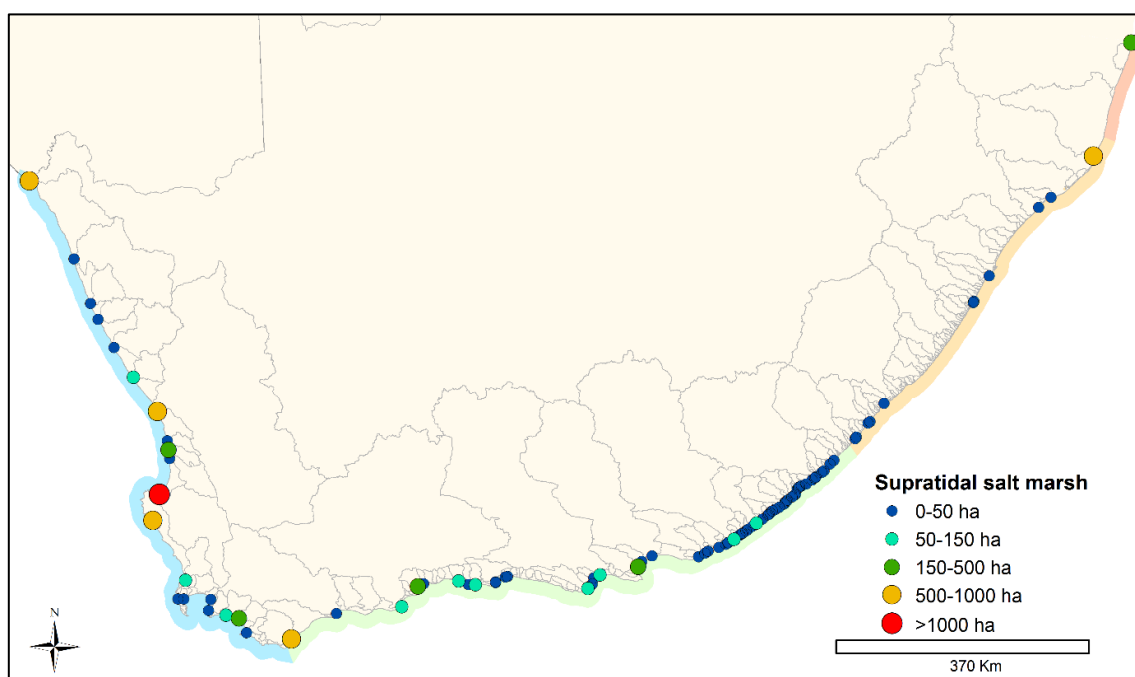


Figure 17. Distribution of supratidal salt marsh habitat in South African estuaries.

Mangroves and Swamp forest are restricted to the subtropical region of South Africa, with a few estuaries in the upper Transkei area (warm temperate) supporting habitat (Figure 18). Presently area is recorded for 31 estuaries in the country. uMhlathuze Estuary supports the largest mangrove habitat (760 ha), with the second highest area occurring at St Lucia Estuary (290 ha). Although not truly estuarine swamp forest habitat occurs within the EFZ of estuaries. The greatest cover of swamp forest was mapped at iMfolozi/uMsunduze Estuary (1 680 ha). Kosi Estuarine Lake also supports a large area of swamp forest habitat (870 ha) and uMlalazi Estuary (100 ha). The other 70 estuaries have cover ranging from 0.01ha at Mnyameni to 17ha at St Lucia.

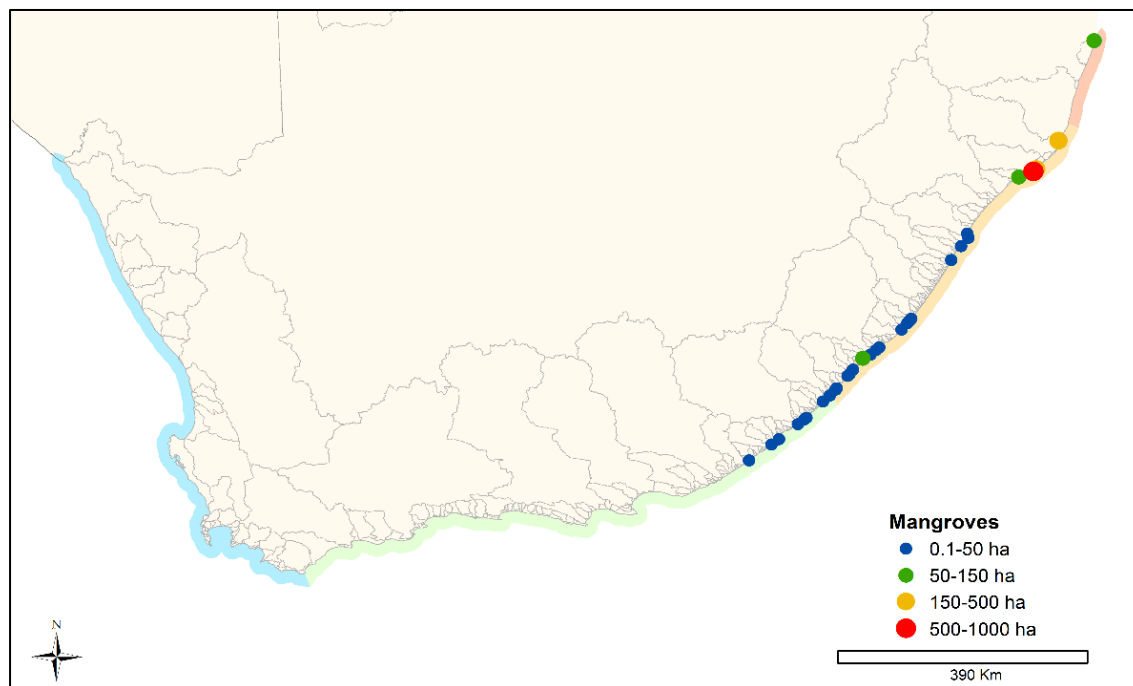


Figure 18. Distribution of mangrove habitat in South Africa.

Only 20% (70 estuaries) of South African estuaries support submerged aquatic vegetation as these species are sensitive to changes to water level, turbidity, nutrients and salinity. Estuarine Lakes provide the most suitable conditions for establishment and the largest areas as found in this scarce estuary type: Kosi (650 ha), St Lucia (430 ha), Knysna (350 ha) and Swartvlei (220 ha) (Adams *et al.* 2016). Only six estuaries in the country supported more than 200ha of submerged macrophyte. The seagrass *Zostera capensis* is a key species but other plants such as *Ruppia cirrhosa*, *Stuckenia pectinata* and *Chara* spp. can also be dominant (Adams 2016). Due to their rapid response to environmental change submerged macrophytes are good indicators of trophic state. This has not been well documented for South Africa's estuarine lake systems and requires investigation. Kosi Estuary is a unique system because of its diverse extensive submerged macrophytes. *Ceratophyllum demersum*, *Najas horrida*, *Najas marina*, *Potamogeton sweinfurthii* and *Urticularia* spp. occurred in the two upper lakes (Lakes 3 and 4). Other species appeared as the salinity increased for example *Stuckenia pectinata* (grows best salinity < 20) was only observed in Lake 3, *Ruppia cirrhosa* in Lake 1 and the seagrasses *Zostera capensis* and *Halodule univervis* in the estuary.

5.3 Species Diversity of Macrophyte Habitats

Macrophyte diversity is available for 276 estuaries in the country, although fourteen of those only have one species recorded thus far. The number of macrophyte species per estuary varies from one to 54, recorded at Kosi Estuary. The presence/absence list has been simplified to 176 estuarine-associated plant species, the majority (56 species) of which are associated with salt marsh habitat (Figure 19). In total 41 wetland, terrestrial and seashore species were included as these taxa occur along the beach dunes or in the terrestrial/estuarine ecotone. The mangrove fern *Acrostichum aureum* was included as a mangrove species. Although not truly estuarine swamp forest species including common trees, ferns and creepers were included due to their presence in KwaZulu-Natal estuaries. Macrophyte species are distributed in 60 families and the dominant families are Cyperaceae (23), Chenopodiaceae (18), Mesembryanthemaceae (14) and Asteraceae (11), while 33 other families had only one representative species.

Only 66 plant species occurred in five or more estuaries in the country. Of these fourteen species occurred in more than 20% of the country's estuaries. Species such as sharp rush *Juncus kraussii* Hochst. (216 estuaries) and common reed *Phragmites australis* (Cav.) Steud (206 estuaries) are widely distributed in estuaries. Although not true estuarine species Brakgras *Sporobolus virginicus* (L.) Kunth (248 estuaries) and Buffalo grass *Stenotaphrum secundatum* (H. Walter) Kuntze (245 estuaries) are also abundant. *Sarcocornia littorea* (Moss) A.J. Scott a common component of beach and dune vegetation was recorded in 136 estuaries. Other species recorded in over 20% of estuaries included: *Schoenoplectus scirpoides* (Schrad.) Browning (74 estuaries), *Bolboschoenus maritimus* (L.) Palla (65 estuaries), *Cotula coronopifolia* L. (63 estuaries), *Bassia diffusa* (Thunb.) Kuntze, *Zostera capensis* Setch., *Crassula expansa* [Soland.] and *Triglochin striata* Ruiz & Pav. In 63 estuaries, respectively and *Typha capensis* (Rohrb.) N.E.Br. (59 estuaries). Veldkornet et al. (2016) described a number of rare species (i.e. those only recorded in one or two estuaries in the country) namely: *Sarcocornia capensis* (Moss) A.J. Scott, *Frankenia pulverulenta* L., *Poecilolepis ficoidea* (DC.) Grau, *S. decumbens* (Toelken) A.J. Scott, *Triglochin elongata* Buchenau, *Suaeda fruticosa* (L.) Forssk. and *S. inflata* Aellen. Refer to the species of special concern chapter for further details.

According to Adams et al. (2016) macrophyte species richness was higher in estuaries of the cool and warm temperate zone than that in the subtropical zone. This included a large number of ecotone species; terrestrial species occurring in the estuary functional zone. Inclusion of the new Tropical bioregion shows that the estuaries there (Kosi & Mgobezeleni) have higher macrophyte species richness than the cool temperate zone (Figure 19) For this analysis only the true estuarine species were used. The estuarine lagoon (Langebaan) had the highest species richness. An in-depth botanical survey was conducted there which may account for this. As expected estuarine bays, lakes and permanently open estuaries followed in terms of the highest number of macrophyte species present (Table 13). A full taxonomic revision is required before these data can be presented with a high level of confidence.

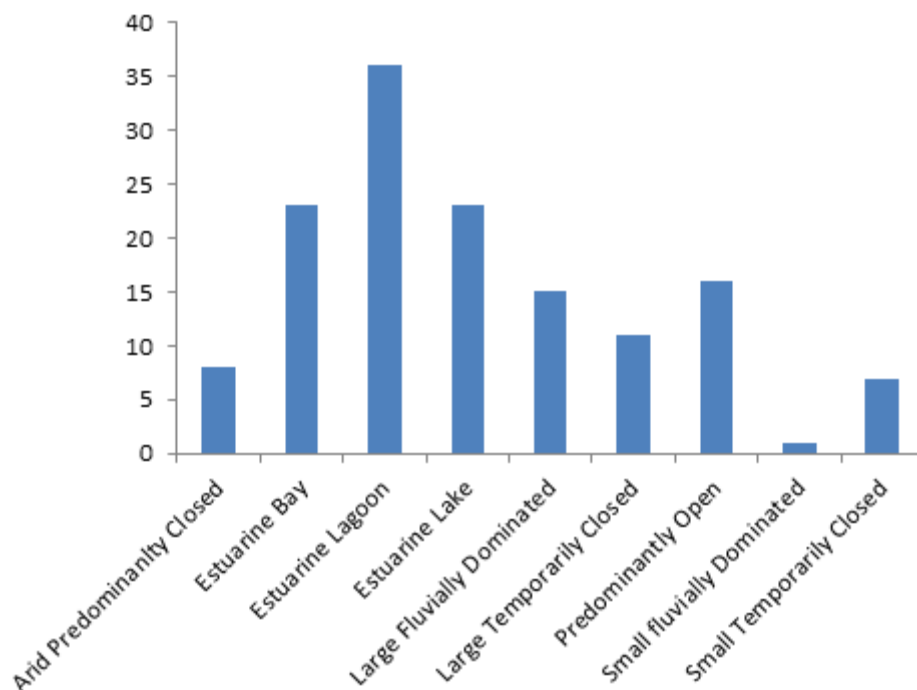
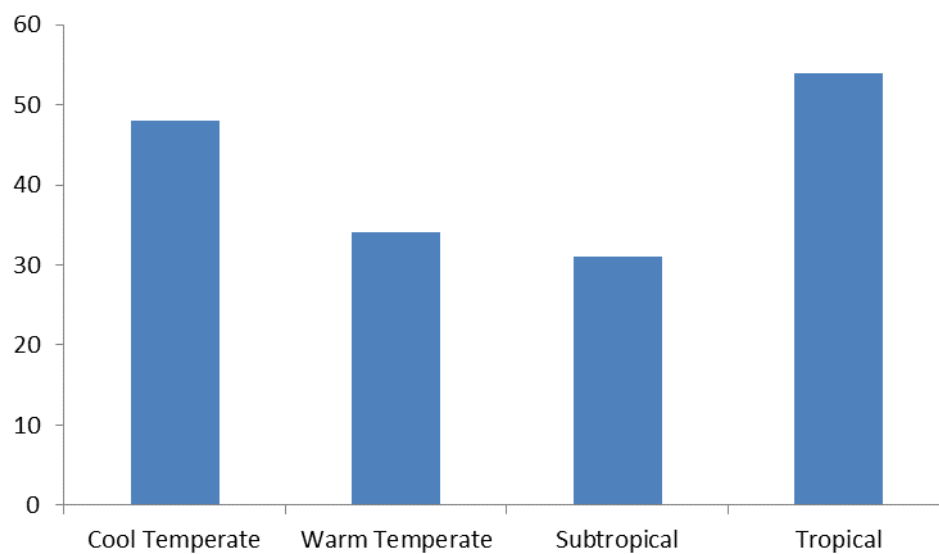


Figure 19. Species richness in four bioclimatic regions (a) and nine types of estuaries (b) in South Africa. The number of estuaries considered is presented in brackets.

Table 13. Families and dominant species present in South African estuaries and their relative species richness.

MACROPHYTE HABITAT	SPECIES RICHNESS	PLANT FAMILIES	DOMINANT SPECIES
Salt marsh	51	Apiaceae, Araliaceae, Asteraceae, Aizoaceae, Chenopodiaceae, Cyperaceae, Frankeniaceae, Iridaceae, Juncaginaceae, Mesembryanthemaceae, Plumbaginaceae, Poaceae, Primulaceae, Rubiaceae, Solanaceae	Intertidal salt marsh: <i>Cotula coronopifolia</i> L. <i>Triglochin striata</i> Ruiz & Pav. <i>Salicornia meyeriana</i> Moss <i>Sarcocornia tegetaria</i> S. Steffen Mucina & G. Kadereit, <i>Limonium scabrum</i> (L.f.) Kuntze, Supratidal salt marsh: <i>Juncus kraussii</i> Hochst. <i>Schoenoplectus scirpoides</i> (Schrad.) Browning, <i>Bassia diffusa</i> (Thunb.) Kuntze
Reeds & sedges	31	Cyperaceae, Juncaceae, Poaceae	<i>Phragmites australis</i> (Cav.) Steud <i>Cyperus textilis</i> Thunb. <i>Bolboschoenus maritimus</i> (L.) Palla <i>Typha capensis</i> (Rohrb.) N.E.Br.
Submerged macrophytes	16	Ceratophyllaceae, Hydrocharitaceae, Lemnaceae, Najadaceae, Nymphaeaceae, Potamogetonaceae, Ruppiaceae, Zannichelliaceae, Zosteraceae	<i>Zostera capensis</i> Setch. <i>Potamogeton pectinatus</i> L. (Stuckenia) <i>Ruppia cirrhosa</i> (Pentag.) Grande
Mangrove forest	6	Avicenniaceae, Combretaceae, Malvaceae, Polypodiaceae, Rhizophoraceae	<i>Avicennia marina</i> (Forssk.) Vierh. <i>Bruguiera gymnorhiza</i> (L.) Lam.
Swamp forest	18	Apocynaceae, Arecaceae, Blechnaceae, Cyperaceae, Euphorbiaceae, Fabaceae, Lecythidaceae, Moraceae, Myricaceae, Nephrolepidaceae, Phyllanthaceae, Smilacaceae, Strelitziaceae, Thelyperidaceae	<i>Hibiscus tiliaceus</i> L. <i>Barringtonia racemosa</i> (L.) Sprengel. <i>Strelitzia nicolai</i> Regel and Körn.

5.4 Trends in macrophyte habitat distribution

Estuaries are by nature resilient systems, because their fauna and flora are adapted to living in conditions of extreme change. However, development surrounding estuaries can cause changes to the structural habitat of an estuary, possibly resulting in local extinctions. Development also prevents lateral movement of habitats such as salt marsh. The construction of hard structures in estuary floodplains is not easily reversible and can only be mitigated. Even recovery from temporary disturbances can take decades to restore to nature conditions. Global sea level rise coupled with these artificial margins, referred to as coastal squeeze, will result in localised extinctions of habitats as the biota will be unable to move landward. The combination of changing temperature, precipitation and increased coastal erosion may result in species distribution changes resulting in shifts along the coastline. The ecotones between salt marshes and terrestrial vegetation need to be maintained to prevent invasion by alien plants and to ensure landward migration of salt marsh vegetation.

Veldkornet *et al.* (2016) in a study on land cover boundaries in South Africa determined that most estuaries are developed with only 28 % considered to be in a completely natural state. Development classified as 'urban built-up' in the National Land cover Classification map was associated with 275 estuaries (6 630 ha) and 168 estuaries (26 860 ha) were identified as having been subject to some cultivation, particularly sugar cane cultivation in KwaZulu-Natal.

Fernandes *et al.* (2017) estimated the extent of estuarine habitat loss by mapping anthropogenic activities occurring within the Estuarine Functional Zone (i.e. 5m topographic contour) of South Africa's estuaries. Visible changes identified from aerial photographs and Google Earth were mapped. These included development, roads, housing, grassed areas, grazing and agriculture. The type of habitat lost (e.g. salt marsh, mangroves) was determined through comparison of historical aerial photographs and literature as well as physical features such as surrounding habitat, elevation, biographic zone and estuary type. Particular interest was focussed on the loss of salt marsh and mangrove habitat. This study only considered loss of macrophyte habitats due to direct removal of habitat for development or other human needs and did not consider indirect impacts such as changes in macrophyte habitats due to changes in flow, water quality or alien invasive plants. These data have been updated since then and are presented in this report.

The results of Fernandes *et al.* (2017) were updated in 2018 using recently completed vegetation maps. A third of the country's estuaries are natural, these are mostly small estuaries located along the rural Transkei coastline in the Eastern Cape and some in inaccessible areas in KwaZulu-Natal and Western Cape provinces. Some estuaries, in particular, river mouths occur in incised valleys and naturally support little to no estuarine habitat (e.g. Steenbras, Tsitsikamma and Storms River). A few estuaries in the country have completely lost functionality as they have been canalised and have no natural habitat remaining. These estuaries are mostly situated in harbour developments such as Sout (Wes) in the Cape Town, Papenkuils and to a lesser degree the Baakens estuaries in Port Elizabeth. Under natural conditions, the Sout (Wes) Estuary would have supported extensive salt marsh and

freshwater marshes. Only patches of Common Reed (*Phragmites australis*), Bulrush (*Typha capensis*), and Sharp Rush (*Juncus kraussii*) remain alongside the roads. Marina developments have altered the natural mouth and open surface water area of estuaries such as Marina da Gama at Zand (Cape Town), Marina Glades at Kromme and Royal Alfred Marina at Kowie Estuary.

The construction of the Durban Bay harbour in the 1800s led to the decimation of mangrove and seagrass habitat. It is estimated that 440ha of mangrove habitat occurred in the bay, the largest area in the country (Begg 1978; Forbes & Demetriades 2009). Presently only 15ha remains in a proclaimed natural heritage protection site. Wetlands, marshes and intertidal reaches have been converted into the concrete walls of the harbour. Infilling, reclamation and dredging lead to the loss of these habitats. The last remaining area of seagrass habitat was lost in the 1960s. Storm water drains flowing through industrial and residential areas deposit nutrient and chemical laden water as well as large quantities of litter into the estuary.

Agriculture, cultivation and grazing often occurs in the floodplains surrounding estuaries as the land is fertile and conveniently situated for irrigation. In KwaZulu-Natal sugar cane cultivation occurs right to the banks and water channel of most estuaries. More recent legislation has prevented cultivation so close to the channel and some of this land has turned into disturbed grassy habitats or invaded by Brazilian Pepper Trees (*Schinus terebinthifolia*). Heuningnes, Berg and Gamtoos estuaries have large expanses of agriculture occurring in the catchment. Salt marsh habitat has been lost in the Heuningnes Estuary (Struisbaai, Western Cape) due to extensive agriculture in the floodplain. Almost the entire catchment of the Gamtoos Estuary situated near Jeffreys Bay in the Eastern Cape has been converted to agriculture and cattle farms.

1.1.1 Salt marsh area

The greatest loss of macrophyte habitat has been of supratidal salt marsh (Table 14). This habitat occurs up to the 2.5m contour and is the furthest from the open water. It is sometimes the ecotone between salt marsh and terrestrial vegetation and therefore the most likely habitat to be developed (Adams et al. 2016). Bridges, causeways and jetties have impacted the area of intertidal salt marsh. At Seekoei Estuary, for example, a causeway near the mouth has resulted in flooding of habitat that would naturally have been intertidal salt marsh.

Intertidal salt marsh has been lost from a number of estuaries (Table 14), Berg, Langebaan and Knysna estuaries, which presently support the largest areas, receive some level of protection in reserves (Maree 2000). Development such as the town of Knysna, Thesen Island, Leisure Isle, the N2 road bridge and embankments has resulted in the loss of large areas of salt marsh habitat in the Knysna Estuary. The Port Alfred Marina, the town of Port Alfred and houses along the banks with jetties has removed intertidal salt marsh habitat from the Kowie Estuary. Footpaths and the caravan park in the lower reaches has disturbed habitat in the Great Fish Estuary.

Table 14. Past and present cover changes for macrophyte habitats in South African estuaries. Arrows indicate the trajectory of change.

HABITAT	PAST (HA)	PRESENT (HA)	CHANGE (HA) & %
Intertidal salt marsh	5 941.6	5 261.3	680 (12.9% ↓)
Supratidal salt marsh	1 4308.4	9 789.6	4 518.8 (31.6% ↓)
Submerged macrophytes	1 437.0	2 806.8	1 369.7 (95% ↑)
Mangroves	1 564.3	1 672.5	108.2 (6.9 % ↑)

Agriculture within the floodplain of estuaries has resulted in the loss of large supratidal salt marsh habitat in the country (Table 14). Nearly 90 % of salt marsh at Gamtoos has been lost to vegetable cultivation and cattle grazing. The Orange River Estuary, a Ramsar wetland of international importance, is the boundary between South African and Namibia. It was placed on the Montreux Record in 1995 because 300ha of salt marsh had become desertified. This loss was attributed to leakage of diamond mine water, the effect of windblown dried slimes dam sediment on the marsh vegetation, construction of flood protection works and a beach access road, and the elimination of tidal exchange into the wetland due to a causeway constructed at the river mouth (Shaw *et al.* 2008). Due to the low rainfall on the West Coast and highly salinized nature of the desertified marsh area there has been little change of the salt marsh status over the last 10 years.

Table 15 and Table 16 indicate that there is some protection for estuaries with large salt marsh areas in South Africa. In addition, estuary management plans are a requirement of the National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008). These plans can be effective in protecting sensitive habitats such as salt marsh through zonation of destructive activities such as boating that leads to erosion. There is a need for formal protection status for the Berg Estuary. The Berg Estuary is currently designated as an IBA (Important Bird Area) where the water and intertidal habitat is managed by CapeNature and the local municipality. Restoration of the salt marsh at the Orange River Mouth is also needed as well as greater protection for the large intertidal salt marshes of Knysna. In the South African National Estuary Biodiversity Plan (Van Niekerk & Turpie 2012) habitat targets were set as 20% of the total area of each estuarine habitat type but this has not been implemented or addressed in any way.

Table 15. Intertidal salt marsh area (ha), population trend (↓: decreasing, ↑: increasing, →: stable), pressures and protection status. Estuaries in bold and shaded indicate those where the greatest loss has occurred.

ESTUARY	PRESENT AREA	PAST AREA (% LOST)	HABITAT TREND	PRESSURES	PROTECTION STATUS*
Orange	144.0	154 (6.5%)	↓	Salinisation	Ramsar site
Olifants	96.6	96.6	↓	Salinisation	None
Berg	1182.4	1573 (23%)	↓	Agriculture	Partial CapeNature
Langebaan	791.7	791.7	↑	Grazing pressure removed	South African National Parks
Knysna	551.9	793.8 (30.5%)	↓	Development	Partial SANParks

ESTUARY	PRESENT AREA	PAST AREA (% LOST)	HABITAT TREND	PRESSURES	PROTECTION STATUS*
Swartkops	209.0	215	↓	Development and industry	Partial De facto PA
Kariega	36.1	36.05	→	Agriculture and development	
Kowie	35.0	82.8 (57.5%)	↓	Development Disturbance	Partial De facto PA & Nature Reserve
Great Fish	133.0	144 (7.6%)	↓		
Keiskamma	210.4	210	↓	Agriculture and grazing	Partial De facto PA
Kosi	58.0	58	↓	Grazing, trampling, fires	iSimangaliso Wetland Park Authority (World Heritage site), Nature reserve, Marine Protected Area

*Note that many of the PA do not include the saltmarsh areas

Table 16. Supratidal salt marsh area (ha), habitat trend (↓: decreasing, ↑: increasing, →: stable), pressures and protection status. Estuaries in bold and shaded indicate those where the greatest loss has occurred.

ESTUARY	PRESENT AREA	PAST AREA (% LOST)	HABITAT TREND	PRESSURES	PROTECTION STATUS*
Orange	626.9	1318.8 (52%)	↓	Salinisation	Ramsar site
Olifants	909.50	1528.5 (40.5%)	↓	Salinisation	None
Berg	3226.20	3753.5 (13.2%)	↓	Agriculture	Partial CapeNature
Langebaan	556.90	523.7 (33% increase)	↑	Grazing pressure removed	South African National Parks
Heuningnes	660.40	792 (16.6% loss)	↓	Agriculture	CapeNature/SANParks
Gouritz	123.4	662.2 (81.4%)	↓	Agriculture	None
Knysna	133.00	374.9 (64.5%)	→	Development	Partial SANParks
Keurbooms	41.8	180.4 (77%)	↓	Development	Partial CapeNature
Gamtoos	80.8	710.72 (89%)	↓	Agriculture	None
Swartkops	338.15	1013.15 (66.6%)	↓	Development and industry	None
Kariega	15.07	65.77 (77.1%)	↓	Agriculture and development	Partial De facto PA
Keiskamma	91.26	311.8 (71%)	↓	Agriculture and grazing	Partial De facto PA
Kosi	229.00	229	↓	Grazing, trampling, fires	iSimangaliso Wetland Park Authority (World Heritage site), Nature reserve, Marine Protected Area

1.1.2 Mangrove habitat

Although the area covered by mangroves in South Africa is small, they form an important biodiversity component and provide a number of ecosystem services and thus conservation and management of these unique habitats is essential. It is estimated that nearly 300ha of mangrove habitat has been lost over time due to development, resource utilisation, grazing and changes in mouth condition (Table 17). Rajkaran *et al.* (2009) described the historic and recent state (2006) of mangroves in small estuaries from uMlalazi to uMtamvuna in Kwazulu-Natal. Infilling for road and railway bridges, sugar cane cultivation, siltation and less freshwater inflow were the main pressures attributing to mangrove loss. Although only supporting small areas of mangrove habitat, this loss represents a loss of connectivity along the coastline. In small estuaries changes in mangrove habitat is dynamic responding to periods of mouth closure resulting in prolonged inundation or flooding events. Adams *et al.* (2004) and Hoppe-Speer *et al.* (2015a) described natural dynamic changes at Mnyameni, Mzimvubu, Bulungula and Kobonqaba estuaries. These natural dynamics make conservation planning challenging as one can only predict what will happen in the future in these ephemeral systems.

Overall, there has been an increase in mangrove area in the country due to expansion at the uMhlathuze Estuary (Table 17). In 1975 only 80ha of mangroves occurred at uMhlathuze Estuary in Richards Bay. Bedin (2001) described how harbour development created a new mouth and altered the river alignment resulting in a larger intertidal habitat and delta. The new habitat was quickly colonised by White Mangrove (*Avicennia marina*) increasing the population by 800% as illustrated by mapping efforts in 2016. Green *et al.* (2006) attributed the increase in mangrove area at Kosi Estuarine Lake to the traditional fish traps trapping sediment and creating new islands for the mangroves to colonise. A cyclone in 1955 and resultant mouth closure and flooding of mangroves decimated the mangrove population in the estuary. There are management concerns that estuary mouth closures may occur in the future, which will lead to the loss of this important habitat. The health of the mangroves at Kosi is also of concern as extensive harvesting for maintenance of fish traps has resulted in shorter, coppicing trees.

Hoppe-Speer *et al.* (2015b) mapped the expansion of a site of planted mangroves at the Nahoon Estuary in the Eastern Cape. The population is increasing at 0.06ha per annum and is expected to expand faster under the higher temperature expected with climate change. Quisthoudt *et al.* (2013) modelled mangrove distribution in South Africa under different climate change scenarios and found that *A. marina* and *B. gymnorhiza* will expand to higher latitudes. Yang *et al.* (2014) found that if space is available mangroves will expand landward as sea levels rise. This study at Mngazana Estuary showed that there would be an initial increase in mangrove habitat, thereafter a loss of 0.32ha yr⁻¹ as the steep surrounding topography limited further expansion. It is important to identify estuaries where mangroves can expand inland for climate change adaptation and protection.

Verle (2013) showed that an increase in sea storm events will result in mangrove mortality. A severe sea storm at Mbashe Estuary in 2009 resulted in the deposition of marine sediment smothering the pneumatophores (air roots). By 2012, a large portion of the mangrove stand had died and the area

had been colonised by salt marsh. The first mouth closure in recorded history at Kobonqaba Estuary resulted in complete mangrove dieback and eventual colonization by salt marsh (Mbense *et al.* 2016). A sea storm caused sediment deposition at the mouth of the estuary, coupled with high freshwater abstraction the mouth closed in 2010. Prolonged closure resulted in high water levels that flooded the mangroves (Figure 20). Within four years the bare ground was colonized by salt marsh vegetation. Mangroves at Kobonqaba Estuary declined from an estimated 281 250 individuals prior to mouth closure to only seven individuals in 2011. By 2015, 27 mangrove individuals were present in the estuary.

Estuaries are becoming less stable due to climate change and this will influence mangrove propagule dispersal, seedling establishment and survival. Population structure in other small east coast estuaries indicates historical single successful recruitment events and persistence linked to initial flooding and connectivity with the sea. The predicted meandering of the Agulhas current on the east coast will increase shelf upwelling possibly influencing propagule dispersal.



Figure 20. a) Mouth closure at Kobonqaba Estuary in July 2010, b) Flooding of mangrove habitat, c) Dead mangroves with clear water line on base in March 2011, d) Colonization by salt marsh habitat in July 2015.

Table 17. Changes in the mangrove areas (ha) for the largest stands in the country. Shaded grey indicates increase in area and shaded teal indicates a decrease. Habitat trend ↓: decreasing, ↑: increasing, →: stable.

ESTUARY	PRESENT AREA (HA)	PAST AREA (HA)	HABITAT TREND	PRESSURES	PROTECTION STATUS
Kosi Bay	71	61	↑	Harvesting	iSimangaliso Wetland Park Authority (World Heritage site), Nature reserve, Marine Protected Area
St Lucia	288	331	↓	Silt and mouth closure	iSimangaliso Wetland Park Authority (World Heritage site), Nature reserve, Marine Protected Area
Richards Bay	171	267	↓	Harbour development	None
Mhlathuze	762	80	↑	Dredging, silt and sediment deposition	Nature Reserve (Ezemvelo KwaZulu-Natal Wildlife)
Mlalazi	61	30	↑	Sedimentation, changes in water quality	Nature Reserve (Ezemvelo KwaZulu-Natal Wildlife), Marine Protected Area
Mgeni	27	20	↑	Water quality changes, mouth closure, restriction of tide	Beachwood Mangrove Nature Reserve (Ezemvelo KwaZulu-Natal Wildlife)
Durban Bay	13.4	451	↓	Harbour development	None
iSipingo	3.8	12.5	↓	Development, tidal restriction	None
Mngazana	118	145	↓	Harvesting, cattle and human trampling	None
Mtakatye	10	8	↑	Cattle browsing, harvesting	None
Mtata	31	42	↓	Harvesting	None
Xhora	26	16	↑	Cattle browsing, harvesting	None
Mbashe	9.2	13	↓	Cattle browsing, harvesting	Dwesa-Cwebe Marine Protected Area, Nature Reserve
Nqabarana/ Nqabara	12	9	↑	Cattle browsing, harvesting	None
Nxaxo/Ngqusi	10	14	↓	Cattle browsing, harvesting	None
TOTAL	1 672	1 564	↑		

Mangroves have been completely lost from the Little Amanzimtoti, Lovu, Msimbazi, Mgababa, Ngane, Mhlongwa, Kongweni, Bilanhlole, Mlangankulu, Khandandlovu estuaries (approximate total area 7 ha).

Due to range shifts and planting mangroves now present in Kei, Kwelera, Nahoon, Tyolomnqa estuaries (approximate total area 3.1 ha).

Over 10 000ha of macrophyte habitat has been lost across the country directly due to a change in land-use i.e. transformation of natural habitat into development and other activities. It is estimated that 4 312.5ha of salt marsh has been lost and over 250ha of mangrove habitat. These losses have had an impact on the provisioning of ecosystem services provided by estuaries. Estuaries have lost vital habitat for refugia and food provisioning for juvenile fish and invertebrates, the ability to provide protection against coastal storms, the ability to remediate waste and filter water and food provisioning services amongst others.

1.1.3 Submerged macrophytes

The changes over time in the area covered by submerged macrophytes is variable and difficult to map and assess. Largest areas occur in the estuarine lakes. Table 18 provides some data for the seagrass (*Zostera capensis*). Adams (2016) reviewed the distribution and status of Eelgrass (*Zostera capensis*) in South Africa. Eelgrass has a wide distribution occurring in 62 estuaries from the Olifants Estuary on the West Coast to Kosi Bay on the east coast. Current distribution and status is uncertain for 9 or 23% of the estuaries. Cover is declining in 13.6% of the estuaries and increasing in 3%. Estuaries with the largest areas of *Z. capensis* are Olifants, Langebaan, Berg, Knysna, Keurbooms, Swartkops and Bushmans, of which only Langebaan and Knysna have some formal protection status (Table 18). The distribution of *Z. capensis* is highly dynamic with cover and biomass removed after large floods and fluctuations in response to bait digging and disturbance by boats. Seagrass is mostly absent from estuaries on the east coast due to development changes and high turbidity. Historically large areas were lost from Durban Bay due to harbour development in the 1950s.

Approximately 30 % of all estuaries with *Zostera capensis* have some formal protection status (poorly protected 0-30%) and 46% have estuary management plans (Adams 2016). These plans can be effective in protecting sensitive habitats through zonation of destructive activities such as boating. On the east coast uMhlathuze Estuary has some protection status by Ezemvelo KwaZulu-Natal (EKZN) Wildlife but not from the threats of nearby dredging and associated increase in turbidity. *Zostera capensis* has been lost from the northern St Lucia Estuary and will not return due to the now fresh and silty conditions. Therefore, uMhlathuze should be prioritised for monitoring and management actions to ensure protection of the limited *Z. capensis* beds there. The next large area occurs at the Keiskamma Estuary (12 ha) followed from north to south by Kariega, Bushmans, Swartkops, Kromme (30-40ha in each estuary). None of these systems has protection status whereas some estuaries with *Z. capensis* along the south and west coast do have protection status e.g. Knysna and Langebaan.

Adams (2016) highlights the dynamic changes in the cover abundance of this submerged macrophyte which fluctuates in response to floods and freshwater abstraction. Nationally it is difficult to predict the future trajectory of change for *Zostera capensis* as sea level rise will increase salinity in estuaries and *Z. capensis* is likely to expand upstream. However, any increase in storminess and high intensity rainfall events might remove *Z. capensis* beds. For these reasons, studies tracking the changes over time of the *Z. capensis* beds in specific estuaries are needed to understand dynamic responses.

Table 18. Estuaries with the largest areas (ha) of *Zostera capensis*, habitat trend (↓: decreasing, ↑: increasing, →: stable), pressures and protection status.

ESTUARY	AREA (HA)	HABITAT TREND	PRESSURES	PROTECTION STATUS	REFERENCE
Kosi	5	→	Mouth closure, human disturbance	iSimangaliso Wetland Park Authority, Nature reserve, Marine Protected Area	DWS (2016)
uMhlathuze	28.5	↓	Silt, dredging	Nature Reserve (Ezemvelo KwaZulu-Natal Wildlife)	Cyrus <i>et al.</i> (2008)
Qora	8.5	↓	Catchment degradation (silt)	None	Colloty (2000)
Keiskamma	12	↓	Catchment degradation (silt)	Partial De facto PA	Colloty <i>et al.</i> (2002)
Kariega	32.6	↓	Boats disturbance, bait digging	Partial De facto PA	NBA (2012)
Bushmans	39.8	↓	Boats disturbance, bait digging	Partial Nature Reserve, Protected Environment, National Park	Jafta (2011)
Swartkops	44.7	↑	Boats disturbance, bait digging, eutrophication	Partial Nature Reserve	Adams (2016)
Kromme	34	↑	Boats disturbance, bait digging	Partial Nature Reserve	Adams (2016)
Keurbooms	64	↑	Boats disturbance, bait digging	CapeNature (partial protection)	Bitou (2008)
Knysna	353	↑	Boats disturbance, bait digging, competition from macroalgae (eutrophication)	Partial South African National Parks	Schmidt (2013)
Langebaan	85.6	↓	Boats disturbance, bait digging	South African National Parks	Van Der Linden (2014)
Berg	206	?	Boats disturbance, trampling	IBA (Important Bird Area), water and intertidal CapeNature, under consideration for RAMSAR	Boucher and Jones (2007)
Olifants	47.74	?	Trampling	None	DWAF (2006); Taljaard <i>et al.</i> (2006)

A national status assessment is also needed for this keystone species that falls under the IUCN category of Endangered.

5.5 Habitat conservation and management priorities

Based on the rate of ongoing decline and pressures on estuaries the following conservation and management priorities are highlighted from a habitat perspective:

- The protection of habitat diversity is particularly important in the following estuaries Berg, Knysna, Mngazana, uMlalazi, St Lucia and Kosi.
- Formal protection status is urgent for the Berg Estuary. This estuary with its expansive floodplain marshes is unique nationally and must be prioritised for rehabilitation. Agricultural impacts, reduced freshwater inflow as well as changes in rainfall patterns and an increase in drought conditions in response to climate change pose a serious threat to the state of the estuary.
- Restoration of the salt marsh at Orange River Mouth is needed as well as greater protection of the nationally important *Zostera capensis* beds and large intertidal salt marshes of Knysna Estuary.
- *Zostera capensis* has been lost from the northern St Lucia Estuary and will not return due to the now fresh and silty conditions. Therefore, Mhlathuze should be prioritised for monitoring and management actions to ensure protection of the limited *Z. capensis* beds there. The next large area occurs 800 km south at the Keiskamma Estuary (12 ha).
- Estuarine Lakes support largest areas of submerged macrophytes and require special protection.
- Kosi is a unique estuary with characteristics of a tropical system as indicated by the seagrass *Halodule univervis* that only occurs here as well as the mangrove species *Lumnitzera racemosa*, *Ceriops tagal* and *Xylocarpus granatum*.
- Changes in St Lucia Estuary in response to freshwater inflow from Mfolozi River will be extensive. The fresher conditions with high water levels will reduce the area covered by salt marsh and mangroves.
- Urban estuaries such as Zand provide important ecosystem services and their health can be improved through management interventions. In Zand the mouth is opened to increase salinity to control the spread of pondweed and prevent harmful algal blooms in the system.
- Higher species richness in the Cool and Warm Temperate zones can be attributed to the large supratidal salt marsh areas and the addition of many fringing / transitional species in these

habitats. Climate change is a future pressure for these sensitive habitats and anthropogenic pressures need to be managed.

- Buffer areas are necessary to allow for landward expansion of salt marsh and mangrove habitats in response to sea level rise.
- The national deterioration in water quality threatens habitat diversity. Seagrass habitat has been lost in Ashmead Channel, Knysna due to macroalgal blooms and there is a rampant spread of alien invasive aquatic plants in the small estuaries of KwaZulu-Natal and upper reaches of estuaries influenced by agricultural return flow.
- Early detection lead to the successful eradication of the invasive grass *Spartina alterniflora* at the Great Brak Estuary. Through regular chemical treatment only a few stems now remain in the estuary. Rapid removal was important as this salt tolerant grass is an aggressive ecosystem engineer that converts open intertidal mudflats to dense monospecific marshes.



White Mangrove (Avicennia marina) creek in the Nxaxo Estuary © Janine Adams

6. KEY PRESSURES ON THE ESTUARINE REALM

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KEY PRESSURES

- A third of freshwater flow no longer reaches the coast, with present inflows reduced from 36 900 to 24 800 x10⁶ m³/a placing 20% of estuaries under severe flow modification pressure.
- Pollution pressure increased, with 33% of estuaries are under severe pollution pressure (e.g. wastewater discharges into estuaries and headwaters totalling about 840 million litres per day).
- Over 3 730 t/annum of fish is caught in South African estuaries, 58 % by illegal gillnetting. In all, 21% of systems are severely impacted by overfishing.
- Severe habitat modification pressures are obvious in 29% of South African estuaries, with agriculture (in the form of croplands) responsible for 10% change in land cover, and urban expansion about 4% change.
- Small-scale and unregulated mining of sand, diamonds and heavy minerals have caused permanent habitat destruction in 12% of estuaries.
- About 15% of estuarine mouths are artificially manipulated, representing more than 60% of the South African estuarine extent.
- Invasive terrestrial vegetation has infested about a third of the country's estuaries, with 6% of systems being highly invaded. Aquatic invasive plant species occur in 8% of estuaries in the country.
- Alien or extralimital (translocated) fish occur in 25 % of South Africa's estuaries.

Human activities are increasingly placing pressures on estuarine ecosystems and impacting their productivity and ability to provide ecosystem services (Borja et al. 2016 & 2017). Unless policy-makers and managers intervene, this valuable natural capital will be lost to society. There is a growing need for science to inform policy (Borja et al. 2016). Management interventions to reduce human impacts on estuarine ecosystems should be informed by scientific information and ideally spatial and temporal predictions of ecosystem condition (Andersen et al. 2015). Additionally, it is critically important to understand levels of anthropogenic pressures (activities and factors that bring about changes in the state of the environment, Elliott et al. 2017) on these systems. In a country-level assessment of estuarine health, Van Niekerk et al. (2013) provided an overview on the key pressure categories threatening South Africa's estuaries. This built on earlier work, assessing and refining the geographical distribution of key pressures on individual estuaries using new data and updated information, and highlighting additional pressure categories that have emerged. In addition, pressures were disaggregated to reflect the new estuarine ecosystem classification (Chapter 3) with the objective of assessing possible pressure-type patterns. Specifically, are certain kinds of pressures occurring more in certain types of estuaries. While high-level pressure assessments can inform strategic decision-making and policy interventions across resource management sectors, an understanding of the associated activities within pressure categories is essential for the identification and prioritisation of management interventions. To address this, the main activities contributing to key pressures on South African estuaries were identified. Where possible these activities were quantified at the country-level and rated according to their contribution to the related pressure category. Finally, new learning gained from the down-scaled pressures/activity assessment was used to propose priority management responses (Chapter 11), and give guidance to urgent research needs (Chapter 12).

6.1 Approach and Methodology

The approach followed in this work was to identify key pressures on all 290 of South African estuaries, and to develop and apply a method of rating the severity of these pressures on each of the country's estuaries. Results were aggregated to assess the prevalence and severity of pressures across different bioregions, and across different types of estuaries. Lastly the relative contribution of different activities to pressures on estuaries was quantified. Five key categories of pressure on South African estuaries have previously been identified as flow modification, pollution, exploitation of living resources, land-use & development, and manipulation of estuary mouths (Van Niekerk et al. 2013). These were regarded as still being important and valid for the 2018 assessment, but from first-hand observations of the authors and in published literature, the distribution and abundance of alien invasive species in South African estuaries is increasing (e.g. Appleton et al. 2009, Adams et al. 2016, Riddin et al. 2016, Viskich et al. 2016, Van Niekerk et al. 2019b). Consequently biological invasions by alien invasive and extralimital species was added as a sixth pressure category for the 2018 assessment.

Data and information for the assessment were drawn from a variety of sources ranging from scientific literature (published and grey), government working groups and documentation, and personal communications (Table 19). Means of quantifying degree pressures on estuaries were drawn predominantly from metrics and scaling currently entrenched in the application of South Africa's Estuarine Health Index (EHI) (DWA 2008, Turpie et al. 2012, Van Niekerk et al. 2013):

Flow modification assessments have historically relied on a macro-scale water resource planning model (WASM) that provided an annual summary of the availability, supply and utilisation of water resources at regional and catchment levels for current and projected future situations (Schultz and Watson 2002, Van Niekerk et al. 2013). More recently, simulated data on natural and present mean annual runoff (MAR) to estuaries have become available through numerous EWR and Classification studies (~ 120 estuaries) (Table 19). In addition, a regional-scale desktop study has produced

simulated natural and present MAR for most estuaries of South Africa's estuaries between the Orange in the west and the iZinkwazi in the east using the WReMP model (developed for strategic water resources planning) (Van Niekerk et al. 2015). Unfortunately, these model outputs only reflect discharges recorded on the DWS system and do not include all return flows from wastewater treatment works. This leads to underestimation of the MAR in some heavily impacted systems. MAR of estuaries north of iZinkwazi (the remaining systems) were based on WSAM outputs or historical EWR studies. Of special concern here, is the uThukela Estuary, (Figure 21) which recently had a large weir constructed just above the estuary for bulk water supply purposes. While no data are available to quantify the impact of this weir on uThukela baseflows, anecdotal information suggest that it is likely to be significant.



Figure 21. uMgeni Bulk Water Supply Scheme on lower uThukela River (Source: F MacKay).

Table 19. Data references for the six key pressures for South African estuaries.

PRESSURE CATEGORY	SOURCE
Flow modification	• Environmental Water Requirement (EWR) and Classification studies (DWS 2015a&b, DWS 2017a&b (including supporting reports), Adams, Cowley and Van Niekerk et al. 2016) • WRC EcoClassification of Temperate Estuaries (van Niekerk et al. 2015) • Provisional Desktop EcoClassification Temperate - Subtropical Transition Zone Estuaries (Van Niekerk et al. 2014) • Water Situation Assessment Model (Schultz and Watson 2002)
Pollution	• Environmental Water Requirement (EWR) and Classification studies (DWS 2015a&b, DWS 2017a&b (including supporting reports), Adams, Cowley and Van Niekerk et al. 2016) • Scientific publications (e.g. De Villiers & Thiaart 2007; Lemley et al. 2014) • WRC EcoClassification of Temperate Estuaries (van Niekerk et al. 2015) • Provisional Desktop EcoClassification Temperate - Subtropical Transition Zone Estuaries (Van Niekerk et al. 2014) • National land cover layer (SANBI 2014) • Green Drop Progress Report (2014)
Exploitation of living resources	• Lamberth and Turpie 2003 (updated in van Niekerk et al 2013 and NBA 2018 (van Niekerk et al. 2019b) • WRC EcoClassification of Temperate Estuaries (van Niekerk et al. 2015) • Provisional Desktop EcoClassification Temperate - Subtropical Transition Zone Estuaries (Van Niekerk et al. 2014) • Subsistence bait collection (field observations) and NBA 2018 • Habitat destruction due to bait collection (field observations) and NBA 2018 • DEFF and KZN-Wildlife records of illegal catches Van Niekerk et al 2019, NBA 2018)
Land-use & development	• 2014 National land cover layer (South African National Biodiversity Institute) • NMU National Estuarine Botanical Database (2018 updates) (Adams et al. 2016) • Environmental Water Requirement (EWR) and Classification studies (DWS 2015a & b, DWS 2018) • WRC EcoClassification of Temperate Estuaries (van Niekerk et al. 2015) • Provisional Desktop EcoClassification Temperate - Subtropical Transition Zone Estuaries (Van Niekerk et al. 2014) • Field observations • Google Earth
Manipulation of estuary mouth	• Environmental Water Requirement (EWR) and Classification studies (DWS 2015a&b, DWS 2017a&b (including supporting reports), Adams, Cowley and Van Niekerk et al. 2016) • Field observations • NBA 2018 (van Niekerk et al. 2019b) • Record of NEMA S30A authorisations issued to “emergency situations”. • Estuary mouth Maintenance Management Plans developed under NEMA.
Biological invasions	• Nelson Mandela University National Botanical Database • Publications (Adams et al. 2016, Riddin et al. 2016) • Environmental Water Requirement (EWR) and Classification studies (DWS 2015a&b, DWS 2017a&b (including supporting reports), Adams, Cowley and Van Niekerk et al. 2016) • DEFF rivers fish species database & Field observations

Available data from the early 2000s were adjusted downwards to reflect this impact, but results are of low confidence. The degree of flow modification pressure on each estuary was derived from the estuarine hydrology indicator used in the South Africa's EHI (Turpie et al. 2012, Van Niekerk et al. 2013). The hydrological indicator considers change in low flows (60%) and floods (40%) or overall percentage reduction in MAR. The hydrology health status is rated as percentage similarity to natural (i.e. unmodified) with the flow modification pressure rated as Low = > 75% similar to natural (Categories A - B), Medium = 75 - 60% (Category C), High = 60 - 40% (Category D), Very High = < 40% (Categories E - F).

Pollution pressure was derived from the estuarine water quality indicator in the EHI as in the previous (Van Niekerk et al. 2013) assessment, but using updated information. These scores were collated from ecological flow requirement and classification studies (~40% of estuaries) and desktop assessment studies using a screening tool developed by Taljaard et al. (2017). Estuarine water quality health status is rated as similarity to natural out of 100 and evaluated as changes in salinity and changes in other water quality components such as nutrients (Turpie et al. 2012). Focussing on just the "other water quality" component of the index pollution pressure was rated as Low = > 75% similar to natural (Categories A - B), Medium = 75 - 60% (Category C), High = 60 - 40% (Category D), Very High = < 40% (Categories E - F).

Exploitation of living resources largely focused on fishing, with catch (in tons) per estuary adjusted from Lamberth and Turpie (2003), Van Niekerk and Turpie (2012) and with available recent data from DEFF and Ezemvelo-KZN Wildlife records of illegal catches. The degree of exploitation of fish resources was partially derived from the fish indicator rating in the EHI, but also considered fishing effort (e.g. number of fishers, gillnets versus fishing rods); catch composition and size, and age distribution of fish in sample datasets. Gillnetting or fish trapping was regarded as indicative of Very High levels of exploitation, while levels of recreational or subsistence exploitation were categorised as High or Medium. Low levels of exploitation were assigned to systems known to have little fishing pressure, acknowledging that fish communities on almost all estuaries reflect some level of fishing impact from beach and nearshore fishing. The few systems with no fish exploitation pressure were those known to have no fish in them (e.g. isolated, hypersaline, predominantly closed estuaries on the arid west coast).

Land-use and development pressure were assigned using Google Earth© and Landsat imagery to assess extent of anthropogenic alteration (e.g. canalisation, riparian infrastructure, infilling) in the estuary functional zone (EFZ) by a team of regional experts in a workshop environment. These ratings were validated by field observations and supporting data extracted from the Nelson Mandela University National Botanical Database (Colloty 2000; Colloty et al. 1998; Adams et al. 2016). To provide a broad indication of the degree of intactness of the EFZ, the 2014 SANBI land cover data were disaggregated into natural and modified classes (artificial water bodies, urban (built-up) areas, mining, plantations and agriculture (croplands). The natural class also include 6% secondary natural (land that has been fallow for decades and is in the process of recovery, i.e. now supporting estuarine-associated vegetation). The pressure rating was derived from the physical habitat indicator rating in the EHI (Van Niekerk et al. 2013), with Low = > 75% similar to natural (Categories A - B), Medium = 75 - 60% (Category C), High = 60 - 40% (Category D), Very High = < 40% (Categories E - F).

Estuary inlets (mouths) that are artificially manipulated were identified through field observations, social media posts, literature, interactions with national and provincial authorities and EWR and Classification studies (Table 19). For systems where manipulation is known to occur, the pressure rating was derived from the hydrodynamic indicator in the EHI, with the pressure rated as Low = > 75% similar to natural (Categories A - B), Medium = 75 - 60% (Category C), High = 60 – 40% (Category D), Very High = < 40% (Categories E – F).

Available literature as well as the Botanical Database of Southern Africa, iSpot and iNaturalist were used to extract data on the extent of **alien invasive plant species** in estuaries (e.g. Adams et al. 2012, Adams et al. 2016, Riddin et al. 2016). The Botanical Database of Southern Africa (available online: <http://newposa.sanbi.org/>) contains records from the National Herbarium in Pretoria, the Compton Herbarium in Cape Town and the KwaZulu-Natal Herbarium in Durban. iSpot (www.ispotnature.org) and iNaturalist (www.inaturalist.org) are citizen science-based websites where observations of species can be recorded. These three sources were used to identify alien vegetation distributions in, or close to estuaries. Alien invasive plant species were categorized as aquatic or terrestrial. This information was tabulated according to the extent along the estuary (lower, middle and upper reaches). The degree of pressure was estimated on a three-tier scale, with Low = alien coverage < 5% of EFZ; Medium = alien coverage 5-15% of EFZ and High = alien coverage > 15% of total EFZ area. Available data on microalgal and macroalgal blooms was also recorded using the same method.

Information on **alien or extralimital (translocated) fish** was sourced from unpublished fish data (Council for Scientific and Industrial Research (CSIR); Harrison 2000, 2005); Lamberth & Turpie (2003); and the 40 CSIR “Green series” Part I and II reports published between 1980 and 1993 (Heydorn 1986; Heydorn and Bickerton 1982; Heydorn and Grindley 1981-1985; Heydorn and Morant 1986 -1990; Heydorn & Tinley 1980). In addition, unpublished DWS freshwater fish lists (Custodians: D Louw and N Kleynhans) and field observations were also considered. A species list per estuary was compiled and alien or extralimital fish categorised as 1) egg and larvae eaters (e.g. Bluegill sunfish *Lepomis macrochirus*, Mosquito fish *Gambusia affinis*, Guppy *Poecilia reticulata*), 2) habitat altering species (Carp *Cyprinus carpio*, Grass carp *Ctenopharyngodon idella*) and 3) predatory species (Smallmouth bass *Micropterus dolomieu*, Spotted bass *Micropterus punctulatus*, Largemouth bass *Micropterus salmoides* and Sharptooth catfish *Clarias gariepinus*). The overall pressure rating for alien or extralimital fish was derived from the number and type of fish species present in each system, with Low = 1-2 species, Medium = 3-4 species, High = 5-6 species OR 1-2 predatory species OR Sharptooth catfish *Clarias gariepinus* present (if extralimital), Very High = >7 species OR 3 to- 4 predatory species.

Down-scaling of pressure categories into the contributing activities, and their quantification and relative ratings relied on data and information from the scientific literature (published and grey), government working groups and documentation, and personal communications (Table 19). It also drew from the contextual knowledge (*sensu* Flyvbjerg 2001) that the authors gathered over more than two decades as scientists active in estuarine management and serving as expert advisors to a range of government departments.

Note: Results of pressure assessment were numerically rounded and normalised to account for the number of estuaries in an ecosystem type. Graphical summaries may therefore not add up to 100%.

6.2 Flow modification

Key activities contributing to flow modification pressures in estuaries in South Africa, comprise eight broad types; run-of river abstraction (impacting on base flows), large and small dam development, catchment alien vegetation infestation, increased base flows as a result of return flow (waste water and agriculture), groundwater abstraction, transfer schemes, hydro-electrical schemes and increased runoff through hardening of the catchment through residential development (Table 20).

The ever-increasing human population and a rapidly growing demand for more freshwater constitutes a major threat to estuaries on a global scale (Rosenberg et al. 2000). Run-of-river abstraction and small farm dams tend to reduce baseflows, while large dam development also impacts on floods (Whitfield and Wooldridge 1994, Van Niekerk et al. 2013).

Table 20. Key activities contributing to flow modification pressure in estuaries in South Africa.

ACTIVITY	RELATIVE INFLUENCE	TRAJECTORY	CONFIDENCE	DATA AVAILABILITY
Run-of river abstraction (baseflows)	●	Increasing	H	L
Dam & weir development	●	Increasing	H	M
Alien vegetation infestation in catchment	●	Increasing	M	M
Return flow (waste water and agriculture)	●	Increasing	M	M
Groundwater abstraction	●	Increasing	L	L
Hardening of the catchment & storm water	●	Increasing	L	L
Hydro-electrical schemes	●	Increasing	H	H
Transfer schemes	●	Stable	H	H

The collective impact of invasive plants species in the catchments of South Africa are estimated between 1 450 to 2 450 x10m³/a, thus significantly reducing baseflows to estuaries in heavily invested catchments (van Wilgen and Wilson 2018). Overall, very few South African estuaries are not threatened by flow modification – most of these systems are fed by small catchments with limited human development. In contrast, inter-basin transfer schemes, waste water treatment works and increased runoff from ‘hardened’ catchments, increase freshwater inflow relative to natural flow regimes (Van Niekerk et al. 2013; Nirupama and Simonovic 2007). In some estuaries wastewater and/or agricultural return-flow have become the main freshwater input during low-flow periods (Van Niekerk et al 2019a, DWS 2017a & b). An additional concern is coastal groundwater abstraction, where for several systems groundwater is the major or only freshwater source, e.g. Kosi and Langebaan.

Flow modification influences directly and indirectly on the ecological functioning of these systems (Van Niekerk et al. 2013). Examples are reduced land-sea connectivity as a result of freshwater flow reduction (e.g. closure of the previously open Kobonqaba and Uilkraals estuaries (Van Niekerk et al 2013). Disruption of sediment erosion/deposition cycles, for example, a recent sediment impact study suggested that the proposed Lower uMkhomazi Bulk Water Supply Scheme could have a long-term effect on coastal sediment budgets due to the volume of sand that will be trapped by the scheme. The resultant coastal erosion over the next decade will initially be most noticeable in the areas close to the mouth of the river. However, in the long-term, the impact, will gradually spread further north and could possibly even result in a reduction of the longshore sand supply to the Durban Bluff area. The long-term implications for coastal development and beach tourism are worrisome and will require innovative responses towards meeting both water demand and ensuring shoreline stability (NM Environmental. 2017).

Most listed activities above were on an increasing trajectory to meet the demands of an ever-growing population. For most systems hydrological models and data existed to make relatively confident estimates of the impact of listed activities on freshwater input to estuaries. The exceptions were the extent to which groundwater abstraction and coastal plantations impact on estuaries and the impact of 'hardening' of the catchment and storm water on baseflows. This is a concern as forestry is set to significantly expand in KZN, which will impact on both surface and groundwater reserves.

More than a third of the freshwater that used to reach the coast is now abstracted, with present inflows down from 36 900 to 24 800 $\times 10^6$ m³/a (see Table 21 and Figure 22). The Cool Temperate region has seen the most significant decline in freshwater inflow, reduced by 55% from 13 700 $\times 10^6$ m³/a under natural conditions to 6 100 $\times 10^6$ m³/a at present (with the Orange Estuary experiencing the largest decline). The Warm Temperate region experienced a 27% decline (from 7 100 to 5 200 $\times 10^6$ m³/a) while the wetter Subtropical region experienced 16% less reduction in flow, from 16 000 to 13 500 $\times 10^6$ m³/a.

Table 21. Estimated freshwater flow abstracted from South African estuaries across biogeographical regions.

BIOGEOGRAPHICAL REGION	MEAN ANNUAL RUNOFF		
	Natural (10^6 m ³ /a)	Present (10^6 m ³ /a)	% Similarity
Cool Temperate	13 703	6 112	45
Warm Temperate	7 121	5 179	73
Subtropical	16 055	13 523	84
Tropical*	0	0	0
TOTAL	36 879	24 814	67

*Groundwater fed systems

Estuaries of the Tropical biogeographical region are largely dependent on groundwater. Available information indicates between a 10% and 20% decline, with especially groundwater depletion and commercial forestation being a key concern during drier periods.

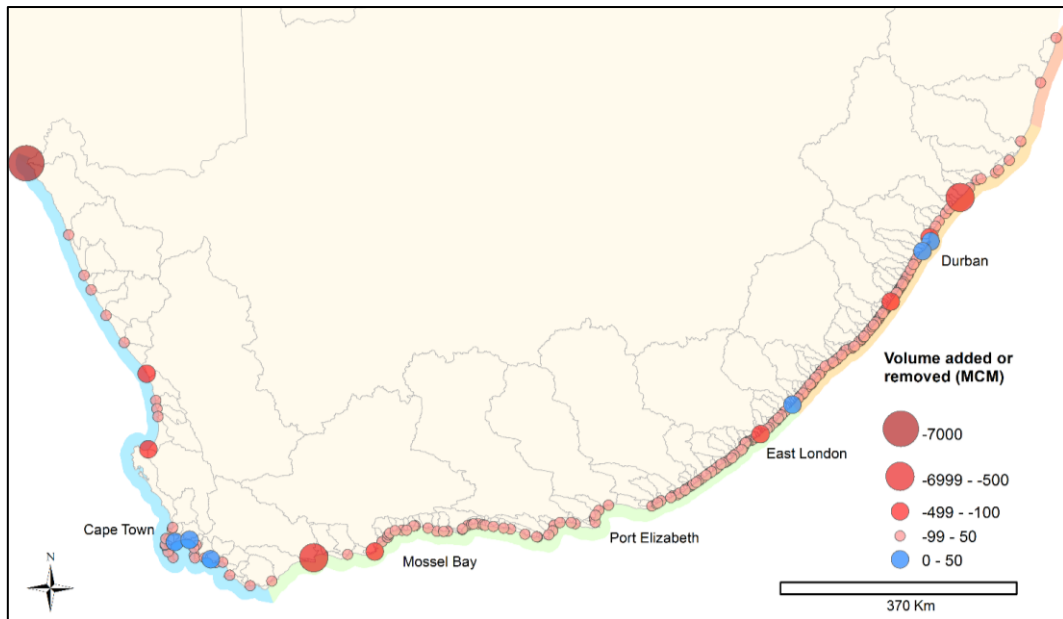


Figure 22. Annual flow modification to the estuaries of South Africa.

Flow modification occurs along the entire coastline of South Africa with systems under severe pressure occurring at regular intervals, with the exception of the Wild Coast estuaries which are still relatively pristine and under little flow modification pressure (Figure 23).

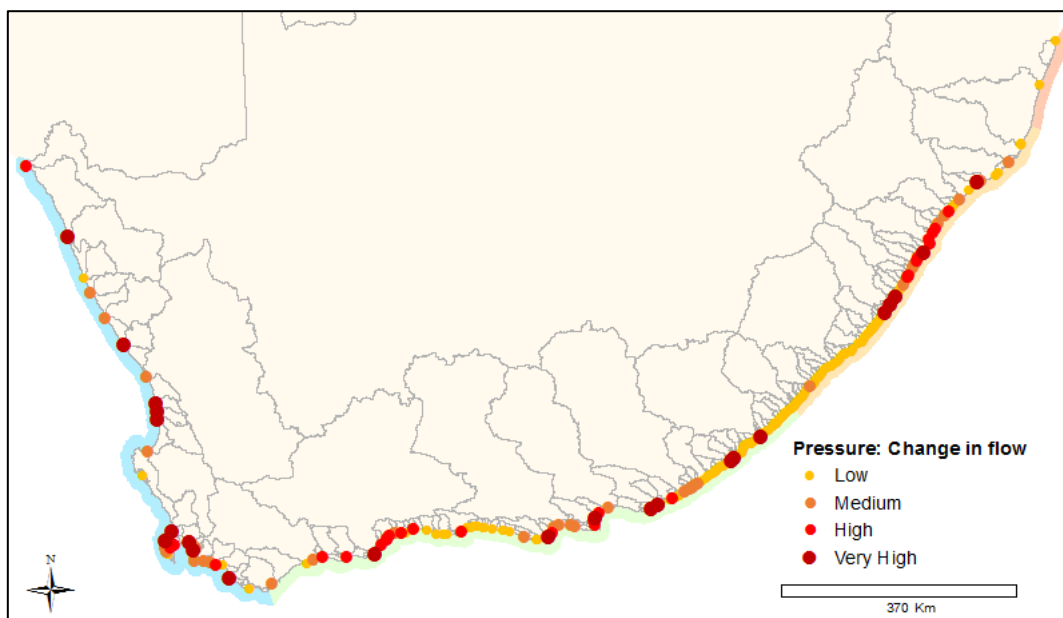


Figure 23. Flow modification pressure on estuaries in South Africa.

The pressure assessment indicated that 20% of South African estuaries are significantly threatened (High to Very High) by freshwater inflow modification (Figure 24), with especially the Cool Temperate region (42%) being affected. A further 14% of South African estuaries are moderately threatened (Medium) by reduced flow modification, with the highest proportion in the Cool Temperate (33%) and Warm Temperate (14%) regions.

Most estuaries that are slightly threatened with respect to flow modification are mainly located in the Warm Temperate (67%), Subtropical (77%) and Tropical (100%) region.

From an ecosystem type perspective (Figure 25) Large and Small Fluvially Dominated (100%), Large Temporarily Closed (55%), Estuarine Lakes (50%), Arid Predominantly Closed (50%) and Predominantly Open (33%) are the most under pressure in the Cool Temperate region. In the Warm Temperate region it is Large Fluvially Dominated (100%) and Predominantly Open (32%) and Small Temporarily Closed (21%), while in the Subtropical region an Estuarine Bay (100%), Estuarine Lake (25%), Large Fluvially Dominated (20%) estuaries are under High to Very High flow modification pressure.

6.3 Pollution

Key activities contributing to pollution pressures in estuaries comprise five broad types, namely wastewater discharges (municipal and industrial), contaminated urban runoff (stormwater), agricultural return flows, solid waste (e.g. litter and plastics), and shipping (e.g. oil spills).

Currently wastewater discharges (including spills), together with urban runoff and agricultural return flows are considered most significant at the national scale (Table 22) based on their relative contribution to water quality deterioration in estuaries. Also indicated in Table 22 is the overall confidence in the relative ratings, as well as the availability of data in terms of quantifying such impact.

The total volume of **wastewater** discharged to estuaries (or just upstream of estuaries) is estimated at 840 000 m³/day, with the largest volumes being disposed of into systems in the Cool Temperate and Subtropical regions (Table 22) (updated from Van Niekerk et al. 2015).

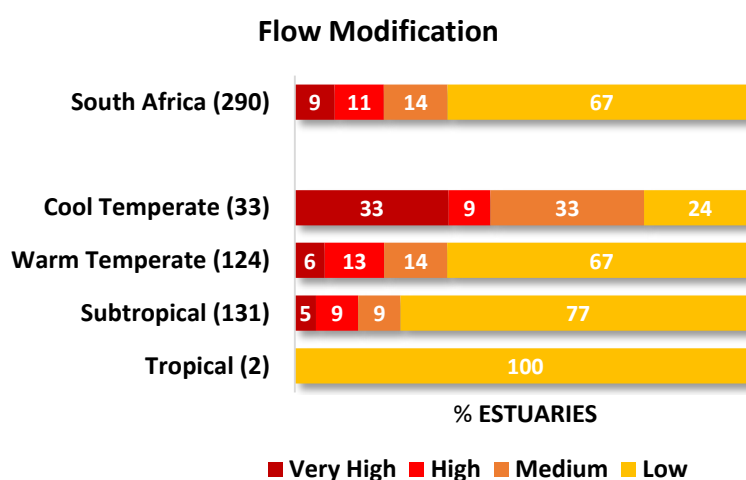


Figure 24. Flow modification pressure across the four biogeographical regions in South Africa.

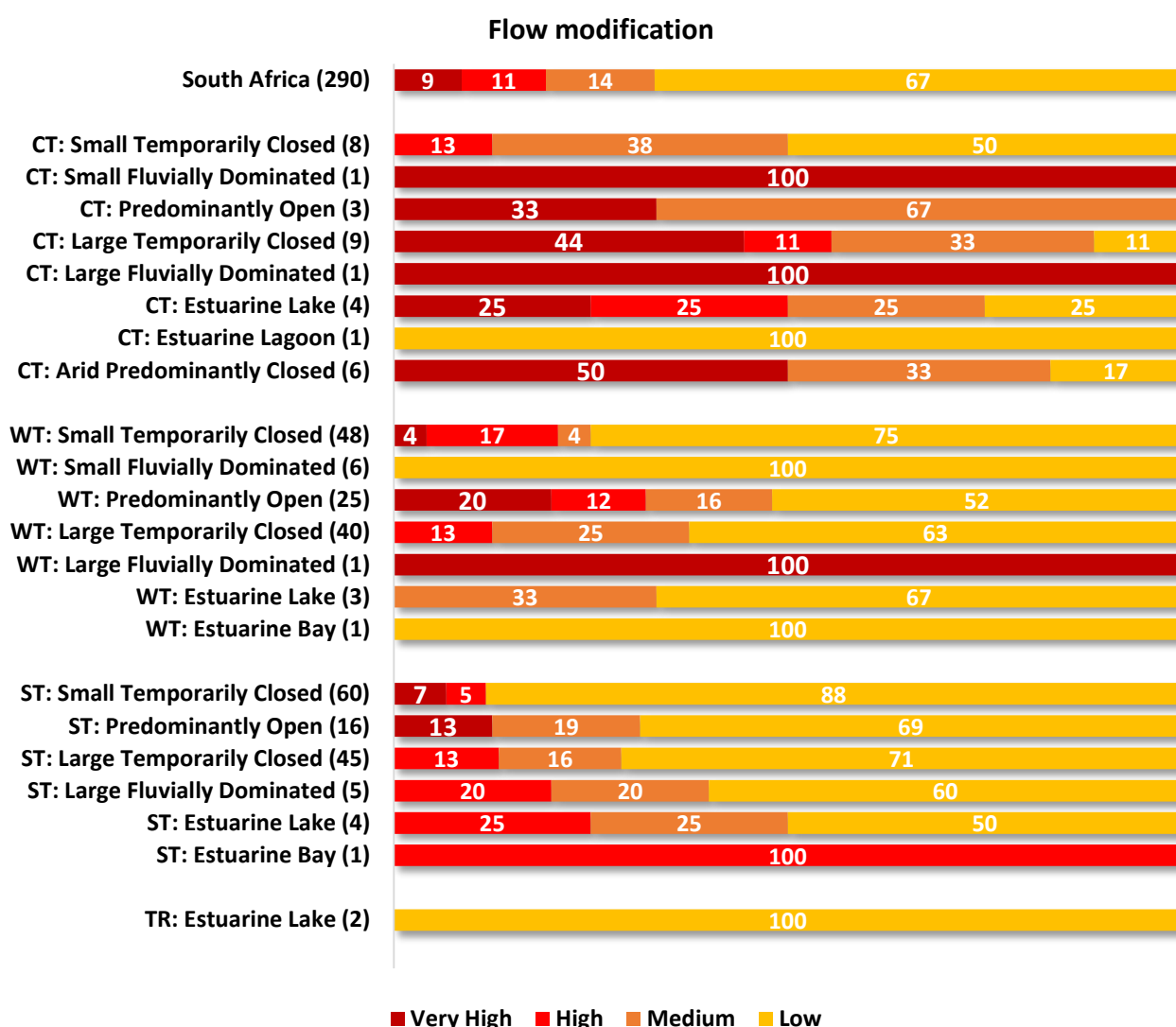


Figure 25. Flow modification pressure on estuarine ecosystem types.

Table 22. Key activities contributing to pollution pressures in estuaries in South Africa.

ACTIVITY	RELATIVE CONTRIBUTION	TRAJECTORY	CONFIDENCE	DATA AVAILABILITY
Wastewater discharges	●	Increasing	H	L/M
Urban water runoff	●	Rapidly increasing	H	L
Agricultural return flow	●	Increasing	H	L
Solid waste (litter & plastics)	●	Rapidly increasing	H	L
Shipping (e.g. oil spills)	●	Stable	M	L/M

Mostly, these discharges originate from municipal wastewater treatment works (WWTWs), some of which also receive trade effluent (especially in the larger urban areas). The only exception is the discharge (~130 000 m³/day) from fish processing industries into the Groot Berg Estuary in the Cool Temperate region (Table 23).

Table 23. Estimated volumes of wastewater discharged daily into estuaries (or just upstream of estuaries) across various biogeographical regions.

BIOGEOGRAPHICAL REGION	WASTEWATER VOLUME		NUMBER OF AFFECTED ESTUARIES
	m ³ per day	10 ⁶ m ³ per annum	
Cool Temperate	521 588	190.38	9
Warm Temperate	79 391	28.98	10
Subtropical	238 858*	87.18*	23
Tropical	0	0	0
TOTAL	839 837	306.54	42

* Excluding SAPPI Saiccor washwater (~19 000 m³/day), abstracted further upstream from river and then re-discharged into uMkomazi Estuary (of similar quality as river intake water)

As expected, the spatial distribution of wastewater discharges is concentrated around large urban centres, such as Cape Town (Cool Temperate region) and Durban (Subtropical region) (Figure 26). Potential pollution risks associated with WWTWs include an array of biogeochemical (e.g. nutrients, organic matter, suspended solids, pharmaceuticals, and various other chemicals introduced through trade effluents) and microbiological contaminants (e.g. bacteria, viruses and other pathogens). Pollution risks from fish factory discharges primarily relate to biodegradable organic and suspended solid loading.

Most wastewater discharges operate under discharge permits or licenses (either under the National Water Act or the ICM Act), which require a certain level of treatment, prior to discharge (e.g. to meet General Standards under the General Authorisation Regulation, DWA 2013). The volume and composition of these discharges are supposed to be monitored regularly, but this often does not occur, or is limited to a selection of parameters (for example, emerging pollutants such as pharmaceuticals are not monitored). Although monitoring data for some WWTWs are being captured in the national water quality database of the Department responsible for Water and Sanitation, it is not available for all wastewater discharges at the national scale.

Rapid population growth in coastal areas generates greater demand for WWTW facilities, resulting in higher effluent volumes having to be disposed of, also to estuaries (Van Niekerk et al. 2013). Coastal municipalities mostly have sewage reticulation systems that in some cases still comply with the legal effluent standards issued as per their permits. However, in some instances the volumes of effluent are simply becoming too large, to meet the assimilative capacity of the receiving environments, especially in temporarily open and closed estuaries characteristic of more than 75% of the systems along South Africa's coast.



Figure 26. Location of industrial and municipal wastewater discharges, as well as estimated daily volumes (m³/day).

In some of the smaller coastal municipalities, resources often are not available to repair or upgrade deteriorating infrastructure, nor do they have the appropriate skills for operational management. As a result, WWTW systems are often overloaded or malfunctioning, causing spillage from pump stations and/or sub-standard effluent to enter rivers and estuaries (Figure 27). Load-shedding also causes WWTW shutdowns and spillages as do WWTW infrastructure and copper-cable theft for scrap, especially in KZN.

Very little data exists to confirm pollutant loads entering estuaries through **agricultural return flow** from adjacent catchments, other than estimating these from catchment land-use and/or water quality of river inflow, where this is monitored in close proximity of estuaries (DWS 2019, De Villiers and Thiert 2007, Lemley et al. 2014, Van Niekerk et al.



Figure 27. An illegal discharge at iZimbokodo Estuary mouth. (Source: ORI Estuary Observer Programme).

2018). However, there are sufficient place-based studies that link this pollution pressure to marked deterioration of water quality in estuaries (e.g. Pearce and Schumann 2001, Lemley et al. 2017).

Despite the growing threat posed by **contaminated urban runoff** (e.g. DWS 2015a&b, DWS 2017a&b) no long-term monitoring or assessment programmes are currently conducted at the national scale to establish pollution loading to estuaries (Figure 27), nor to the nearshore coastal environment. Contaminated urban runoff introduces an array of pollutants including microbial contaminants, excessive nutrients and organic matter, high suspended-solid loads and toxic chemicals (e.g. trace metals, persistent organic pollutants and hydrocarbons) (Vermeulen and Wepener 1999, Binning and Baird 2001, Mzimela et al. 2003, Jackson et al. 2005, Jackson et al. 2009). In rapidly growing urban areas, where coastal communities are not connected to central sewage reticulation systems, they either do not have sewage treatment systems, or the capacity for alternative systems (e.g. septic tanks, soakaways and conservancy tanks) is exceeded. The result is diffuse, untreated sewage entering nearest watercourses, usually rivers and estuaries.

Solid waste (including plastics) is increasingly becoming a pollution pressure in estuaries (Table 22). This is especially relevant in South Africa because of the large amount of informal settlements around cities and towns, often not being provided with sufficient solid waste management facilities. While numerous education and awareness programmes (e.g. international coastal cleanup day, DEA 2019b) have been launched in an effort to fight solid waste pollution in coastal environments, long-term monitoring programmes at the national scale is not yet forthcoming.

Indications are that pollution pressure associated with **shipping** currently remains fairly small, with no specific trends being evident. Except for isolated events, major pollution pressures in estuaries from shipping activities are limited to the three systems supporting commercial ports, namely the Buffalo, Durban and Richards Bay estuaries.

Even though quantitative data on pollutant loading from the various pollution pressures is limited, there is sufficient evidence from numerous site-specific monitoring and research studies conducted in the estuarine space to link these pollution pressures to deterioration in estuarine water quality (e.g. Pearce and Schumann 2001, Snow et al. 2000, Snow and Taljaard 2007, Lemley et al. 2014, Lemley et al. 2017, Taljaard et al. 2017b). The water quality status of estuaries (as adapted from Van Niekerk et al. 2018, Taljaard et al. 2017a) could therefore be used as proxy to rate pollution pressures on estuaries along South Africa's coast, as is spatially depicted in Figure 28.

Evident from the map is that pollution pressures on estuaries (as derived from the present water quality status) are not limited to urban centres (e.g. Cape Town and Durban) but are occurring along the entire coast. Exploring in greater detail the relative contribution of various activities to these pressures, urban runoff and wastewater discharges are mostly contributing to the deterioration of water quality in the urban systems, while agricultural return flow is the dominant source of pollution in the more rural systems. Indeed, it is estimated that agricultural return flow is the most common source of pollution in estuaries (Table 24), followed by urban runoff and wastewater discharges.

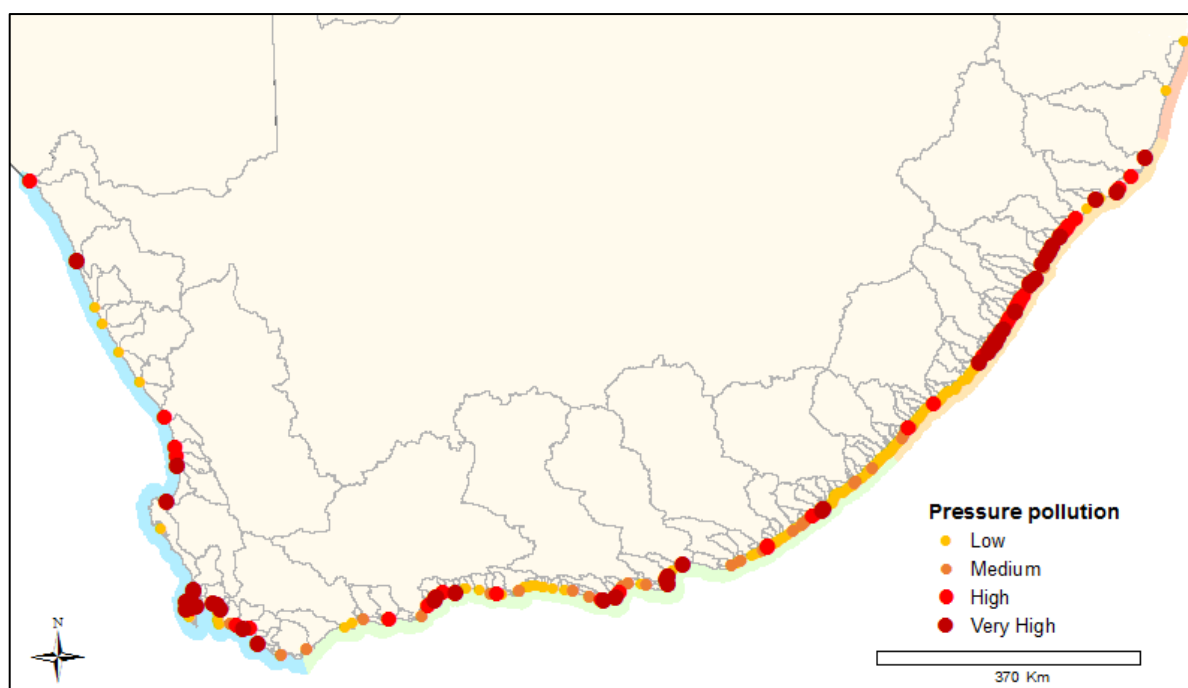


Figure 28. Pollution pressures on estuaries.

However, where agriculture return flow is the major contributing source, pollution pressure ratings mostly fall in a Medium category, with some in the high category.

On the other hand, in systems where urban runoff and wastewater discharges are the major contributing sources, pollution pressure ratings mostly fall within the severe (High to Very High) category. Thus, while agricultural return flow may be the most common source of pollution in estuaries the most severe pollution pressure appears to stem from urban runoff and wastewater discharges and spillages.

Table 24. Contribution of pollution pressures or combinations thereof, to water quality deterioration in estuaries (ranked as Medium, High and Very High).

KEY ACTIVITY	# AFFECTED ESTUARIES	EFFECT ON DETERIORATION IN WATER QUALITY		
		Medium	High	Very High
Mostly wastewater discharges & spills	4	1	-	3
Mostly urban runoff	31	8	9	14
Wastewater discharges & urban runoff	18	1	4	13
Mostly agricultural return flows	56	33	13	10
Agricultural return flows & wastewater discharge	11	2	5	4
Agricultural return flows & urban runoff	22	6	12	4
Combination of activities	3	-	2	1

While solid waste is not yet viewed as a significant contributor to pollution pressures in estuaries, it is fast emerging as a major issue, especially in urban areas supporting large informal housing settlements

where solid waste collection facilities often are insufficient or lacking. For example, solid waste pollution in Durban Bay resulted in the closure of the port after heavy rainfall events. This impacted vessel traffic and consequently had negative economic impacts too. Subsequently, The National Port Authority (TNPA) had to appoint service-providers to fast-track cleanup and minimise port disruption. Solid waste disposed of in tributaries located near informal settlements ends up in estuaries and bathing beaches after heavy rainfall events. This negatively impacts the ecology, bathing water quality and safety, recreational use, tourism and destination-reputation. Although shipping is not considered a major contributing factor to estuarine pollution at the national scale, it does contribute to pollution in the three estuaries supporting commercial ports. There is also increasing concerns over fuel contamination from outboard engines (e.g. Breede and Kaaimans estuaries). On the latter, pollution concerns over two-stroke motors have led them to be prohibited in favour of much cleaner and efficient four-stroke engines in the USA. Unfortunately, Africa, especially countries to our north, have a dumping ground for these second-hand motors.

Assessing the extent of pollution pressures on estuaries at the national and biogeographical scales (measured in terms of present water quality status) (Figure 29), results reveal that about 33% of South Africa's systems (expressed in terms of number of estuaries) already are under severe pressure (High to Very High). This includes more than half of the systems in the Cool Temperate region (63%), about 39% of systems in the Subtropical region and at least 18% of systems in the Warm Temperate region. Systems under moderate pollution pressure total about 17% of all estuaries, comprising

18% of those in the Warm Temperate region and 17% of systems in the Subtropical region. Only 50% of the country's estuaries are still encountering low pollution pressures, which include both systems in the Tropical region (100%) and about 63% of the systems in the Warm Temperate region.

Reflecting on pollution pressures across the 22 estuarine types (Figure 30) those most severely affected (High to Very High) (based on number of estuaries) are Large Fluvially Dominated (100%); Large Temporarily Closed (89%); Small Temporarily Closed (51%) in the Cool Temperate region; Estuarine Bays (100%) in the Warm Temperate region and Estuarine Lakes (75%); Large Fluvially Dominated (80%); Large Temporarily Closed (42%) in the Subtropical region.

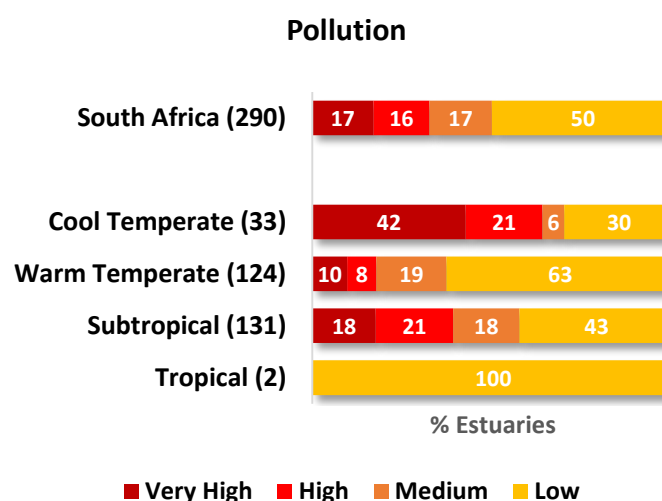


Figure 29. Pollution pressure in estuaries across biogeographical regions.

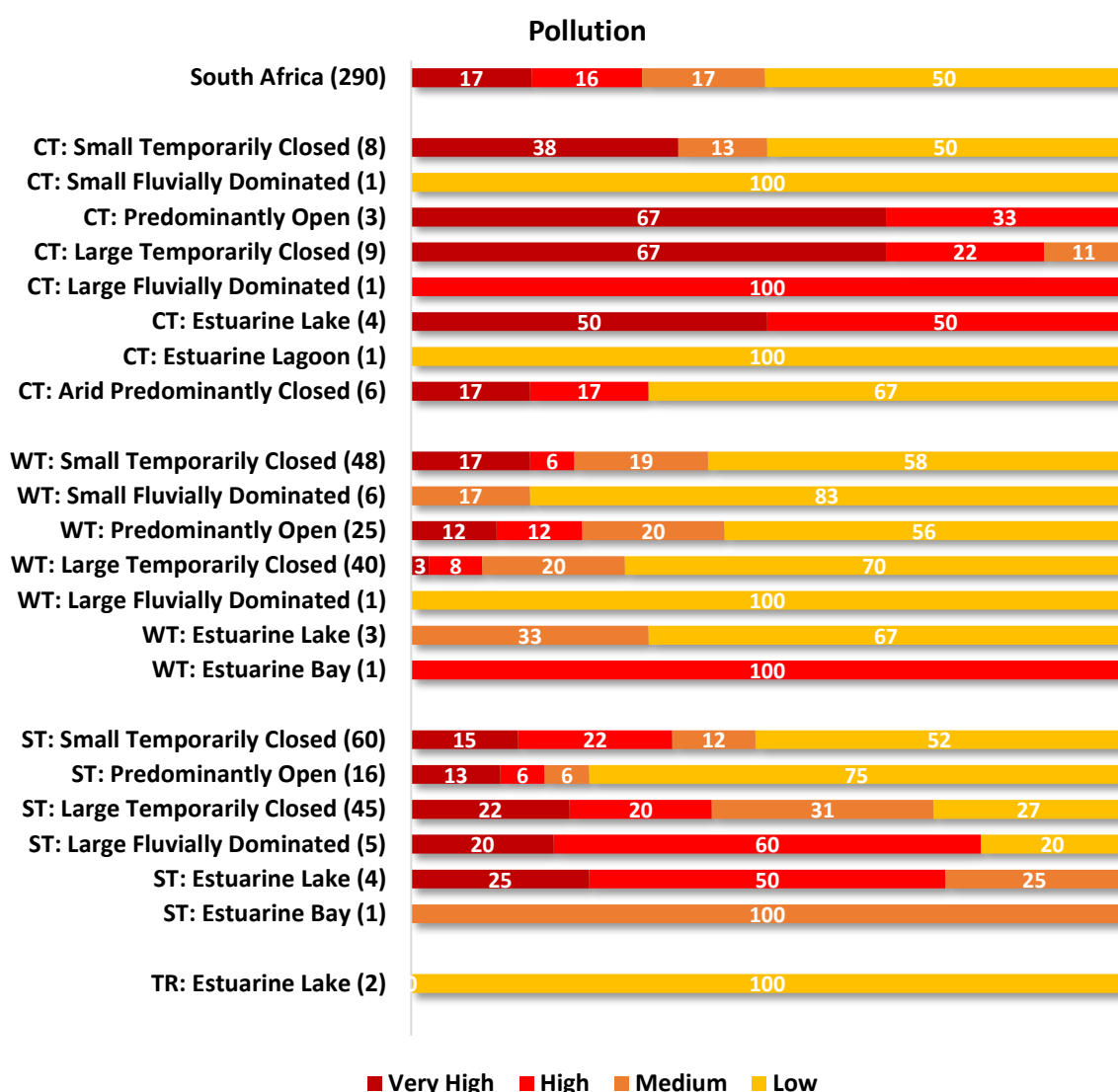


Figure 30. Pollution pressure on estuarine types.

Reflecting on the above assessment on pollution pressures, the root causes of increasing deterioration of water quality in estuaries are three-fold, namely rapid (often uncontrolled) population growth in coastal areas, the general lack of strategic planning on appropriate sewage and solid waste treatment facilities, and the ineffective operational management of such facilities (often due to lack of capacity or resources).

Due to insufficient treatment or high volumes of wastewater effluent, nutrient overloading is causing excessive eutrophication and low oxygen conditions to develop in estuaries, decreasing their natural productivity and important ecological roles (e.g. nursery areas). For example, in the Knysna Estuary nutrient enrichment is causing a loss of seagrass beds (favouring macroalgal blooms) which is threatening the habitat of the rare and endangered Knysna seahorse.

TEXT BOX 2: OCCURRENCE OF FISH KILLS AND PATHOGENS IN SOUTH AFRICAN ESTUARIES

In addition to exploitation pressures, fish and invertebrates are also subjected to die-off events (called fish kills) resulting from poor water quality, disease, poor land use practises, flow reduction and manipulation of estuary inlets (Figure 1). Such events have been observed in 13% of estuaries, with the majority occurring in the last decade. Many systems have multiple observations with regular events occurring seasonally or even during each inlet closure event. Fish kills are in most cases indicative of ecosystems reaching ecological tipping points. As a result of their high retention and limited assimilative capacity, estuaries subjected to nutrient enrichment and organic loading are prone to eutrophication, especially when their mouths close during low-flow and drought conditions. (Taljaard et al. 2017). Die-off of algal blooms creates high detrital loads, causing reduced dissolved oxygen levels which negatively impact invertebrates, fish and water birds (van Niekerk et al 2019a).

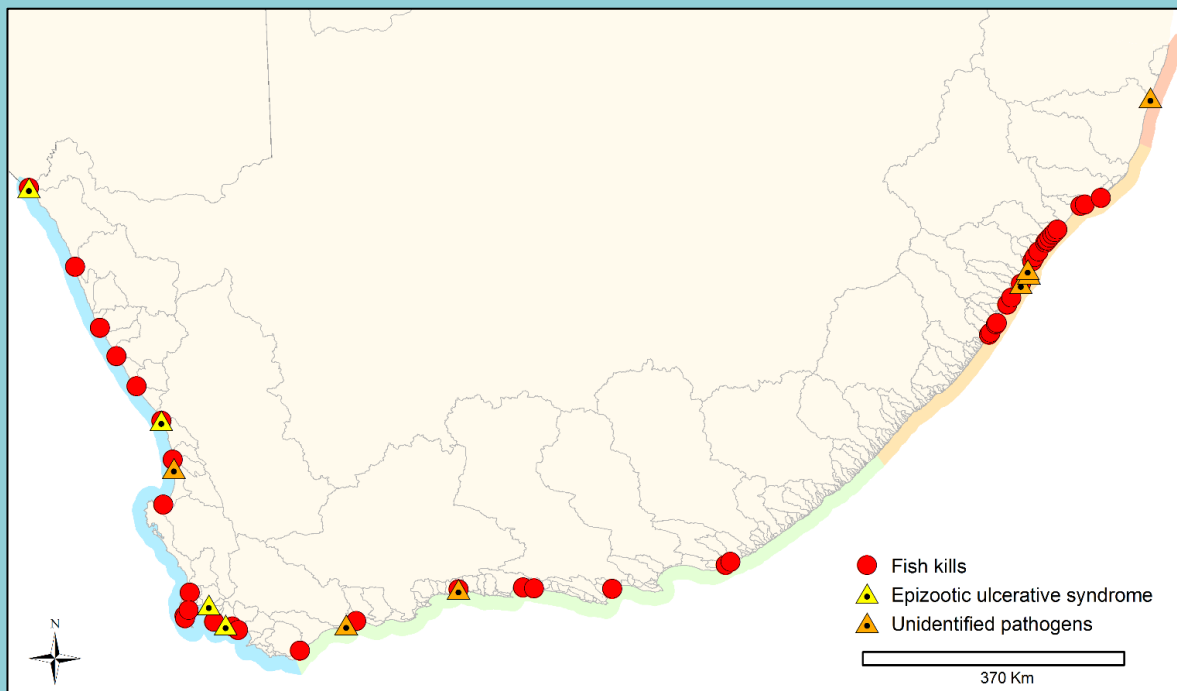


Figure 1. Occurrence of fish kills and pathogens in South African estuaries (Updated from Van Niekerk et al. 2015).

Flow reduction and inlet manipulation impacts on circulation and increase retention times, therefore increasing the risk of fish kills, while poor land-use practises can cause nutrient enrichment or even increase sediment loads to the point where it causes smothering during floods and high flow events. Hyper-salinity above 65 *psu* as a result of high evaporation rates and low freshwater inflow rates also contribute to fish kills, albeit deemed a natural occurrence in some of the Arid, Predominantly Closed estuaries (van Niekerk et al 2019c).

Most pathogens and harmful algae resulting in large-scale estuarine fish mortalities originate on other continents and arrived here and spread via a number of vectors including fishing gear, recreational craft and equipment, contaminated clothing, human excrement and via import of fish, plants and invertebrates for aquaculture and the ornamental fish trade. Golden algae *Prymnesium parvum* first appeared in Zand Estuary during the 1970s but lay dormant until a massive bloom in 2012 whereupon it caused gill haemorrhaging, stress-induced spawning and 100% mortality of all estuarine fish in the system. It has not been isolated in any other estuaries but there are unconfirmed reports of it in the Rietvlei-Diep Estuary in Table Bay.

The water-mold Epizootic Ulcerative Syndrome (EUS) first appeared in South Africa amongst fish in a trout *Oncorhynchus mykiss* farm on the Palmiet River in 2011 and amongst feral catfish *Clarias gariepinus* in the Eerste River in the same year. The first estuarine occurrence was in the Palmiet Estuary in 2015 where it only infected gobies but also confirmed amongst multispecies in the Orange and Olifants rivers and estuaries shortly thereafter. Unconfirmed occurrences have been reported from within the iSimangaliso Wetland Park and a number of eThekweni estuaries including Durban Bay. More recently in 2019, mass mortalities of fish in the Touw Estuary in Wilderness have been ascribed to poor water quality and mixed multiple bacterial and fungal infections (Figure 2).



Figure 2. Mass mortalities of fish in the Touw Estuary ascribed to poor water quality resulting in compounded bacterial and fungal infections (Photo: Kyle Smith, SANParks)

Lamberth, S.J and Weerts, S.P. & Van Niekerk, L. 2019. Occurrence of fish kills and pathogens in South African estuaries in South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A

In extreme situations, such conditions have resulted in harmful algal blooms (HABs) and subsequent fish kills mostly in systems situated within the larger urban centres of the Cool Temperate (e.g. Zand Estuary) and Subtropical regions (e.g. Isipingo and uMdloti estuaries) (See Text Box 3). Increasingly, sewage spills from failing infrastructure (reported and unreported) are also contributing to estuary nutrient loading, e.g. leading to regular fish kills and beach closures along the KZN coast (iSipingo, Durban Bay and uMhlanga).

Although to a lesser extent, intensified agriculture is also contributing to increased pollution in estuaries, as a result of poor management practices (e.g. Lemley et al. 2017). Responsible application of fertilizers, herbicides and pesticides in crop production as well as sound waste management practice in living stock farming (e.g. dairy farms) are required to mitigate such impacts, amongst others. Poor water quality reduces resilience and creates opportunities for invasive species, parasites, pathogens and diseases to establish in estuaries, as has been encountered in some of the heavily polluted systems in the Subtropical region along the KwaZulu-Natal coast.

Globally, studies are revealing the shocking consequences of solid-waste pollution (especially plastics) on ocean and coastal ecosystems. Such consequences are also going to continue escalating in our estuarine ecosystems if government and societal responses to the above-mentioned root causes are going to be ignored.

Along South Africa's high energy coastline, estuaries provide some of the few naturally safe environments for recreation and tourism. Deterioration in estuarine quality, together with increased microbiological contamination, thus also poses a risk to the socio-economic value (e.g. tourism and attractive real estate) offered by estuaries, ultimately affecting local business opportunities and livelihoods.

6.4 Exploitation of fish and invertebrates

Exploitation of living resource pressure can be disaggregated into recreational, commercial and small-scale / subsistence and Traditional/ artisanal fishing, illegal gillnetting (poaching), aquaculture, traditional medicine including muti trade, ornamental (pet) fish and bait collection (Table 25).

Estuaries function as nurseries and provide vital habitat for a number of commercially important estuary-associated marine fish species (Lamberth and Turpie 2003, Pradervand et al. 2003, Meynecke et al. 2008). Over-exploitation of living resources by recreational, subsistence, traditional and commercial fisheries can have both direct and indirect consequences for marine and estuarine ecosystems (Barange et al. 2004, Whitfield and Cowley 2010). These consequences include changes in population size, biomass, sex-ratios, size/age distributions, community composition and trophic structure (Pauly et al. 1998, Blaber 2000, Whitfield and Cowley 2010).

In areas where there has been continuous and systematic overexploitation of target species, recruitment failure has been recorded as juvenile and adult fish are "mined out" of the population, lowering the overall reproductive capacity of the population (Hutchings et al. 2008, James et al. 2008a).

Table 25. Summary of exploitation of living resources pressures on estuaries.

ACTIVITY	RELATIVE IMPACT	TRAJECTORY	CONFIDENCE	DATA AVAILABILITY
Recreational fishing	●	Increasing	H	M
Commercial fishing	●	Stable	H	M
Small-scale / subsistence	●	Effectively open access	H	M
Traditional/ artisanal	●	Effectively open access	H	M
Illegal gillnetting	●	Increasing, open access KZN	H	L
Ornamental fish collection	●	Trade increase, recreational stable	L	L
Aquaculture	●	Increasing	H	H
Traditional medicine including <i>muti</i> trade	●	Increasing	M	L
Bait collection	●	Increasing	H	M

The effects of vulnerable life-history characteristics such as estuary-dependence, “natal homing” and predictable aggregations are exacerbated by anthropogenic influences such as fishing and flow modification, ultimately leading to recruitment failure or even population extirpation (Lamberth and Joubert 2000, Griffiths and Lamberth 2002).

Gillnetting has long been regarded as an inappropriate fishing method for South African estuaries. Bycatch mortality is very high as most fish are extremely difficult to release without damaging nets. Selectivity of the most common retrieved nets of 40 to 50 mm mesh-size is for fish of about 40 mm body-depth which in most cases is within the first year of life (see Text box 4). Consequently, illegal and legal gillnet fishing is responsible for much of the recruitment and growth overfishing and collapse experienced by harders, dusky kob and other high-value nearshore and estuarine species. Gillnets are also increasingly being used to augment traditional fishing gears, one example being the lining of artisanal Kosi Bay fish traps which has resulted in a substantial increase in fishing power and the catch of immature and undersize fish.

Up until a decade ago, excessive fishing effort was mostly confined to large estuaries in the Cool Temperate and Tropical regions. Since then, there’s been a substantial increase in fishing effort in estuaries elsewhere on the coast especially in the subtropical and tropical bioregions (Figure 31). The latter was exacerbated by the effective open-access to resources that arose with the then DAFF’s non-renewal of monitoring and compliance contracts held by the provincial authorities and near-collapse of fisheries compliance and enforcement in KwaZulu-Natal. In the previous 2011 NBA, total catch was more or less equally distributed among the three biogeographic regions but the Cool Temperate

region was severely threatened by overexploitation as almost the entire catch came from a handful of estuaries (Olifants, Berg, Bot). In 2018, the current open access nature of KZN resources and the unchecked proliferation of gillnet poaching has seen total catch now skewed towards the subtropical and tropical bioregions.

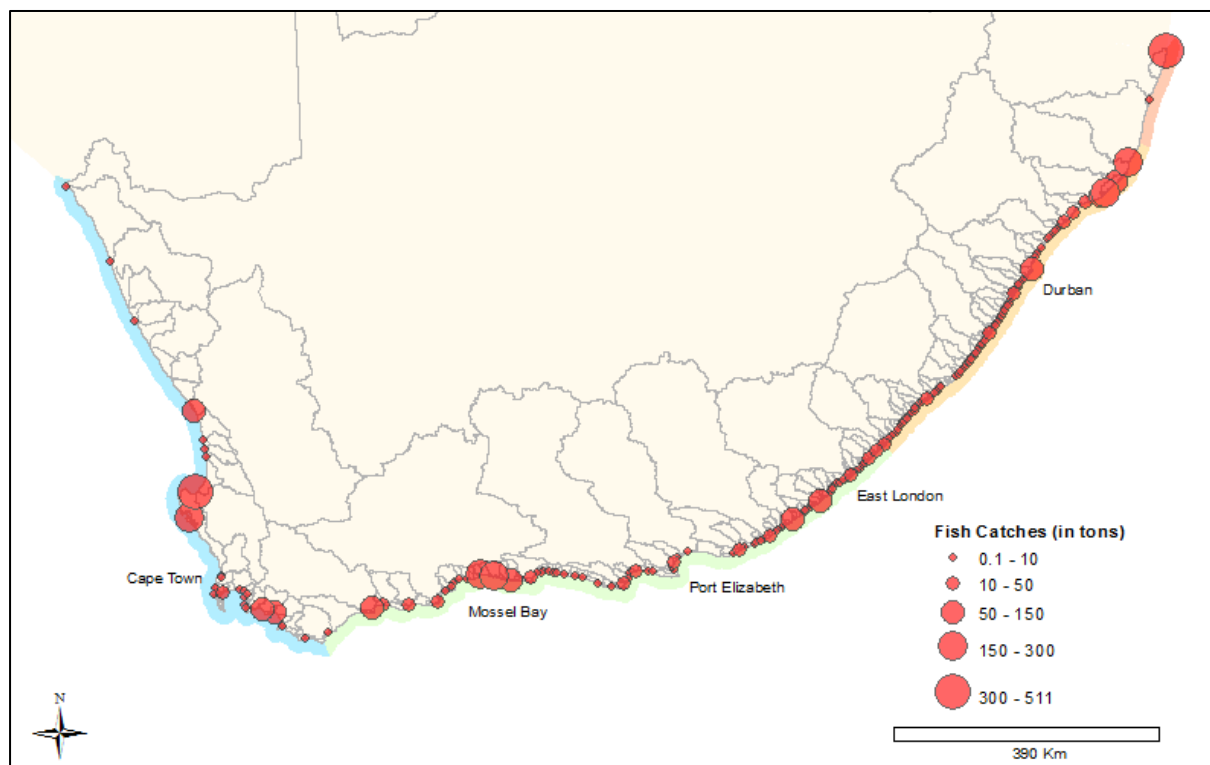


Figure 31. Estimated annual fish catches in estuaries across the four biogeographical regions of South Africa (Updated from Van Niekerk et al. 2013).

Over 3 730 t of fish is caught annually in contrast with 3 030 tons in in 2011 (Table 26 and Figure 32). Whilst illegal gillnet catches have remained high but stable to the west of Agulhas, conservative estimates are a 600 t increase in landed catch for this fishery in KZN. Total estuarine gillnet catch is now in the region of 2 200 t per annum. The unpalatable reality is that nearly 60% of fish landed in South African estuaries comprises illegal gillnet catch.

Table 26. Estimated annual landed fish catch (tonnes) in estuaries overall and in each biogeographical region.

BIOGEOGRAPHICAL REGION	LANDED CATCH TONNES	NUMBER OF AFFECTED ESTUARIES
Cool Temperate	1 035	27
Warm Temperate	1 167	121
Sub-tropical	1 172	131
Tropical	354	2
TOTAL	3 728	281

** KZN tonnage is an underestimate as it was derived from data collected in protected areas*

Most of the above listed activities in Table 25 were on an increasing trajectory with the exception of commercial fishing which has been largely stable over the past decade. While some data were available on most fishing activities very little is known about the impacts of the ornamental fish collection/aquarium trade and international and local traditional medicine and *muti* trade on South African fish and other aquatic resources (Figure 32).

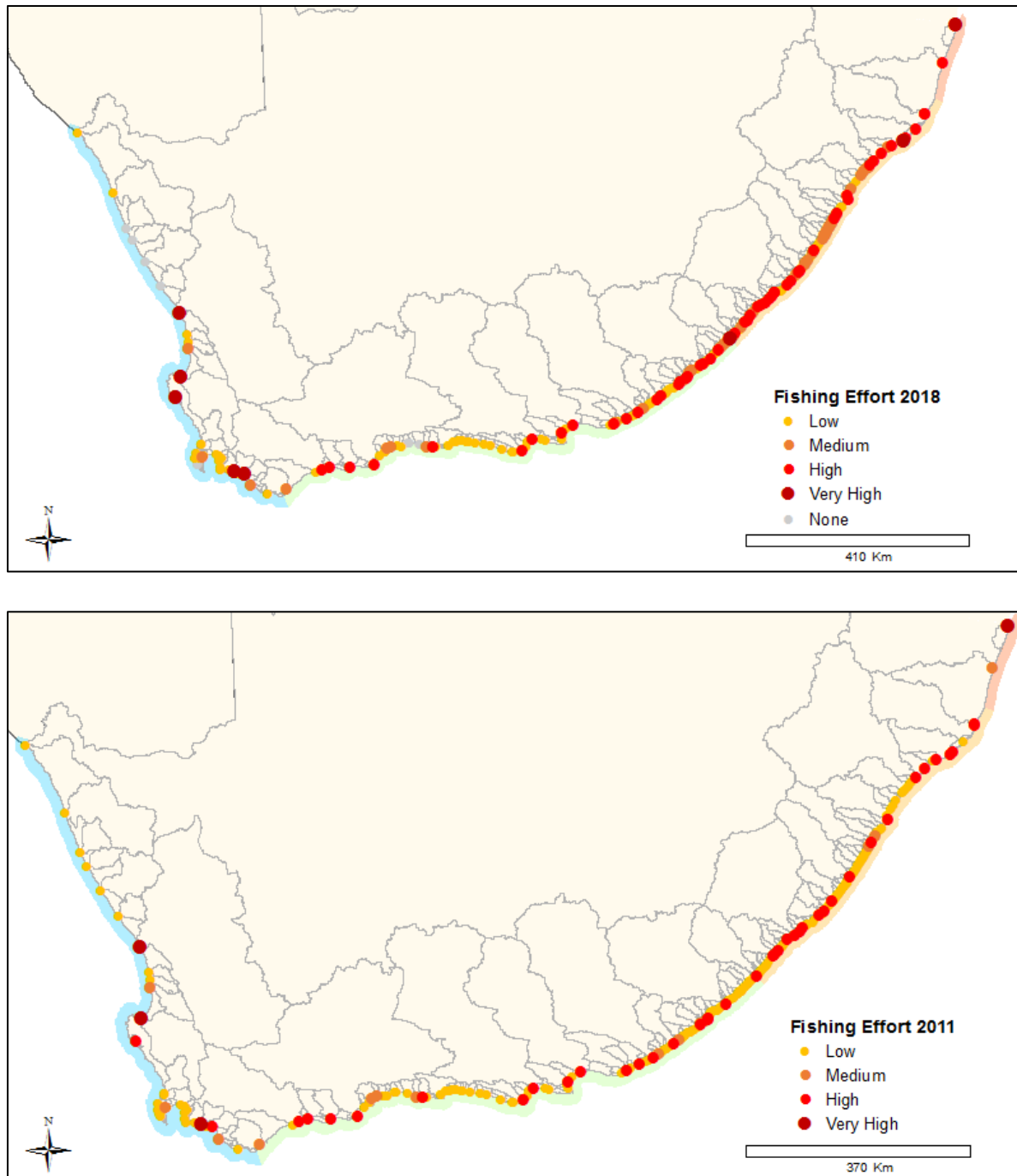


Figure 32. Relative degree of fishing pressures on estuaries between 2018 (top) and 2011 (bottom).

Given the high risk of introduction of alien fish, pathogens and parasites associated with ornamental fish collection/aquarium trade there is an urgent need for more regulation, monitoring and assessment of this sector. Similarly, current compliance efforts to control the traditional medicine/*muti* trade need to be supported and strengthened, especially in the light of iconic endemic fish species such as the Knysna seahorse being recorded and verified on foreign markets.

Overall 21% of estuaries are subjected to High to Very High fishing pressure. Countrywide, there's been a 2-fold increase in estuaries subject to Medium to Very High fishing pressure with only 60 % of systems under low fishing pressure as opposed to 80% in the previous assessment period (Figure 33).

Much of this increase is attributable to a collapse in compliance and monitoring and associated uncontrolled escalation of illicit gillnetting throughout KwaZulu-Natal whereas previously it was mostly confined to St Lucia and Kosi.

This said, even the fishing power of the traditional Kosi fish traps has increased with the use of gillnet and other synthetic lining material. Gillnet poaching remains high from Cape Agulhas westwards. Future scenarios include accelerated expansion of the illegal KZN gillnet fishery into Wild Coast estuaries and similarly from Cape Agulhas eastwards. Small Scale Fisheries (SSF: commercial, subsistence line, bait and cast-net) in estuaries are effectively open-access fisheries throughout KZN, Port St Johns to Kei Estuary and thereon to the Swartkops Estuary in Port Elizabeth. Albeit at a lower intensity, SSF effort has intensified all the way down to Mossel Bay. Less than one percent of estuaries are not under some (Low) fishing pressure as few have national, provincial or municipal protection or 'no-take' status.

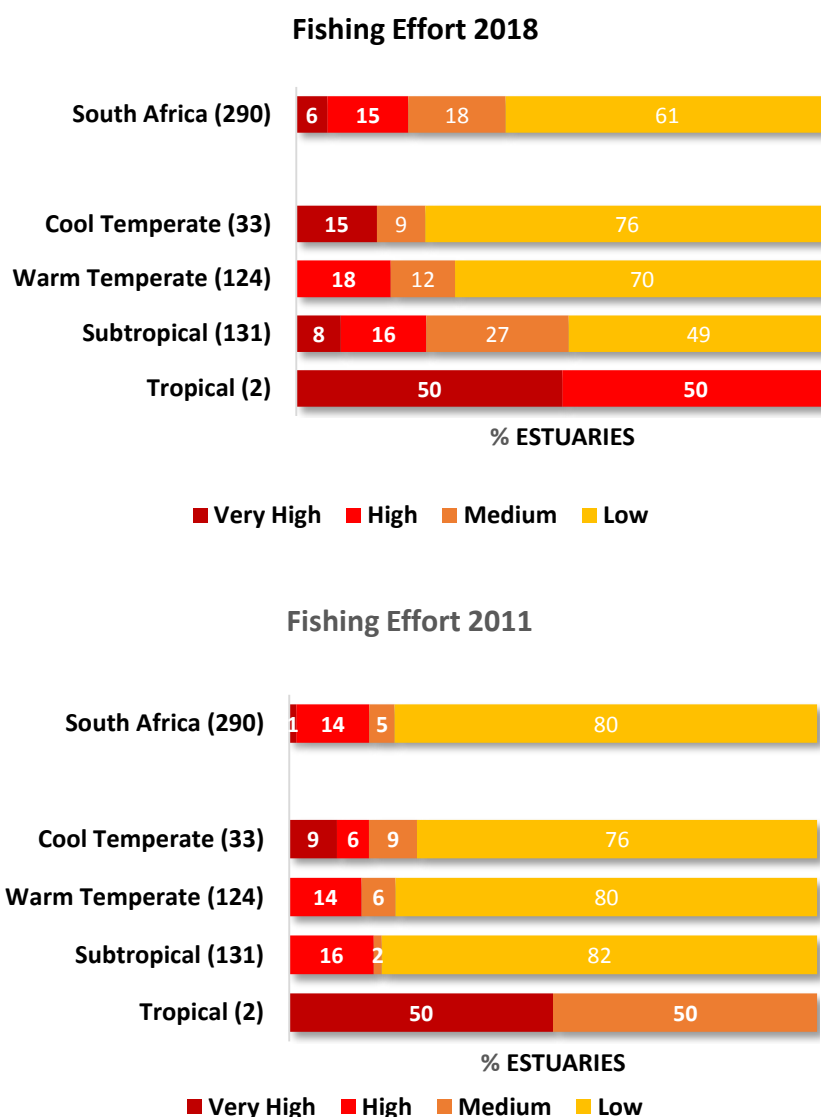


Figure 33. Fishing pressure in estuaries across biogeographical regions for 2018 and 2011

From an ecosystems type perspective, Estuarine Bays, Estuarine Lakes, Estuarine Lagoon and Predominantly Open systems in all four biogeographical regions have been most affected by the overexploitation of linefish species and this requires urgent management intervention to protect nursery function and ensure that fish stocks do not collapse (Pradervand and Baird 2002) (Figure 34). Both legal and illicit use of gillnets is problematic as these cause immense damage because of high mortalities and selectivity for certain species (Marais 1985, Hutchings and Lamberth 2003, Hutchings et al. 2008).

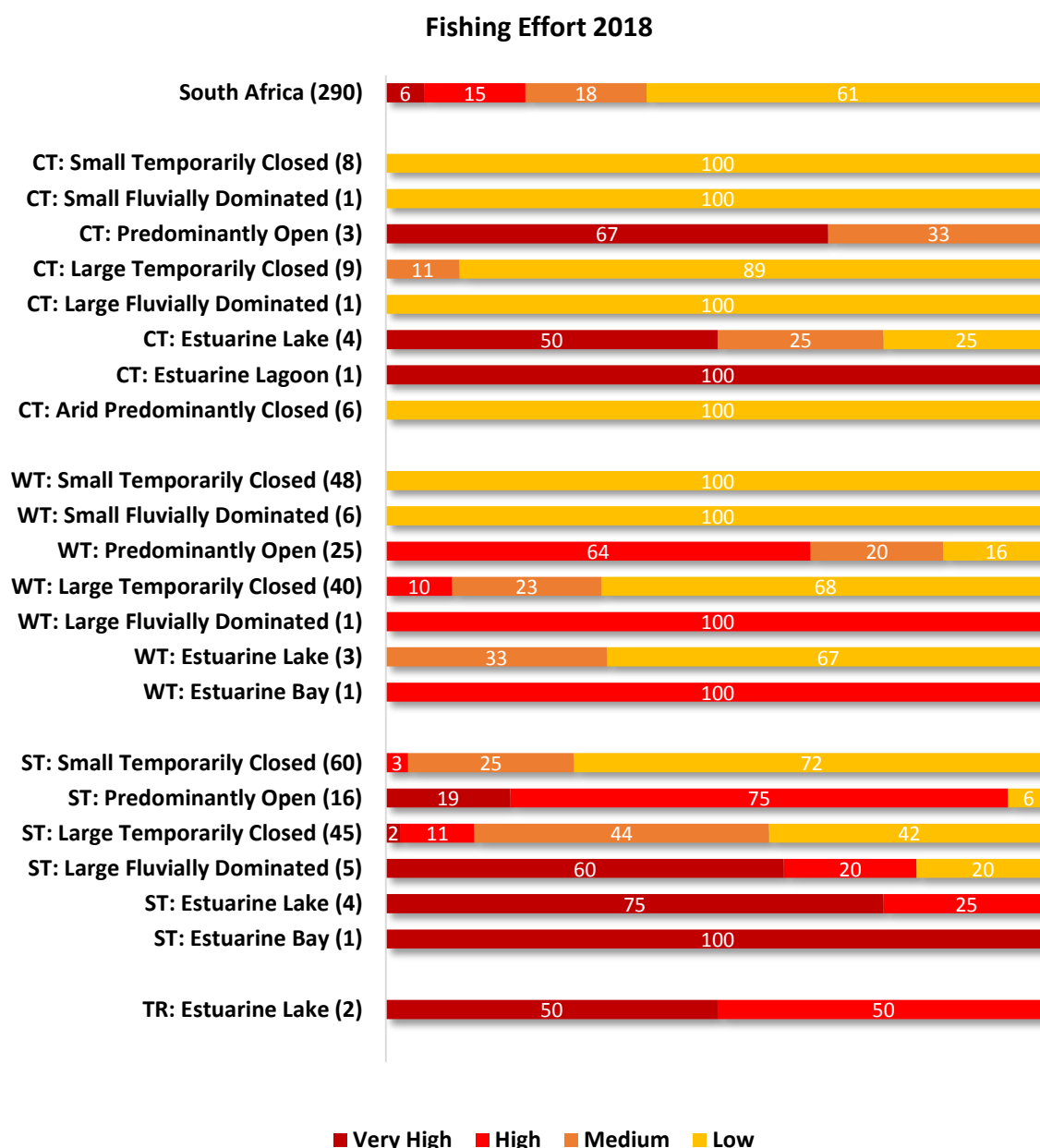


Figure 34. Fishing pressure on estuarine types.

TEXT BOX 4: ILLEGAL AND UNSUSTAINABLE GILLNET FISHING IN ESTUARIES CAUSES COLLAPSE OF THE HARDER CHELON RICHARDSONII RESOURCE.

Closure of the Berg River Estuary gillnet fishery in 2001 saw small-scale commercial gillnet fishers reporting an increase in the numbers and size of harder *C. richardsonii* caught in St Helena Bay. In turn, continued monitoring before and after fishery closure resulted in a recovery in the numbers and size of harder and by-catch species such as elf in the Berg Estuary. Protecting this estuarine fish nursery from gillnetting had resulted in improved catches reported by the legal commercial gillnet fishery in the adjacent St Helena Bay. However, this recovery was short lived as monitoring indicated that the illegal gillnet (poaching) catch in the estuary escalated to approximately 400 tons per annum by 2018. There has also been a corresponding steep decline in total reported catches from 1 500 tons of harders in 2006 to 400-500 tons in 2008-2018 by the legal fishery in the sea. This decline is directly attributable to the poached 400 t which were caught before they could grow double in size to 800 t, a phenomena referred to as recruitment or growth overfishing. Illegal fishing, much of which takes place at night, jeopardizes the legal fishery, and if allowed to continue may do so to the extent that the legal fishery becomes unviable. This may already be the case as only 28 of 84 gillnet and beach-seine right-holders in St Helena Bay remained active in the fishery in 2019. Those remaining all report running at a loss. Consequently, for the marine fishery to survive, compliance support and funding should be directed at eliminating gillnetting poaching from the Berg River Estuary.

The nearby Langebaan Estuarine Lagoon is experiencing similar problems with respect to oversubscribed gillnet fishing effort. Langebaan is an MPA and National Park and consequently gillnetting effort was set at 10 right-holders who were allowed to fish in the controlled zone of the Lagoon but excluded from the restricted and sanctuary zones. A series of legal challenges and political opportunism saw effort levels more than double to 27 rights, permit and exemption holders and open access in the restricted zone from which fishers were previously excluded. The resultant continuing decline in catch-per-unit effort (CPUE), together with the reduction in the mean size of the fish caught in Langebaan, raised concern and subsequently formal stock assessments were prioritised.

In 2018 / 19 an assessment of the Saldanha and Langebaan harder netfishery was conducted. The assessment investigated changes in sex ratio, mean length (mm), standardised catch-per-unit-effort (CPUE) and a per-recruit assessment was applied. Analyses of sex ratios over time indicated a significant switch between two periods (1998-2002 and 2017), from a predominantly female (larger individuals) to a male (smaller individuals) biased population (1.7 males: 1 female).

Three length-frequency distributions of commercial catch of *C. richardsonii* (1998-2002, 2009-2011 and 2017) indicate a reduction in mean total length (TL) of 36.5 mm over time (Figure 1). The standardized CPUE of harder for the period 2008-2016 has declined, indicating a reduction in relative abundance of *C. richardsonii* of approximately 30% (Figure 2) over this time.

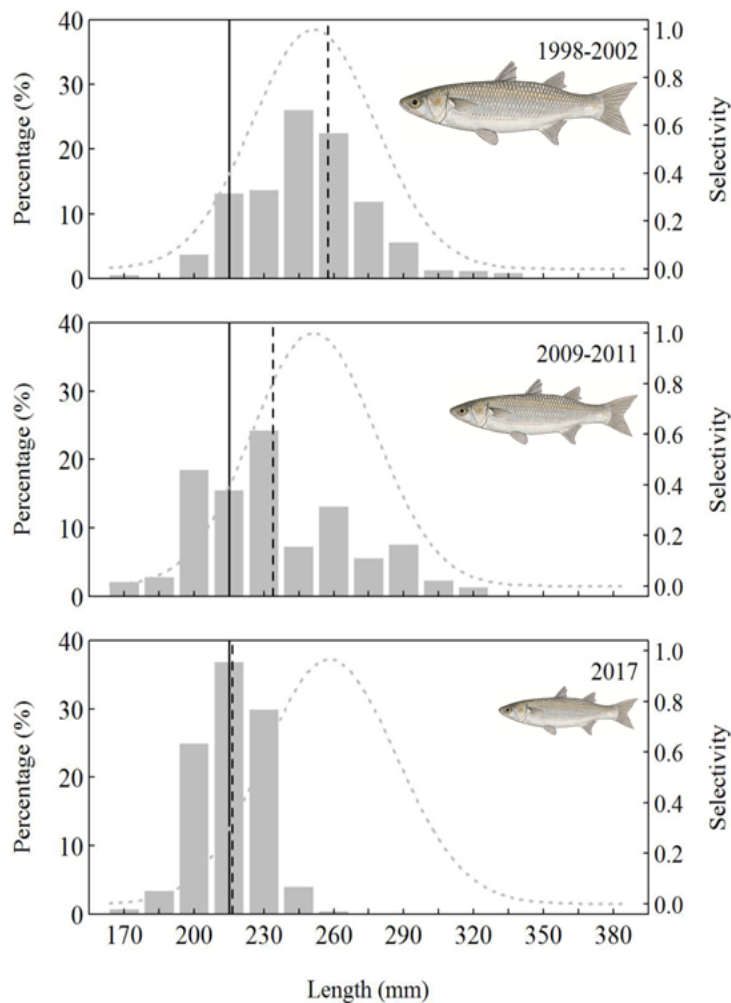


Figure 1: Length-frequency distributions of harders *Chelon richardsonii* caught in Saldanha and Langebaan by the commercial gillnet fishery fleet for three different periods. The solid vertical line represents length-at-50% maturity (215 mm) and the dotted vertical line is the mean total length TL (mm) for that length-frequency series. The bell shaped selection curve is the selectivity of the gillnets that were deployed during that particular time series. After Horton et al. (2019). For comparison, the fish pictures are to scale and illustrate the average size in each of the time series

A spawner biomass-pre-recruit model revealed that the stock is heavily depleted, with the stock currently collapsed at only 24 % of the estimated pristine biomass (Figure 3) and recruitment is likely to be seriously impaired. The multifaceted diagnostic assessment approach applied to the Saldanha and Langebaan harder gillnet fishery highlights several characteristics of overfishing, especially that on relatively isolated fish populations in estuarine environments.

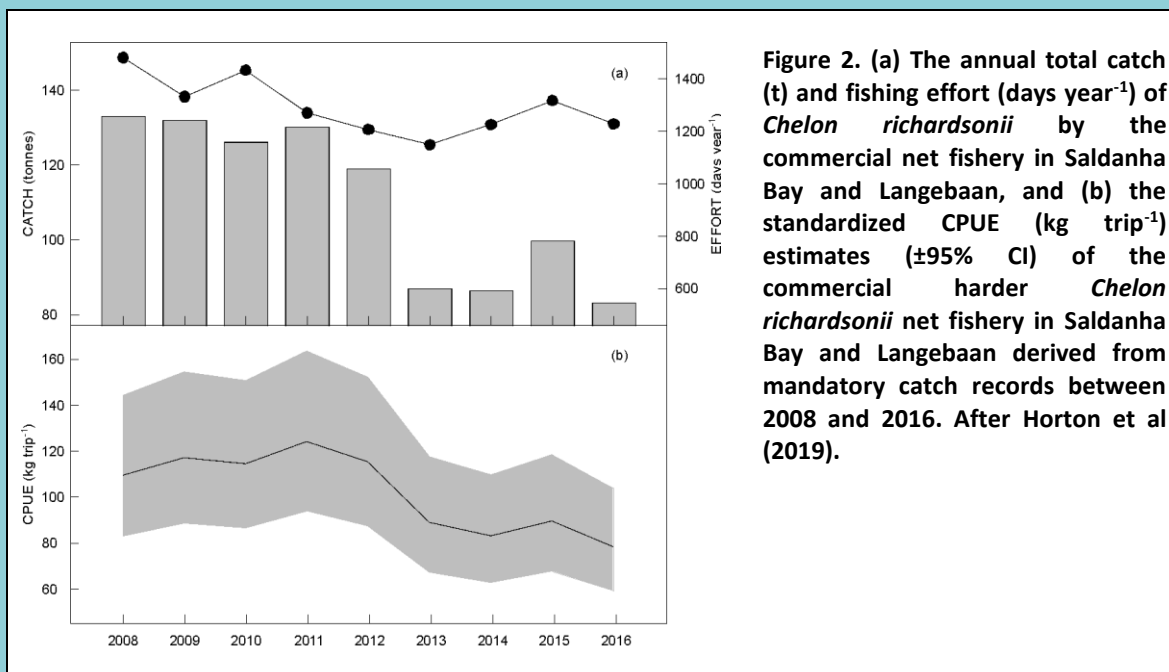


Figure 2. (a) The annual total catch (t) and fishing effort (days year⁻¹) of *Chelon richardsonii* by the commercial net fishery in Saldanha Bay and Langebaan, and (b) the standardized CPUE (kg trip⁻¹) estimates ($\pm 95\%$ CI) of the commercial harder *Chelon richardsonii* net fishery in Saldanha Bay and Langebaan derived from mandatory catch records between 2008 and 2016. After Horton et al (2019).

Together, the change in sex-ratio and reduction in both CPUE and mean TL (mm) characterise an overexploited fishery. These negative results are likely due to the combined effects of the Total Allowable Effort (TAE) being exceeded by 50%, gillnetting occurring in the Restricted Area of the Langebaan MPA and fishers reducing mesh size to maintain catch rates.

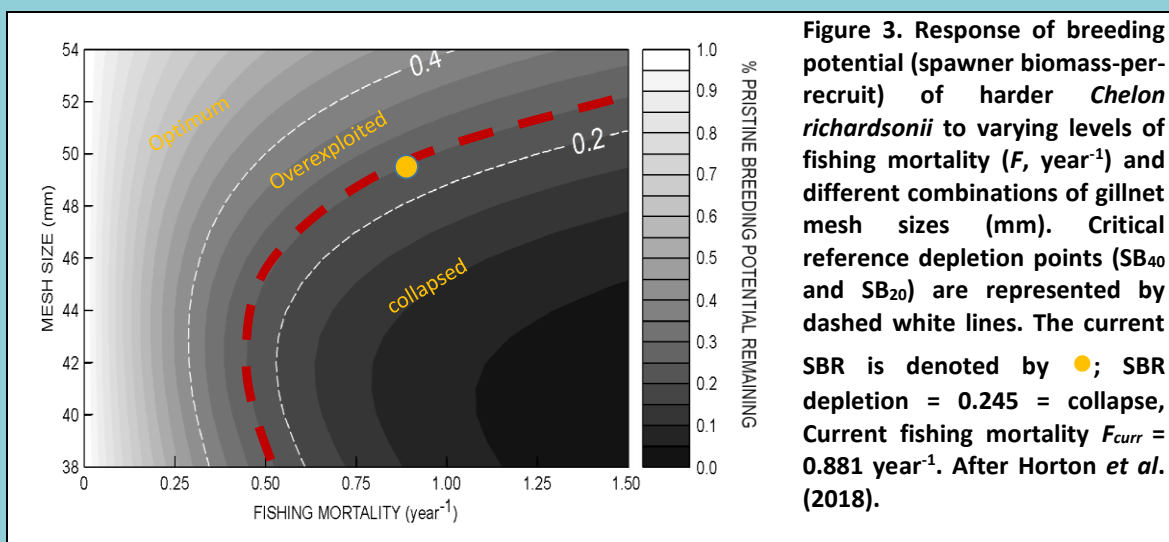


Figure 3. Response of breeding potential (spawner biomass-per-recruit) of harder *Chelon richardsonii* to varying levels of fishing mortality (F , year⁻¹) and different combinations of gillnet mesh sizes (mm). Critical reference depletion points (SB₄₀ and SB₂₀) are represented by dashed white lines. The current SBR is denoted by ●; SBR depletion = 0.245 = collapse, Current fishing mortality $F_{curr} = 0.881$ year⁻¹. After Horton et al. (2018).

Citation: Horton M. 'Illegal and unsustainable gillnet fishing in estuaries causes collapse of the harder *Chelon richardsonii* resource' in South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A.

Sources: Horton M., Parker D., Kerwath S., Lamberth S.J., Winkler H., Hutchings K. 2019. Age, growth and per-recruit stock-assessment of *Chelon richardsonii* in Saldanha Bay and Langebaan, South Africa. *African Journal of Marine Science* in press.

Bait collection

It is estimated that bait collection occurs in 84% of South African estuaries. However, in most of these systems the threat of overexploitation is low due to the high resilience of key species within the invertebrate communities targeted (Wynberg and Branch 1991, Hanekom and Baird 1992). However, habitat destruction and the status of non-target species were not included in the current assessment and bait collection could potentially pose a threat, especially to Temporarily Closed Estuaries during closed mouth conditions and low water levels (Wynberg and Branch 1994, Wooldridge 1999).

Exploitation of invertebrates used as bait by recreational and subsistence anglers is a ubiquitous activity in most estuaries around the South African coast. Commonly targeted species include *Upogebia africana* (mud-prawn), *Callichirus kraussii* (sand-prawn), *Solen spp.* (pencil bait), *Arenicola loveni* (bloodworm) and ribbon worm *Polybrachiorhynchus dayi* (Branch et al. 2002, Branch et al. 2010). Utilization of these living resources and the impact on other organisms and associated habitats may be persistent (e.g. close to urban environments) or more seasonal in nature (e.g. holiday resorts). In some estuaries e.g. Swartkops, the impact of bait collection is considered to be severe (de Villiers and Hodgson 1999).

Bait collection not only removes targeted species, but also results in habitat destruction and a reduction in the biomass of non-target species as a consequence of inappropriate collection methods, e.g. spades and pitchforks (de Villiers and Hodgson 1999).

6.5 Land-use and development

Key activities contributing to land-use and development pressures in estuaries are urban development, transport infrastructure (roads, crossings and culverts), riparian infrastructure (fences, bank stabilisation and low-lying developments), agriculture (clearing for crops, grazing), in-stream infrastructure (jetties and launching sites), raw material harvesting for housing (reeds, sedges and mangroves), mining, harbours infrastructure, marina infrastructure and salt works (Table 27). Habitat degradation or loss is considered a serious threat because of the risk of irreversible change.

The degree to which estuaries have been modified was assessed visually using 2014 National land cover data, Google Earth© and Spot 5 imagery, supported by country-wide datasets, flow requirement studies and field observations. The assessment indicated that the most severe and widely occurring land-use changes and developments affecting South African estuaries are urban development, agricultural activities, road infrastructure, mining and port and marina developments, together with their associated dredging activities. Some of the more notable impacts include changes to erosion/depositional cycles, direct habitat loss during construction, changes to flow velocity and circulation patterns, reduced tidal prism, premature mouth closure, smothering of submerged habitats by excessive sedimentation, increased turbidity, reduced primary production, destruction of riparian and instream habitats and biota, contamination and associated poor water quality (Morant

Table 27. Key activities contributing to land-use and infrastructure development pressure in estuaries.

KEY ACTIVITY	ECOLOGICAL IMPACT	TRAJECTORY	CONFIDENCE	DATA AVAILABILITY
Urban development (housing, resorts, hotels)	●	Increasing	H	H
Transport infrastructure (roads, crossings and culverts)	●	Stable	H	M
Riparian infrastructure (fences and low-lying developments)	●	Increasing	M	M
Agriculture (croplands, grazing)	●	Increasing	H	H
In-stream infrastructure (jetties and boat launching sites)	●	Increasing	M	M
Raw material harvesting for housing (reeds, sedges and mangroves)	●	Increasing	M	M
Mining	●	Increasing	L	L
Harbours infrastructure	●	Stable	H	H
Marina infrastructure	●	Stable	H	H
Salt works	●	Stable	H	H

and Quinn 1999, Whitfield et al. 2012, Van Niekerk et al. 2013). Habitat degradation can also render an estuary more prone to alien invasions. Some of the activities listed above are discussed in more detail as they represent ubiquitous pressures or a significant emerging pressure.

There are a large number of case studies in South Africa where **road infrastructure** across rivers and estuaries were built with little consideration of the environmental consequences (Morant and Quinn 1999). The minimum and cheapest structure to convey a road or railway over a river or estuary, whilst still meeting safety requirements (e.g. 1:50 year flood), usually results in a comparatively narrow multi-span bridge with long-approach embankments. One of the obvious impacts is that it stabilises dynamic estuarine channels. In turn, the combination of stabilised channels and heavy floods being forced through constricted areas, leads to the extensive erosion of sediments underneath the bridge. Erosion beneath the bridge can also occur in conjunction with extensive deposition downstream from the bridge. The changes in flow velocity, and related sediment distribution, can lead to changes in habitat and biota, e.g. loss of bloodworm *Arenicola loveni* from Uilkraals Estuary (Heydorn and Bickerton 1982). If tidal flows are impaired through the build-up of sediment, or bad bridge construction, this can lead to premature mouth closure in smaller temporarily open and closed estuaries, e.g. Seekoei. The most extensive series of bridges over estuaries in South Africa are those spanning systems on the KwaZulu-Natal South Coast. The South Coast railway spans every estuary, usually very close to the sea, for the entire distance from Durban to the iZothsa Estuary some 150 km

to the south (Begg 1978). In addition, the N2 arterial highway and ancillary roads span the same rivers or estuaries.

While **sand, mineral and diamond mining** do not occupy a large spatial footprint in the EFZ, physical habitat alteration is a growing concern as long-term impacts on the environment have not been fully quantified and verified. Mining is an intense form of pressure, with long-term direct and indirect impacts on species and ecosystems. Direct impacts linked to clearing natural habitat are captured in the land cover changes dataset. While other impacts, such as water abstraction, stream bed modification and contamination of water bodies; and indirect impacts, such as migration of pollutants; and induced impacts, such as those linked to mine associate industrial and urban development; are only quantified on a site level and also not reflected in the land cover change analyses.

Based on NLC data, mining is of particular concern in the Cool and Warm Temperate regions at 1-3% of estuarine area respectively. However, not all mining activities are reflected in the dataset as 37 out of 74 systems in KZN have sand-mining in, or upstream of, an estuary, with 17 systems directly impacted by mining in the EFZ. (Unpublished data, ORI). Mining operations (e.g. roads, vegetation clearing) intersect EFZs at 72 locations (31 active in 2018) (Figure 35), while operations upstream of EFZs total 239 (90 active in 2018). Mining operations in KZN target Large Temporarily Closed estuaries (20), Small Temporarily Closed estuaries (9), Predominantly Open (6), and Large Fluvially Dominated (2) estuaries. Similar datasets are not available for the rest of South Africa, but urgently needed.



Figure 35. Sand Mining in the iLovu Estuary upper reaches (Source: CoastKZN, ORI).

Sand from estuary and coastal environments is one of South Africa's most valuable resources, but over the last decade there has been a drastic increase in uncontrolled and unauthorised sand mining activities in rivers, valleys and estuaries throughout the country (Chevallier 2014). The frameworks governing small-scale sand mining in South Africa lack the necessary capacity to support better environmental compliance, and the enforcement mechanisms to successfully deter illegal activities are weak (Chevallier 2014). Consequently, there has been a high number of new entrants to the sector, creating a system fraught with social, environmental, legislative and structural challenges. Illegal alluvial sand extraction is performed mainly through open pit methods, and requires only basic equipment. The extracted sand is then transported a short distance and sold privately to local sand companies and individuals. The barriers to entry are thus low while the operations are highly lucrative.

Most of the illegal operators are in KwaZulu-Natal and the Eastern Cape. Although these operations from a spatial perspective, appear small and localised, they remove important stabilising riparian vegetation and constantly move location, leaving behind unproductive and unrestored land. Although the cumulative impact of these illegal activities is yet to be fully determined, existing policy and management responses do not have the urgency required to prevent the irreversible destruction of riverbeds and associated estuarine zones (Chevallier 2014). Rare mineral and fertiliser extraction, e.g. titanium, cadmium, phosphate also represents a growing concern with a number of estuaries under pressure from this type of mining, e.g. Verlorenvlei (in catchment), Langebaan, Wild Coast, iNlabane. While most of the Arid, Predominantly Closed systems are under pressure from diamond mining in the EFZ or adjacent environs.

The construction of **small-boat harbours and marinas** is limited but except for Cape Town and Mossel Bay, all the large commercial ports are situated in or near estuaries, i.e. Saldanha, Port Elizabeth, Ngqura, East London, Durban and Richards Bay. All of these developments coincided with significant habitat destruction and/or modification. There are 12 proclaimed fishing harbours located mainly along the southern and western Cape coast, three of which are in estuaries, Groot Berg, Knysna and Kowie (Port Alfred). Several dedicated yacht harbours and marinas have also been built along the South African coastline from the Groot Berg in the west to Port Alfred in the east. Dredging is vital for harbour and marina construction/expansion and maintenance of the channel and basin depths required for shipping and sailing. Potential dredging impacts include increased turbidity, smothering, changes in mouth stability, contaminated sediment (e.g. trace metals and hydrocarbons) released into the environment (DEAT 2008). Harbours and marinas, particularly those situated adjacent to cities and larger towns, are also vulnerable to pollution. Structures (e.g. quays) create areas of poor water circulation and as a result pollutants entering the sheltered areas, either from the land (e.g. contaminated stormwater runoff) or from activities in the harbour or marina (e.g. dredging), often accumulate with detrimental consequences to marine and estuarine life (e.g. fish kills). Private slipways and jetties cannot be ignored as these are ubiquitous in estuaries throughout the coast and represent substantial hardening and loss of intertidal habitat.

In addition, physical changes associated with habitat degradation negatively affect the biota, with cascading effects through the food web. Ultimately, changes in the structural habitat of an estuary can result in local extinctions, change in population size or biomass, community composition and structure, ratios of generalist to specialist biota and life-history patterns (Morant and Quinn 1999, Vorwerk et al. 2003, Levin and Stunz 2005, Niklitschek and Secor 2005, Lamberth et al. 2008, 2010). Estuary carrying is also diminished, especially for species at higher trophic levels. Habitat degradation can also render an estuary prone to invasion by more generalist alien species such as the invasive North America cordgrass *Spartina alterniflora* and the Asian mollusc *Tarebia granifera* (Adams et al 2012b, Appleton et al. 2009, Jones et al. 2017).

However, of most concern are **urban development and agricultural activities in the EFZ** that have direct impacts on estuaries in the form of habitat loss and indirectly in the form of contaminated stormwater and agricultural return-flow polluting the systems. To provide a broad indication of the

degree of intactness of the EFZ, the 2014 SANBI land cover data was disaggregated into natural and modified classes (artificial water bodies, urban (built-up) areas, mining, plantations and agriculture (croplands) (Table 28).

The natural class includes 6% of secondary natural which is land that has been fallow for decades and is in the process of recovering and supporting estuarine-associated vegetation. The land cover data indicate that about 84% of the EFZ still has relatively natural land cover. Agriculture (in the form of croplands) was responsible for about 10% and urban areas for 4% of land cover change. Mining, plantations and artificial water bodies contributed 0.8%, 0.6% and 0.2% of land cover change. Estuarine ecosystem types that have undergone a high degree of overall land-use change by area are ST: Estuarine Bay (50 %), ST: Large Fluvially Dominated (56%), CT: Large Temporarily Closed (59%), ST: Predominantly Open (66%), CT: Small Temporarily Closed (66%), ST: Large Temporarily Closed (71%), WT: Estuarine Lake (72%), WT: Estuarine Bay (75%), CT: Predominantly Open (76%).

Table 28. Summary of percentage land-use changes within the EFZ as proxy for key activities contributing to habitat loss.

ESTUARY ECOSYSTEM TYPE	% NATURAL (INCL SECONDARY NATURAL)	% MODIFIED	% SECONDARY NATURAL	% ARTIFICIAL WATERBODIES	% URBAN INFRASTRUCTURE	% MINING	% PLANTATIONS	% AGRICULTURE (CROPLANDS)
CT: Arid Predominantly Closed	91.3	8.7	3.2	0.0	1.3	7.3	0.0	0.0
CT: Estuarine Lagoon	99.9	0.1	0.6	0.0	0.1	0.0	0.0	0.0
CT: Estuarine Lake	96.5	3.5	1.9	0.0	1.1	0.2	0.1	2.1
CT: Large Fluvially Dominated	82.9	17.1	4.6	0.0	0.3	16.8	0.0	0.0
CT: Large Temporarily Closed	58.8	41.2	5.2	6.7	34.6	0.0	0.0	0.0
CT: Predominantly Open	75.6	24.4	3.7	0.6	1.9	3.1	0.1	18.7
CT: Small Fluvially Dominated	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CT: Small Temporarily Closed	66.0	34.0	4.1	1.3	32.7	0.0	0.0	0.0
WT: Estuarine Bay	75.3	24.7	3.6	0.1	23.5	0.0	0.4	0.7
WT: Estuarine Lake	71.7	28.3	10.8	0.0	0.8	0.0	1.0	26.6
WT: Large Fluvially Dominated	99.9	0.1	0.5	0.0	0.1	0.0	0.0	0.0
WT: Large Temporarily Closed	82.3	17.7	6.9	0.1	4.8	2.8	0.1	9.9
WT: Predominantly Open	80.6	19.4	7.3	0.1	4.6	1.3	0.1	13.4
WT: Small Fluvially Dominated	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WT: Small Temporarily Closed	93.4	6.6	7.8	0.0	5.9	0.0	0.1	0.6
ST: Estuarine Bay	50.3	49.7	9.0	0.1	49.6	0.0	0.0	0.0
ST: Estuarine Lake	93.5	6.5	5.7	0.0	1.3	0.2	1.0	3.9
ST: Large Fluvially Dominated	55.8	44.2	2.3	0.1	0.1	0.0	0.8	43.3
ST: Large Temporarily Closed	70.5	29.5	15.6	0.2	7.0	0.1	0.2	22.1
ST: Predominantly Open	65.8	34.2	12.4	0.3	12.0	0.0	0.9	21.0
ST: Small Temporarily Closed	81.7	18.3	16.6	0.0	11.2	0.0	0.9	6.2
TR: Estuarine Lake	98.5	1.5	0.7	0.0	0.5	0.0	0.0	1.0
TOTAL	84.2	15.8	5.9	0.2	3.9	0.8	0.6	10.3

Looking at different types of land-use, built-up urban areas within the EFZ were especially prevalent in ST: Estuarine Bay (50%), CT: Large Temporarily Closed (35%), CT: Small Temporarily Closed (33 %), WT: Estuarine Bay (24%), ST: Predominantly Open (12%), ST: Small Temporarily Closed (11%). Mining had a large impact on CT: Large Fluvially Dominated (17%).

Agricultural activities (using Croplands) within the EFZ also occurred in a high number of estuary types with by area ST: Large Fluvially Dominated (43%), WT: Estuarine Lake (27%), ST: Large Temporarily Closed (22%), ST: Predominantly Open (21%), CT: Predominantly Open (19%) and WT: Predominantly Open (13%). Agriculture in Subtropical estuaries is mainly sugarcane farming. In the Warm Temperate estuaries floodplains were intensively cultivated in the 1950s to 1970s but then left fallow, for example in the Keiskamma and Great Fish estuaries. Cattle grazing and alien plant growth are now common in these fallow areas. In the Cool Temperate systems floodplain areas are also prone to agricultural development (e.g. grain and fodder, fruit orchards, vineyards) and grazing by sheep and cattle. In addition farmers often set reeds alight in the hope of improving grazing or giving livestock access to water. Harvesting of plants are also common in some estuaries. Targeted species are *Juncus kraussii* (ncema grass) and *Phragmites australis* (common reed). They are used for traditional crafts and construction including thatching. Mangroves in some estuaries such as uMkhomazi, Mngazana and Nxaxo-Ngqusi are also targeted, mainly for construction purposes. Browsing of mangroves by cattle is also a problem (Hoppe-Speer and Adams 2015).

Combining the impact of the activities listed above and the results of the EHI a habitat degradation pressure level was assigned to each of the estuaries and aggregated to national, bioregional and ecosystem type level (Figure 36). Overall, 29% of South African estuaries are subject to severe (High to Very High) pressure from habitat modification and development, mostly in the Cool Temperate (63%) and Subtropical (34%) regions. An

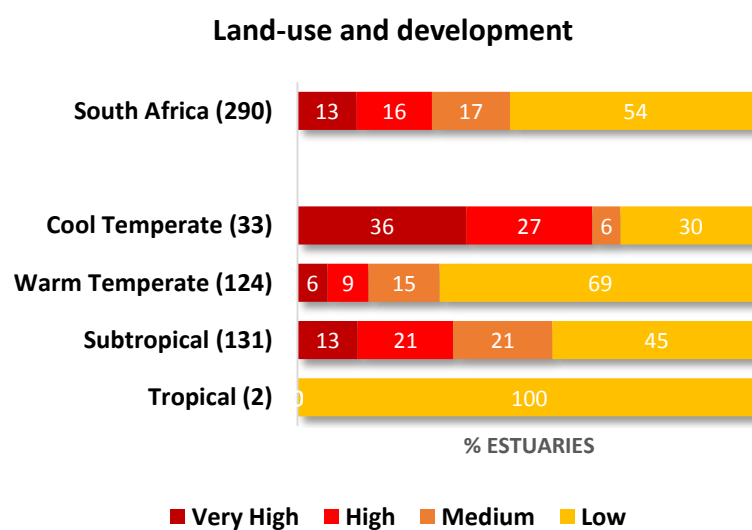


Figure 36. Land-use and development pressure in estuaries across biogeographical regions.

additional 17% of estuaries in South Africa are under a moderate (Medium) degree of land-use and development pressure, with estuaries in the subtropical (21%) and the Warm Temperate (15%) regions being the most affected. Less than 10% of all estuaries in South Africa are under no pressure from development; most of these being smaller systems confined to national, provincial or municipal protected areas.

From an ecosystem perspective (Figure 37) estuary types subjected to severe habitat degradation pressure (High and Very High) in order of severity are: ST: Estuarine Bay (100%), CT: Large Fluvially Dominated (100%), CT: Large Temporarily Closed (100%), CT: Predominantly Open (100%), ST: Estuarine Lake (75%), ST: Large Fluvially Dominated (60%), CT: Arid Predominantly Closed (50%), CT: Estuarine Lake (50%), ST: Large Temporarily Closed (47%), CT: Small Temporarily Closed (38%), WT: Estuarine Lake (33%), WT: Predominantly Open (28%), ST: Small Temporarily Closed (22%). Estuarine Lakes and Bays, together with Large Fluvially dominated and Predominantly Open types are those under the most riparian development pressure.

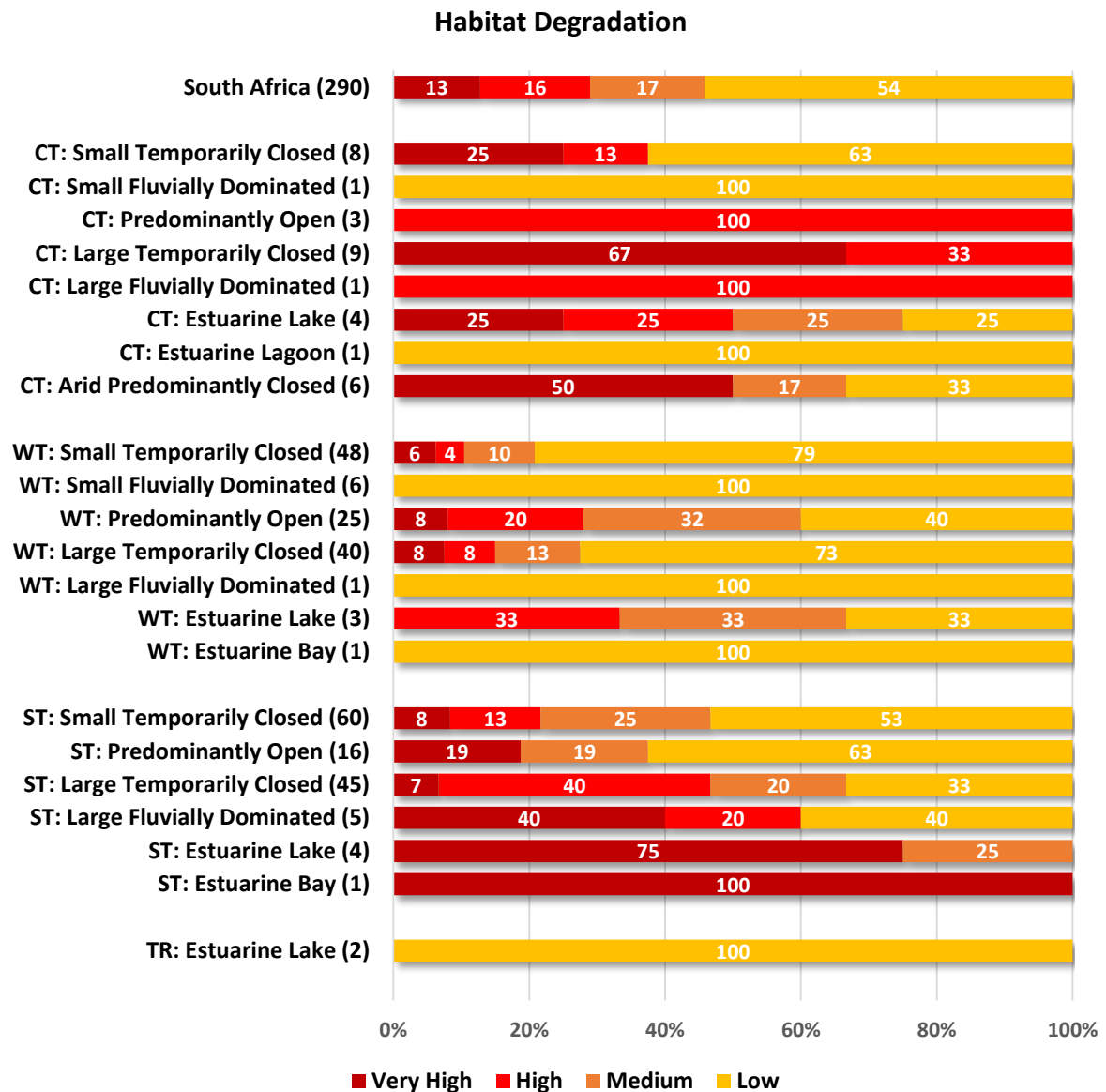


Figure 37. Land-use development pressure on estuarine types.

From a spatial perspective, estuaries in the urban centres (Durban, Port Elizabeth, Mosselbay and Cape Town) present the highest cluster of systems with degraded habitat (Figure 38). This highlights the need for appropriate land use planning in urban environments. Along the drier parts of the country agriculture in the EFZ is also contributing significantly to land degradation.

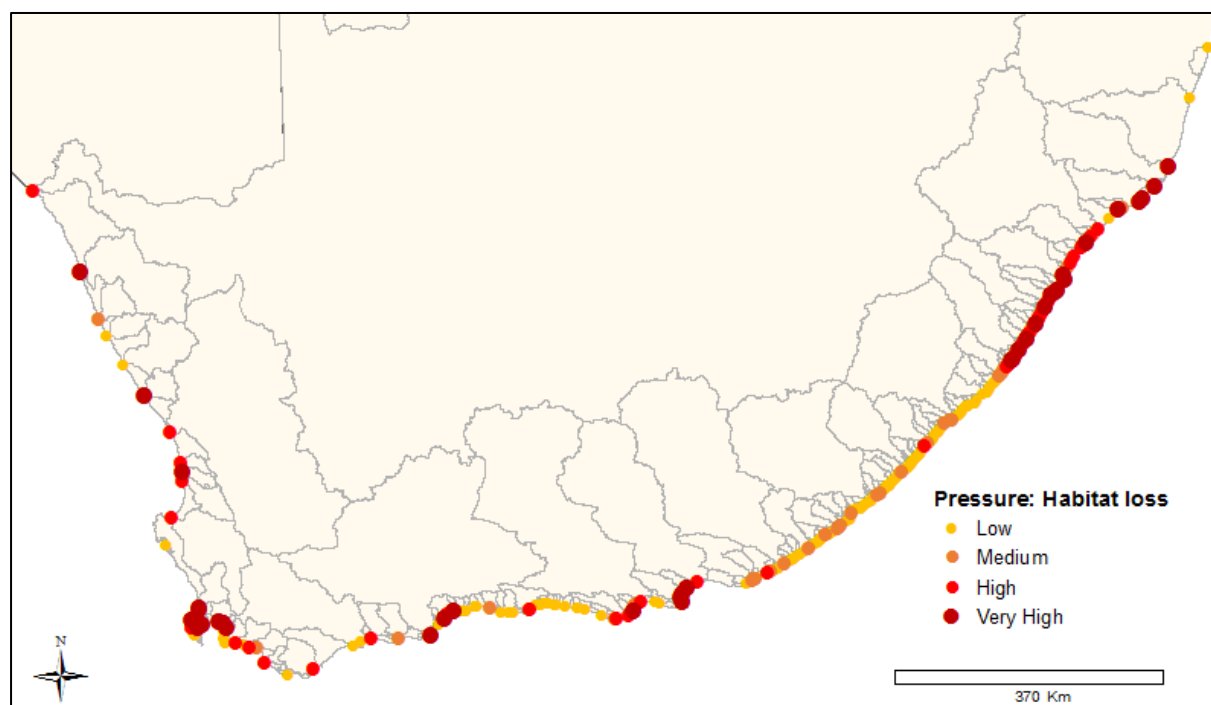


Figure 38. Spatial distribution of estuaries under land-use and development pressure.

6.6 Estuary mouth manipulation

As a consequence of inappropriate floodplain development, estuary mouths are manipulated in order to increase access and prevent property damage. Mouth manipulation includes artificial breaching (e.g. Klein, Swartvlei, Heuningnes, uMhlanga, uMdloti, iSipingo, aManzimtoti, iKongeni estuaries), stabilisation or canalisation (e.g. Seekoei, Zand, Great Berg estuaries), and the creation or diversion of an inlet (e.g. Ratel mouth) (Table 29).

Table 29. Key activities contributing mouth manipulation pressure on estuaries.

PRESSURE/ACTIVITY	Ecological Impact	Pressure trajectory	Confidence	Data availability
Artificial breaching (premature at lower levels)	●	Increasing	M	L
Mouth stabilisation/canalisation	●	Stable	H	M
Inlet diversion	●	Increasing	M	M

Estuary mouth manipulation may change the type of estuary, e.g. from a temporarily open to a permanently open system. In most cases the need for mouth manipulation is the result of inappropriate development in the estuary functional zone. About 15% of South African estuaries are breached artificially (Van Niekerk et al. 2013, NBA 2018 Estuary Management and Monitoring register). Most of these systems are clustered around urban centres in the Cool Temperate and Subtropical biogeographical regions, with only a few recorded in the Warm Temperate region (Figure 39). However, artificially breached systems account for 62% of the total estuarine habitat in South Africa.

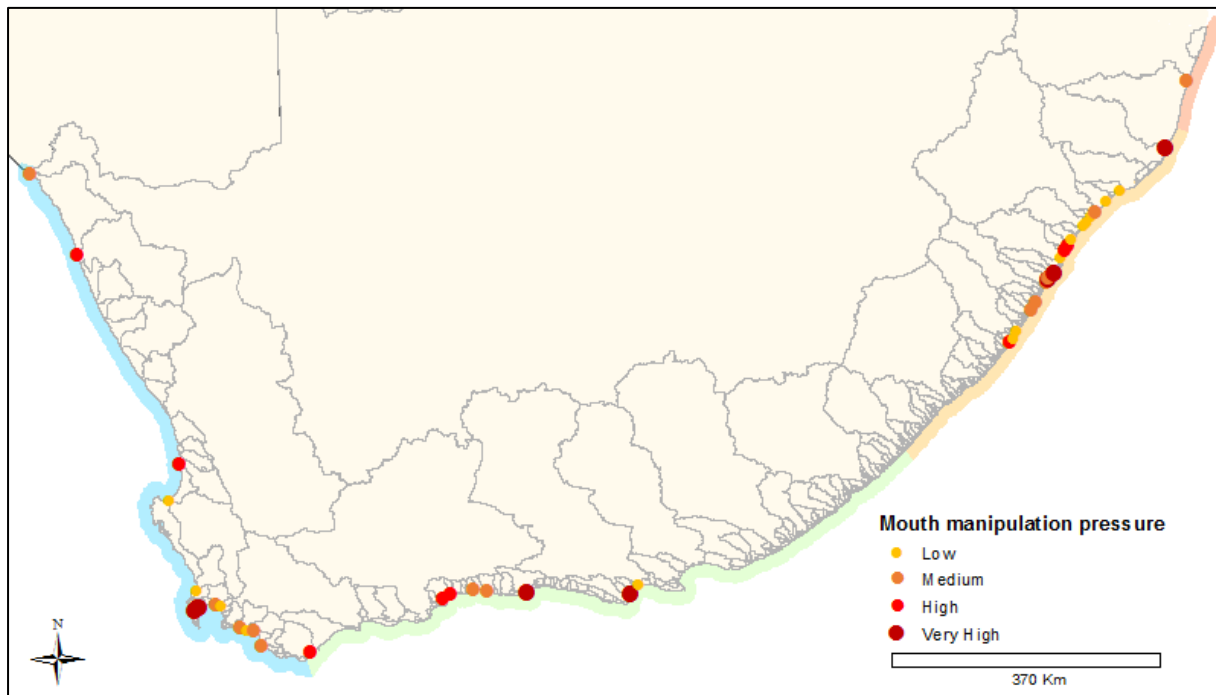


Figure 39. Mouth manipulation pressure on estuaries (updated from Van Niekerk et al. 2015).

Estuary mouth manipulations are often driven by an increase in closed mouth conditions, which in turn are concomitant with water resource development. Artificial breaching is the most pervasive of these manipulations and occurs when there is back-flooding of adjacent low-lying developments (Whitfield et al. 2012, Van Niekerk et al. 2013). For example, reduction in freshwater flow can lead to an estuary mouth being closed more frequently and for longer periods, leading to increased sand berm levels and back-flooding of adjacent low-lying developments before breaching. An increase in closed-mouth conditions also causes increased retention and gradual freshening of estuarine water due to restricted marine inputs and continuous seepage losses through the sand berm which is offset by limited surface or groundwater freshwater inflow. These more stagnant conditions, especially where there is nutrient enrichment, can cause nuisance algae or macrophyte blooms (e.g. Bot and Zand), which are often intentionally flushed out of the system by artificial breaching of the estuary mouth.

However, the artificial breaching of an estuary mouth is most often not timed to coincide with natural freshwater inflow events and can have potential cascading effects on the physico-chemistry of the estuary and the biological components. A key concern is the tendency of recent breachings, e.g. Touw/Wilderness, to occur well below recognised breaching levels, thus resulting in premature closures.

A change in natural estuary mouth dynamics often results in increased sedimentation, caused by a decrease in flushing potential when premature breaching takes place at low water levels. It can also be due to the ingress of marine sediments when an estuary mouth is kept open artificially for long periods and ultimately leads to a restricted inlet, reduced tidal flows, and over time result in premature closure. Related changes in salinity, sediment structure, tidal flushing and biogeochemical processes can have severe effects on primary productivity, species composition, recruitment of larval fish and invertebrates (Whitfield et al. 2012). In addition there are changes to the normal migration of marine species back to sea, and genetic exchange between estuaries and the adjacent marine environment.

Mouth manipulation is mainly a result of South African legislation not recognising back-flooding areas as being part of the EFZ, which is not restricted to the area below the high water mark. Consequently, inappropriate low-lying developments (i.e. housing, urban infrastructure, golf courses or agricultural land) within the back-flooding areas (i.e. that inundated under natural breaching levels) are being protected at the cost of the natural estuarine environment.

Mouth manipulation occur along the entire coastline of South Africa (Figure 40), but is more pervasive along the Temperate Western Cape and Subtropical KZN urban areas, very little manipulation occurring along the Wild Coast where most development is set back from the EFZ.

The pressure assessment indicated that 6% of South African estuaries are significantly threatened (High to Very High) by mouth manipulation (Figure 40), with especially the Cool Temperate region (15%) being affected. A further 5% of South African estuaries are moderately threatened (Medium) by mouth manipulation, with again the highest proportion also in the Cool Temperate region (15%).

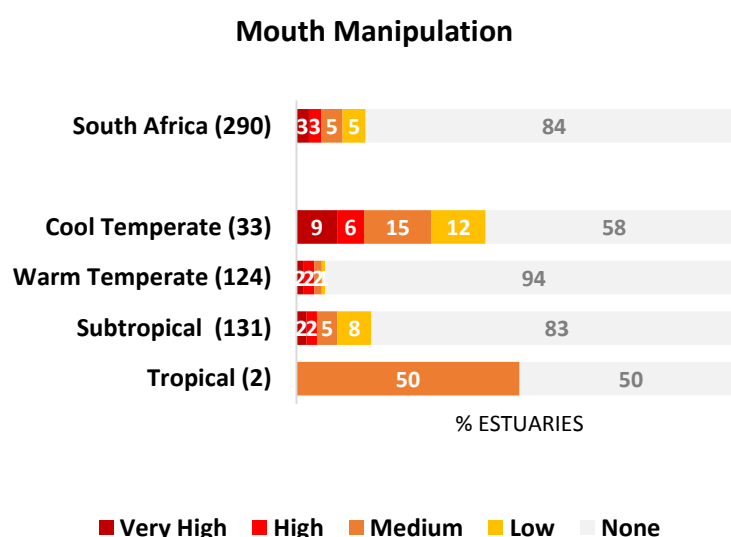


Figure 40. Mouth manipulation pressure across the four biogeographical regions.

From an ecosystem type perspective (Figure 41), Estuarine Lakes are by far the most threatened with Cool Temperate (50%), Warm Temperate (22%) and Subtropical (25%) lakes under severe pressure (High to Very High). Similarly Cool Temperate Large Temporarily Closed systems (22%) are also under severe pressure. While 17% of Arid Predominantly Closed systems are under severe pressure.

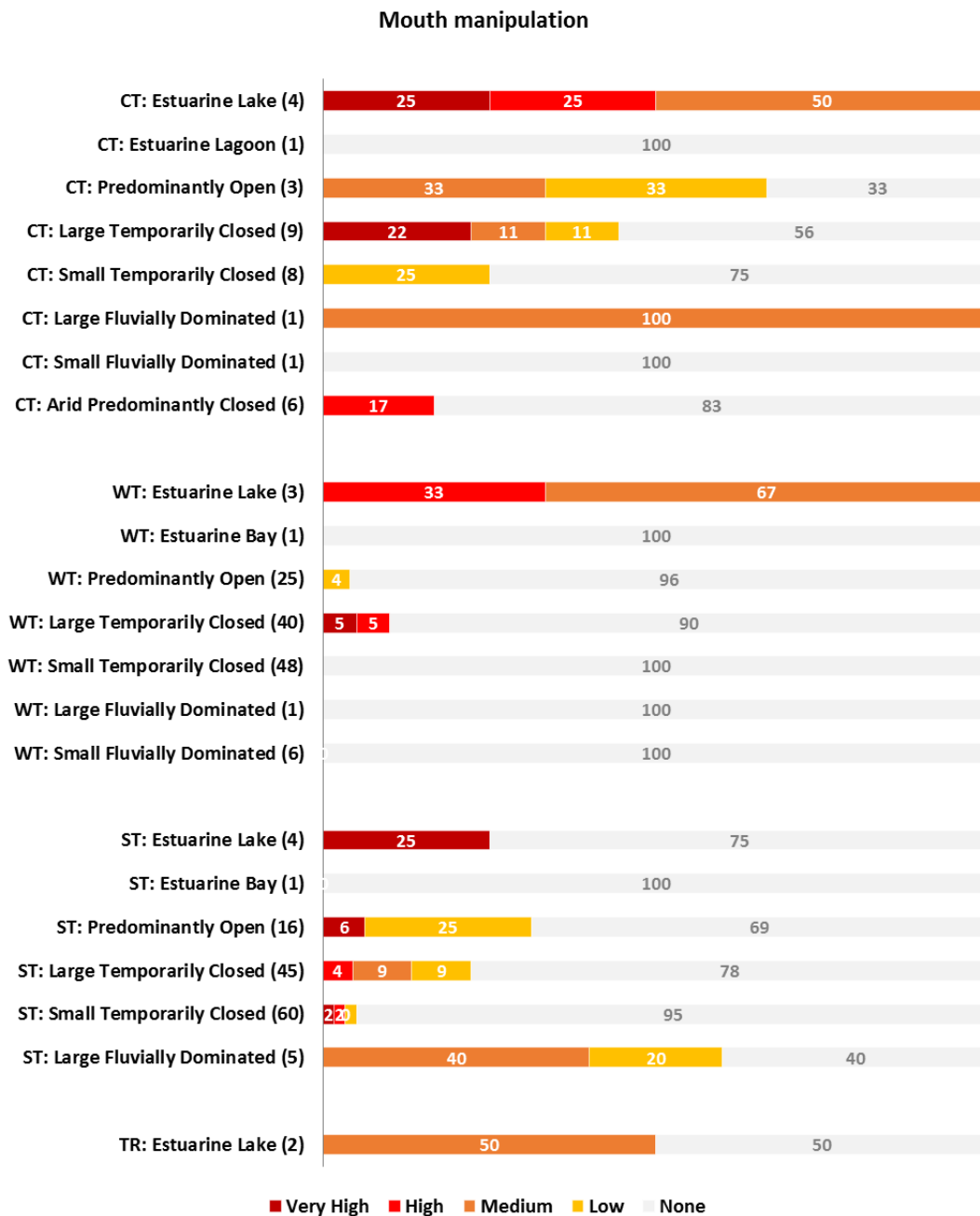


Figure 41. Mouth manipulation pressure on estuarine ecosystem types.

6.7 Biological Invasions

Terms and definitions used in this section are based on the Convention on Biological Diversity (CBD 1992, 2000): an “Alien species” is defined as a species, subspecies, or lower taxon introduced outside its normal past or present distribution. An “established alien species” is an alien species that is reproducing in the wild and has established a durable population in an area. An “Invasive alien species” is an alien species whose establishment and spread threaten ecosystems, habitats or species with economic or environmental harm. “Introduction” is defined as the movement, by human agency, of a species, subspecies, or lower taxon outside its natural range (past or present). “Cryptogenic species” may be either a native species or an introduced species, with clear evidence for either origin being absent.

Most alien species found in South Africa today were intentionally introduced many years ago, either with the goal of establishing feral populations in nature, or for horticulture, agriculture, forestry or the pet trade from where some escaped to become invasive. The remainder were introduced accidentally as contaminants or as stowaways on transport vectors. While the rate of intentional introduction of high-risk species is expected to decline due to improved regulation, it is also expected that the rate of unintentional introductions will increase due to increases in trade and tourism.

The rate at which species are arriving in the country appears to be increasing. Once an alien species is introduced to South Africa, further spread within the country is highly likely and very difficult to stop. There is a thriving trade in alien species for a variety of purposes within South Africa’s borders.

Invasive alien species pose a significant threat to estuaries where they cause both ecological and economic damage (Table 3). Alien species can exert a significant impact upon community structure and functions, by modifying spatial and food chain resources, with direct or indirect effects on the occurrence of indigenous species (Drake et al. 1989, Leppa” Koski et al. 2002, Elton 1958). Economic concerns include, for example, burrowing activities that can destabilise embankment (causing erosion), clogging of water intake filters of industrial cooling water (during mass occurrences), and alien species preying heavily upon native species of commercial importance. In recent years, national and international environmental policy and legislation has begun to reflect these threats and respond accordingly (e.g. CBD 1992, IMO 2004, European Commission 2008).

There are four main arguments for explaining observed settlement characteristics in estuaries (Nehring 2006), namely: a) Estuaries have a higher potential infection rate than other aquatic ecosystems types as a result of their high exposure to direct vectors, e.g. proximity to international shipping lanes and ports (ballast water and invasive species attached to the ship hulls); aquaculture activities, the aquarium trade and live bait associated with fishing activities. b) Estuarine species tend to be generalists and due to their physiological characteristics, are more likely to be transported alive than marine or freshwater species and they may also have a higher establishment potential after release. c) Estuaries have the greatest natural ‘indigenous species minimum’ or lowest number of indigenous species of all aquatic domains so that more alien species can potentially establish in this domain. This may be especially true in South Africa due to the sporadic flushing (resetting) of systems

by relatively large floods, allowing for potentially unsaturated ecological niches at times. d) Freshwater alien species introduced into inland waters, especially those tolerant of brackish conditions, will expand into estuaries.

The combination of brackish waters colonised by physiologically generalist species, potentially unsaturated ecological niches, and high exposure to international ship traffic in some of the larger estuaries, leads to the highest potential infection rates amongst all aquatic systems. In addition, estuaries are also subjected to a two-sided invasion pressure by alien species, via the ocean and via inland waters. The identification of such patterns is an important prerequisite for the development of a forward-looking alien monitoring and management strategy.

6.7.1 Invasive Alien Plants

Pathways contributing to introduction of invasive plants in South African estuaries include introduction for ornamental garden plants (horticulture), agriculture, forestry, and the accidental introduction of aquatic invasive by the ornamental fish trade, as ornamental plants for garden water features and aquaculture (Table 30).

Table 30. Key activities contributing to the introduction of invasive plants in estuaries in South Africa.

ACTIVITY	RELATIVE IMPACT	PRESSURE TRAJECTORY	CONFIDENCE	DATA AVAILABILITY
Ornamental garden plants (horticulture)	●	Increasing	H	H
Agriculture (pathway)	●	Increasing	H	M
Forestry (escapees)	●	Stable	L	L
Ornamental fish trade & garden water features (aquatic weeds)	●	Increasing	M	H
Aquaculture (aquatic weeds)	●	Increasing	L	L

The status of invasive plants in South African estuaries has received little attention in recent years. The aim is therefore to collate available information on IAPs in and surrounding South African estuaries. Aside from locality of individuals it is also important to obtain information about the physiology and characteristics of emerging AIPS from the countries of origin or other countries where invasions have been recorded.

This knowledge is important from a management perspective to ensure that AIPS are contained and hopefully eradicated so that future restoration can occur. Estuaries are dynamic and resilient habitats

that are able to quickly recover following disturbances and thus it is possible to reclaim South Africa's estuaries from IAPs.

More than a third of estuaries have invasive terrestrial plants occurring within the estuarine functional zone. Hundred-and-three of these are considered to be significantly invaded (Table 31, Figure 43). Aquatic invasive species have been recorded at 23 estuaries in the country (Table 32). These are conservative estimates and are likely much more widespread than reported in the literature. It also does not take into account estuaries for which little to no data is available i.e. Wild Coast coastline.

In total 70 invasive plant species were reported. Invasive *Acacia* species, particularly rooikrans *Acacia cyclops*, and *Eucalyptus* trees were abundant along the cool and warm temperate coastline. *Acacia* species were introduced to South Africa for dune reclamation. The species produces large numbers of seeds establishing seedbanks that can withstand low intensity fires. *Eucalyptus* trees were likely planted decades ago for shade or other purposes and are not as fast spreading as *Acacia* spp.

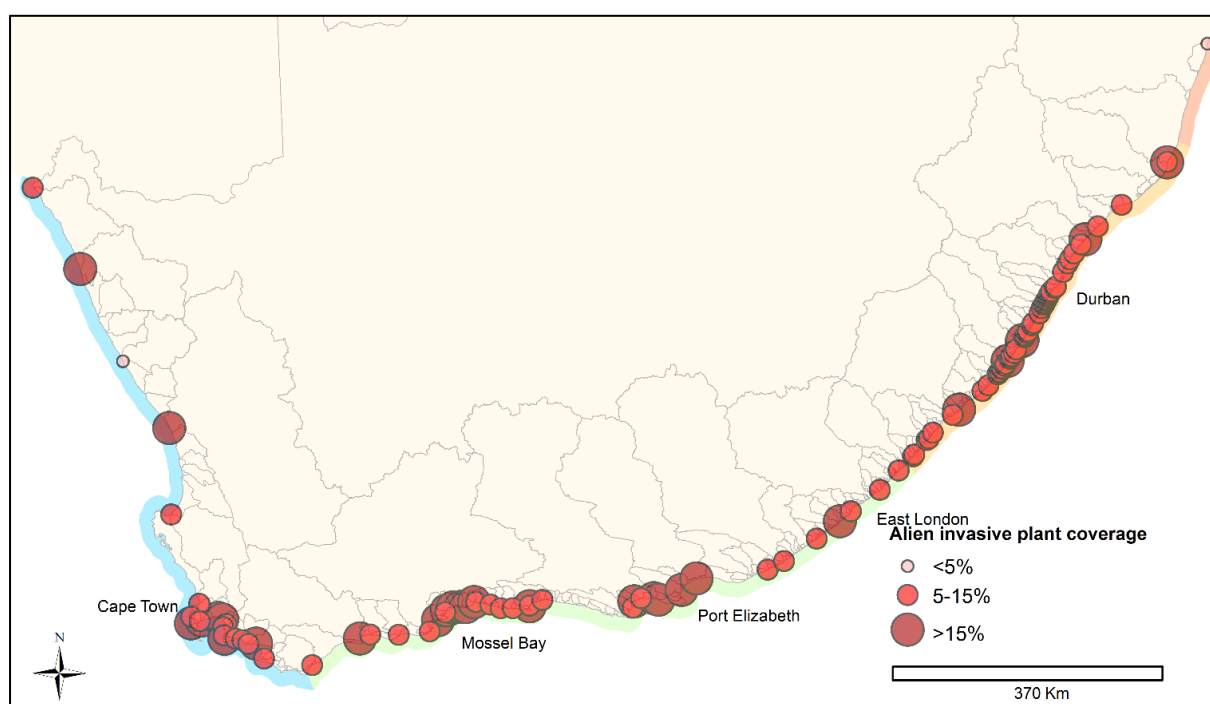


Figure 42. Location and extent of alien invasive plant coverage in South Africa.

The majority of invaded estuaries are situated in coastal towns and thus are disturbed by anthropogenic activities (Figure 43). The banks of the small Blinde Estuary is completely colonized by *Acacia cyclops*. Although little development surrounds the mouth of this estuary, its catchment is under agriculture and plantations. Kikuyu grass *Pennisetum clandestinum*, classified as NEMBA Category 1b in protected areas and wetlands, was also prevalent.

Table 31. Estuaries with a high density of terrestrial invasive alien plants.

Estuary	Terrestrial invasive plants in estuary reaches			Species richness
	Lower	Middle	Upper	
Buffels	M	M	H	3
Zeekoe	H	H	H	4
Lourens	H	H	H	8
Buffels (Oos)			H	5
Klein	H			1
Blinde	H	H	H	1
Klein Brak	H		L	2
Groot Brak	H	M	M	4
Maalgate	H	H	H	2
Gwaing	H	M	M	5
Kaaimans			H	1
Piesang	M	H	H	13
Sundays	M			1
Nahoon	H	H	H	
Mntafufu	M	H	M	4
Msikaba	H	H	H	4
iDombe	M	H	M	6
uMkhomazi	M	M	H	15
uMvoti	M	M	H	18
Msunduzi/Mfolozi	H	H		13

A greater diversity of invasive plant species occur along the subtropical KwaZulu-Natal coastline. Dominant tree species include Brazilian pepper tree *Schinus terebinthifolius* Raddi, *Casuarina equisetifolia* and *Sesbania punicea*. The urbanised estuaries of KwaZulu-Natal are highly disturbed and often the riparian vegetation consists only of invasive alien plants. Fernandes et al. (2016) showed that despite the 100 km distance between uMvoti and uMkhomazi estuaries they shared the same dominant alien invasive plants (Spanish reed *Arundo donax* L. *S. terebinthifolius*, *S. punicea* and peanut butter bush *Senna didymobotrya* (Fresen.) Irwin & Barneby). The disturbed catchments result in a similar invasive alien plant composition downstream.

Brazilian pepper trees *Schinus terebinthifolius* are widespread along the subtropical coast of South Africa. The fruits of this tree have inhibitory effects on other plants preventing growth surrounding these trees. Donnelly et al. (2008) reported that mangrove seedlings would not grow in soil containing the small red berries and that complete removal of the entire tree is needed to prevent accumulation of inhibitory compounds in the soil. *Lantana camara* also produces allelopathic chemicals that inhibit plant growth and are poisonous when ingested, as is castor oil bush *Ricinis communis* (Verdien et al. 2012, www.invasives.org.za).

Although there has been implementation of a biological control programme, water hyacinth *Eichhornia crassipes*, still remains the worst aquatic weed in South Africa (Coetzee and Hill. 2012).

Table 32. Estuaries supporting aquatic invasive alien plants.

Estuary	Aquatic invasive plants in estuary reaches			<i>Azolla filiculoides</i>	<i>Ceratophyllum demersum</i>	<i>Eichhornia crassipes</i>	<i>Myriophyllum aquaticum</i>	<i>Pistia stratiotes</i>	<i>Salvinia molesta</i>
	Lower	Middle	Upper						
Olifants	H	H	H	x					
Berg (Groot)	M	M	M			x			
Rietvlei/Diep	M	M	M	x		x			
Wildevleivlei	M	M	M						
Bokramspruit	L	L	L						
Zand	M	M	M	x	x	x	x		x
Zeekoe		M	M			x			
Eerste			H			x	x		
Lourens	M	M	H	x					x
Onrus	M	M	M	x					
Breede			H			x			
Blinde	M	M	M	x					
Hartenbos	M	M	M	x					
Wilderness	M	M	M						
Swartvlei	M	M	M	x					
Swartkops			H			x			
Sundays			H	x					
uMhlangomkhulu	H	M	M	x					
aManzimtoti	M	M	M					x	
iZimbokodo	M	M	M			x		x	
uMgeni	M	M	M	x		x		x	
uMdloti	M	M	M	x		x		x	
uTongathi	M	M	M			x		x	x
uThukela	M	M	M			x			

The species can survive and thrive in eutrophic conditions displacing rare submerged macrophyte species. When water hyacinth begins to invade the water surface, evaporation rates increase, stream flow decreases and nutrient cycles become altered (Charmier et al. 2012). There is some evidence to suggest that eutrophication at Swartkops Estuary and the large water hyacinth areas have displaced *Zostera capensis* in the middle-upper reaches of the estuary.

TEXT BOX 5 ERADICATION OF INVASIVE *SPARTINA ALTERNIFLORA* FROM GROOT BRAK ESTUARY



Smooth cordgrass *Spartina alterniflora* Loisel. (Poaceae), an aggressive ecosystem engineer in multiple countries, was first observed in Groot Brak Estuary in 2004 by a local resident. Due to its rapid growth and large underground biomass, the species is able to change open, intertidal mudflats into dense, monospecific marshes.

This results in habitat loss, a change in benthic communities and a trophic shift from algal-based to a detritus-based food web. From four little patches in the lower reaches in 2004 the species quickly colonised the estuary with mapping efforts in 2006 and 2011 indicating the species covered 10,221 m². Genetic identification showed that this was the first time the species has been recorded in South Africa, and also the first time recorded in a temporarily open/closed estuary. This is indicative of its highly adaptive nature as in the Groot Brak Estuary the intertidal area where it occurs can be flooded for up to eight months at a time. Starting in 2011 persistent summer chemical control was used to eradicate the



species. Over time cover was greatly reduced to only 149 live stems in the whole study area in November 2015. By 2015 native salt marsh species began recolonising the area and species richness began increasing, to pre *S. alterniflora* conditions. Total costs for the management of *S. alterniflora* in the Groot Brak Estuary were ZAR 103 047 over the 3-year study period (2013–2015).



To date *S. alterniflora* has been completely eradicated from the Groot Brak Estuary as plants were observed in 2017 and 2018. Although there were delays in initial control efforts, the threat posed by *S. alterniflora* was clear and the need for eradication was followed through by SANBI. Progress was enhanced by enthusiastic and supportive local stakeholders, organized in the form of the local residents' association and Groot Brak Estuary management forum. The SANBI Invasive Species Programme provided a responsible authority and resources to oversee the progress towards eradication.



Spartina alterniflora in 2009 (left) and at same site in 2014 after chemical treatment (right).

Sources: Adams et al. 2012, Adams et al. 2016, Riddin et al. 2016

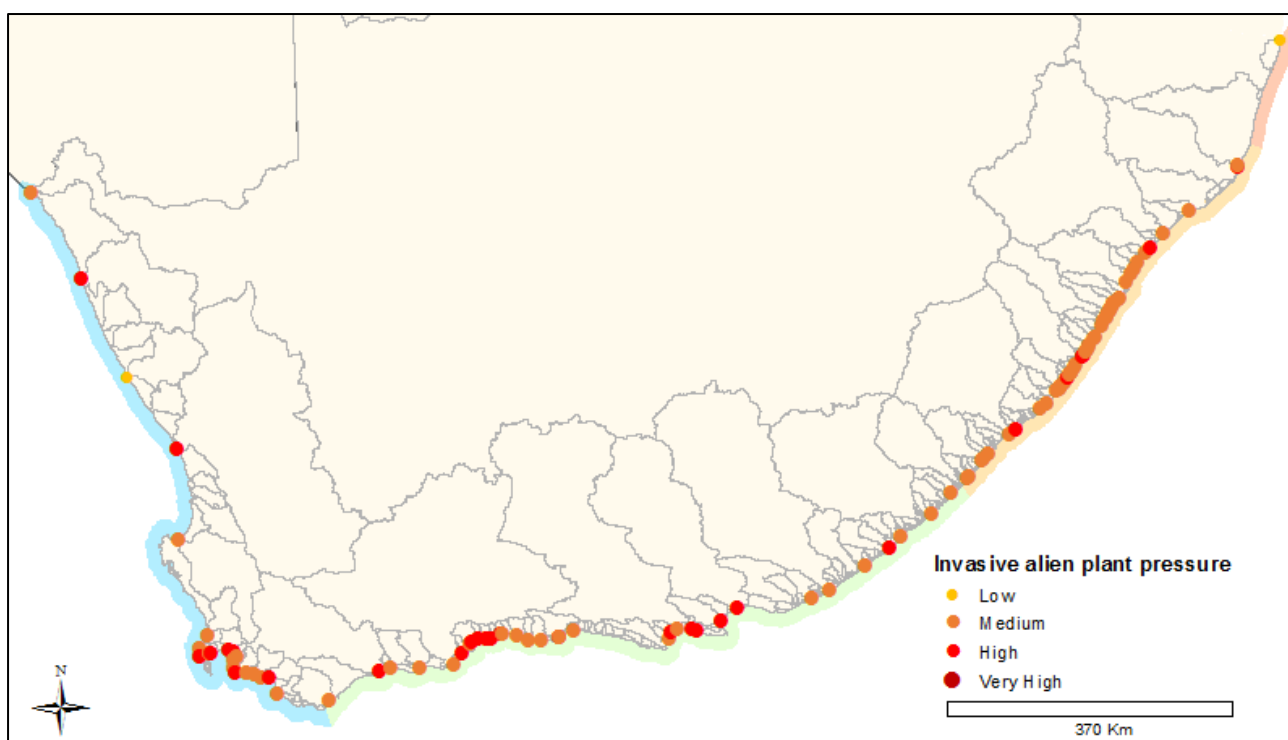


Figure 43. Spatial distribution of alien invasive plant infestations in estuaries.

Invasive plant species occur relatively regularly along the entire coast of South Africa (Figure 43). However, estuaries near urban centres tend to have more invasive species in them and/or a higher percentage cover of infestation, reflecting the concomitant impact of greater exposure to introduced species and the supporting impact of poor water quality (nutrient enrichment). Sewage spills are particularly problematic and feeding the increase of alien invasive species in some systems, examples being the escalation of *Pistia stratiotes* (water lettuce) in the iKhoshwana and uMahlongwane estuaries on the southern KwaZulu-Natal coast.

Over a third of estuaries have invasive terrestrial and/or aquatic invasive plants occurring within the estuarine functional zone, with 10% of systems under a High and an additional 27% of systems under Medium pressure (Figure 44).

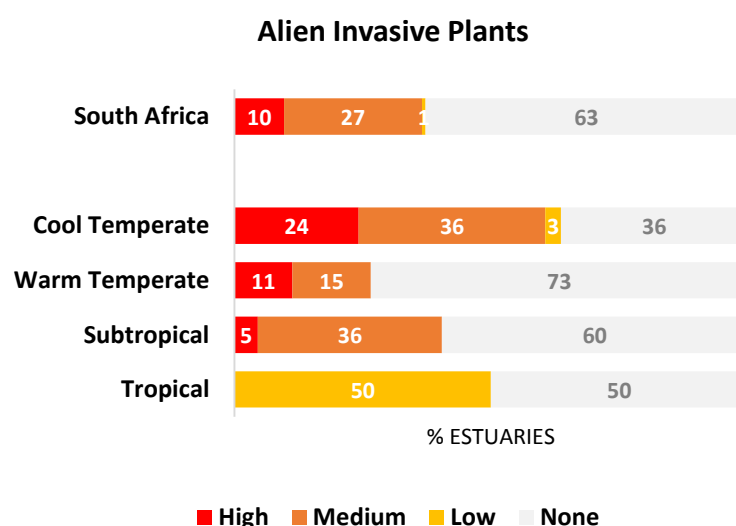


Figure 44. Alien invasive plant pressure in estuaries across biogeographical regions.

The Cool Temperate region (61%) has the most systems under severe pressure (High), followed by the Subtropical region (41%) and the Warm Temperate (27%). No high levels of pressure were observed in the Tropical region, probably related to the fact that these systems are largely groundwater fed and thus lack the catchment vector of most estuaries.

From an estuarine ecosystem perspective (Figure 45), Estuarine Lakes (50%) and Predominantly Open (33%) types are most under pressure in the Cool Temperate regions; while in the Warm Temperate region Predominantly Open (20%) and Large Temporarily open (18%) types are most at risk. In the Subtropical region it is Large Fluvially Dominated type systems (40%) that are severely under pressure from invasive plant species.

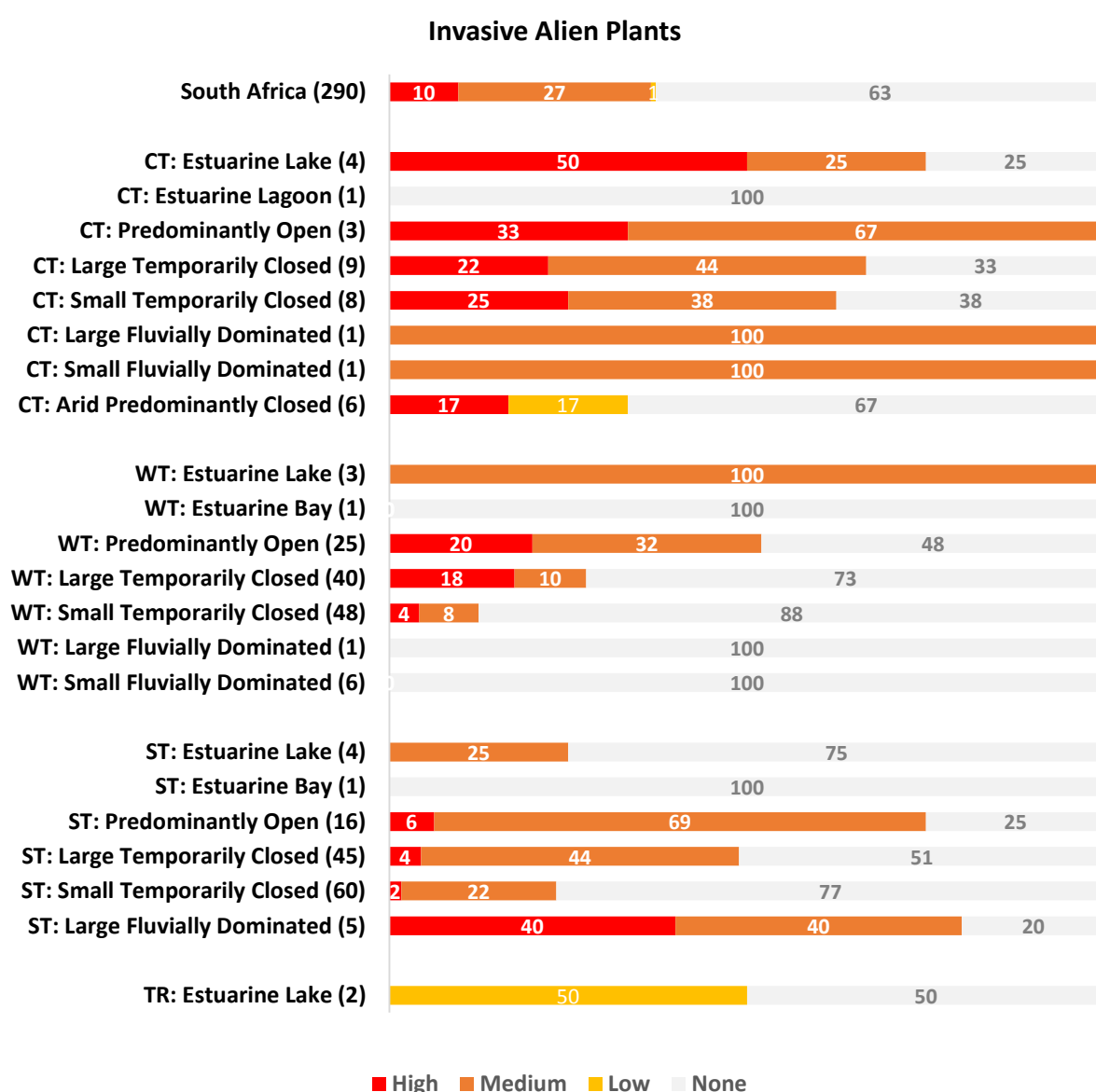


Figure 45. Alien invasive plant pressure on estuarine types.

These types are mostly associated with larger catchments, serving as both an introduction pathway and providing freshwater input preferred by most invasive species. Similarly, the relatively lower and reduced connectivity of Estuarine Lakes systems, also results in a more fresh environment conducive to the establishment of alien species. In contrast the marine dominated Estuarine Bays and Estuarine Lagoon types are not under pressure from invasive alien plants.

6.7.2 Alien or extralimital fish

Pathways contributing to introduce alien or extralimital fish in South African estuaries are introduction for food security and sport fishing (e.g. fly fishing), release of ornamental (pet trade) fish and aquaculture (Table 33).

Table 33. Key activities contributing to introduced or extralimital fish in estuaries in South Africa.

ACTIVITY	RELATIVE IMPACT	PRESSURE TRAJECTORY	CONFIDENCE	DATA AVAILABILITY
Introduction for food security	●	Increasing (illegal)	H	H
Introduction for sport fishing	●	Increasing	H	M
Release/escape of ornamental fish	●	Increasing (trade)	L	L
Aquaculture	●	Increasing	M	H

All of the introduced or translocated fish in South African estuaries are freshwater species (Table 34 and Table 35). Most of these, e.g. smallmouth bass *Micropterus dolomieu* and carp *Cyprinus carpio*, were introduced from the northern hemisphere in the late 1800s until the 1970s to enhance freshwater angling, as indigenous fish were regarded as unsuitable. Smaller species such as bluegill sunfish *Lepomis macrochirus* and mosquitofish *Gambusia affinis* were imported either as fodder fish to feed the larger introduced species or as mosquito control. Some, e.g. guppy *Poecilia reticulata*, are home aquaria escapees that established wild populations. A similar philosophy was followed with regards to southern African species, which were translocated either as angling fish or in the hope of establishing an aquaculture industry. Range expansion of both introduced and translocated species throughout South Africa was further facilitated by interbasin transfer schemes, irrigation and stormwater networks as well as intentionally or inadvertently by recreational anglers and other water users as they moved between water bodies.

Apart from facilitating the import and establishment of alien invasive species, marine and freshwater aquaculture have the potential to directly and indirectly impact the wild populations of estuary-associated species through genetic, pathogenic and parasitic contamination, to the overexploitation of indigenous fry and larvae for ranching purposes. Continent-wide collapse of European and Asian

anguillid eel populations has been directly attributed to a combination of all these factors. Since then, industry attention has shifted to the southern hemisphere, especially South Africa, where eel populations are deemed healthier than elsewhere.

Despite strict control and an embargo on imports from across this country's borders, some east coast river systems have become contaminated by parasites and other pathogens that have been traced back to illegally imported Madagascan eels (Weyl et al. 2010).

Table 34. List of introduced fish species in the estuaries of South Africa.

Species name	Common name	# Estuaries	SA range
<i>Micropterus salmoides</i>	Largemouth bass	41	Olifants -Mhlathuze
<i>Micropterus dolomieu</i>	Smallmouth bass	32	Olifants - Thukela
<i>Cyprinus carpio</i>	Carp	29	Orange - Thukela
<i>Lepomis macrochirus</i>	Bluegill sunfish	18	Olifants - Thukela
<i>Micropterus punctulatus</i>	Spotted bass	18	Olifants - Thukela
<i>Oncorhynchus mykiss</i>	Rainbow trout	13	Sand - Thukela
<i>Gambusia affinis</i>	Mosquitofish	13	Orange - Knysna
<i>Salmo trutta</i>	Brown trout	5	Olifants - Thukela
<i>Tinca tinca</i>	Tench	3	Lourens - Breede
<i>Poecilia reticulata</i>	Guppy	7	Mgeni - Tongati
<i>Ctenopharyngodon idella</i>	Grass carp	2	Zeekoei - Thukela
<i>Xiphophorous hellerii</i>	Swordtail	2	Durban Bay - uMngeni
<i>Pterygoplichthys disjunctivus</i>	Vermiculated sailfin catfish	1	uMhlathuze

Table 35. List of Extra-limital (translocated) fish species in the estuaries of South Africa.

Species name	Common name	# Estuaries	SA range (estuary northwards)
<i>Tilapia sparrmanii</i>	Banded tilapia	36	Orange - Mtamvuna
<i>Oreochromis mossambicus</i>	Mozambique tilapia	22	Bushmans
<i>Clarias gariepinus</i>	Sharptooth catfish	15	Orange - Mtamvuna
<i>Tilapia rendalli</i>	Redbreast tilapia	4	Sibaya, KZN estuaries?
<i>Labeobarbus aeneus</i>	Smallmouth yellowfish	4	Orange
<i>Tilapia zillii</i>	Redbelly tilapia	1	Uncertain
<i>Oreochromis niloticus</i>	Nile tilapia	1	Not from SA, Rift Valley

Given their freshwater origin, most of the impact of introduced and translocated fish occurs within the river estuary interface or the freshwater reaches of estuaries. In some systems, the suite of introduced species forms an effective barrier against the upstream migration of the young elvers of catadromous eels or facultative catadromous mullet. Recruitment of the larvae and juveniles of estuary-dependent marine species, and the survival of the eggs and young of estuary residents, may be severely compromised through predation by introduced species in estuarine headwaters. Introduced species may also have a competitive advantage but this is likely to be of minor consequence compared to predation. The exception is the Mozambique tilapia *Oreochromis*

mossambicus which is tolerant of hypersalinity and is known to opportunistically invade river and estuary reaches from which other species have been excluded by adverse conditions (Lamberth et al. 2010). Territorial and aggressive reproductively active males may also exclude any fish of similar shape and size (Lamberth 2008).

This said, Mozambique Tilapia did occur south to the Bushman's Estuary in the Eastern Cape and is tolerant of salinity far higher than seawater. This raises the intriguing possibility that some of its dispersal westwards may not have been by deliberate introduction but naturally via sea and facilitated by flood events. A review of documented introductions and dispersal of this species is needed.

The location and number of alien and extra-limital fish species in South African estuaries is shown above in Figure 46. As can be seen from this figure, introduced fish occur in relative high numbers throughout the Cool Temperate and Warm Temperate regions. However considering overall impacts of egg and larvae eaters, habitat altering and especially predatory species, the assessment indicate that the most severe pressure is distributed along the Warm Temperate and subtropical biogeographical regions.

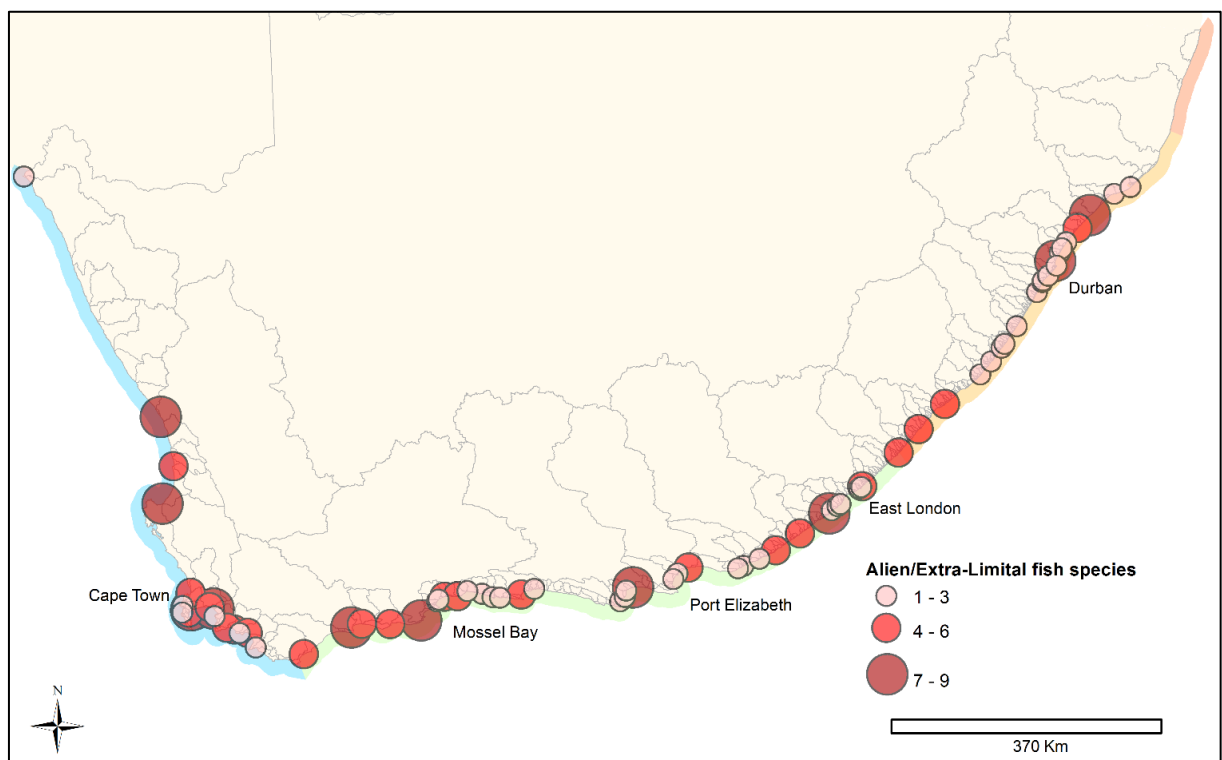


Figure 46. Location and extent of alien and extra-limital fish species in South African estuaries.

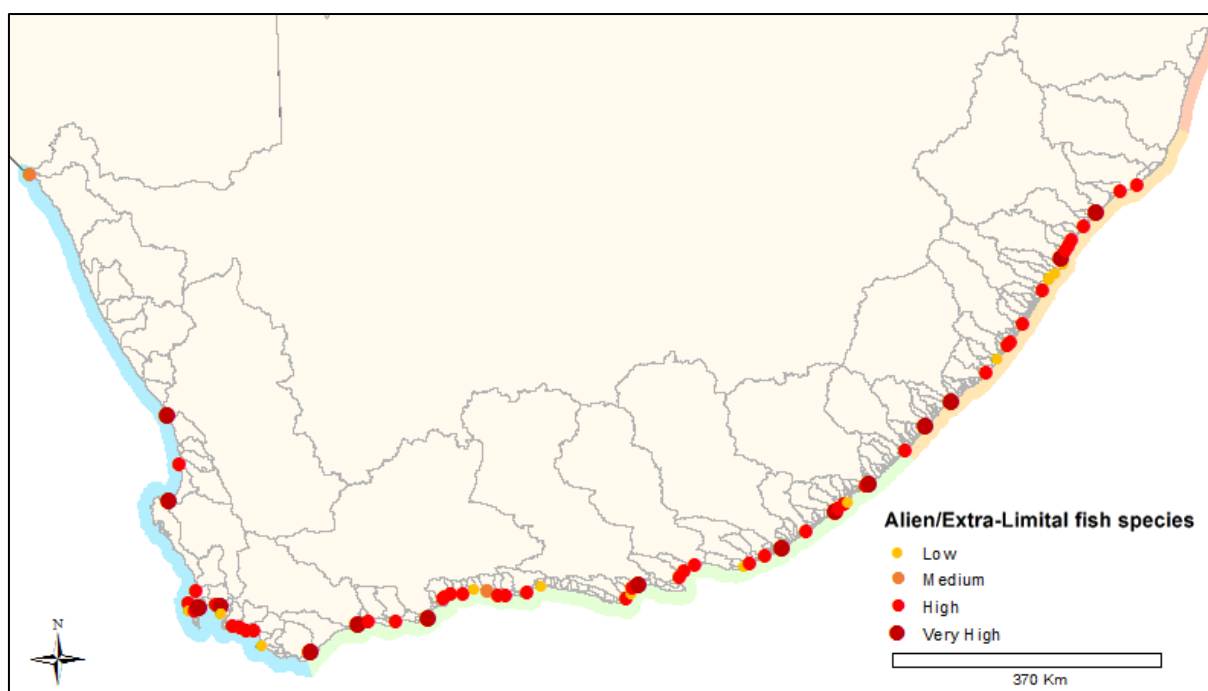


Figure 47. Spatial distribution of alien invasive and extralimital fish pressure on estuaries.

Alien or extralimital fish occur in 25% of South Africa's estuaries and their headwaters (Figure 47 and 48). Overall about 6% of estuaries are under Very High pressure and an additional 14% under High pressure from alien or extralimital fish. The highest infestation rates occur in the Cool Temperate region with 15% and 27% of systems under a Very High or High degree of pressure respectively. The Warm Temperate region also reflects the impact of this pressure with 6% and 17% of systems under High to Very High degree of stress; while the Subtropical region only have 3% and 9% of systems under High to Very High levels of pressure.

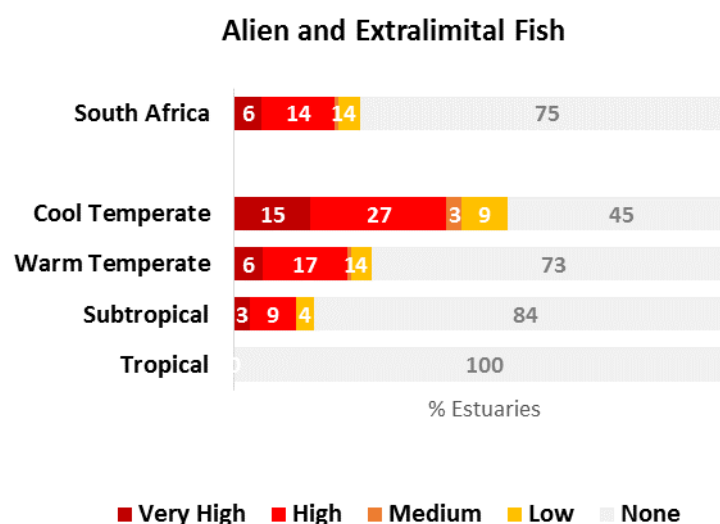


Figure 48. Alien invasive and extralimital fish pressure in estuaries across biogeographical regions

The relatively high number of alien species in the temperate biogeographical regions is largely an artefact of those originating from temperate regions elsewhere. The growing ornamental fish trade with its emphasis on “tropical” species is likely to see this change as escape, survival and successful invasion increase in our tropical and sub-tropical regions.

From an estuarine ecosystem perspective (Figure 49), Estuarine Lake (100%) and Predominantly Open (67%), Large Temporarily Closed (57%) types are under severe pressure (High to Very High) from introduced fish in the Cool Temperate region. In the Warm Temperate region Large Fluvially Dominated (100%), Estuarine Bays (100%), Predominantly Open (64%) and Estuarine Lakes (33%) types are most at risk. While in the Subtropical region Large Fluvially Dominated (80%), Predominantly Open (32%) and Estuarine Lake (25%) types are under the most severe pressure.

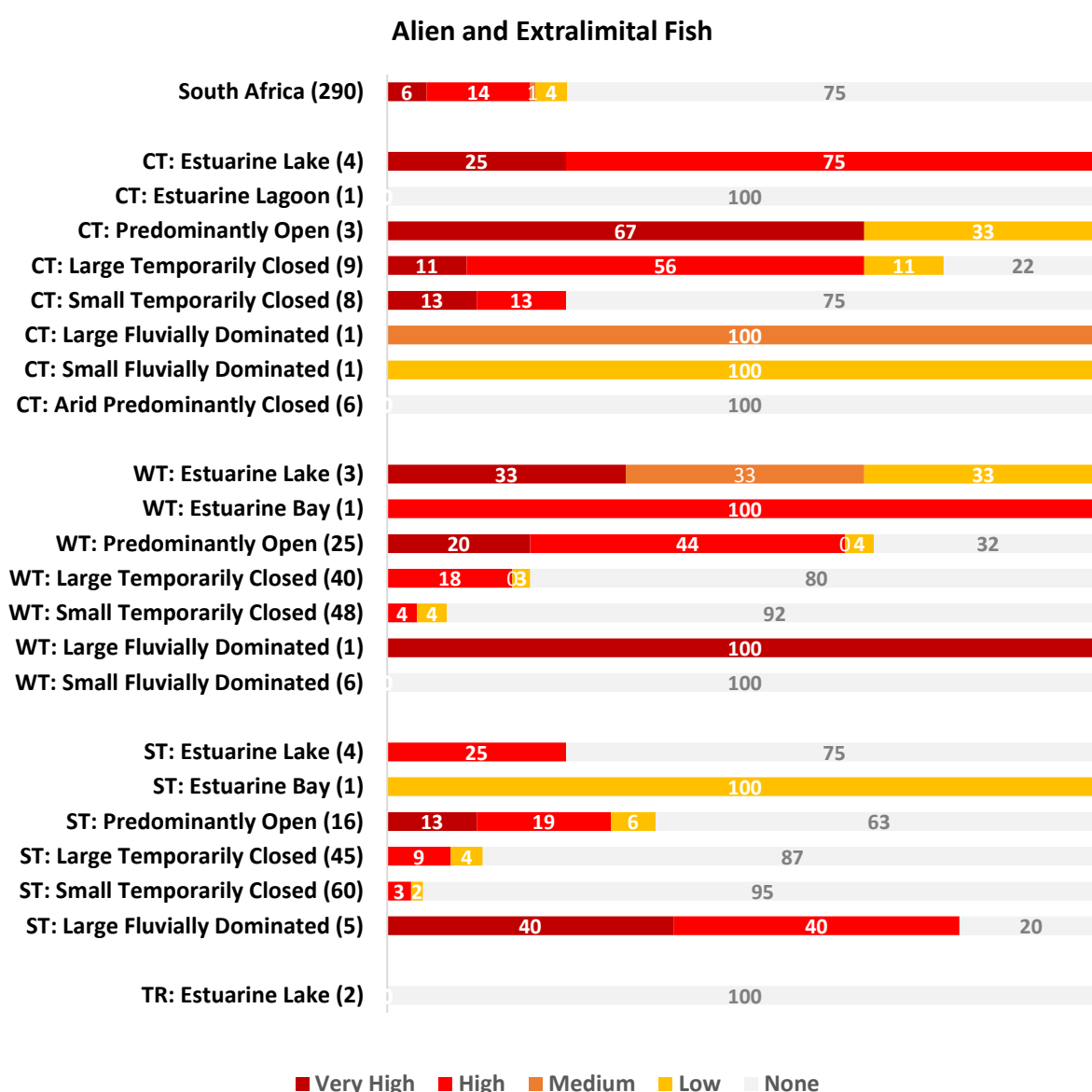


Figure 49. Alien invasive and extralimital fish pressure on estuarine types.

The high occurrence in Predominantly Open and Fluvially dominated systems reflect the impact of historical introductions of alien or extralimital fish species in the large catchments associated with these types of estuaries.

6.7.3 Invertebrates

The dearth of invertebrate community data across South Africa's estuaries has not been remedied since the previous biodiversity assessment (Van Niekerk and Turpie 2012, Van Niekerk et al. 2013). Without species inventories (even aggregated to bioregions), it is difficult to report accurately on the occurrence of aliens and invasive species affecting estuaries. South African non-indigenous species (NIS) has been rationalised as the overarching term for both alien and invasive species (Robinson et al. 2016). Where an alien species is a non-indigenous species translocated to outside its natural distribution range by human activities, but which exhibits no apparent socio-ecological or economic effects and where invasive species through translocation, influence or have the potential to impact, ecological, social or economic environments. Unlike in estuaries, marine NIS assessments have been better reported on (e.g. Griffiths 2000, Griffiths et al. 1992, Robinson et al. 2005, Griffiths et al. 2009, Mead et al. 2011a, Mead et al. 2011b, see also Marine Realm Alien and Invasive Chapter 5 in NBA 2018), but large areas of coast are still understudied in this regard (Robinson et al. 2005, Griffiths et al. 2009) or some have not been studied at all (Mead et al. 2013). The issue of non-indigenous invertebrate species in South African estuaries is a large research gap, where much work is needed.

Management should take not only the approach of focussing on individual potential invaders, but also use the method outlined in Swart et al. (2018) which identifies invasion patterns and applies biological trait analysis to identify taxa that are likely to invade.

As a proxy, the status and types of marine invertebrate bio-invaders can be considered where they also have the potential to occupy specific estuaries. The motivation is that for many of the known invasions, first inoculation and area of invasion was in a port or bay (Griffiths et al. 2009,) – a few of South Africa's largest estuaries are also harbours. Also, the highest concentrations of marine alien species occur in the vicinity of urban areas (Picker and Griffiths 2017), often also concentrated around estuaries. On the factors influencing NIS occurrence across South Africa's MPA network, specific prediction outcomes were the size of a nearby port ($>2.1 \text{ km}^2$) or presence of a yacht moor ($\leq 3.7 \text{ km}$ away) (Table 36). Around smaller ports, regional richness (>1016 species per km) increases the likelihood of NIS (Brooker 2016).

The Cool Temperate Benguela ecoregion has the highest numbers of marine introductions (Mead et al. 2011a) mostly of northern hemisphere origin, southern hemisphere NIS establishing better on the subtropical, tropical east coast. Although there is limited success of species transitioning from harbours to the open coast because of the different environmental conditions presented by South Africa's open, high-energy coast (Peters et al. 2014), colonisation may be more successful when considering estuaries as calm, sheltered environments.

Table 36. Key activities contribution to alien and invasive invertebrates in estuaries in South Africa

ACTIVITY	RELATIVE IMPACT	TRAJECTORY	CONFIDENCE	DATA AVAILABILITY
Vessel traffic (ships and yachts) and associated ports and harbours	●	Increasing	H	H
Aquaculture (incl. ornamental species trade)	●	Increasing (aquaculture)	M	M
Passive transportation (accidental inoculation) through human/animal movement	●	Increasing	H	L

Variable numbers of NIS marine species are reported; the list of Mead et al. (2011a) with 86 introduced and 39 cryptogenic species, edited by Robinson et al. (2016) is taken as the latest, inclusive record from which to draw potential risk species for South African estuaries. However, it likely represents an underestimation of introductions (Mead et al. 2011, Peters et al. 2014) and is limited by insufficient knowledge and measurement error (Robinson et al. 2016). The degree of establishment of South Africa invasive marine fauna was assessed according to the categories developed for the biological invasion framework of Blackburn et al. (2011). Picker and Griffiths (2017) determined 18 species with self-sustaining populations around point of origin, 9 species having extended significantly away from point of origin and 24 species that are fully invasive at multiple sites. Discussed further are those Invasive estuarine species on a trend of spreading across biogeographical zones with possible recent inoculations, and those that are likely to irreversibly change estuarine habitats and ecosystem function.

Ficopomatus enigmatus

Estuarine health integrity critically compromised by other human pressures may also increase vulnerability to bio-invasion; including developments that change unconsolidated natural sediments to artificial hard surfaces (Glasby et al. 2007). For example, changes to natural function and habitat by the invasive, ecosystem engineering, reef building *Ficopomatus enigmatus* polychaete in the Zand Estuary, Cape Town has quadrupled in a quarter of a century (McQuaid and Griffiths 2014). Since reefs support a greater biomass of the animal community than the neighbouring sandy areas, the total invertebrate biomass in the estuary is estimated to have increased significantly (x200 in 70 years, McQuaid and Griffiths 2014). *Ficopomatus enigmatus* is a calcareous, tube-building serpulid with origins in Australia and tolerant of disturbance (Borja et al. 2000), has been found in estuaries from Table Bay to Kosi Bay (Mead et al. 2011a,b).

Crassostrea gigas

This is an alternate representation of *Magallana gigas* on WoRMS (www.marinespecies.org), and is an Asia-Pacific native oyster, but its success as a cultivated species enabled introductions to North, South and Central America, Europe, Australia, New Zealand and South Africa (Figure 50). It is an estuarine species attaching to hard substrates but also mud and sand, with a wide range of tolerance for salinity and temperature (10 - >35 psu, -1.8 to 35 °C) (Helm 2005). Deteriorating water quality and increased pH in naturally acidic Cape south coast estuaries has facilitated its recruitment and settlement in these systems from which it was previously excluded.

By 2015, *C. gigas* populations were present in the Breede, Goukou, Gouritz, Groot Brak, Kaaimans, Touw and Swartkops estuaries (Keightley et al. 2015, Lamberth DEFF, unpublished information), but as of 2018 had been recorded further north (with genetic confirmation) in the Qora, Durban Bay, uMhlathuze and Richards Bay estuaries (D. Pearton ORI, unpublished information). Given its wide habitat preferences, it is assumed present in many more estuaries across the warm temperate, subtropical and tropical bioregions.



Figure 50. *Magallana gigas* in Richards Bay harbour (Source: D Pearton, ORI).

Tarebia granifera

South Africa's most notable estuarine invasion from the tropical and spreading down the subtropical biogeographical region, has been of the freshwater snail *Tarebia granifera* (Lamarck, 1822) (Figure 51). First reported in South Africa in 1999 (Appleton and Nadasan 2002), it is now widespread across the country, with evidence to suggest that it reduces benthic macroinvertebrate biodiversity (Jones et al. 2017) and with prolific local abundance (up to 21000 individuals.m⁻²) (Appleton et al. 2009) and nutrient limitation, it may also result in reduced growth rates for other resident macroinvertebrates (Riley and Dybdahl 2015). As a highly adaptable parthenogenetic species, giving birth to fully developed juveniles (Miranda et al. 2011) and high tolerances of temperature (0-45°C) and salinity (up

to 30 psu) for several days (Miranda et al. 2010), the spread is likely unstoppable across estuaries, and natural and artificial freshwater systems to which it is currently biogeographically acclimated.

Tarebia granifera (Figure 51), has an Asian origin and has been transported across the globe via the aquarium trade, where now it is widely distributed (Appleton 2003). In 2012, the gastropod was positively identified in 25 KwaZulu-Natal estuaries, north of the uMhlabashana (van Niekerk et al. 2013), increasing to 38 systems in 2019 (ORI unpublished data) in a survey of all provincial estuaries (Figure 52). This rapid spread across estuarine types and associated ecological states is an indication of the success of this species in being able to colonise 50% of KZN, and 17% of South Africa's freshwater, brackish and saline estuaries under wide-ranging temperature conditions (Appleton et al. 2009, Miranda et al. 2010). The current trend of a movement south to other subtropical estuaries poses a serious risk to the near-pristine Transkei estuaries.



Figure 51. *Tarebia granifera* habitat modification in oHlangeni Estuary (Source: ORI Estuary Observer Programme).

With no known control measures for *T.granifera* and no known competitors or predators (Cañete et al. 2004), invasion seems irreversible (Pointier 2001; Appleton 2003).

The key suggestion for regulation is public awareness of the potential dangers of inadvertent spread of invasive molluscs (de Kock and Wolmarans 2007) and evaluating the risks to

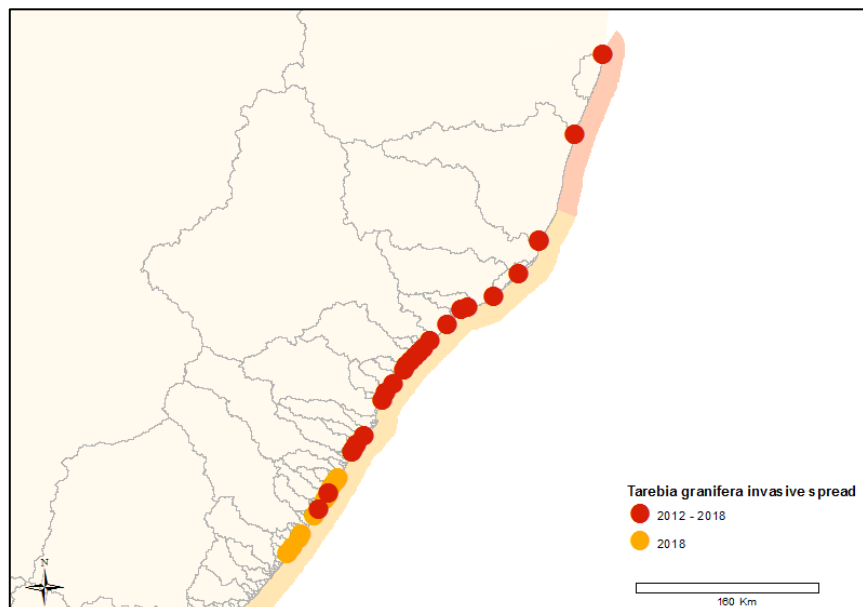


Figure 52. Rapid spread of *Tarebia granifera* from 2011 to 2019 in KZN estuaries.

non-invaded systems through passive transportation by boats and trailers, water weeds, (Appleton et al. 2009), illegal gillnets used across multiple systems and water birds (Reynolds et al. 2015).

6.8 Emerging pressures

In addition to the pressures affecting estuaries identified by the more systematic approach, additional emerging pressures are highlighted as being of significant concern and in need of future investigation: disturbance caused by recreational activities, toxic substance and metal pollution in sediments, aquaculture and discharges from desalination plants. More recently globally emerging issues such as marine litter (e.g. large volumes of micro-plastics in Kosi Estuary) and underwater noise pollution (e.g. disrupting fish behaviour in the Breede Estuary) have also been identified as relevant pressures in South African estuaries (personal observations, Borja et al. 2016b). See Text Box 6 and 7.

Recreational disturbance can have significant negative impact on the natural environment and its birdlife. Recreational activities have been linked to the loss of habitat available to species, reduction in species' range, and long term population declines. The effect of recreational disturbance on estuarine birds varies greatly between different species, and depends upon the source of the disturbance, the size and characteristics of the estuarine water body and the availability of alternative sites. Different species of birds react to disturbance in different ways and their sensitivity varies throughout the year depending on their specific activity at each location. Breeding birds and overwintering migrants are particularly sensitive to disturbance.

Recreational activities such as swimming, power-boating and water-skiing, kite and wind surfing and jet skis represent an increasing pressure in estuaries that is not well quantified. For example, kite surfing is becoming increasingly popular, especially on the larger systems. Kite surfing tends to produce rather powerful disturbance stimuli. There are numerous studies elsewhere in the world showing that the kites mimic raptors (predatory birds), given the kites' quick movements, sudden changes in direction and high speeds, with sensitive species unable to habituate to kite surfers' presence. Kite surfing has been found to displace foraging and roosting birds, including staging migrant waders, sometimes for extended periods, and has a significant impact on the fledgling success of waders and other water birds. In classifications of water-based (watercraft) sources of disturbance, kite surfing is often only surpassed by the disturbances caused by motorised, fast-moving watercraft, emitting substantial noise (e.g. speed boats, jet skis). Langebaan commercial and recreational fishers there and elsewhere, claim regular collisions of kite-surfers with their gear and cite kite-surfing as responsible for fish disturbance and declines in catches but this has not been tested. Kite-surfing management plans and regulations have been developed elsewhere in the world and can be drawn upon to develop these for South Africa's estuarine, marine and freshwater ecosystems.

As epitomized by kite surfing, disturbance with respect to water craft is not only related to sound (i.e. motor boats) but also to visual presence. While motor boating is often found to be the greater source of disturbance; where birds have a propensity to be disturbed, sailing, human-powered and motorised craft all have the potential to cause impacts. Even relatively silent water craft activities, such as canoeing or kayaking, may induce major disturbance, because of their penetration in areas ('sanctuaries') otherwise inaccessible to other water craft or pedestrians.

Consideration should therefore also be given to nature based recreation: outdoor recreation activities that are dependent on the natural environment, but do not require substantial modification of the natural surroundings, and have an appreciation of nature as a key motivational factor. Nature based recreational activities, such as wildlife viewing, hiking, trail running, cycling, mountain bike riding, canoeing, horse riding and dog walking, are often perceived as having little to no effect on the environment, but their potential impacts cannot be ignored. Nature based recreation has been shown to have numerous, negative environmental effects. For example, Steven et al.'s (2011) literature review of the impacts of nature based recreation highlights the negative impacts on birds, such as changes in bird physiology (e.g.: temperature, heart rate or stress hormone secretion), immediate behaviour (e.g.: foraging, vigilance and evasion), as well as changes in abundance (e.g.: habitat use and range) and reproductive success (reduction in the number of nests built, eggs laid, and chicks hatched or fledged), all with differing ecological significance, from local, sometimes temporary, disturbance effects, to significant population impacts.

Dog-walking in particular has been shown to be a significant source of disturbance in natural areas, especially if the dogs are not kept on leash. In addition, people walking dogs are more likely to leave designated paths, or to allow or encourage their dogs to leave paths, which increases disturbance intensity. However, considerate management of activities such as dog-walking on beaches has resulted in positive impacts for shorebird breeding success, and can be applied to sensitive estuarine areas, such as the mouth (particularly when closed), surrounding dune areas, and the estuary shoreline.

TEXT BOX 6: THE OCCURRENCE AND DISTRIBUTION OF MICROPLASTICS IN SOUTH AFRICAN ESTUARIES

The presence, movement and fate of man-made particles, such as plastics, in aquatic systems threatens the health of the biota within them and is considered a global risk. Plastic in the marine environment is a global problem despite widespread banning of dumping of waste in water bodies. The problem originates from the terrestrial ecosystems with 80% of marine debris originating on land (Jambeck et al. 2015).

The connectivity features between the terrestrial environment and the ocean, rivers and estuaries, are the main pathways which introduce plastics into oceanic environments (Bakir et al., 2014). National Oceanic and Atmospheric Administration (NOAA) defined microplastics (MP) as particles <5 mm in length, which are further classified as primary and secondary MP based on their origin. Primary MP enter an ecosystem as nurdles, pellets or microbeads and secondary MP arise through the mechanical- or UV-mediated breakdown of larger plastics. The occurrence, source and fate of MP in estuarine and marine environments forms part of a growing research theme.

In 2010, Jambeck et al. (2015) rated South Africa (SA) eleventh out of twenty countries in terms of mismanaged waste producers. The status of MP in the water and sediment of estuaries is poor known and has been estimated from the subtropical and cool temperate estuaries with greater confidence of this threat in the subtropical estuaries of Kwa-Zulu -Natal. In the tropical biogeographical zone, research is underway at Kosi Bay and MP have been recorded around fish traps (G.K. Moodley, *pers. comm.*, 29/08/2019, Van Niekerk 2018). Additionally, Naidoo et al. (2015) reported MP concentrations in five estuaries in the subtropical zone, viz. uMdloti, uMgeni, Durban Bay, iSipingo, iLovu. In the sediment, MP concentrations ranged from 13.7 at iLovu to 159.9 particles/ 500 ml at Durban Bay; concentrations in the water column ranged from 7.4 at iLovu to 31.07 particles/ kL at iSipingo. At uMgeni and iSipingo, ongoing research by Govender et al. (in prep.)² has recorded concentrations three-fold higher than Naidoo et al. (2015) in the sediment of four mangroves. Microplastics in the water column at these estuaries were also higher than previous studies (Govender et al. (in prep.)). However, there is a paucity of MP data for subtropical and warm temperate estuaries in the Eastern and southern Cape. In terms of the cool temperate estuaries of the Western Cape, an unpublished (low sampling effort) study by Jamalie (2018) on estuarine sediment from vegetated and non-vegetated areas of the Uilkraals, Klein, Bot, Palmiet, Rooiels, Lourens and Zand presents a slightly different picture. The study found no MP in the sediment collected at the mouth of Bot Estuary (this should be verified further), low levels (<10 particles/ 500 ml) at Klein, Palmiet, Lourens, Zand, and >10 particles/500 ml at Rooiels Estuary. Furthermore, the findings suggested that there were no clear indications of the salt marsh vegetation increasing the deposition of MP in the intertidal zone. Despite the availability of data for estuaries in some biogeographical zones in the country, greater sampling effort and frequency is required to improve our understanding of the threats MPs pose in these systems.

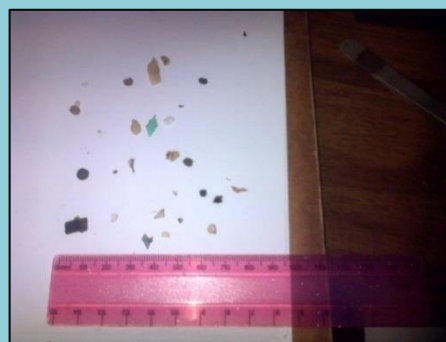


Plate 1. Plastic particles recovered from sediment cores at the uMgeni Estuary (Photo: T Naidoo).

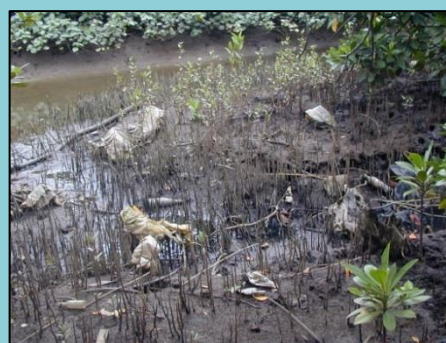


Plate 2. Plastic litter found in the mangroves at iSipingo Estuary (Photo: A Rajkaran).

Reports of MP ingestion by aquatic fauna are increasing with a particular interest in fish. In fish this is based largely on the negative health consequences, which include decreased growth (Naidoo and Glassom, 2019). At Durban Bay more than 73% of 70 mullet sampled showed signs of MP consumption (Naidoo et al. 2016). Naidoo et al. (in prep.) have recently also quantified and characterised MP ingested by juvenile fish of four species characteristic of estuaries with mangroves in KwaZulu-Natal. Overall, more than 50% of the juveniles from the four mangroves sampled had microplastics present. No information on other faunal groups have been published from South African estuaries but research is underway and validated by the findings reviewed here.

Citation: Anusha Rajkaran, Joelene Govender, Trishan Naidoo, Sershen Naidoo (2019). The occurrence and distributions of Microplastics in South African Estuaries. South African Estuary. Volume H: Estuarine Realm. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/VolH/A

TEXT BOX 7: NOISE POLLUTION INTERRUPTING THE DAWN CHORUS OF ESTUARINE FISH

Soniferous fish use sound to communicate often having a whole range of vocalizations used in fighting, aggressive territorial display, sounding alarm, feeding, courtship, spawning, shoaling behaviour and echolocation. Sound and vocalization is especially important in turbid, low visibility estuarine and nearshore habitats. Fish sound is produced in a number of ways; the most common being the drumming muscles vibrating against the swim bladder (the drum) particularly in the Sciaenidae (drum) species such as our endemic estuarine dusky kob. A number of families including the Haemulidae (grunts) such as spotted grunter and Carangidae (kingfishes) grunt and growl by rubbing their pharyngeal-teeth together. Cichlidae, including Mozambique tilapia, stridulate their pharyngeal jaws together, whereas Ariidae e.g. barble /white seacatfish have evolved a complex array of both pectoral fin and swimbladder stridulation, similar mechanisms to those in chirping insects such as cicadas and crickets. Syngnathidae, pipefish and seahorses click, growl and purr by rubbing modified neck vertebrae and skull-plates together. Water and air pulses are also used to produce sound, many Clupeidae e.g. estuarine round-herring using synchronized farting to maintain shoal integrity. Soniferous fish have well developed hearing with larger otoliths (ear stones) and are drab compared to their vividly marked and coloured counterparts in clear-water habitats. Different populations of fish such as spotted grunter may be identified by their dialects and may even ignore one another if they don't like their respective accents (Coetzee et al. 2018). Just like birds, many estuarine fish sing together in an underwater dawn and dusk chorus to herald the waxing and waning of the day.

Anthropogenic noise disturbs fish communication, alters behaviour and causes physiological stress. By far the main source of noise pollution in South African estuaries is from motorised boats (Figure 1) but mining, excavation, construction sites and more recently wind-farms are also contributors. Dusky kob called more frequently, louder and longer just to be heard over noisy humans in the background (Prinsloo et al. in litt.). Rest and recovery was also much longer indicating higher energy expenditure in dealing with the stress of anthropogenic noise. Higher energy expenditure results in reduced growth rates. Changes in calling behaviour of soniferous fish may influence mate recognition and courtship, lead to

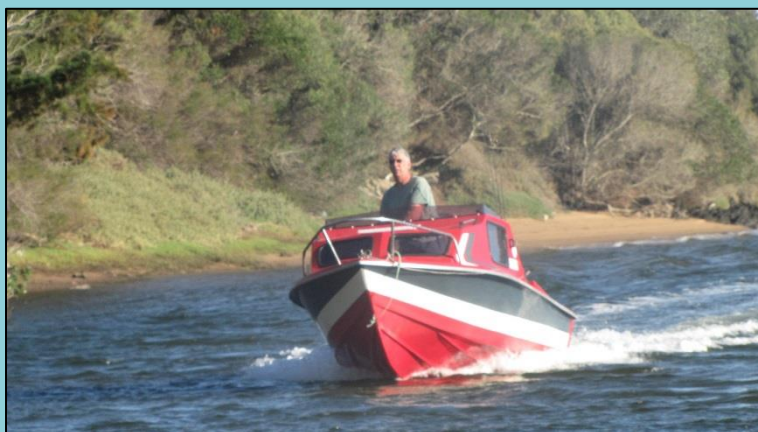


Plate 1. Boat traffic on the Goukou Estuary (Photo: CSIR).

exhaustion and ultimately reduced breeding success.

Fortunately, noise pollution is one of the more easily managed sources of anthropogenic stress in estuaries. Limitations on engine use, including levees on horsepower can go a long way to reducing noise from motorised vessels. There's also the option to phase out noisier two-stroke in favour of quieter four-stroke motors. Apart from being quieter, another advantage of four-strokes is that emissions are 20 – 40 times less than their two-stroke counterparts.

Limiting fishing or boat traffic at night is also easily implementable. Soniferous fish call mostly at night as hunting, courtship and spawning are largely under the cover of darkness. The prohibition on fishing at night in the Breede Estuary was aimed at further protecting Dusky Kob, especially large and vocal reproductively active adults. An unanticipated but positive consequence of this regulation was a substantial reduction in night-time motorised boat traffic and noise. This added benefit provides further support for the prohibition on night-fishing in estuaries and its nationwide implementation.

Citation: Lamberth, S.J. (2019). Noise pollution interrupting the dawn chorus of estuarine fish. South African Estuary. Volume H: Estuarine Realm. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3A

Despite potential ecological and human health risks posed by toxic substances such as trace metals and persistent organic pollutants (e.g. herbicides and pesticides), there is very little research on, and monitoring of, the distribution and accumulation of these compounds in South African estuaries. (See Government response chapter for new initiatives). Expert knowledge was used to identify estuaries where this was considered to be a significant pressure. Similarly, while the detrimental impacts of marine and freshwater aquaculture are currently not evident in South African estuaries, aquaculture was identified as an activity that can contribute to the destruction of estuarine habitats as well as the pollution of coastal waters (Pauly et al. 2002). If not managed effectively, aquaculture operations can also promote the spread of microbial contaminants, thus introducing disease, such as EUS, as well as parasites to wild populations (Goldberg and Naylor 2005).

South African coastal municipalities are increasingly turning to reverse osmosis (RO) desalination technology to meet bulk water demands. Plant design can be complex, with extensive pre-treatment of the source water required to prevent clogging and biofouling of plant infrastructure and the RO membranes. Any residual chemicals or other additives used in the pre-treatment process are frequently discharged after dilution together with the brine into the receiving environment (usually the sea). Poorly designed or inappropriately situated RO desalination plants may, however, have significant negative impacts on estuaries, e.g. Piesang Estuary. Direct or beach-well abstraction of source water from an estuary, and/or brine effluent directly discharged into an estuary (or the adjacent nearshore) from where it may enter the estuary prior to sufficient dilution, can have severe negative impacts on estuarine functioning. Monitoring of the existing three plants situated within estuaries show that RO desalination plants do have impacts of varying significance on estuaries (Bornman and Klages 2004).

7. CONDITION OF SOUTH AFRICA'S ESTUARINE ECOSYSTEMS

Chapter Citation: Van Niekerk, L., Taljaard, S., Adams, J.B., Clark, B., Lamberth, S.J., MacKay, C.F. & Weerts, S.P., 2019. 'Chapter 7: Condition of South Africa's estuarine ecosystems', *South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm*. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A.

Estuarine Condition

- Overall 21% of estuaries in South Africa are in a Natural state (A category), 40% in a Near Natural state (B category), 20% in a Moderately modified state (C category), 12% in a Heavily modified state (D category), and 7% in a Severely/Critically modified state.
- However, while > 60% of SA estuaries are relatively healthy, this amounts to only 22% of total estuarine extent, comprised mostly of small estuaries.
- More than 63% of estuarine area is significantly modified with important ecological processes under severe pressures that reduce productivity, food security, fisheries livelihood, property values and recreational enjoyment.
- Estuaries in Natural and Near natural state are mainly located in the Warm Temperate (73%) and Subtropical (56%) regions, while the Cool Temperate region is characterised by estuaries in a Heavily to Severely /Critical modified state (54%).

7.1 Condition assessment approach

Ecological status assessments should consider ecosystem structure, function and processes through the linking of natural physical, chemical, geographic and climatic factors (Borja *et al.* 2011; Borja *et al.* 2014; Mulik *et al.*, 2017). These should be integrated with anthropogenic impacts within the system concerned (Borja *et al.* 2014; Korpinen & Andersen 2016; Borja *et al.* 2016a; Halpern *et al.* 2008, 2015). There is also a strong argument for the ecological integrity of an estuary to be evaluated using all available information, including as many biological elements as is reasonable in an overall ecosystem-based approach (Borja *et al.* 2008, 2009a; Chiu *et al.* 2014).

Over the past decade, the assessment of Estuarine health in South Africa has progressed from a limited integrative index (Harrison *et al.* 2000) used for a snapshot country-wide survey (based on only geomorphology, ichthyofauna, water quality and aesthetics), to the more comprehensive Estuarine Health Index (EHI) used as part of Ecological Flow Requirement studies (previously called Resource Directed Measures (RDM)) (DWA 1999; Adams *et al.* 2002; Turpie *et al.* 2012; Van Niekerk *et al.* 2013). This assessment considered both abiotic and biotic components, namely hydrology, hydrodynamics and mouth condition, water chemistry, sediment processes, microalgae, macrophytes, invertebrates, fish and birds (Figure 53). Both abiotic and biotic variables are evaluated because the exact relationships between them are often not well understood and because the biotic responses to specific abiotic variables generally occur after a lag period (Whitfield *et al.* 2008, Van Niekerk *et al.* 2013). The fact that the physical conditions in estuaries are more dynamic when compared with other aquatic ecosystems means that severe degradation of an estuary may involve a shift from a dynamic to a more stable system. Hence, the loss of dynamic function per se is an important indication of declining estuarine health (DWA 1999). In an estuarine health assessment, measures of these

different states need to be sufficiently robust so that different practitioners or disciplines will arrive at the same categorisation.

An estuary is assigned a condition score based on the similarity to natural for various abiotic and biotic components. For each of the components (abiotic and biotic), the change in health is estimated as a percentage (0 – 100%) of the natural state. Scores are weighted (25% for each abiotic and 20% for each biotic component) and aggregated (50:50) to provide an overall score that reflects the present health of the system as a percentage of that under natural conditions.

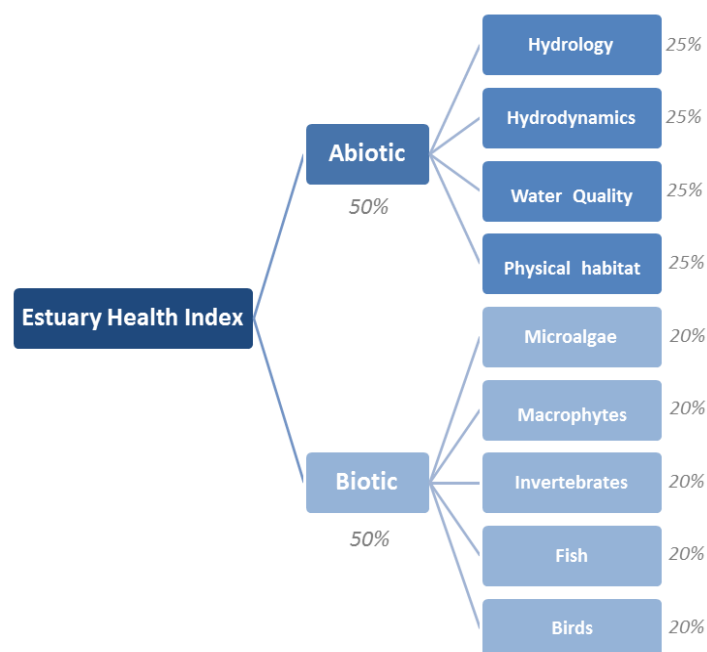


Figure 53. Components and weightings of the Estuarine Health Index (DWAf 1999).

The degree of similarity reflects six broad categories of estuarine condition (A to F scale), ranging from natural to extremely degraded (Table 37). These categories in turn relate to decreasing levels of ecosystem function. The loss of function occurs on a continuum, with estuaries retaining more than 90% of their natural function rated as “Natural” and estuaries degraded to less than 40% of natural function as “Severely or Critically Modified”. It must be emphasised that the A to F scale represents a continuum, and that the boundaries between categories are conceptual points along the continuum. There may therefore be cases where there is uncertainty as to which category a particular estuary belongs, potentially having components that have membership in two categories.

To reflect this, straddling categories (± 3 from the category scoring range) were therefore introduced in this study, denoted by A/B, B/C, C/D, and so on. Smaller, more sensitive estuaries tend to degrade rapidly to the lower health Categories (C to F), while the larger, permanently open estuaries demonstrate a degree of resilience and can generally maintain a boundary category if pressures are not increased (Van Niekerk *et al.* 2013). Individual health assessments can, in turn, be further aggregated for homogenous estuarine types or specific management units (e.g. protected areas or Water Management Areas).

The method requires that a multidisciplinary group of estuarine scientists assesses the health of each estuary in a workshop setting and is based on their collective understanding of likely impacts affecting

that system (DWAF 1999). Available information and expert knowledge are used to build a ‘conceptual picture’ of the probable natural state of each estuary and the changes that have occurred under current conditions. In order to develop a clear understanding of the status of estuarine health within South Africa, large complex systems such as the uMhlathuze Estuary and Richard’s Bay Harbour were evaluated separately. Consequently, the health assessment was conducted for a total of 290 estuaries.

Table 37. The relationship between loss of ecosystem condition and functionality (modified from Van Niekerk *et al.* 2013).

Condition (% of pristine)	≥91%	90-75	75 - 61	60 - 41	40-21	≤20					
Continuum	A	A/B	B	B/C	C	C/D	D	D/E	E	E/F	F
Ecological Management Category (DWS)	A Natural	B Largely natural / few changes		C Moderately modified		D Largely modified		E Highly degraded		F Extremely degraded	
NBA Ecological modification	Natural/Near natural			Moderate		Heavily		Severe/Critical			
Functionality	Retain Process & Pattern (Representation)			Some loss of Process & Pattern		Significant loss of Process & Pattern		Little Process & Pattern			
Restoration cost	None/ Low			Low/ Medium		High		Very high, potentially irreversible structural changes			

Category	Description
A	Unmodified, approximates natural condition. The natural abiotic processes should not be modified. The characteristics of the resource should be determined by unmodified natural disturbance regimes. There should be no human induced risks to the abiotic and biotic processes and function.
B	Near natural with few modifications. A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged.
C	Moderately modified. A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
D	Heavily modified. A large shift natural processes and ecosystem functions and/or loss of habitat, biota have occurred.
E	Severely modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	Critically modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural abiotic processes and associated biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

For comparative reasons (with previous assessments) the individual health scores were aggregated as illustrated in Figure 53. Note that in estuaries, unlike in the terrestrial environment, degradation or loss of habitat seldom means a complete loss of an estuary. This only happens when an estuary becomes completely degraded or transformed, e.g. canalized and in-filled to create a parking lot or golf course. In most cases, degradation means the loss of processes or biological functionality, e.g. the estuarine space is filled with a different salinity condition or different species composition.

In 2004, the first National Spatial Biodiversity Assessment (NSBA) was conducted by the South African National Biodiversity Institute (SANBI) to provide a high-level summary of the state of biodiversity within South Africa (Driver *et al.* 2005; Turpie 2004). From an estuary perspective, however, that summary was based largely on the findings of a health assessment conducted in 1995 (Whitfield 2000),

supplemented with information derived from a limited number of ecological flow requirement studies (Turpie 2004). This was followed by the 2011 health assessment (Van Niekerk & Turpie 2012; Van Niekerk *et al.* 2013) that used the approach described above.

The 2018 NBA also follows the same method but is based on more accurate and up-to-date input data (e.g. pressure data) and relies on more systematic assessment methods (e.g. modelled hydrology and water quality data). For most estuaries, updated condition information was available from EWR and Classification studies, which was only updated if more recent information indicated a change in fishing pressure, water quality or flow reduction (DWS 2015a&b; DWS 2017a&b; Adams, Cowley & Van Niekerk *et al.* 2016). The input dataset is illustrated in Figure 54, with estuary condition reflected on the vertical axis (estuaries higher on graph are in better condition) and grouped into six size categories (larger bubbles represent larger estuaries). The dataset is plotted west to east with distance from Orange Estuary used to indicate estuary distribution along the coast.

7.2 Estuarine condition across biogeographical regions

The 2018 assessment determined that 21% of estuaries in South African are considered to be in a Natural state (A category), 40% in a Near natural state (B category), 20% in a Moderately modified state (C category), 12% in a Heavily modified state (D category), and 7% in a Severely /Critical modified state. Estuaries in Natural and Near natural state are mainly located in the Warm Temperate (73%) and Subtropical (56%) regions, while the Cool Temperate region is characterised by estuaries in a Heavily to Severely /Critical modified state (54%) (Figure 55). That analysis is biased towards the state of the large number of small estuary types occurring along the South African coast (For more detail on individual estuaries see Appendix D.)

When analysed according to estuarine area rather than the number of estuaries, the majority (63%) of estuarine area is in a Heavily modified state or worse, and only about 5% and 17% in a Natural and Near natural state, respectively. The latter are mainly located in the Warm Temperate region and Subtropical region (Figure 55). An additional 15% are in a moderately modified state. Part of this result is an artefact of the 'Lake St Lucia effect'. This Subtropical system accounts for 56% of South African estuarine extent and is currently classified as being in a Heavily modified state, an improvement from the 2011 NBA, due to the artificial diversion of the uMfolozi River away from the lake and an extended drought in the region (Bate *et al.* 2011).

As many of these pressures are reversible, a restoration programme is now being implemented that reconnects the uMfolozi River to the St Lucia Estuary, thereby increasing freshwater inflow and improving the status of the system. Over the next few decades the long-term full recovery of St Lucia is likely to continue to have a marked effect on the overall health status of South African estuaries.

The Cool Temperate region had the highest number of estuaries in a degraded condition as it supports estuarine habitat mainly in the Severely to Serious/Critical modified categories, especially the large to small temporarily open systems near Cape Town and other coastal urban centres. The Warm Temperate region, on the other hand, was characterised by a large number of estuaries in a Natural to Near Natural condition, possibly due to the undeveloped nature of large parts of the coast in this biogeographic region. The Subtropical region had the second highest number of estuaries in a degraded state, mainly due to pollution, very high fishing pressure (illegal gillnetting), direct habitat loss, sand mining, and intensive sugar cane farming in the catchments and estuary functional zone.

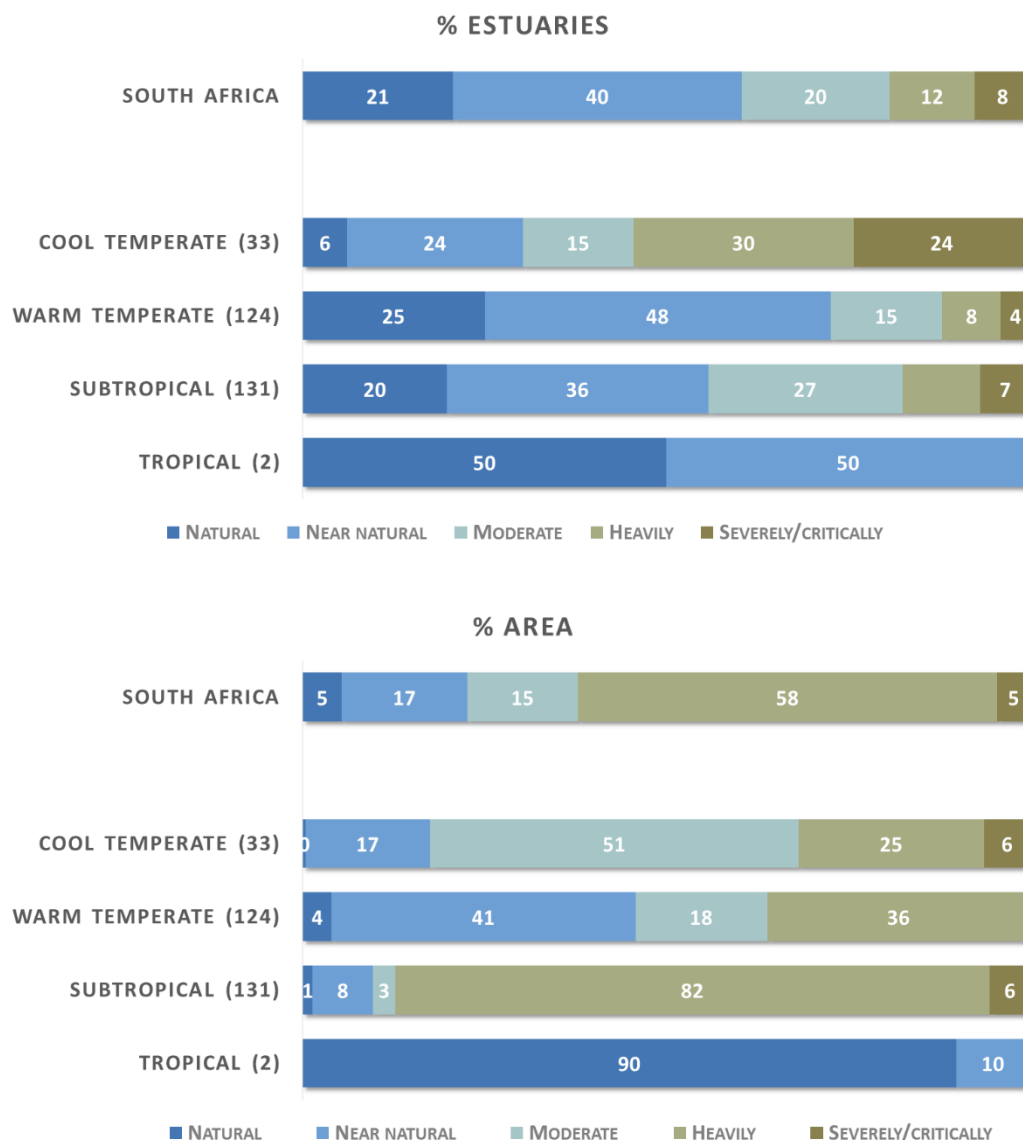


Figure 55. Different perspectives arise when the National Health Assessment is presented either as “Percentage estuaries” or “Percentage Estuarine Habitat”. The percentage area analysis highlights the fact that the majority of South African estuarine area is in a degraded state.

TEXT BOX 8: ST LUCIA ESTUARINE LAKE RESTORATION IS AN ONGOING PROCESS - NOT WITHOUT STRESS TO CRITICAL HABITAT

Rapid changes are occurring in the St Lucia Estuary in response to the reconnection with the uMfolozi River. Silt loads have increased turbidity, particularly in the mouth and Narrows region where levels > 200 NTU are frequently recorded. Filter feeding organisms are under strain and the structure of planktonic and benthic communities has changed. The sediment composition at the mouth now has a higher percentage contribution of mud. The mouth has remained closed preventing flushing of silt to the sea.



View from inland to sea with Mapelane on right. Dead mangrove trees line the back channel linking the Mfolozi with the St Lucia Narrows (Ezemvelo KZN-Wildlife, 18 June 2018).



Mangroves are dying in the back-channel area as expected due to the higher water level and inundation of the pneumatophores (aerial roots). Reeds, sedges and rushes are expanding into the main water channel in response to the lower salinity, nutrient input and high silt load. Pondweed (*Stuckenia pectinate*) is growing at Charters Creek and along the Eastern Shores in the vicinity of the old jetty. Ultimately, it is expected to play an important role here, stabilizing sediments and reducing turbidity.

The silt-laden freshwater inflow from the uMfolozi River has increased nutrient loading in the system. Shifts in the phytoplankton community composition towards groups characteristic of fresh and eutrophic conditions are dominant within the estuary. The persistence of nutrient tolerant euglenoids is of concern considering that changes in phytoplankton communities imply shifts in food web structure.



View of St Lucia Bridge (22 May 2018).



Illegal gillnetting continues in the lake with the catches made up mainly of tilapia (*Oreochromis mossambicus*) and barbel (*Clarius gariepinus*), reflecting the low salinities in the system.

Low water level and silty conditions at the St Lucia mouth (26 Jan 2018).

Janine Adams, Nicky Carrasco, Caroline Fox, Monique Numes. St Lucia Estuarine Lake restoration is an ongoing process - not without stress to critical habitat.

In comparison to the 2004 National Spatial Biodiversity Assessment on 259 estuaries (Turpie 2004), there is a reduction in the number of estuaries considered to be in an excellent state. However, fewer estuaries were also recorded to be in a poor state. The drop in the number of estuaries in excellent health can be attributed to the increase in human pressures and related degradation, but also to the refinement in the methods used in the 2011 and 2018 assessments (Figure 56). The 2011 NBA was largely based on a desktop approach (Van Niekerk *et al.* 2013). During the 2018 assessment, estuary experts used the more in-depth EWR and “Classification” studies to benchmark their evaluations. Desktop type assessments often overestimate the health of degraded estuaries by about 5-10%, i.e. they generally considered them to be in a better health than they are. This was a positive outcome, as the results of this type of assessment are often used for planning purposes. In this context, estuaries should not be discounted or ignored if they could contribute to biodiversity targets or prioritised for management interventions. Reasons for the elevated health scores were: lack of good hydrological (inflow) data, accurate land use data, good water quality data; and the large spatial scale at which the study was conducted (i.e. estuaries were evaluated by means of remote sensing imagery rather than field visits).

The initial findings of the 2011 assessment were further affirmed against a number of more detailed flow requirement studies conducted subsequent to the initial assessment. The results show that the desktop estimates deviated by between 1% and 14% from the more recent in-depth assessments, e.g. Orange (-5%), Groot Berg (+5%), Diep/Rietvlei (-1%); Wildevleovlei (+2%), Zand (-2%), Eerste (-5%), Bot (+10%), Klein (-4%); Duiwenhoks (-10%); Goukou (-2%), Gouritz (-10%), Klein Brak (-8%), Sundays (+1%), Bushmans (+4%), Great Fish (-3), Mzimvubu (+7%), uMzimkulu (+9%), uMkomazi (+3%), Little aManzimtoti (-10%), uMbokodweni (+2%), uMngeni (-18%), iZotsha (+7%), uMvoti (+9%) (Van Niekerk & Turpie 2012). The desktop assessments tended to be more accurate if the flow data used in the assessments were accurate, with the degree of deviation being lower in the categories Natural and Near Natural, but less accurate in the case of degraded systems (i.e. categories Heavily and Severely/Critically modified). This was especially the case for small estuaries with high pollution loads.

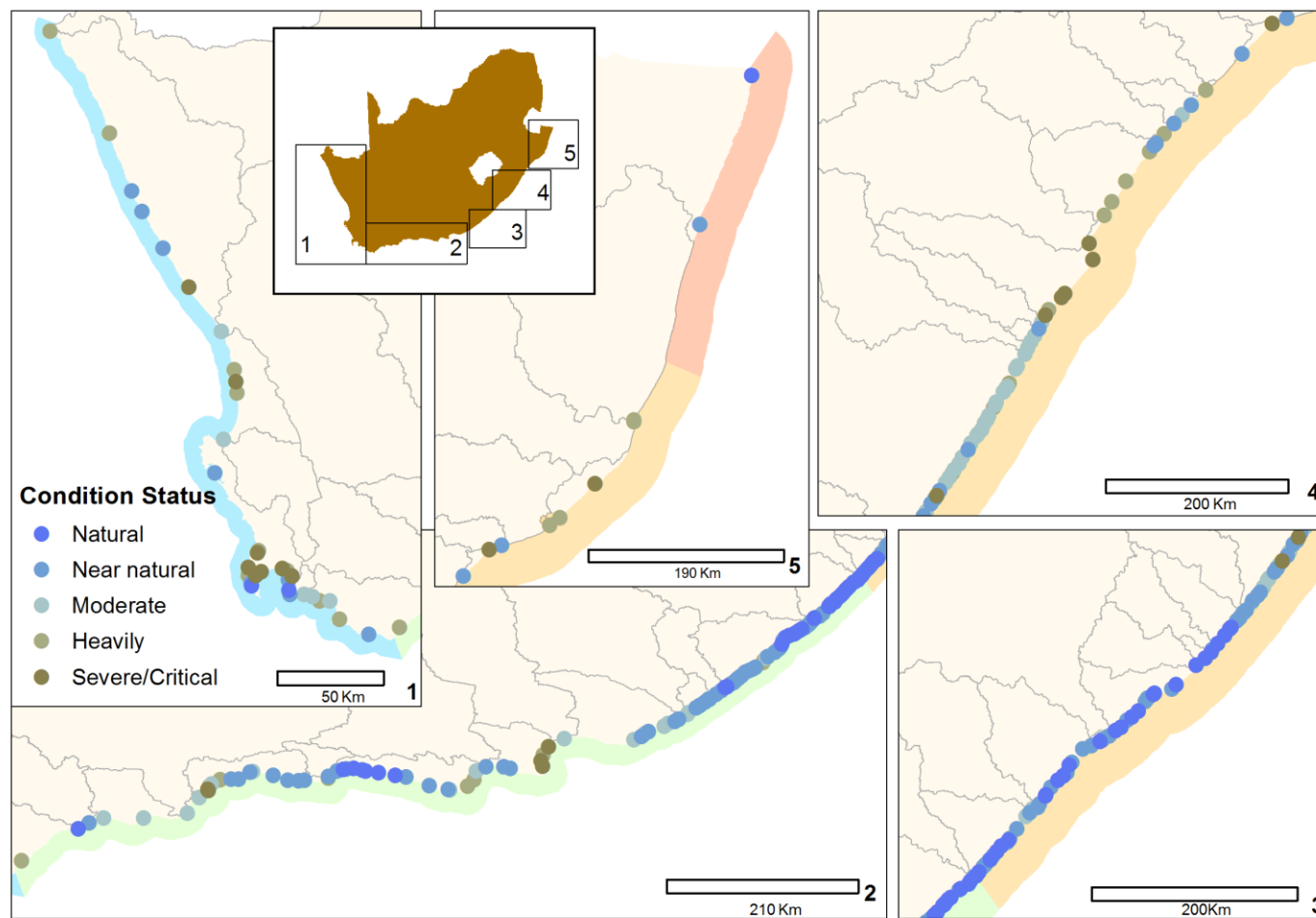


Figure 56. Map showing condition of South African estuaries spatial distribution.

7.3 Condition of estuarine ecosystem types

From a Estuarine Ecosystem perspective, the Cool Temperate Biogeographical region had the highest number of ecosystem types (see chapter 3 for more on types) in a Heavily to Severely/critically modified state in Large Fluvially Dominated (100%), Large Temporarily Closed (99%), Arid Predominantly Closed (78%), Small Temporarily Closed (55%) and Estuarine Lakes (37%) reflecting key pressures such as flow reduction, pollution and fishing pressure of the region (Figure 57).

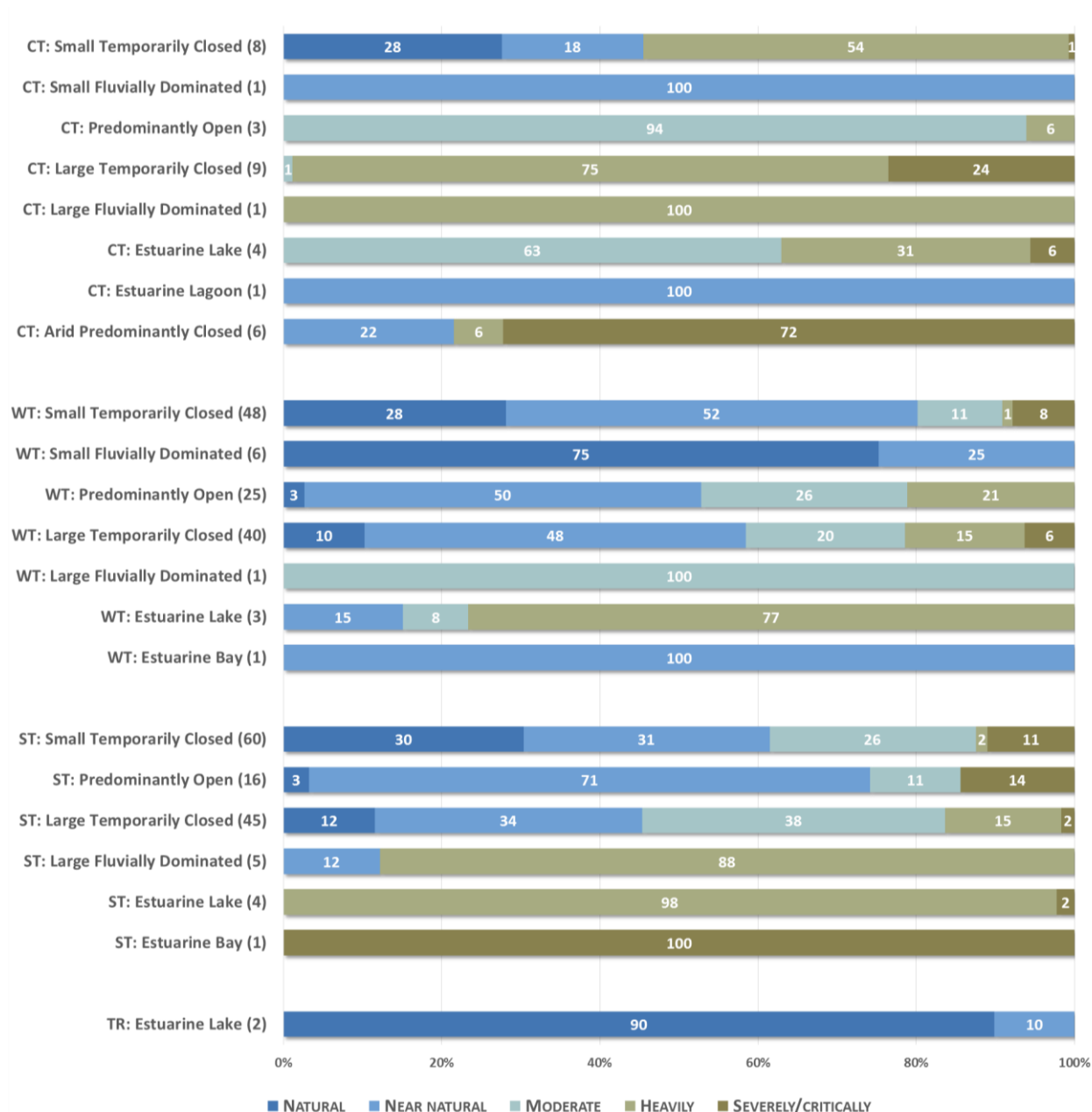
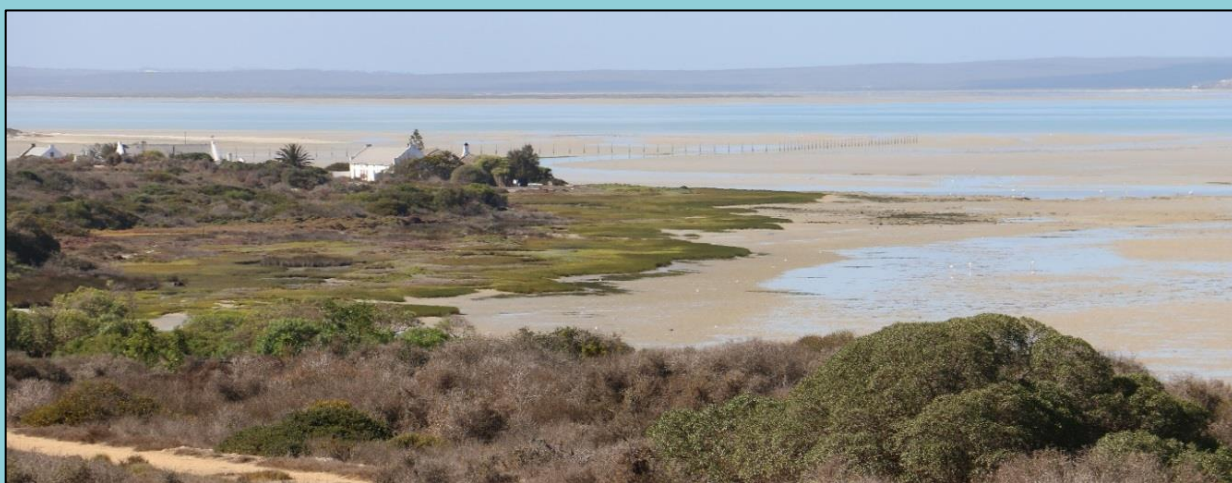


Figure 57. Ecosystem type condition based on estuarine area.

TEXT BOX 9: LANGEBAAN LAGOON: ECOSYSTEM HEALTH AND PRESSURES

The unique, sheltered waters of Langebaan Estuarine Lagoon have for centuries attracted human use. This extensive system that comprises of shallow intertidal sand banks and deeper channels experiences tidally driven input of nutrient rich, upwelled water from the sea and groundwater input in the upper reaches. Together, this creates an ecologically productive system that supports long-standing fisheries. The natural beauty of Langebaan Lagoon, with clear blue waters contrasting with Eelgrass Beds (*Zostera capensis*), fringed by colourful saltmarsh (dominated by Cordgrass (*Spartina maritime* and *Sarcocornia perennis*) and the Dune Slack Rush (*Juncus kraussi*)), and surrounded by coastal fynbos, in combination with the sheltered and sun-warmed waters, have attracted tourism and extensive residential development. Langebaan lagoon has long been the focus of scientific study and interest, owing to its conservation importance as well as its many unique features. The conservation value of the lagoon is well recognised, and the surrounding area is formally protected within the West Coast National Park with the Lagoon itself and nearby important seabird islands declared a Marine Protected Area (with Controlled, Restricted and Sanctuary Zones).



(Source: J.K. Turpie)

Ongoing development, associated with Saldanha Port maintenance and activities (hydrocarbon imports and iron ore exports), various industries in the Saldanha Industrial Development Zone, mariculture and the recently approved Aquaculture Development Zone, nearby phosphate mining, ongoing commercial and recreational fishing, water sports (e.g. kite surfing) and residential development (with associated discharges), all represent important threats to Langebaan Lagoon.

Cognisant of these ongoing and increasing threats to the natural ecosystem functioning of the lagoon, the Saldanha Bay Water Quality Forum Trust (SBWQFT), a voluntary organization representing various organs of State, local industry and other relevant stakeholders and interest groups was established in 1996. The SBWQFT initiated monitoring of important ecosystem indicators in 1999, with ongoing annual monitoring undertaken since 2008 and reported on in the “State of the Bay” technical report series.

Current and potential future threats to Langebaan Lagoon identified during ongoing State of the Bay monitoring include:

- Overexploitation of key fish species particularly White Stumpnose (*Rhabdosargus globiceps*) and harders (*Chelon richardsonii*). Declines in fishing effort are required to rebuild stocks and improve yields, but management authorities are under pressure to increase access to the MPA and participation in commercial fisheries.
- Expanded shellfish production and the introduction of finfish aquaculture in Saldanha Bay, as envisioned in the recently approved ADZ, may negatively impact the Lagoon through organic and inorganic waste input, and the introduction of alien fish, parasites and disease. Implementation of effective mitigation and careful monitoring of potential impacts is required to minimize the risk.
- Introduction of alien marine species associated with shipping activity and ballast water discharge. Twenty-five of these species have been confirmed from Saldanha Bay and/or Langebaan Lagoon, of which all but one are considered invasive.
- Planned groundwater extraction for phosphate mining at Elandsfontein, which if not carefully managed, may influence freshwater flows into the head of the lagoon, potentially negatively impacting vegetation, invertebrate communities and higher trophic levels.
- Pollution risks associated with port expansion, increased shipping and industrial development including, hydrocarbon, brine and trace metal contaminants and elevated turbidity due to dredging. Tidal currents can transport pollutants into the sensitive intertidal lagoon habitats and significant changes in subtidal macrophytes and macrofauna have been linked to large-scale blasting and dredging events in the past.
- Increased wastewater discharge (treated sewage) and storm water run-of associated with residential and industrial development.
- Increased recreational boating and water sports such as kite surfing, can cause significant disturbances to breeding populations of threatened seabirds, resident and migratory waders, which have all shown significant population declines. Birds are facing additional threats including declines in prey availability due to overfishing and potentially climate induced shifts in the distributions of prey species, seal predation, loss of breeding habitat and hunting along migration routes.

Despite the large number of identified impacts on Langebaan Estuarine Lagoon, formal protection, ongoing monitoring and management, have largely been successful in preserving the ecological functioning of the system and it remains in a relatively good state of health. Major perturbations in macrophyte (e.g. *Gracilaria* and *Zostera*) and benthic macrofaunal communities have occurred in response to large anthropogenic impacts (e.g. dredging), but these ecosystem components appear to have recovered or at least stabilized.

However, a concerning declines in higher trophic level species, particularly fish and birds, however, reveal the ongoing pressure on the lagoon ecosystem and the need for urgent intervention on activities such as fishing.



(Source: J.K. Turpie)

Citation: Hutchings, K. *Langebaan Lagoon: Ecosystem Health and Pressures Volume 3: Estuarine Realm*. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A

In the Subtropical Biogeographical region, the highest number of ecosystem types in a Heavily to Severely/Critical modified state are the Estuarine Lakes (100%), Estuarine Bay (100%), and Large Fluvially Dominated (88%) systems reflecting habitat transformation, pollution and fishing pressure of the region. In the Warm Temperate region only the Estuarine Lakes (77%) reflect significant degradation due to development in the EFZ, flow reduction and artificial breaching. In addition, 21% of Predominantly Open and Large Temporarily Open ecosystems are also significantly degraded. None of the ecosystem types in the Tropical Biogeographical region are in a severely degraded state.

7.4 Evaluation of condition of abiotic and biotic components

Figure 58 summarises change from a process and pattern perspective across all South African estuaries. An overview of the abiotic components suggests that the hydrological processes are in a good health (in a Natural or Near Natural state) in about 67% of estuaries. The hydrodynamics component, in turn, points to an 8% improvement in condition from the hydrological component, alluding to some resilience in this component, i.e. not all flow modification translate directly into shifts in hydrodynamic condition.

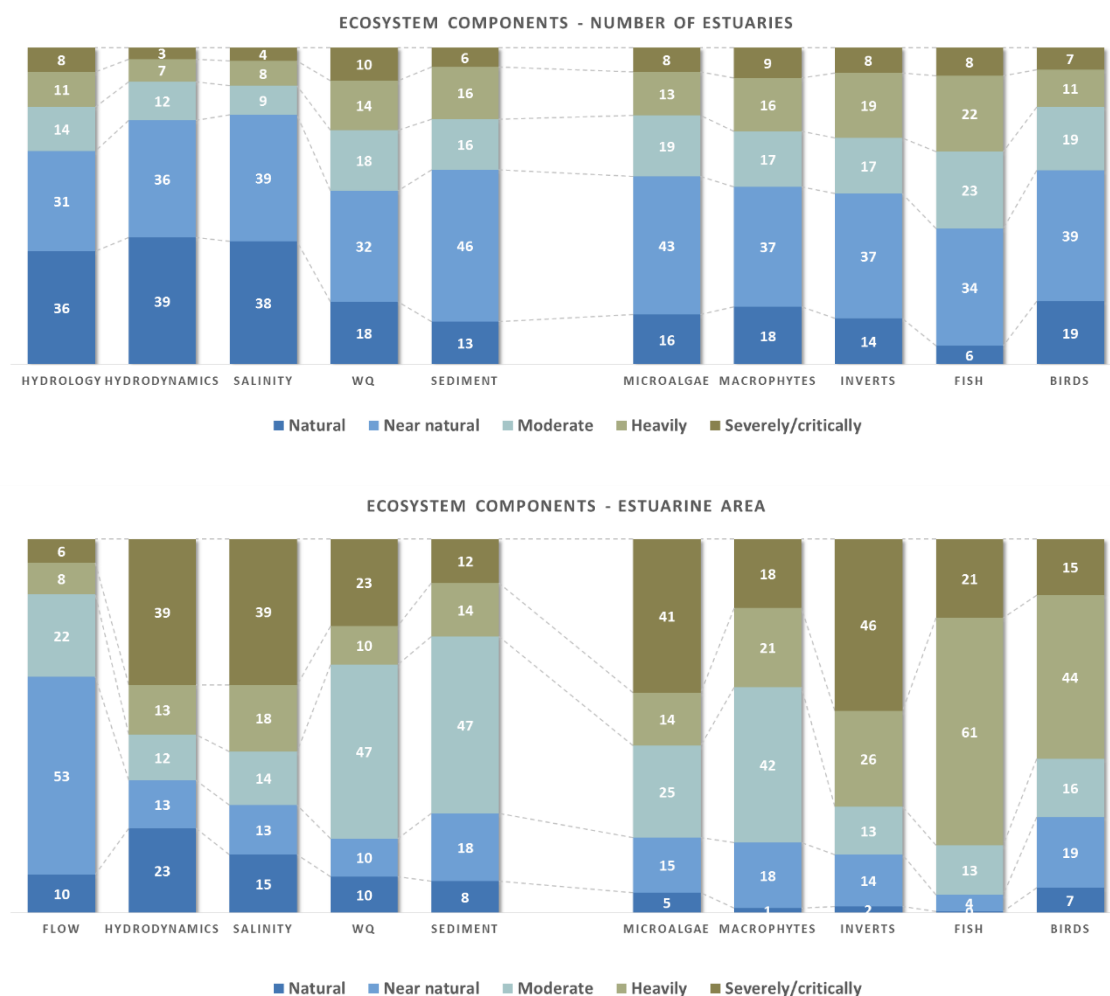


Figure 58. Deteriorating processes and patterns in South African estuaries summarised as percentage estuaries (top) and normalised by area (bottom).

This is somewhat misleading as a high number of large estuaries, specifically the estuarine lakes, are under severe pressure from mouth manipulation and flow reduction, which is evident when taking estuarine area into account. The salinity, water quality and the physical habitat (sediment) components, at 77%, 50% and 59% of estuaries respectively, exhibited a relatively similar pattern in health linked to flow reduction, coastal development, and impaired water quality.

A comparison between the primary producers, the microalgae and macrophyte components of the ecosystem, indicate that roughly 59% and 55% of these communities in South African estuaries are in an Natural or Near Natural State (A to B Category). Unfortunately, as stated above, this is mostly associated with the smaller estuaries. The macrophyte communities, associated mostly with the larger estuaries, are by and large in fair or poor health because of non-flow related pressures, e.g. coastal development and agricultural activities.

Thus, from a biotic components perspective, there is a decrease in health as one move up the food chain from microalgae (58%) and macrophytes (54%), to invertebrates (51%), and fish (40%), thus reflecting the cumulative effects of flow and non-flow related impacts such as fishing. In contrast, the overall bird component is still in a relatively good state with over 58% of estuaries still in an Natural or Near Natural State, thus highlighting the robustness of the bird community to anthropogenic pressures. Overall, the fish component is in the poorest condition, owing to the combined indirect and direct pressures on this group.

7.5 Understanding declining condition and estuarine connectivity and inter-estuary recruitment

The health of individual estuaries matters as it contributes to the overall resilience of the network of estuaries along a section of coast. Understanding of the degree to which the health of adjacent estuaries influences each other is poor, however. Aggregating estuary condition in 100 km sections of the coast provides a measure of how connectivity between estuaries is declining as it visually represents sections of the coast where estuarine abiotic and biotic processes are suboptimal for coast-wise connectivity, e.g. recruitment, flood recovery, and genetic exchange. For example, there exists a 300 km functional gap in the network of estuaries in the Subtropical region (Figure 59) as most of the systems in this region are small and in a poor state of health (Van Niekerk *et al.* 2019). Similar gaps are starting to form in the Cool Temperate region (around Cape Town and the arid West Coast) and the urban centres of the Warm Temperate (Mossel Bay, Port Elizabeth and East London). In many cases, the gaps are driven by the ongoing degradation of small, seemingly insignificant estuaries that are not individually valued by resource managers.

In future, it is expected that mark and recapture, telemetry and genetic studies will assist in 'Making the case for estuarine connectivity' and the development of appropriately informed guidelines for regional resource allocation.

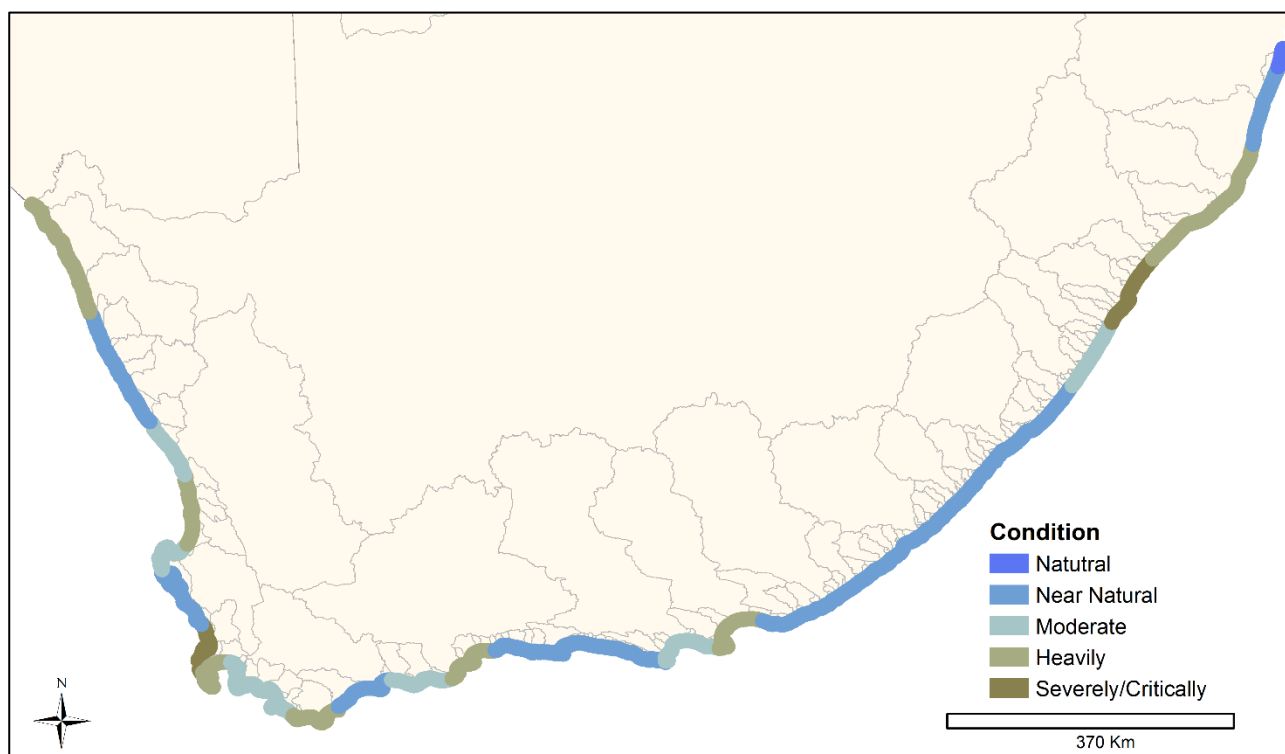


Figure 59. Declining estuarine connectivity illustrated in 100km sections of the South African coastline.

7.6 Conclusion

Overall, while a significant number of the estuaries in South Africa are in excellent to good health, these are mostly small systems in rural areas with few pressures. In these areas, smaller estuaries tend to be in a better state of health because there are fewer pressures on them. However, these systems tend not to be as resilient to change as large estuaries, primarily due to their small size and higher residence time brought about by limited tidal exchange. This is one of the key reasons for the poor conditions of the urban systems.

On the other hand, larger systems, which are important as fish nursery grounds and of higher economic and ecological importance, are mostly in declining health due to indirect pressures from the catchment and direct pressures such as development in the estuary functional zone and fishing. Most of the estuarine extent in South Africa is in a modified moderately to heavily modified state and there is a risk that this percentage could increase further if appropriate management actions are delayed.

The St Lucia Lake System accounts for more than half of the estuarine extent in South Africa and it is in relatively poor condition. Fortunately, however, the St Lucia and uMfolozi systems are in the process of being reconnected, and an adaptive management and monitoring programme has been initiated to assist with the long-term recovery of this World Heritage Site.

Monitoring of both abiotic and biotic parameters is seen as fundamental to validating the findings of the condition assessment. In order to benchmark the findings, monitoring also needs to cover the full spectrum of near-natural to heavily degraded estuaries in all four bioregions following the standardised methods developed for flow requirement studies (DWAF 1999).

Ideally, research and assessment should be underpinned by modelling studies that encompass the functional linkages between ecosystem components and overwhelming pressures on the environment, such as Climate change and ocean acidification (Borja *et al.* 2016b). Such modelling studies can provide evidence needed for setting realistic targets for resource use, and can also underpin better long-term resource planning.



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8. ECOSYSTEM THREAT STATUS AND ECOSYSTEM PROTECTION LEVEL

Chapter Citation: Van Niekerk, L., Skowno, A., Adams, J.B., Lamberth, S.J., Turpie, J., MacKay, C.F. & Sink, K., 2019. 'Chapter 8. Ecosystem Threat Status and Protection levels', *South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm*, South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A.

Ecosystem Threat Status & Protection Levels

- The estuarine realm is the most threatened of all realms in South Africa, both for the number of ecosystem types and for area.
- Eight-six percent of estuary types are threatened with 9% Critically Endangered, 45% Endangered and 32% Vulnerable. By area, 99% is threatened with 3% Critically Endangered, 74 % Endangered and 22% Vulnerable.
- Estuaries are under-protected in South Africa with only 18% of ecosystem types and 1% of estuarine area well protected.
- Since 2011, there has been erosion of estuary protection caused by removal of no-take restrictions and developing commercial fisheries in Marine Protected Areas (MPAs).
- Several under-protected ecosystem types can advance to well protected, solely by improved management of fishing and water quality, e.g. 32% of types and 10% of area can be well protected if fishing effort is limited in the Langebaan, Knysna and Kosi systems.

There are two high level indicators for assessing the state of South Africa's biodiversity: ecosystem threat status and ecosystem protection level. Ecosystem threat status indicates the degree to which ecosystems are still intact or alternatively losing vital aspects of their structure, function and composition. Ecosystem protection level indicates whether ecosystems are adequately protected or under-protected.

8.1 Ecosystem threat status (Red List of ecosystems)

8.1.1 Ecosystem threat status calculation method

The International Union for Conservation of Nature (IUCN) developed a Red List of Ecosystems (RLE) framework (here to referred as the IUCN RLE) 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 since 2008, the IUCN RLE framework 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 (Nicholson *et al.* 2009; Rodríguez *et al.* 2011; Keith *et al.* 2013, 2015; Bland *et al.* 2017a&b, 2018). There is growing uptake of the IUCN RLE standards (Bland *et al.* 2017a) with number of sub-global assessments (including North America, Philippines, Australia, Colombia, France, Finland) adopting the RLE approach. Ultimately other national and sub-global assessments undertaken using these 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 the ecosystem function and services are linked with biodiversity (Bland *et al.* 2017a), the relationships can be complex. Consequently, the RLE focusses specifically on risks to biodiversity (Keith *et al.* 2013a). The RLE requires consistent and clearly defined units of assessments (i.e. ecosystem types) that can be delineated spatially, while at the same time needs to be able to effectively assess risks across widely contrasting ecosystems (Keith *et al.* 2013a). The RLE framework used the concept of ecosystem collapse as the ‘end point’ of ecosystem decline, this is equivalent to species extinction, and is defined as a ‘transformation of identity, loss of defining abiotic or biotic features and characteristic native biota are no longer sustained’ (Keith *et al.* 2013a).

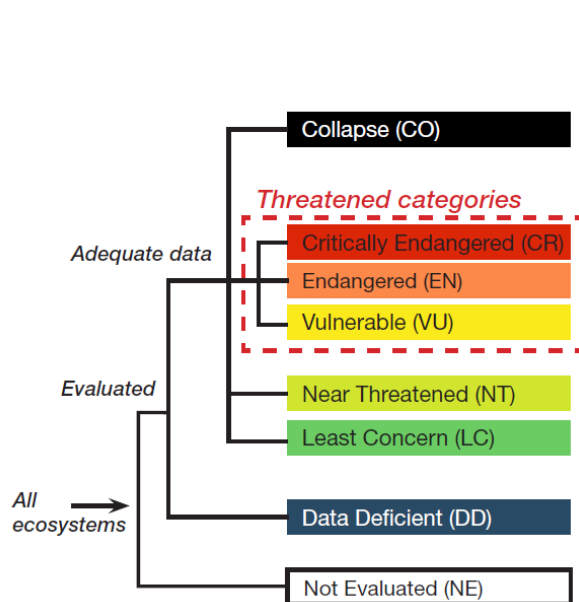


Figure 60. IUCN RLE threat categories, see glossary of terms of definitions. Source: Bland *et al.* (2017a).

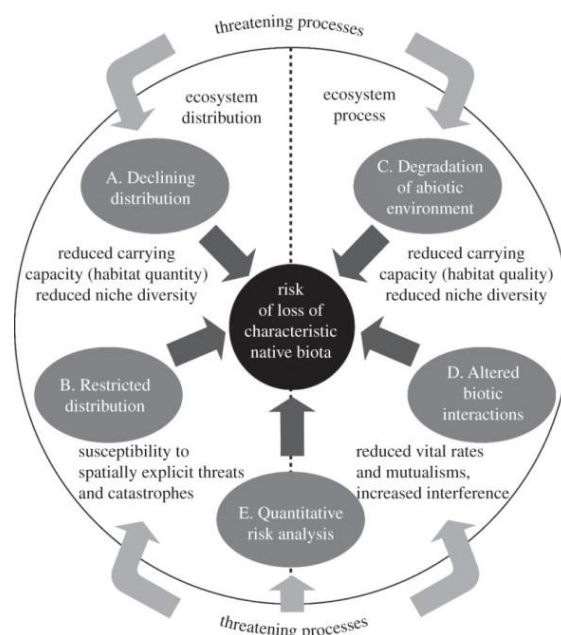


Figure 61. IUCN RLE framework for assessing the risk of ecosystem collapse. Source: Keith *et al.* (2013).

The risk assessment model for the IUCN RLE is illustrated schematically in Figure 60 and Figure 61. Declining distributions (A) and restricted distributions (B) are considered distributional symptoms of decline; and degradation of abiotic environment (C) and altered biotic function (D) are considered functional symptoms of decline. It is possible for these mechanisms to interact and produce additional symptoms of decline (Keith *et al.* 2013a). The mechanisms in the conceptual model (Figure 60) translate into five rule-based criteria with thresholds for the distributional and functional symptoms (Table 38). Ecosystem types are categorised as critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT) or least concern (LC), with CR, EN and VU ecosystem types collectively referred to as threatened or endangered categories. For definitions of the ecosystem threat status categories, see Text box 10.

TEXT BOX 10: DEFINITIONS OF ECOSYSTEM THREAT CATEGORIES (CR, EN, VU, LT)

Critically endangered ecosystems are ecosystem types that have very little of their original extent (measured as area, length or volume) left in natural or near-natural condition. Most of the ecosystem type has been severely or heavily modified from its natural state. These ecosystem types are likely to have lost much of their natural structure and functioning, and species associated with the ecosystem may have been lost. We are in danger of losing the last remaining natural examples of these ecosystem types. Any further loss of natural habitat or deterioration in condition of the remaining healthy examples of these ecosystem types must be avoided, and the remaining healthy examples should be the focus of urgent conservation action.

Endangered ecosystems are ecosystem types that are close to becoming critically endangered. Any further loss of natural habitat or deterioration of condition in these ecosystem types should be avoided, and the remaining healthy examples should be the focus of conservation action.

Vulnerable ecosystems are ecosystem types that still have the majority of their original extent (measured as area, length or volume) left in natural or near-natural condition but have experienced some loss of habitat or deterioration in condition. These ecosystem types are likely to have lost some of their structure and functioning and will be further compromised if they continue to lose natural habitat or deteriorate in condition. Identified biodiversity priority areas should guide planning, resource management and decision-making in these ecosystems types.

Least threatened ecosystems are ecosystem types that have experienced little or no loss of natural habitat or deterioration in condition. Identified biodiversity priority areas should guide planning, resource management and decision-making in these ecosystems types.

South Africa independently developed indicators of ecosystem threat prior to the IUCN Red List of Ecosystems (RLE) (Keith *et al.* 2013a)(www.iucnrl.org). These indicators addressed the need to identify risk for higher-levels of biodiversity organisation such as ecological communities (Noss 1990; Rodríguez *et al.* 2011; Keith *et al.* 2013a; Bland *et al.* 2017a). The South African List of Terrestrial Threatened Ecosystems was conceptualised as a national indicator of ecosystem conservation status in the early 2000s. Since 2004, South Africa has been reporting on the threat status of all its ecosystem types to identify conservation priorities, promote responsible natural resource use and influence government policies (Driver *et al.* 2004, 2012; Van Niekerk & Turpie 2012).

In South Africa the assessment of ecosystem threat status links directly to the Biodiversity Act. Chapter 4 of the Act allows the Minister or an MEC to list threatened or protected ecosystems, thus providing a powerful mechanism to address biodiversity conservation effectively at an ecosystem scale. The ecosystem threat status categories used in the NBA (CR, EN and VU) have been deliberately aligned with the terms and definitions used in the Biodiversity Act.

A group of similar-type estuaries within a biogeographical zone, herein referred to as an ecosystem type (see Chapter 3 for new estuary classification), is implicitly assumed to represent a single 'ecoregional' type, supporting a characteristic suite of estuarine processes and biodiversity.

Table 38. IUCN criteria and thresholds for the Red listing of ecosystems (Rodríguez *et al.* 2011).

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) 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 ...	≤ 2,000 km ²	≤ 20,000 km ²	≤ 50,000 km ²
B2	The number of 10 × 10 km grid cells occupied (Area of Occupancy) AND at least one of a-c above (same subcriteria as for B1).	≤ 2	≤ 20	≤ 50
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 (%)		
		≥ 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:	CR	EN	VU
		EN	VU	
		VU		
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:	CR	EN	VU
		EN	VU	
		VU		
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:	CR	EN	VU
		EN	VU	
		VU		

D. Disruption of biotic processes or interactions over ANY of the following time periods:				
		Relative severity (%)		
		≥ 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:	CR	EN	VU
		EN	VU	
		VU		
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:	CR	EN	VU
		EN	VU	
		VU		
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:	CR	EN	VU
		EN	VU	
		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

The NBA 2011 and 2018 primarily identifies the status of ecosystems based on their current ecological condition (Section 9). In the case of estuaries, the ecosystem threat status does not relate to the complete loss of an ecosystem type (i.e. loss due to development or infilling of the entire estuarine area) but rather to the loss or degradation of ecosystem processes and abundance, community composition or species richness of associated biota (i.e. pattern). Critically endangered and endangered statuses refer to a significant loss of process and pattern, while vulnerable indicates some loss of ecosystem processes and/or abundance and distribution of biota. As a result of direct harvesting of living resources, ecosystem processes may still be intact, while the biota associated with

that ecosystem type are severely degraded, thus these two aspects are not necessarily related. For the NBA 2018, the estuary ecosystem threat assessments were based on 2018 Estuary Ecosystem Classification (Chapter 3), updated estuary spatial delineation as captured by the EFZ (Chapter 4), and the updated ecosystem condition results (derived from individual health assessments) (Chapter 7). Initially, the 2011 South African estuary health assessment method and the new 2017 IUCN Red Listing Ecosystems method were both applied with the aim of comparing the results.

However, the 2011 South African approach, which focused only on Natural (Category A) and Near Natural (Category B) condition estuaries yielded divergent, 'binary' results with most of the ecosystem types either Critically Endangered or Least Concern. An additional concern was that the South African method was not able to reflect regional-scale transformation and/or estuary degradation occurring along the Subtropical biogeographical region of South Africa.

In contrast, the IUCN method yielded a gradient of results across the different threat status categories. Additional benefits of using the IUCN system include more reliance on scientific evidence and recognition of the resulting RLE by the IUCN and alignment with international conventions and assessment processes, thus outweighing the drawbacks of deviating from a locally accepted method. Consequently, the NBA 2018 Estuaries component followed the IUCN RLE approach for this assessment.

8.1.2 The IUCN Red List of Ecosystems Framework

8.1.3 Implementation of the IUCN RLE for the NBA 2018

The IUCN Red List of Ecosystems (RLE) method for the NBA 2018 was applied using a systematic assessment based on IUCN Criteria C (criteria linked degradation of ecosystems) for all estuarine ecosystem types. This assessment, referred to as the 'core' assessment, was then supplemented with additional assessments based on IUCN Criteria A (habitat loss within the EFZ) and B (restricted geographic range and ongoing decline). It is envisaged that the preliminary RLE resulting from this assessment will be considered as the baseline, and that it will be updated as additional information becomes available. If the threat status of an ecosystem type is: a) considered an underestimate; or b) if the data used in the assessment is considered inaccurate or inadequate; or c) if a researcher can develop new datasets to address additional criteria for selected ecosystems; then further supplementary assessments should be undertaken.

Input data

For the NBA 2018 the estuarine ecosystem threat assessment was based on the 2018 Estuary Ecosystem Classification, revised estuary spatial EFZ delineation, and the updated ecological condition results (derived from individual estuary health assessments) (Criteria C3). In addition, the national land cover change dataset (Chapter 3, Terrestrial Realm) and the national vegetation map (Chapter 6, Terrestrial Realm) provided the input to the assessments for Criteria A3 and B3. (Table 39).

Table 39. Input data sources for the red list of ecosystem analysis.

ASSESSMENT	DATASET	DESCRIPTION	REFERENCE
Core assessment: Criteria C3	2018 EFZ	Revised 2018 Estuary delineation (incorporating both estuary and shores)	Van Niekerk, L., Adams, J., Fernandes, M., Harris, L., Lamberth, S.J., MacKay, C.F., Petersen, C., Ramjukhad, C-L., Riddin, T., Van Deventer, H. & Weerts, S.P., 2019, 'Chapter 5: Extending the Estuary Functional Zone to include all processes', in South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Environment.
	Estuary ecosystem type map	Revised 2018 Estuary Classification assigned to each EFZ	Van Niekerk, L., Adams, J.B., James, N., Lamberth, S.J., MacKay, C.F., Turpie, J.K., Rajkaran, A., Weerts, S.P. & Whitfield, A.K., 2019, 'Chapter 4: A new Ecosystem Classification for South African estuaries', in South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Environment.
	Estuary Condition	Updated 2018 Estuary Condition assigned to each EFZ	Van Niekerk, L., Adams, J.B., Clark, B., Lamberth, S.J., MacKay, C.F. & Weerts, S.P., 2019, 'Chapter 7: Condition of South Africa's estuarine ecosystems' in South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Environment.
Supplementary assessment Criteria A3, A2b	National land cover	Land cover change raster developed by SANBI with two time points 1990, 2014. Based on national land cover products by GeoTerra Image 2015.	Skowno, A.L., 2018, 'Terrestrial habitat modification change map (1990-2014) for South Africa: a national scale, two time point, land cover derived, map of terrestrial habitat modification', in NBA 2018 Technical Report. Pretoria, South Africa. GeoTerralimage, 2015, Technical Report: 2013/2014 South African National Land cover Dataset version 5. Pretoria, 53 pp. GeoTerralimage, 2015, Technical Report: 1990 South African National Land cover Dataset version 5.2. Pretoria, 63 pp.
Supplementary assessment: Criterion B3	2018 EFZ	Revised 2018 Estuary delineation (incorporating both estuary and shores)	Van Niekerk, L., Adams, J., Fernandes, M., Harris, L., Lamberth, S.J., MacKay, C.F., Petersen, C., Ramjukhad, C-L., Riddin, T., Van Deventer, H. & Weerts, S.P., 2019, 'Chapter 4: Extending the Estuary Functional Zone to include all processes' in South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Environment.
	Estuary pressure assessment	Updated 2018 Estuary pressures assigned to each EFZ	Van Niekerk, L., Adams, A.B., Lamberth, S.J., Taljaard, S., MacKay, C.F., Bachoo, S. Parak, O., Murison, G., Weerts, S.P. 2019, 'Chapter 6: Pressures on the Estuarine Realm' in South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Environment.

Core assessment

Criteria C3 – Environmental degradation since 1750

The estuarine condition (A to F scale) was used to assess the estuarine ecosystem types of South Africa using Criteria C3 (*Environmental degradation since 1750*) (Table 38). This criterion considers both the severity of degradation (50%, 70% or 90%) and the extent of the degradation (50%, 70% or 90%) to ecosystems. Categories E and F were considered equivalent to the RLE framework's 90% relative severity class due to large scale disruption of a wide range of biotic processes such as species composition, richness, biomass. Categories D-F were considered equivalent to the RLE framework's 70% relative severity, and categories C-F were considered equivalent to 50% relative severity. The ecosystem types that have reached this point are likely to have 'lost' important structure and functioning and will be further compromised if they continue to lose natural habitat or deteriorate in condition. The extent of degradation within each relative severity/condition class within in each ecosystem type was expressed as a percentage of the estuarine type extent (proxy for historical extent) and the thresholds as per Table 38, were applied. In addition to the estuarine extent encapsulated with in the EFZ, the analysis also considered just using estuarine habitat area. However, the latter did not reflect the loss of large areas due to land-use and development, while using the EFZ more accurately reflected the impacts since 1750.

How is ecosystem threat status assessed? Figure 62 provides a diagram of the processes followed to aggregate condition status to ecosystem threat status. Once ecosystem types have been identified and pressures assessed, the condition or ecological integrity of ecosystems can be established. The proportion of each ecosystem type that remains in relatively good condition is then evaluated against a series of thresholds to determine ecosystem threat status.

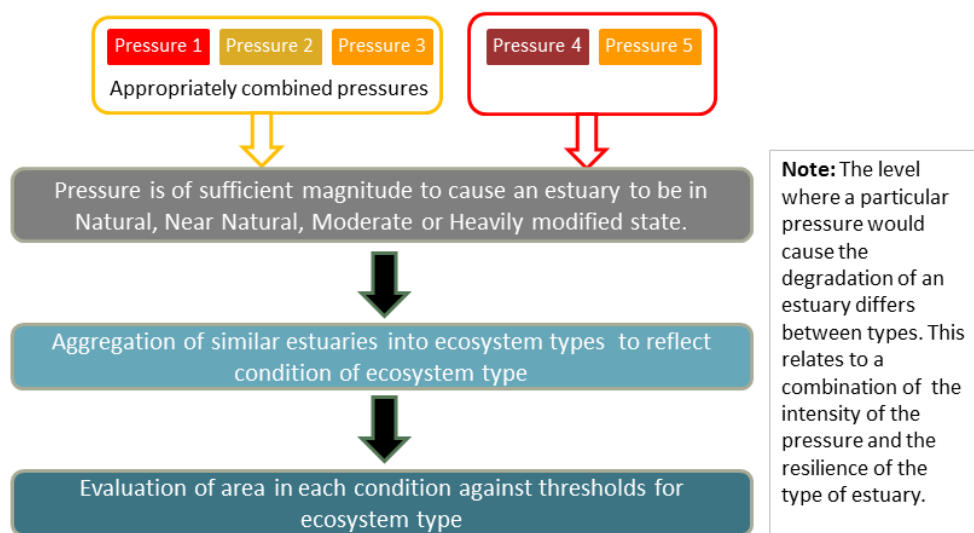


Figure 62. Process and criteria by which ecosystem threat status is determined.

In 2011 only Natural and Near Natural condition estuaries were included in the assessment. In the 2018 assessment the Moderately and Heavily degraded categories were also considered. The assessment considered the 2018 EFZ extent (representing the historical extent as much as possible).

Supplementary assessments

To complement the core assessment, several additional datasets were compiled to ensure the ecosystem risk assessments were based on best available data. The supplementary assessment focused on Criteria A and B.

Criteria A3 – historical and future reductions in geographic range

The ecosystem type data (2018 estuary classification) and the ecosystem condition data (using land cover as proxy for habitat) were cross tabulated within a geographic information system and changes in natural extent from the reference condition (circa 1750) to 1990 and 2014 were computed for each ecosystem type. The remaining extent of each ecosystem type (circa 2014) was expressed as a percentage of the reference extent of the ecosystem type (circa 1750), allowing for application of Criteria A3 (historical reductions in geographic range).

Criterion B1, B2 and B3 – Restricted geographic range

The first step for the assessment under this criterion was to combine the habitat modification data for 2014 with the ecosystem type data to produce an 'ecosystem remnants' layer circa 2014. This layer (in geotiff format) was used to compute the Extent of Occurrence (EOO) and Area of Occupancy (AOO) for each ecosystem type with the package [redlist] (Lee & Murray 2017) within the statistical software R (R Core Team, 2014) for Criteria B1 and B2. However, as South Africa's estuaries are very small (< 2 000 km²), 99% of estuarine ecosystem types would have qualified as endangered or critically endangered under Criterion B1 and B2, leaving little resolution between types. Thus, criterion B3 (fewer than 5 locations) was deemed the more appropriate measure. However, ecosystem types only qualify for consideration under Criterion B if they are experiencing ongoing declines in extent or condition (observed or inferred). Qualifying estuarine ecosystems types were therefore evaluated using a 'Trajectory of Change' approach based on the current and envisaged future level of pressures on the ecosystem type. Systems with a 'stable' condition did not qualify for Criteria B3.

8.1.4 Results of the ecosystem threat assessment

The first implementation of the IUCN RLE for South African estuarine ecosystems (22 types) for the NBA 2018 resulted in the listing of two Critically Endangered, ten Endangered and seven Vulnerable ecosystems (Figure 63 & Figure 64). While 9% of ecosystem types are Critically Endangered, this amounts to about <5% of the extent of estuarine area in South Africa. In contrast, Endangered ecosystems make up 45% of ecosystems by type and 74% by extent. About 41% of ecosystems types are Vulnerable, amounting to 22% of the estuarine area in South Africa.

The most influential criteria in the RLE assessment were: Criterion C3 (historical environmental degradation), which contributed to the listing of ten ecosystem types, the supplementary assessment of Criteria A (historical and future reductions in geographic range) contributed to the listing of seven types, while Criteria B (restricted distribution with continuing declines in geographic distribution) contributed to the listing of two types.

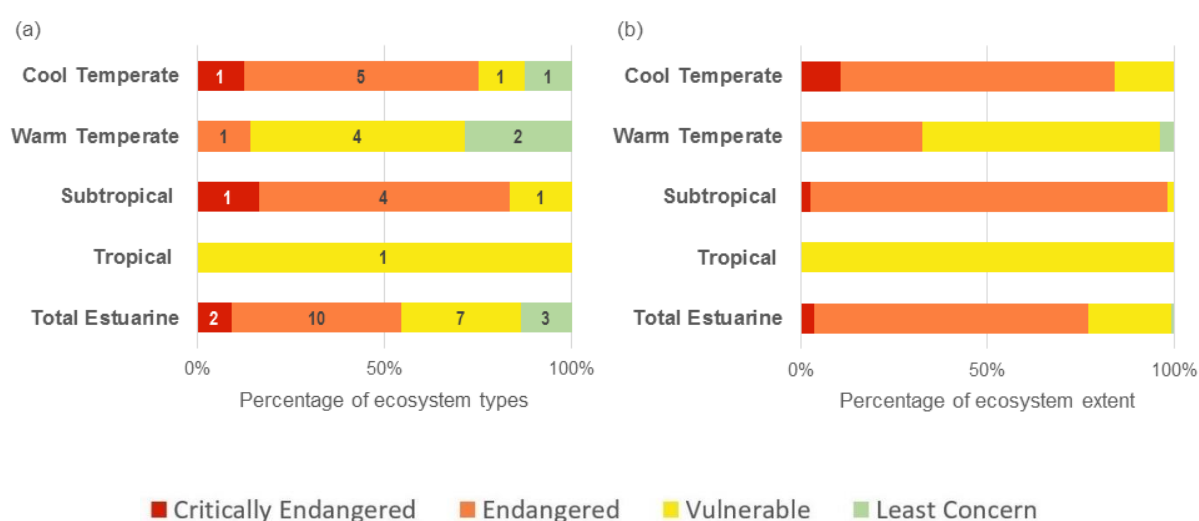


Figure 63. Ecosystem threat status of South Africa's estuaries presented as percentage of ecosystems types (a) and percentage area of ecosystems types (b).

Table 40. Summary of the assessment outcomes; including the number of ecosystem types per category & proportion of the natural areas remaining per category.

CATEGORY (IUCN RLE)	# ECOSYSTEM TYPES	EXTENT OF ESTUARINE HABITAT (HA)	% ESTUARINE AREA
Critically Endangered	2	6 764	3
Endangered	10	147 625	74
Vulnerable	7	1 749	22
Least Concern	3	44 598	1
Total for South Africa	22	200 736	100%

Table 41. Summary of ecosystem threat status based on the IUCN Red List of Ecosystems criterion A, B and C.

TYPE	CRITERIA B & C	CRITERION C				CRITERION A	CRITERION B				CORE	SUPPLEMENTARY		Overall IUCN RLE
	Ecosystem area (Km2)	E+F > 90%	D+E+F > 70%	C+D+E+F > 50%	AVE Condition	% Natural of EFZ	Extent of Occurrence (km ²)	Area of Occupancy (# 10x10km grids cells)	# Ecosystem type features	Trajectory as indicator of ongoing decline (increasing pressures)	RLE C3	RLE A	RLE B3	
CT Arid Predominantly Closed	13.2	77.2	81.6	81.6	D	91.3	2 654	2	6	N/A	EN	LC	LC	EN
CT Estuarine Lagoon	60.2	0.0	0.0	0.0	B	99.9	69	4	1	Negative trajectory (fishing, invasives from port, ground water abstraction)	LC	LC	VU	VU
CT Estuarine Lake	67.2	5.6	39.3	100.0	D	96.5	10 418	10	4	Negative trajectory (fishing, flow reduction, pollution, development, artificial breaching at lower levels)	EN	LC	VU	EN
CT Large Fluvially Dominated	26.3	0.0	100.0	100.0	D	82.9	54	2	1	Negative trajectory (water resource development (Vioolsdrift dam), pollution, grazing, hunting)	EN	VU	VU	EN
CT Large Temporarily Closed	34.6	21.5	99.0	100.0	E	58.8	7 031	9	9	N/A	CR	EN	LC	CR
CT Predominantly Open	152.9	0.0	5.9	100.0	C	75.6	12 018	13	3	Negative trajectory (water resource development, fishing, development in EFZ)	VU	EN	VU	EN
CT Small Fluvially Dominated	0.0	0.0	0.0	0.0	B	100.0	0.01	0	1	Stable (in parks)	LC	LC	LC	LC
CT Small Temporarily Closed	3.1	0.5	73.5	73.5	C	66.0	2 387	1	8	N/A	VU	EN	LC	EN

TYPE	CRITERIA B & C	CRITERION C				CRITERION A	CRITERION B				CORE	SUPPLE- MENTARY		Overall IUCN RLE
	Ecosystem area (Km2)	E+F > 90%	D+E+F > 70%	C+D+E+F >50%	AVE Condition	% Natural of EFZ	Extent of Occurrence (km ²)	Area of Occupancy (# 10x10km grids cells)	# Eco- system type features	Trajectory as indicator of ongoing decline (increasing pressures)	RLE C3	RLE A	RLE B3	
WT Estuarine Bay	29.9	0.0	0.0	0.0	B	75.3	49	4	1	Negative trajectory (riparian development, fishing, pollution (stormwater & WWTW), recreational use)	LC	VU	VU	VU
WT Estuarine Lake	142.4	0.0	76.8	84.9	C	71.7	3 090	8	3	Negative trajectory (water resource development, development in EFZ, pollution, artificial breaching at lower levels)	VU	EN	VU	EN
WT Large Fluvially Dominated	5.0	0.0	0.0	100.0	C	99.9	26	2	1	Negative trajectory (Fishing pressure, Water Resource development)	VU	LC	VU	VU
WT Large Temporarily Closed	56.7	6.3	23.0	46.0	C	82.3	36 914	17	40	N/A	VU	VU	LC	VU
WT Predominantly Open	163.3	0.0	22.3	48.3	C	80.6	52 310	32	25	N/A	VU	VU	LC	VU
WT Small Fluvially Dominated	0.5	0.0	0.0	0.0	A	100.0	71	0	6	N/A	LC	LC	LC	LC
WT Small Temporarily Closed	8.0	11.4	11.8	22.1	B	93.4	40 305	0	48	N/A	LC	LC	LC	LC
ST Estuarine Bay	28.1	100.0	100.0	100.0	E	50.3	40	3	1	Negative trajectory (Fishing (gillnetting), Development, Pollution)	CR	EN	VU	CR
ST Estuarine Lake	816.5	2.3	100.0	100.0	D	93.5	3 350	27	4	Negative trajectory (Fishing (gillnetting), water resource)	EN	LC	VU	EN

TYPE	CRITERIA B & C	CRITERION C				CRITERION A	CRITERION B				CORE	SUPPLE- MENTARY		Overall IUCN RLE
	Ecosystem area (Km2)	E+F > 90%	D+E+F > 70%	C+D+E+F >50%	AVE Condition	% Natural of EFZ	Extent of Occurrence (km ²)	Area of Occupancy (# 10x10km grids cells)	# Eco- system type features	Trajectory as indicator of ongoing decline (increasing pressures)	RLE C3	RLE A	RLE B3	
ST Large Fluvially Dominated ST Large Temporarily Closed	104.4	0.0		89.0	D	55.8	12 565	12	5	development, pollution, catchment land-use)				EN
			89.0							N/A	EN	EN	LC	
	43.2	1.5	17.3	54.9	C	70.5	6 097	13	45	N/A	VU	EN	LC	EN
	69.9	15.5	15.5	27.0	C	65.8	8 524	18	16	N/A	VU	EN	LC	EN
ST Small Temporarily Closed	12.5	11.0	12.8	45.6	B	81.7	6 366	3	60	N/A	LC	VU	LC	VU
TR Estuarine Lake	81.2	0.0	0.0	0.0	B	98.5	539	8	2	Negative trajectory (fishing (fish traps), invasive invertebrates, EUS, groundwater abstraction & forestry, harvesting of mangroves)	LC	LC	VU	VU

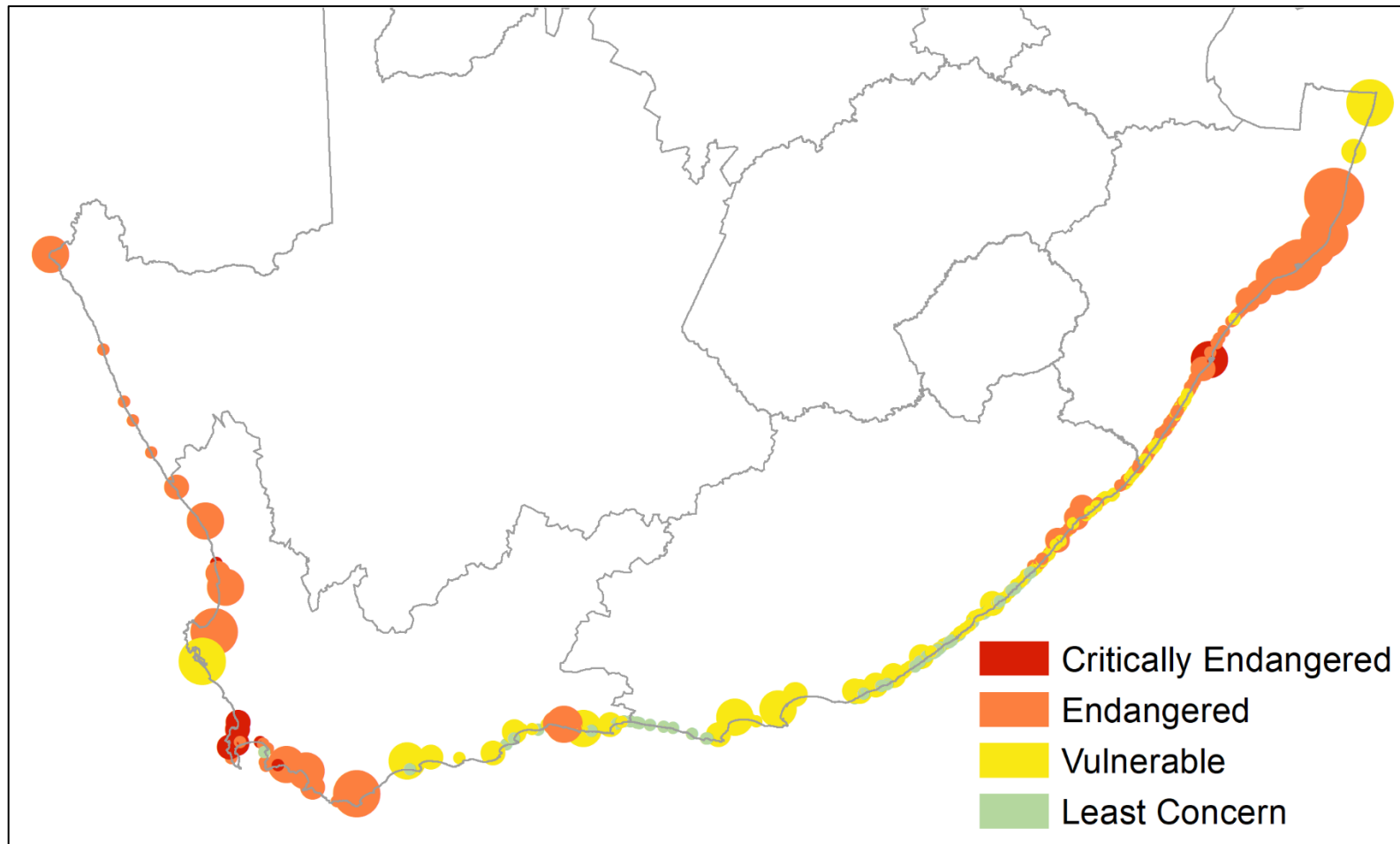


Figure 64. Map showing the distribution of threatened estuarine ecosystems according to the IUCN Red List of Ecosystems (size of the dot represents area of the individual estuary). Note: there are many overlaps between points that can obscure the status of smaller estuaries; consult the GIS data viewer via the NBA website for detailed spatial data. Cartographic corrections from Synthesis Report included.

1.1.1 Summary of ecosystem threat status by biogeographical region

Approximately 75% of the Cool Temperate bioregion ecosystem types are Critically Endangered or Endangered, while 13% are Vulnerable. Of Warm Temperate types, 57% are Vulnerable and 29% are of Least Concern. Eighty-three percent of the Subtropical bioregion ecosystem types are Critically Endangered or Endangered, while 17% are Vulnerable. In comparison, 100% of the Tropical bioregion is Vulnerable (Figure 63a).

However, if analysed by estuarine area, nearly 84% of the Cool Temperate bioregion habitat is Critically Endangered or Endangered, while less than 13% is Least Concern. In contrast most of the ecosystem types in the Warm Temperate are Vulnerable and Least Concern, representing 64% and 29% respectively of the area in this zone. About 98% of the Subtropical estuarine area is Critically Endangered or Endangered (Table 42 and Figure 63b).

Table 42. Biogeographical summary of ecosystem threat status assessment.

BIOGEOGRAPHICAL REGION	ECOSYSTEM THREAT STATUS	% ESTUARY ECOSYSTEM TYPES	% ESTUARINE AREA
COOL TEMPERATE	CE	12.5	10.5
	EN	62.5	73.5
	VU	12.5	16.0
	LC	12.5	0.0
WARM TEMPERATE	CE	0.0	0.0
	EN	14.3	32.3
	VU	57.1	63.7
	LC	28.6	3.9
SUBTROPICAL	CE	16.7	2.6
	EN	66.7	95.6
	VU	16.7	1.9
	LC	0.0	0.0
TROPICAL	CE	0.0	0.0
	EN	0.0	0.0
	VU	100.0	100.0
	LC	0.0	0.0

Ecosystem threat status trends

While there is a noticeable increase in key pressures such as pollution, (i.e. increase in wastewater discharges or poorly treated wastewater) with an expected related impact in conditions, there has also been a number of refinements to methods and approaches in assessment estuary condition. Thus,

it was not appropriate to compare the NBA 2011 results with those of the NBA 2018 to establish overall trends; the comparison would have confounded these outcomes.

8.1.5 Ecosystem threat status limitations

While the condition assessments for most systems have been updated, the under-pinning survey data is between 20 and 30 years old. It is therefore of critical importance that more up to date nation-wide surveys be conducted to improve our overall confidence in the estimated change for the different ecosystem types and to inform future assessments.

Estuaries are interconnected over local, bioregional and global scales. Ecosystems threat status are just one of a range of measures that document the decline in condition and the response to an escalating human footprint. The results of the ecosystem threat status assessment should not be decoupled from the overall regional findings and the deeply concerning trend of large gaps in functioning estuaries due to collective poor condition along urban coastlines.

8.2 Ecosystem protection level

8.2.1 Input datasets

Protected areas are areas of land or sea that are protected by law and managed mainly for biodiversity conservation. Protected areas are vital for ecological sustainability and climate change adaptation. They also serve as the backbone of the ecological infrastructure network, protecting the areas that deliver important ecosystem services to people. Generally, protected areas recognised in the National Environmental Management: Protected Areas Act (Act 57 of 2003) or the Living Marine Resources Act (No 18 of 1998) are considered protected areas in the NBA. The Protected Areas Act provides for several categories of protected area, including special nature reserves, national parks, nature reserves, marine protected areas and protected environments. In addition, it also recognises world heritage core sites, specially protected forest areas, and mountain catchment areas.

The NBA uses a narrower definition of protected areas than the Convention on Biological Diversity (CBD) and IUCN, which acknowledges a broader range of area-based conservation measures in protecting biodiversity. These areas could include conservation areas not formally protected by law but informally protected by the current owners and users, and managed, at least partly, for biodiversity conservation. They can also include a range of other mechanisms such as the intact and conservation zoned areas of UNESCO biospheres, buffers zones on world heritage sites, areas protected by spatial planning laws (e.g. zoning for conservation use), and areas protected by conservation servitudes. In the marine context this may include specially zoned fishery management areas. In the absence of legally binding measures that prevent loss of natural habitat and require effective management, these other area-based conservation measures do not provide full and permanent protection. For this reason, the NBA currently only evaluates protected areas and a narrow range of legally secure effective conservation measures as meeting protection targets.

1.1.1.4 Protected Ares layer used in the NBA 2018 assessment

A South African Protected Areas Database (SAPAD) is maintained by the Department of Environment, Forestry and Fisheries (DEFF). This spatial dataset formed the core of the protection level analysis. However, the database does not yet represent all existing protected areas and requires restructuring to allow for protection level analysis.

The spatial data used for analysis:

- SAPAD 2018Q2 was recompiled into non-overlapping protected area classes, maintaining designation dates, and as far as possible overlaps and inconsistencies resolved.
- Recent provincial and South African National Parks (SANParks) protected area spatial data were sourced, compiled and cleaned up. Areas that did not agree with the DEFF SAPAD data were manually checked with effort priority given to largest features. Likely valid protected areas missing from SAPAD were appended (e.g. adding the Goukou Estuary declaration). In rare instances likely erroneous SAPAD protected areas were deleted after verification based on cadastre data and source proclamations.
- Reserve sub-types were designated as de facto where provincial or SANParks datasets indicated areas being managed as nature reserves but not present in SAPAD, and where gazetted status could not be easily located online. In most cases these areas are probably formal protected areas in terms of NEM Protected Areas Act of 2003, but in a few instances, it is possible that these areas have no legal status but may nevertheless be owned and managed by the relevant agency as a nature reserve.

8.2.2 The extent to which estuaries are represented in the protected areas estate

Protected area expansion over the last decade has taken advantage of alternatives to state owned and run nature reserves, with use of biodiversity stewardship mechanisms to proclaim fully compliant nature reserves and protected environments for private land, usually with the landowner as the management authority. However, traditional Provincial Nature Reserves (> 30%) and National Parks (>5%) still make up by far the largest total estuaries protected area estate (Table 43). A large percentage of the estuaries protected by this type of formal protection are also still in a natural or near natural condition. This is further bolstered by de facto Provincial Nature Reserves which represented 8% of the estate. A deep concern is that less than 1% of the protected estate is no-take areas. Collectively representing just over 1% of the estuary protected estate, Local Nature Reserve, Contractual Park National Parks, Private Nature Reserve, Forest Nature Reserve, Bird Sanctuary, Nature Reserve Stewardship Programme and Mountain Catchment Areas make up a very small proportion of total protected areas. Like Private Nature Reserves, they are recognised by NEMPAA, but nearly always lack a management plan and appropriate conservation management. The estuary under this type of protection also varies significantly in condition. In the dataset used for this analysis, de facto types probably mostly do have formal status, but documentation was not available. Some may be actual de facto protected areas, managed and treated as a protected area, but without any formal declaration recognised in terms of NEMPAA.

Table 43. Protected area estate for the estuaries of South Africa. Condition is indicated as a % of total area in category and extent shown in ha and as a percentage of the total estuarine area.

PROTECTED AREA TYPE	ESTUARINE CONDITION PER PROTECTED AREA TYPE (% of type total)				TOTAL AREA (ha)	% of total area
	NATURAL/ NEAR NATURAL	MODERATE	HEAVILY	SERIOUS/ CRITICAL		
Not in protected area	23	26	43	8	104 677	52.1
Provincial Nature Reserve or Nature Reserve	14	1	85	0	61 146	30.5
De facto - Provincial Nature Reserve	2	0	98	0	16 307	8.1
National Park	68	14	18	0	8 175	3.2
National Park - Marine Protected Area	100	0	0	0	3 774	1.9
Protected Environment	94	5	1	0	1 530	1.7
Marine Protected Area - No Take	77	9	9	5	1 464	0.7
Local Nature Reserve	17	26	35	23	1 135	0.6
Marine Protected Area	39	47	12	1	1 040	0.5
National Park - Contractual Park	6	0	94	0	538	0.3
Private Nature Reserve (ordinance)	43	32	19	7	453	0.2
Forest Nature Reserve	4	15	82	0	353	0.2
Nature Reserve - Bird Sanctuary	0	0	0	100	82	<0.1
Nature Reserve Stewardship Programme	0	0	4	96	41	<0.1
De facto - easement or environmental authorisation	100	0	0	0	12	<0.1
Mountain Catchment Area	100	0	0	0	1	<0.01
De facto - Local Nature Reserve	0	0	100	0	0	<0.01

8.2.3 Ecosystem protection level calculation method

Ecosystem protection level tells us the extent to which ecosystems are adequately protected or under-protected relative to the biodiversity target: Moderately protected, poorly protected and unprotected ecosystem types are collectively referred to as under-protected ecosystems, as shown in Table 44 and

Figure 65. For estuarine ecosystems it was computed by determining the proportion of each ecosystem type that is in a reasonably functional state (i.e. PES category A-D) that falls within the protected area network.

Table 44. Unprotected, poorly protected and moderately protected ecosystem types are collectively referred to as under-protected ecosystems.

PROTECTION LEVEL	% OF BIODIVERSITY TARGET	
Well Protected	≥ 100%	
Moderately Protected	50% - 100%	} Under-protected ecosystems
Poorly Protected	5% - 50%	
Unprotected	< 5%	

As with the ecosystem threat status, no ecosystem specific biodiversity targets have been set for estuary ecosystem types, and a fixed target of 20% was used. The categories for protection level are: Well Protected where the extent protected exceeds the biodiversity target; Moderately Protected where the extent protected is between 50 and 99% of the target; Poorly Protected where the extent protected is between 5 and 49% of the target; and Not Protected where the extent protected is less than 5% of the target.

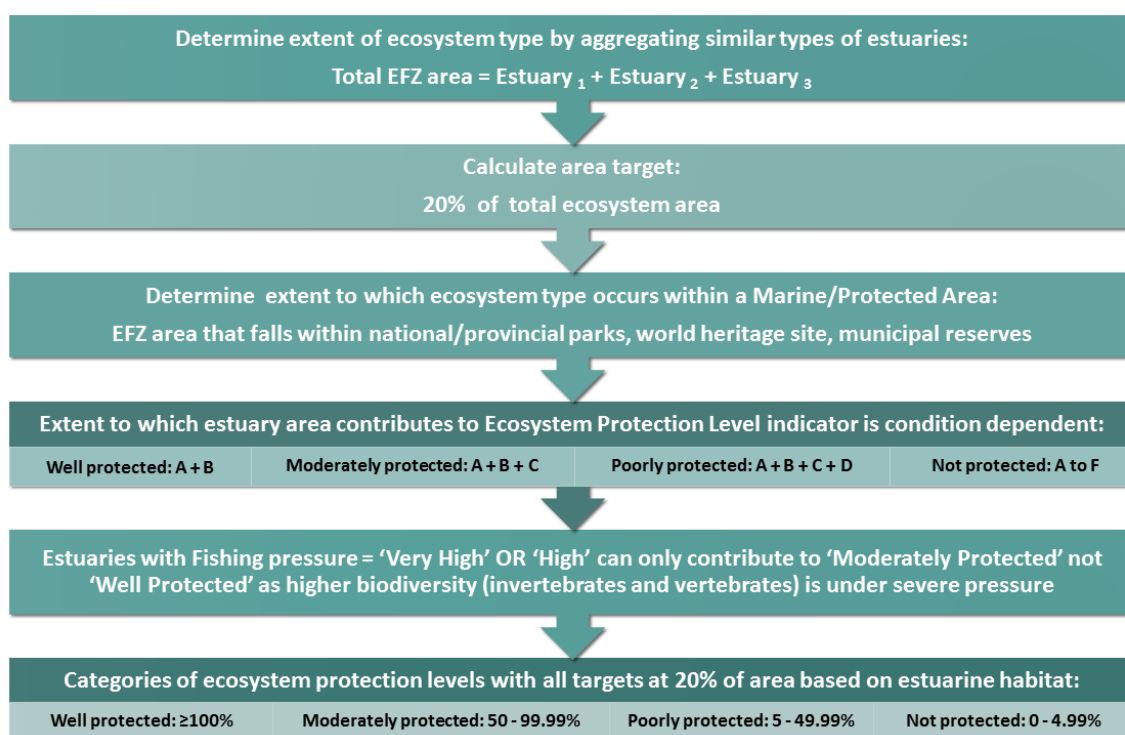


Figure 65. Schematic representation of the process followed in determining the estuary ecosystem protection levels.

The protection level indicator was adjusted for estuaries by applying two additional rules (Figure 65):

- 1) Only Natural / Near natural condition (Present Ecological Status, PES = A-B) estuaries were eligible for the Well Protected category, only Natural to Moderately modified (PES = A-C) estuaries were eligible for the Moderately Protected category and only Natural to Heavily (largely) modified (A-D Category) estuaries were eligible for the Poorly Protected category;

- 2) To reflect the impact that overutilisation of living resources has on the faunal component of estuaries, good condition systems (PES = A-B) that were subject to high or very high levels of fishing pressure were not eligible for the Well Protected category. However, it should be noted that this impact is reversible in the short-term.

8.2.4 Ecosystem protection level results

Ecosystem protection levels for the 22 ecosystem types calculated according to the above-mentioned criteria Figure 65 are listed in Table 45. The table provides a summary of protection levels per ecosystem type for each of the four biogeographical regions based on the total EFZ area, the percentage area in marine/protected areas, the ecosystem condition, level of fishing pressure in natural and near natural condition systems (i.e. the degree these areas can contribute to the well protected category).

Estuarine ecosystem protection levels are low, both in terms of number of types and in area. Overall, nearly 82% (19 out of 22 types) of South Africa's estuarine ecosystem types are under-protected. Only 18% of estuarine ecosystem types are Well Protected (4 types), while about 36% are Moderately Protected (8 types) and 32% are Poorly Protected (7 types) (Figure 66 & Figure 67). The representation becomes even more grave if evaluated by estuarine area, with less than 2% of systems Well Protected, 25% Moderately Protected, and 69% and 11% Poorly and Not Protected, respectively.

On a positive note, this headline indicator is sensitive to the condition of the greater St Lucia Estuarine Lake System. As St Lucia improves in condition in the short to medium term, the overall protection levels will increase. Immediate gains can also be achieved through the management of fishing pressure in three key priority estuaries: Langebaan, Knysna and Kosi, allowing the Well Protected category to increase from 18% to 32% (10% of total estuarine area) without any additional declarations or legislation. This in turn will also assist with the recovery of key fish species such as Steenbras.

8.2.1 Ecosystem protection level trends

While the National Estuaries Biodiversity Plan was endorsed by government there has been little increase in the estuarine protected estate since NBA 2011, except for Sundays and part of the uThukela estuaries that was added as part of the newly declared offshore MPAs (less than 15 km²).

An even more disturbing occurrence was/is the opening up of protected areas that restrict fishing to exploitation. Thus, representing an effective erosion of protection levels for estuaries since 2011. This compromises nursery function and increases the need to control fishing in the open system.

Table 45. Summary of the input data and ecosystem protection levels.

ECOSYSTEM TYPE	TOTAL AREA (km ²)	BIODIVERSITY AREA TARGET: 20% (km ²)	% IN PROTECTED AREA/ MARINE PROTECTED AREA	PA/MPA ECOSYSTEM CONDITION EXPRESS AS % SA EFZ AREA				% AREA OF NATURAL/NEAR NATURAL SYSTEMS UNDER VERY HIGH & HIGH FISHING PRESSURE	ECOSYSTEM PROTECTION LEVELS
				Natural/Near natural	Moderate	Heavily	Serious/Critical		
CT: Arid Predominantly Closed	14.4	2.9	13	83	0	0	17	100	Moderately
CT: Estuarine Lagoon	60.2	12.0	99	100	0	0	0		Moderately
CT: Estuarine Lake	72.4	14.5	15	0	66	0	34		Poorly
CT: Large Fluvially Dominated	30.2	6.0	0	6	0	0	0		Not protected
CT: Large Temporarily Closed	39.5	7.9	44	0	0	91	8		Poorly
CT: Predominantly Open	154.6	30.9	1	0	0	100	0		Not protected
CT: Small Fluvially Dominated	0.0	0.0	38	100	0	0	0		Well
CT: Small Temporarily Closed	5.5	1.1	38	77	0	23	0		Well
WT: Estuarine Bay	30.1	6.0	99	100	0	0	0	100	Moderately
WT: Estuarine Lake	143.9	28.8	31	30	24	46	0		Moderately
WT: Large Fluvially Dominated	5.7	1.1	3	0	100	0	0		Poorly
WT: Large Temporarily Closed	70.0	14.0	12	80	12	8	0		Moderately
WT: Predominantly Open	177.8	35.6	14	35	45	20	0		Poorly
WT: Small Fluvially Dominated	1.2	0.2	83	100	0	0	0		Well
WT: Small Temporarily Closed	16.2	3.2	22	95	4	1	0		Well
ST: Estuarine Bay	28.2	5.6	0	6	0	0	0	19	Not protected
ST: Estuarine Lake	818.6	163.7	76	0	0	100	0		Poorly
ST: Large Fluvially Dominated	107.7	21.5	46	6	0	94	0		Poorly
ST: Large Temporarily Closed	52.1	10.4	7	60	33	6	0		Poorly
ST: Predominantly Open	76.9	15.4	19	94	2	0	4		Moderately
ST: Small Temporarily Closed	20.5	4.1	25	78	6	1	15		Moderately
TR: Estuarine Lake	81.7	16.3	92	100	0	0	0	100	Moderately

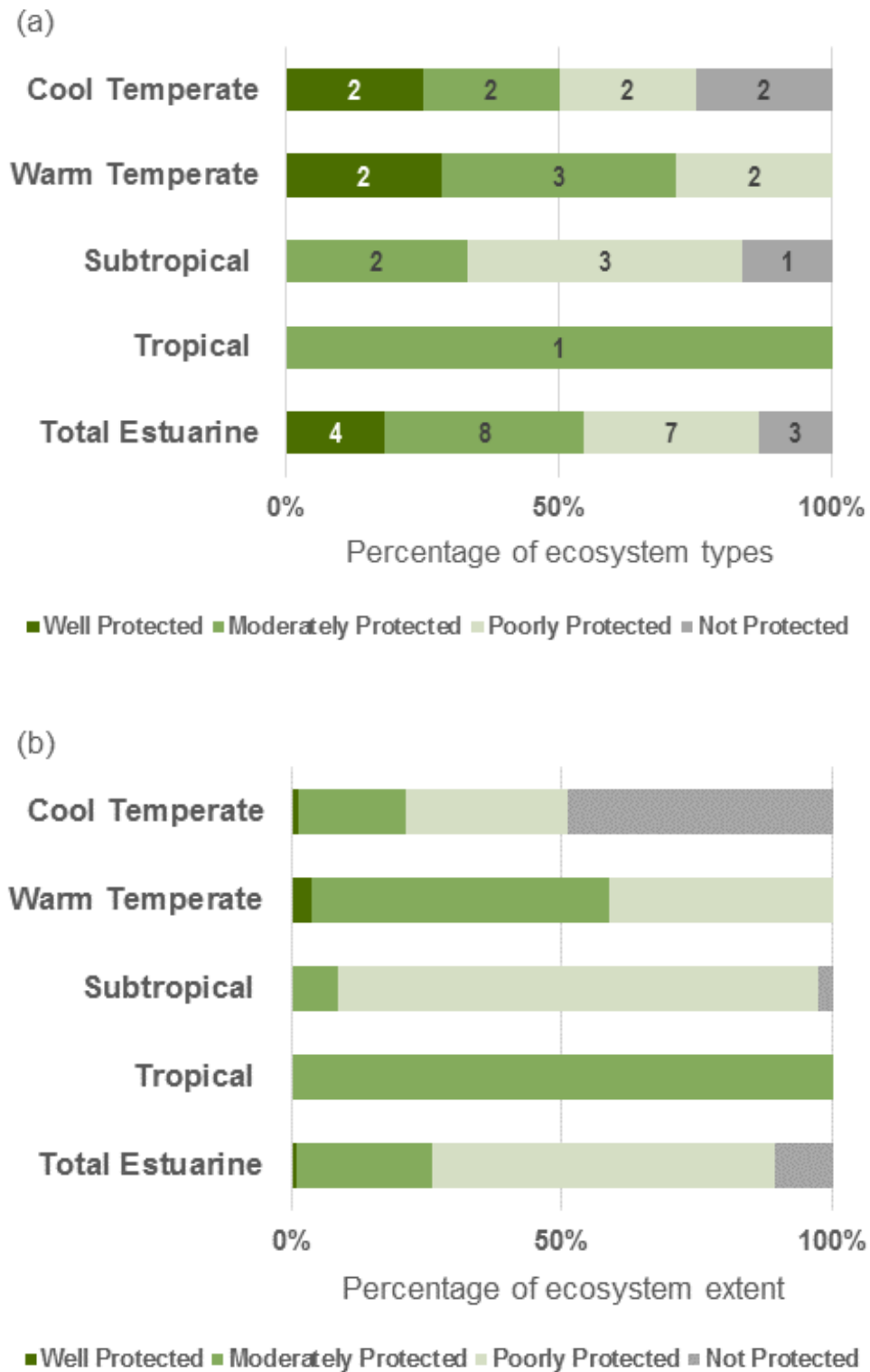


Figure 66. Estuarine Ecosystem Protection Levels in South Africa by percentage of types (a) and percentage area (b).

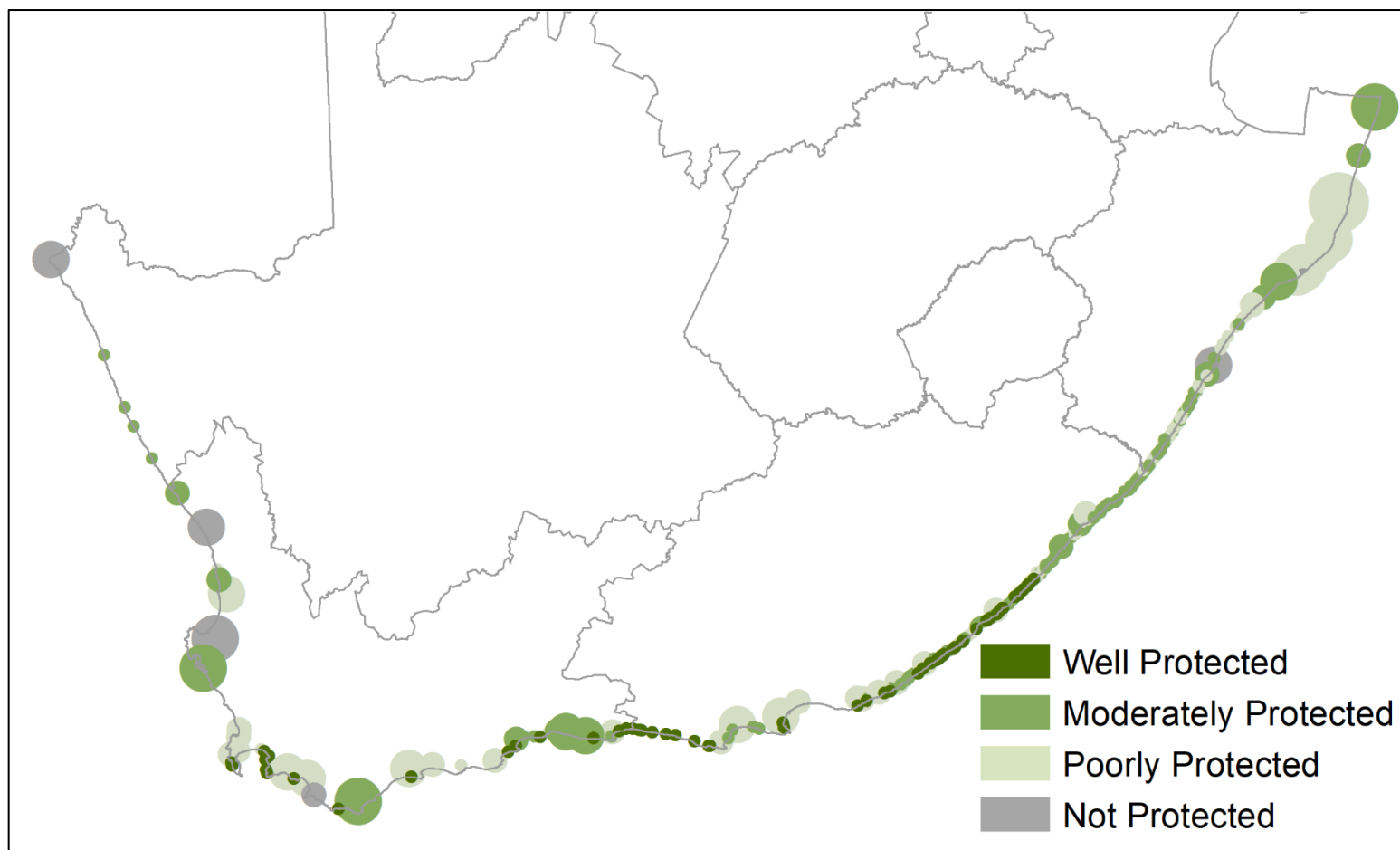


Figure 67. Schematic representation of estuarine ecosystem protection levels (size of the dot represents area of the individual estuary).
Note: there are many overlaps between points that can obscure the status of smaller estuaries; consult the GIS data viewer via the NBA website for detailed spatial data. Cartographic corrections from Synthesis Report included.

8.2.2 Ecosystem protection level limitations in this environment

Ecosystems protection levels are just one of a range of measures that document the progress in the protection of estuaries. The results of the ecosystems protection level assessment should not be decoupled from progress in environmental flow allocations, fisheries control measures and land-use and infrastructure development processes and measures. Estuaries are open systems and can only be judged to be well protected if all these aspects are concurrently addressed.

8.2.3 Ecosystems of conservation priority that are highly threatened and not protected

Of the 22 estuarine ecosystem types, 18 are threatened and under protected. Three of these are highly threatened (Critically Endangered or Endangered) and Not Protected (Table 46). These estuary types, which include most of the Large Fluvially Dominated, Estuarine Bays, Predominantly Open types of the Western Cape and KwaZulu-Natal, represent urgent priority estuarine ecosystem types for protected area expansion and management planning.

Table 46. Cross tabulation of estuarine ecosystem threat status and protection levels, highlighting those types that are under protected and highly threatened.

	NOT PROTECTED	POORLY PROTECTED	MODERATELY PROTECTED	WELL PROTECTED	TOTAL
CRITICALLY ENDANGERED	1	1	0	0	2
ENDANGERED	2	4	3	1	10
VULNERABLE	0	2	5	0	7
LEAST CONCERN	0	0	0	3	3
TOTAL	3	7	8	4	22

9. INDIGENOUS SPECIES ASSESSMENTS

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Indigenous Species Assessment

- Of the 66 species assessed 18 (27%) are threatened with extinction.
- There are 176 estuarine-associated plant species, the majority of which are associated with salt marsh habitat.
- About 50 of the 150 estuarine-associated fish species are Southern African endemics, of which 20 are exclusively found in South African waters. Some estuarine fish and invertebrate species are confined to 5, or less, systems. Several linefish species are threatened e.g. Dusky Kob which is Critically Endangered and at <1% of pristine reproductive adult biomass or breeding potential; White Steenbras is Endangered at <6%.
- Overall 35 bird species are considered highly dependent on estuaries. About 14% of estuarine bird species are threatened with extinction, with nearly ~265 000 waterbirds lost from South African estuaries since the 1980s.

9.1 Species Diversity in the Estuarine Realm

Species diversity is high in South African estuaries due to the diversity of estuary types as well as the change in biogeographic zones around the coast. There are 176 estuarine-associated plant species, the majority of which are associated with salt marsh habitat. Macrophyte species richness is higher in estuaries of the Cool and Warm Temperate region compared to the Subtropical and Tropical region. Macrophyte species are distributed in 58 families, predominantly *Cyperaceae* (23 species), *Chenopodiaceae* (18), *Mesembryanthemaceae* (14) and *Asteraceae* (11), while 33 other families have only one representative species. Only *Juncus kraussii* and *Phragmites australis* occur in more than half of South African estuaries. Only 66 plant species occurred in five or more estuaries in the country.

Endemicity assessments of invertebrates are scarce across estuarine biogeographical regions and within habitats. Estuary classification provides an indication of the propensity for euryhaline organisms to dominate, given that open systems are also inhabited by marine taxa (thus increasing system biodiversity). Marine invertebrate species contribute significantly to total marine endemicity (28%) of South Africa (Griffiths & Robinson 2015), particularly amongst non-motile and non-broadcast spawning groups. Assuming a similar pattern in estuaries from shallow water marine systems *Pericardid* crustaceans (Amphipoda, Isopoda, Cumacea) are highly endemic with species endemicity reported at >70% for the latter groups and >30% for the amphipods. *Decapoda* and phyla such as *Mollusca* (Gastropoda and Bivalvia) and *Annelida* (Polychaeta) similarly show high endemicity. Little taxonomic work has done for other worms (Nematoda, Nemertea, Sipuncula), these likely to yield high endemicity too, given specific estuarine habitat requirements. The cool temperate, southern coast has without exception the highest endemicity (Awad *et al.* 2002), and apart from the Amphipoda, groups increase in species richness eastwards to the warm temperate, subtropical regions. In these regions it is not uncommon for complex associations of congeneric species to occur, seemingly partitioned

according to microhabitats within a single estuary e.g. *Grandidierella lignorum*, *G. lutosa*, *G. chelata* amphipods in subtropical estuaries from Mbashe to southern KwaZulu-Natal.

Approximately 50 of the 150 estuarine-associated fish species that regularly occur in our estuaries are Southern African endemics of which 20 are exclusively found in South African waters. Some estuarine fish and invertebrate species are confined to a less than a handful of systems. For example the iconic Knysna seahorse (*Hippocampus capensis*) only occurs in three estuaries (Knysna, Swartvlei, Keurbooms), the Botrivierklipvis (*Clinus spatulatus*) in two estuaries (Bot/Kleinmond and Klein) and the Estuarine Pipefish (*Syngnathus watermeyerii*) in five estuaries (Bushmans, Kariega, Kasouga, East and West Kleinemonde) – more recently only confirmed in the Bushmans and Kariega estuaries. Even important ‘bait’ invertebrate species Sandprawn (*Callichirus kraussii*), Mud Prawn (*Upogebia africana*) and the Caridean Shrimp (*Macrobrachium petersii*) are southern African endemics, while the Freshwater Sand-shrimp (*Palaemon capensis*) is a South African endemic.

The importance of South Africa’s estuaries for resident and migratory waterbirds has long been recognised (Hockey *et al.* 1992; Turpie 1995). A total of 35 bird species are considered highly dependent on estuaries as more than 15% of their regional population is found in coastal lagoons and estuaries. The 118 waterbird species found in South African estuaries belong to eight orders, 25 families and 73 genera. While most species are found throughout the coast, there are some species which are predominantly confined to the west of the country, and in general, species richness increases towards the east, into the subtropical and tropical regions, resulting in a small level of variation from 90 to 110 species around the coast (Turpie & Forsythe *subm.*). The strongest predictor of bird species richness is estuary size, biogeographic region and water clarity resulting from the type of catchment also impacts species-richness: area relationship (Turpie & Forsythe *subm.*).

9.2 Species Assessment methodology

Threat status of South Africa’s estuarine species was calculated using the latest version of the IUCN Red List Categories and Criteria, version 3.1 (IUCN 2012a). The categories are summarised in Figure 68, and the criteria thresholds are summarised Table 47. The IUCN Red List system is a quantitative, objective system that can be consistently applied across a 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. Key data that was collected for each species in order to apply the IUCN Red List Criteria include: distribution (Extent of Occurrence), area of occupied habitat (Area of Occupancy), population size and structure, changes in population size over a specified time period, pressures to each species and the impact that these pressures have on the population size and the quality of available habitat (Table 47) for what key sources of information were used for each taxonomic group).

The assessment scope was South Africa's geopolitical domain; non-endemic species assessments were conducted using the IUCN's regional assessment criteria (IUCN 2012b).

All Red List assessments produced for this NBA are published on the Red List of South African Plants <http://redlist.sanbi.org/> or the Red List of South Africa's Animals <http://speciesstatus.sanbi.org/>.

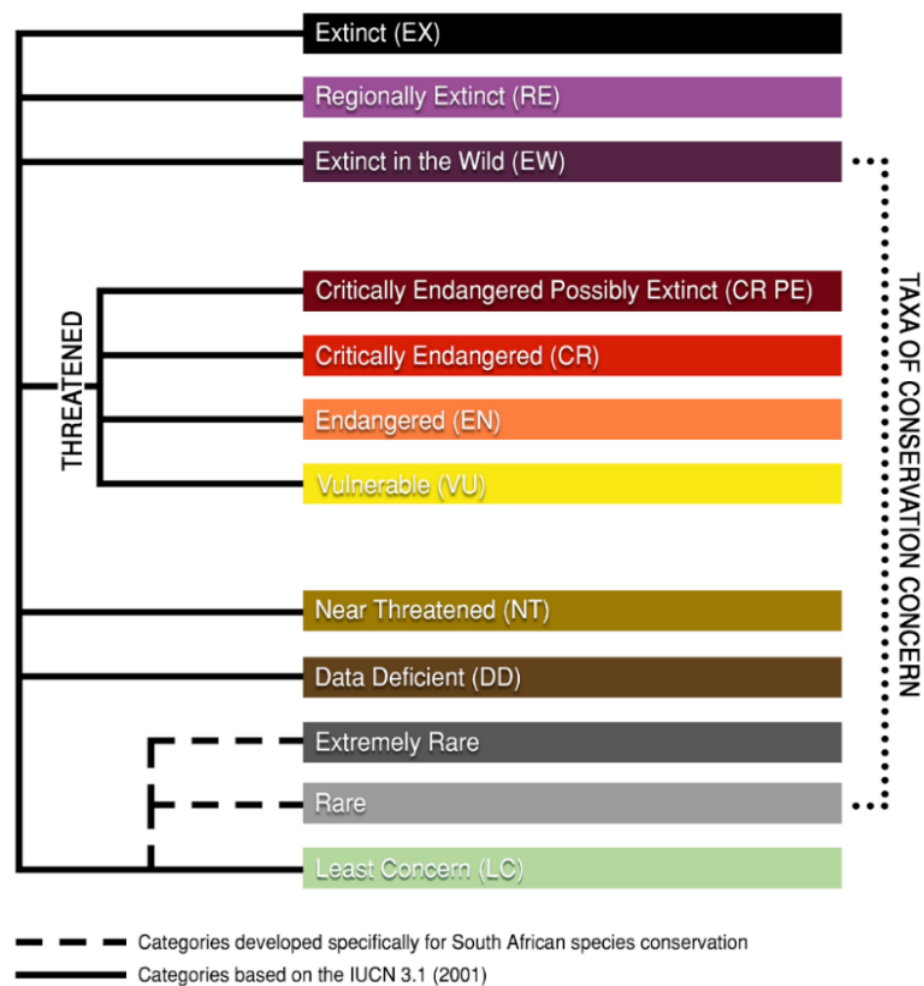


Figure 68. Categories for species red list assessment work, note South Africa uses the IUCN Red List Categories and Criteria, version 3.1 (IUCN, 2012a). National categories of rarity apply to restricted range species that have no anthropogenic pressures.

Table 47. 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.	<i>based on any of the following:</i>		(a) direct observation [except A3]
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.			(b) an index of abundance appropriate to the taxon
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].			(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality
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.			(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 km ²	< 5,000 km ²	< 20,000 km ²
B2. Area of occupancy (AOO)	< 10 km ²	< 500 km ²	< 2,000 km ²
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 km ² 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 Input Data

Selected invertebrates, plants and fishes were included in this assessment with criteria for selection including endemism, economic importance, whether they were crucial for estuarine habitat formation, and/or indicative of realm connectivity (catadromous species requiring intact habitats and freedom of movement across realms) (Table 48). Bird taxa associated with estuaries were extracted from a comprehensive national Red List Assessment completed by BirdLife (Taylor *et al.* 2015). In total 66 species were assessed: 35 birds, 20 fishes, five invertebrates and six plants.

Table 48. Primary input data used for estuarine species threat status assessments.

PLANT
Colloty (2000) collated an initial list of macrophyte species occurring in South Africa's estuaries. This has subsequently been updated by the Nelson Mandela University through site visits, graduate research projects, ecological water requirement studies and other initiatives that included macrophyte mapping and a detailed assessment of species composition (Adams <i>et al.</i>, 2016). These data are managed in an Estuary Botanical Database which includes: • Location, habitat area and human pressures such as extent of development; • Habitat cover available for 18% (53/297) of South Africa's estuaries; • Presence of macrophyte species collected in 297 different estuaries; • Habitat richness which includes the number of estuary habitats in each estuary.
INVERTEBRATES
Consolidating records of the five selected species was conducted at a desktop level based on published historical literature (assembled where possible from mid-century onwards), grey literature investigational reports and various unpublished data. Data were collated, recording the reference for each datum, and the presence/absence/density of the subject species. Where available, additional data on sampling methods (including sieve mesh size and area sampled) were included. Additional notes emanating from the wide-ranging studies were tabulated to inform interpretation wherever possible; e.g. the definition of terms such as 'rare', or the spatial distribution of the subject species within an estuary. Where information on aspects of the biology or ecology of species was lacking, additional literature reviews on related species were conducted to facilitate deductive reasoning about the likely life history traits of the species of interest. The NBA 2019 Estuarine Management and Monitoring Register was used to correlate pressures with presence of invertebrates and based on expert guidance these data were extrapolated to estimate population declines.
FISH
Fish distribution, abundance, species composition and assemblage / community structure data were obtained from current monitoring programmes and historical surveys, published and unpublished literature. The prime historical data source is Harrison 1994 with sampling catch data, totalling 145 species, from the lower, middle and upper reaches of 232 estuaries from the Orange to Kosi Bay. Recent data includes 45 estuaries regularly surveyed by DEFF Fisheries Research & Development since 1998. These data include seine and gillnet sampling from at least 10 sites in medium to large estuaries and lower, middle and upper reaches in small systems. See the NBA 2019 Estuarine Management and Monitoring Register for detail and specific systems.
BIRDS
Trends in abundance of birds was determined by comparing historic count data collected between 1977 and 1982 for the entire coast of South Africa (with the exception of the inaccessible Transkei Wild Coast between the Kei to uMthavuna estuaries) with data collected as part Co-ordinated Waterbird Counts (CWAC; cwac.adu.org.za), collected from 1992 onwards. The data collected between 1977 and 1988 covered 171 estuaries (94% of the estuarine area in

South Africa) in which almost 390 000 birds of over 100 species of non-passerine waterbirds were recorded (Ryan *et al.* 1988, 1986; Ryan & Cooper 1985; Turpie *et al.* subm.; Underhill 1987; Underhill & Cooper 1984).

The CWAC programme has monitored 72 estuaries since 1992, with at least 25 of these still ongoing. Given underrepresentation of the Transkei Wild Coast in early counts and in the CWAC programme, two counts were made of these estuaries in 2002 and 2012, respectively (Turpie *et al.* 2004; Turpie & Whittington, unpubl. data). In addition, various counts have been made of individual estuaries for other studies. Based on the list of estuarine birds published in Hockey & Turpie (1999), Turpie and Forsythe (subm.) and Turpie *et al.* (subm.) collated and analysed these and other existing South African estuary count data for 118 non-passerine, indigenous estuarine waterbird species (i.e. excluding vagrant, extra-limital exotic, domestic species and hybrids). The species were also grouped into 14 functional groups for the analysis.

9.4 Species threat status in the estuarine realm

Of the 66 species included in this assessment, 18 (27%) are threatened with extinction (Figure 69). While this finding corresponds well with the ecosystem assessment where a high proportion of ecosystems are highly threatened (Chapter 8), it is based on a limited set of species assessments that include a high proportion of range restricted endemics, economically important species or habitat forming species. Of the groups considered, only birds were comprehensively assessed. Future assessments need to include all representatives of a taxonomic group to remedy this bias.

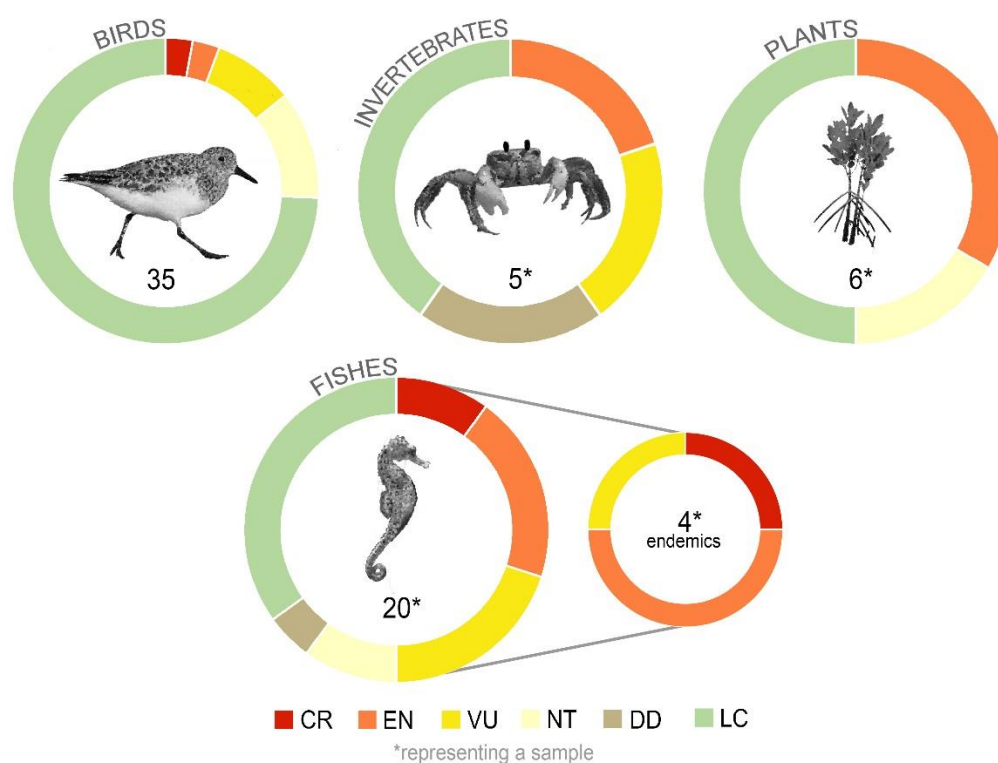


Figure 69. The proportion of indigenous estuarine species assessed to date in each of IUCN Categories of extinction risk: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Data deficient (DD), Least Concern (LC). Only birds were assessed comprehensively.

9.4.1 Plants

Six plants species were selected for assessment as part of the estuarine component of the National Biodiversity Assessment these included five species of mangrove and seagrass (*Zostera capensis*) (Figure 70 and Table 50). There are in fact six species of mangrove in South Africa, however the Mahogany mangrove *Xylocarpus granatum* consists of only one non-reproductive individual at Kosi Bay, near the border of Mozambique. And while the possibility exists of recolonization by means of long-distance drift seed dispersal from populations outside of South Africa, this has not occurred in over 30 years, this species was therefore excluded from the assessment.

The majority of mangrove species have a very small distribution on the South African coast relative to their global distribution. However, with this being their southernmost distribution, conservation of their habitat is critical to provide opportunity to respond to climatic change. Mangroves are relatively resilient and are able to recolonise sites after disturbance, but there have been a number of cases of permanent losses, when river mouths are closed for extended periods. Mangroves have been lost from some KwaZulu-Natal estuaries largely due to urban and industrial development along the coast. Harvesting activities, cattle browsing, pollution and competition from invasive species are also of concern (Hoppe-Speer et al. 2015, Adams et al. 2016).

One mangrove species has been assessed nationally as Endangered (*Lumnitzera racemosa*), one as Near Threatened (*Rhizophora mucronata*), while three species are assessed as Least Concern (*Ceriops tagal*, *Bruguiera gymnorhiza*, *Avicennia marina*). Major pressures impacting the two species of conservation concern are harvesting, habitat degradation by agricultural activities causing eutrophication and, in the past, habitat loss to urban and industrial development. *Lumnitzera racemosa* is only known from a single location and is declining as a result of harvesting. The species occurs in the upper drier parts of the Kosi Bay Estuary which makes the species more accessible to harvesters. The branches are harvested for firewood and building fish traps. A recent study by Rajkaran (2011) found a higher ratio of adults to seedlings, which may indicate that recruitment is being negatively impacted. This one subpopulation occurring in South Africa qualifies as 'Critically Endangered', however as this species is widespread outside of South Africa, the IUCN regional criteria were applied and the species status was adjusted to Endangered. While species assessed as Least Concern are also facing pressures, their overall population in South Africa have remained stable with reductions in certain estuaries offset by increases in others.

Unlike White Mangrove (*Avicennia marina*) and Black Mangrove (*Bruguiera gymnorhiza*) that have stable populations, Red Mangrove (*Rhizophora mucronata*) is declining, but is not yet considered close to extinction. Red mangrove occupies the same habitat as *Bruguiera gymnorhiza*, however it is unable to regenerate as quickly following disturbance. The Indian Mangrove (*Ceriops tagal*), which in South Africa is restricted to a small area around Kosi Bay, northern KwaZulu-Natal but extends northwards along the Mozambican coast to Somalia and is also commonly found throughout South East Asia. This species was previously been listed as 'Rare' in South Africa (Hall et al. 1980; Hilton-Taylor 1996) however with its wide global range and no known decline within South Africa it is considered Least Concern.

The Freshwater Mangrove (*Barringtonia racemosa*) is sensitive to changes in water salinity in estuarine areas as it does not have the high salt tolerance adaptation of true mangrove species (Osario *et al.* 2014). Mass diebacks have been reported following changes (mostly due to infrastructure development and water abstraction) in the flow dynamics of tidal inundation. The species is able to recover and re-establish after die-backs. According to Rajkaran *et al.* (2009) upstream damming and water abstraction, which leads to reduced flow and more frequent and prolonged estuary closed-mouth conditions, may be increasing available habitat for *B. racemosa*, to the detriment of other true mangrove species. Other threats to *B. racemosa* include fungal disease, which cause fruit abortion (Osario *et al.* 2015), and climate change induced sea-level rise (Naidoo 2016). Although the current population trend is not known, it is suspected to be either fluctuating or increasing, particularly in smaller estuaries on the KwaZulu-Natal South Coast.

Seagrass (*Zostera capensis*) occurs along the southeast coast of Africa from South Africa to Kenya, yet despite its seemingly large global distribution the species occupies a very small area. Seagrass provides habitat in the form of substrate for epiphytes and periphyton, and foraging and nursery areas for many fishes and invertebrates. Globally seagrass is assessed as Vulnerable, but in South Africa it qualifies as Endangered based on the very small areas of occupancy mapped to be between 11-13 km². It is experiencing continued loss of populations and degradation of habitat from extended mouth closures, dredging, eutrophication, competition from invasive aquatic species and recreational disturbances. Its largest population in South Africa occurs in an area 3.53 km² in the Knysna Estuary. It has been lost from both the Durban Bay and St Lucia systems. It experiences extreme fluctuations in population size, due to the dynamic changes in cover abundance in response to floods, droughts, sedimentation and freshwater abstraction. A recent review of *Zostera capensis* in South Africa shows that it remains present in 62 estuaries along the coastline (Adams 2016). Recent and ongoing studies regarding the blue carbon potential of this species is improving our understanding of its dynamics and providing more detailed distribution maps.

In addition to species assessed for the National Biodiversity Assessment, macrophytes that have been recorded to be associated with South Africa's estuaries by Colloty (2000) and updated by Adams *et al.* (2016) were checked to determine if additional species of conservation concern occur within South Africa's Estuaries (Table 50). Many plant additional plant species of conservation concern found within estuarine functional zones occur in the Western Cape due to the high levels of plant endemism in this part of our country.

These include *Cotula filifolia*, (Near Threatened) which is most typically associated with coastal wetlands and *Psoralea repens* (Near Threatened) and *Podalyria sericea* (Vulnerable) both associated with coastal fynbos vegetation. The main threat to these species is coastal development and inappropriate fire management. The sedge (*Ficinia pygmaea*) and a species of sea lavender (*Limonium depauperatum*), are also Western Cape endemics and are categorised as 'Near Threatened' and 'Endangered' respectively, with declining populations. *Limonium depauperatum* is known from Berg River floodplain and estuarine banks. Historic records from Greenpoint in Cape Town are likely to be lost. Another species of sea lavender (*Limonium linifolium*) (Near Threatened) is a South African

endemic that occurs in the Western and Eastern Cape in saline pans and estuaries (Helme & Van Der Colff 2015) it has been recorded as a main component of the supratidal salt marsh in 15-20 estuaries and is fairly tolerant of disturbance.



a) Kobonqaba Estuary



b) Nxaxo Estuary



c) Keurbooms Estuary



d) Kariega Estuary

Figure 70. a) *Zostera capensis* exposed during low tide in the Kobonqaba Estuary (July 2015). b) White Mangrove (*Avicennia marina*) propagules growing in the *Z. capensis* beds (Nxaxo Estuary, May 2016), c) Small fish in *Z. capensis* beds at Keurbooms Estuary (March 2013), d) Healthy *Z. capensis* with epiphytes in the Kariega Estuary (October 2015).

Three hydrophytes listed as of conservation concern include: *Aponogeton angustifolius* (Vulnerable), *Pseudalthenia aschersoniana* (Critically Endangered) and *Wolffiella denticulate* (Vulnerable). The first two are found in the Western Cape, with *Aponogeton* occurring in freshwater pools, vleis and slow moving rivers where it is threatened by changes in flow regimes associated with urban expansion and agriculture. *Pseudalthenia aschersoniana* is only known from the Cape Peninsula where it occurs in brackish pools near the sea and is highly threatened by urban development. *Wolffiella* occurs in upper KwaZulu-Natal in the St Lucia Estuarine Lake and Richards Bay area. These species were last assessed a decade ago and should be monitored to determine the current status of populations

While the above covers species that have been recorded in South Africa's Estuary Botanical Database, a number of other aquatic plant species of conservation concern are associated with estuaries but are so poorly known that they have not yet been included. One priority species is *Cotula myriophylloides* (Critically Endangered) this species used to occur commonly in the estuaries of the Cape Peninsula but has gone extinct here. This species is now only known from three isolated, very widely separated estuaries, scattered over an area of over 400 kilometres. *Kewa arenicola* (Data Deficient) is another rare and very poorly known species, recorded from three widely disjunct localities. It is possibly localized to estuaries, but the most recent record dates from 1957, and all records have imprecise locality descriptions. Historical localities on the Cape Flats are likely to be locally extinct due to habitat loss, but it possibly still survives at De Hoop and the Swartkops Estuary near Redhouse, Port Elizabeth. Other estuaries between Cape Town and Port Elizabeth need to be surveyed for the presence of this species.

Preliminary research was completed on the population genetics of estuarine macrophyte species (intra- and interspecific genetic diversity). The aim was to identify estuaries (the smallest unit in estuarine conservation) that contain evolutionary significant units (ESUs) at intraspecific level, as well as those that contain a high level of phylogenetic diversity (PD). In total 31 estuaries had unique haplotypes or Evolutionary Significant Units (ESUs). These include large systems such as the Langebaan Lagoon, Olifants and Groot Berg estuaries, that contain unique ESUs of *Sarcocornia pillansii*, *Triglochin striata* and *Sarcocornia tegetaria*. However, some smaller estuaries were also identified as having unique haplotypes (ESUs); for example, the Hartenbos, Verlorenvlei and Uilkraals contain unique haplotypes for *J. kraussii*, *S. tegetaria* and *S. pillansii*. These data can be used to prioritise estuaries for conservation. Phylogenetic Diversity (PD) was greatest in 41 estuaries. Along the west coast these estuaries included the Orange, Groen, Langebaan and the Olifants. Phylogenetic Diversity (PD) was lowest along the south coast where estuaries with the highest PD were Van Stadens and Swartkops estuaries. Along the south-east coast PD was highest in estuaries with greater habitat diversity (i.e. combination of mangrove and salt marsh habitats).

Ongoing monitoring of Estuaries and Estuarine Functional Zones for the presence of macrophyte species of conservation concern is a priority going forward. Data on these species need to inform environmental authorisations associated with development applications earmarked to take place within Estuarine Functional Zones.

Table 49. Macrophyte species assessed for this National Biodiversity Assessment.

SPECIES	FAMILY	COMMON NAME	CATEGORY	DISTRIBUTION	HABITAT	THREATS	REFERENCE
<i>Avicennia marina</i> (Forssk.) Vierh	Avicenniaceae	White Mangrove	LC	Widespread across the east coast from Chalumna to Kosi Bay and occurs in a large number of estuaries.	Common and often dominant constituent of mangrove swamps (usually the seaward fringes of mangrove associations) and is also a pioneer of new mud banks.	Continuous habitat loss due to urban, industrial development and infrastructure development	Adams <i>et al.</i> 2016a.
<i>Bruguiera gymnorhiza</i> (L.) Lam.	Rhizophoraceae	Black Mangrove	LC	Widespread along the east coast of South Africa from the Nahoon to Kosi Bay.	Evergreen woodlands and thickets along the intertidal mud-flats of sheltered shores, estuaries and inlets, mainly towards the landward side of mangrove formation.	Estuary mouth closure, increase in water level and flooding	Adams <i>et al.</i> 2016b.
<i>Ceriops tagal</i> (Perr.) C.B.Rob.	Rhizophoraceae	Indian Mangrove	LC	Very limited distribution on the coast of South Africa	Evergreen woodlands and thickets along the intertidal mud-flats of sheltered shores, estuaries and inlets. The most inland of the <i>Rhizophoraceous</i> mangroves.	No major threats	Adams <i>et al.</i> 2016c.
<i>Lumnitzera racemosa</i> Willd. var. <i>racemosa</i>	Combretaceae	Tonga Mangrove	EN B1ab(ii,iii,v)+2 ab(ii,iii,v)	Kosi Bay	Mangrove swamps, usually on the landward side.	Harvesting for firewood	Rajkaran <i>et al.</i> 2017.
<i>Rhizophora mucronata</i> Lam.	Rhizophoraceae	Red Mangrove	LC	Nahoon to Kosi Bay	Evergreen woodlands and thickets along the intertidal mud-flats of sheltered shores, estuaries and inlets, mainly along channels in estuaries and sometime in the seaward side of the mangrove formation.		Rajkaran <i>et al.</i> 2016.

SPECIES	FAMILY	COMMON NAME	CATEGORY	DISTRIBUTION	HABITAT	THREATS	REFERENCE
<i>Xylocarpus granatum</i> J.König	Meliaceae	Mangrove Mahogany	NA	Single individual in Kosi Bay	Tidal mud of mangrove swamps, especially towards their upper limits.		SANBI 2017.
<i>Barringtonia racemosa</i> (L.) Roxb.	Lecythidaceae	Powder Puff Tree	LC	Coastal areas between the Eastern Cape and KwaZulu-Natal	Streamsides, freshwater swamps and less saline areas of coastal mangrove swamps.	Sensitive to salinity changes thus tidal intrusion caused by infrastructure development and water abstraction as well as sea level rise associated with climate change is the main threat. Fungal disease and chemical pollution is also problematic.	Von Staden 2016.
<i>Zostera capensis</i> Setch.	Zosteraceae	Eelgrass	LC	Olifants River Mouth on the Cape West Coast to Kosi Bay, northern KwaZulu-Natal.	Intertidal zone of permanently open estuaries. It occasionally persists in temporarily closed estuaries when conditions are saline.	Development, freshwater abstraction, catchment disturbance, disturbance by boats & bait diggers, eutrophication resulting in shading and competition.	Adams & Van der Colff 2016; Adams 2016.

Table 50. Additional macrophyte species of special concern recorded in the Estuary Botanical Database (Adams *et al.* 2016).

Species	Family	Category	Distribution range	Habitat	Reference
<i>Aponogeton angustifolius</i> Aiton	Aponogetonaceae	Vulnerable A2c; B1ab(iii)	Gouda to Worcester and the Cape Flats.	Sandy lakeshores that dry out in summer, shallow pools or slowly flowing rivers, in water up to 1m deep.	Sieben <i>et al.</i> 2010.
<i>Cotula filifolia</i> Thunb.	Asteraceae	Near Threatened B2ab(ii,iii,iv,v)	Cape West Coast, from Hondeklipbaai to the Cape Peninsula, and on the Agulhas Plain.	Marshy ground, pools and damp places.	Powell <i>et al.</i> 2013.
<i>Ficinia pygmaea</i> Boeck.	Cyperaceae	Near Threatened B1ab(ii,iii,iv,v)	Lambert's Bay to Bredasdorp.	Seasonally wet coastal pans.	Muasya & Raimondo 2008.
<i>Limonium depauperatum</i> (Boiss.) R.A.Dyer	Plumbaginaceae	Endangered B1ab(i,ii,iii,iv)	Cape Flats and West Coast.	River and estuary banks.	Victor & Mucina 2004.
<i>Limonium linifolium</i> (L.f.) Kuntze is	Plumbaginaceae	Near Threatened B2b(ii,iii)	Gansbaai to Kei Mouth.	Coastal saline pans and estuaries.	Helme & Van der Colff 2015.
<i>Pseudalthenia aschersoniana</i> (Graebn.) Hartog	Potamogetonaceae	Critically Endangered B2ab(iii)	Cape Peninsula.	Brackish pools near the sea.	Raimondo <i>et al.</i> 2007.
<i>Wolffiella denticulata</i> (Hegelm.) Hegelm.	Lemnaceae	Vulnerable D2	Northern KwaZulu-Natal between Mtunzini and Kosi Bay and in Mozambique.	Floating in coastal freshwater marshes, lakes or slow moving streams.	Scott-Shaw & Von Staden 2007.

9.4.2 Estuarine invertebrates

Estuarine macroinvertebrates assessed for the first time in this NBA are also declining. The Giant Mud Crab (*Scylla serrata*) has experienced a significant increase in fishing pressure over the past five years. Traditionally this species was subjected to very low fishing pressure in South Africa, however the establishment of formalised syndicates along the Eastern Cape coastline to supply the rapidly growing demand for seafood, has led to increases in illegal harvesting. Furthermore, enforcement efforts have decreased on the KwaZulu-Natal coastline, which has resulted in increased pressure from cross-border subsistence fishing. This species is nationally assessed as vulnerable based on an estimated decline of more than 30% in the past 15 years.

Also in decline is the Sandprawn (*Callichirus kraussii*) (Figure 71), an important bait species and ecosystem engineer, whose sandbank habitat is threatened in KwaZulu-Natal as a result of sand mining in, and upstream of estuaries. Sand mining results in sand movement downstream, either smothering burrows of this species or completely removes sand habitats. Sand mining at various scales continues unabated despite the recent economic downturn and decline in coastal development, suggesting pressure for building



Figure 71. The Sandprawn (*Callichirus kraussii*) exposed on the sandy sediment surface (Photo: George Branch).

material inland. Upstream freshwater abstraction to support agriculture, domestic use and industry not only exposes river beds making these easier to mine, but also alters the natural salinity regimes of estuaries influencing the preferred physiological habitats for successful survival of this species.

Sandprawns have an active influence on the estuarine environment as they are important bioturbators and filterers affecting species diversity, community composition and the productivity of soft sediment environments through their burrowing activities (Pillay & Branch 2011). They are also important to estuarine food webs, being a food source for many bird and fish species (Clark 1998; Pillay & Branch 2011). The Sandprawn is one of the most popular bait organisms used by recreational and subsistence fisherman, although there are current bag limits for recreational collection of Sandprawn as a bait species (50 per person per day), there are no limits on the number of permits issued by the relevant authorities and cumulative impacts remain unquantified. With 39% of estuaries where this species occurs being impacted by sand mining and/or regular pollution events and harvesting for bait taking place at 90% of estuaries, decline in its habitat in estuaries is ongoing. Opportunities for recruitment from other estuaries are limited, given that larvae are

non-planktonic and remain in the parent burrow (Forbes 1973). Fortunately, this species is also known to still occur in marine bays, with two inshore marine populations recorded in the very sheltered portions of Algoa Bay and Table Bay (Cockroft & Tomalin 1987). Despite decline in habitat, this species has not yet crossed one of the IUCN thresholds for assessing a species as threatened and is currently listed as Least Concern.

Under far more pressure is the near endemic Mud Prawn (*Upogebia capensis*) (Figure 72) which occurs in temporarily open/closed and permanently open estuaries as well as estuarine bays and lakes and river mouths in South Africa and Mozambique along ~3 400 km from Lamberts Bay, in the west to Inhambane, in the east (Hanekom & Erasmus 1988, Branch *et al.* 2010). Their temperature tolerance is likely to limit their ability to inhabit estuaries further north in Mozambique (Hill 1971).



Figure 72. The Mud Prawn (*Upogebia africana*) crawling on a muddy, seagrass habitat (Photo: Alan Whitfield).

They have been identified in 69 of South Africa's c. 290 estuaries between 1956 and 2014. Estuarine, Mud Prawns have an obligatory marine phase, where first-stage juveniles migrate out of the estuary on the nocturnal ebb tide and return as post larvae to the estuary on the nocturnal flood tide (Wooldrige 1999). This obligatory marine phase leaves Mud Prawns particularly vulnerable to anthropogenic impacts, as altered flow into the estuary alters mouth state and breaching frequency. Nineteen (27%) of the estuaries where this species has been recorded in South Africa have had their flows significantly altered (Very High, and Highly modified), these changes in flow affect the mouth state of the estuary, resulting in prolonged mouth closure, which is known to have a deleterious effect on Mud Prawn communities (Day 1981; Wooldrige 2007), mouth closure for periods in excess of three years will result in complete loss of Mud Prawn populations. In addition, Mud Prawn are sensitive to sediment grain size, particularly the amount of fine sediment present. Wide scale changes in catchment land use, increased sand abstraction in rivers and direct physical changes to estuaries such as the construction of bridges result in a significant change to sediment grain size.

Thus while it is difficult to assess Mud Prawn populations directly, changes to mouth state as a result of altered freshwater inflow and sediment grain size is suspected to have resulted in an overall decline of the population in the past ten years. Its current status is Least Concern but ongoing monitoring is urgently required given this species sensitivity to long term flow modification.

A number of South Africa's crabs associated with estuaries are also under pressure, the River Swimming Crab (*Varuna litterata*) (Figure 73) is a catadromous tropical/subtropical species that has obligate freshwater and marine phases in its life history. It is therefore dependent on estuaries to provide the critical link between habitats for the completion of its life cycle (Figure 74). It has an Indo-Pacific distributional range; the South African portion of which has seen 31%



Figure 73. The River Swimming Crab (*Varuna litterata*)
(Source: Fiona MacKay).

of the estuaries which this species uses, suffering extremely high levels of flow reduction. The majority of these systems no longer opening to the sea at the correct time of year to allow for this species to migrate in and out of catchments (see Chapter 6). Furthermore, 59% of estuaries where this species has been recorded have high pollution levels. Migration events are specifically timed and movement from the ocean to rivers are events where significant numbers of megalopae (the final larval stage) return at once over a few days. Mass migration events that were regularly observed across many estuaries, have dwindled over the past five years. In addition, the St Lucia system used to be prime habitat, but *V.litterata* currently does not occur there as the estuary has had no recent connection to the ocean for a combination of reasons; the historical artificial diversion of the uMfolozi River away from the St Lucia mouth, manipulated catchment hydrology and an extended regional drought. With grouping of pressures across estuaries, the population is suspected to have declined by more than 50% over the past 10 years, it is therefore listed nationally as Endangered.



Figure 74. The River Swimming Crab (*Varuna litterata*)
recruitment through uThukela Estuary prior to
construction of the upstream weir (Source: Fiona
MacKay).

As this species does occur widely in the subtropical and tropical zones of the Western Indian Ocean, Eastern Indian Ocean and the Western Central Pacific Ocean, the regional population in South Africa is highly likely to experience immigration of individuals, however due to habitat modification it is likely that colonisation of formerly occupied habitats may be limited. An estuary restoration programme currently being implemented, to reconnect the uMfolozi River to the St Lucia Estuary, should result in a large area of habitat

(formerly 70% of this species South African estuarine habitat) once again being available for this species.

The genus *Solen* (Pencil Bait) includes a few of the few bivalve species found in South African estuaries. A recent study of the global distribution of Solenidae has determined that razor clam species tend towards high levels of endemism and that species richness is high on the southern African coast (Saeedi *et al.* 2017). One species *Solen capensis*, is endemic to estuaries in the warm temperate and cold temperate bioregions in South Africa. It occurs from the Olifants Estuary on the West Coast to St Lucia on the East Coast. In the warm temperate South Coast, there is an overlap in distribution with the more sub-tropical East Coast species *S. cylindraceus*. These two species can only be told apart by a trained taxonomist, that undertakes dissection of specimens. As a result, it is unclear in how many estuaries our endemic species *Solen capensis* occurs.

Unfortunately, all species of *Solen* that occur in South African waters are under major pressure as a result of changes in salinity associated with estuary mouth closure linked to water abstraction and drought. For example, the once extensive beds of *Solen* found in St Lucia Estuary (Nel *et al.* 2012) have now disappeared since 2017 as a result of mouth closure and persistent freshwater conditions. Additional pollution loading in the form of diffuse runoff from the catchment and point source discharges of domestic and industrial wastewater are known to have resulted in habitat loss for estuarine biota, and this is compounded by direct disturbance during bait harvesting (Wynberg & Branch 1994). At present, there are bag limits for subsistence or recreational use of this bait species (20 per person per day), however there are no limits on the number of permits issued by the relevant authorities and cumulative impacts remain unquantified. The level of risk associated with harvesting pressures is unknown, although Baird *et al.* (1981) found Pencil Bait in lower numbers in exploited communities than in protected (inaccessible) communities within the same estuary, and recent assessments have observed a general decline in abundance/density (Anchor 2015). Urgent monitoring is required to determine the current status of *Solen* populations in estuaries and to provide specimens for taxonomic identification, which will clarify the species transitions and overlap ranges in estuaries.

In addition to habitat destruction, altered freshwater flow and agricultural pollution, multiple incidences of untreated sewage into estuaries of KwaZulu-Natal has led to rapid and persistent eutrophication, facilitating invasion by invasive aquatic plants and invertebrates which displace indigenous invertebrates.

9.4.3 Fish

Several economically important linefish species that are estuarine-dependent are threatened by overfishing (especially gill-netting), reduced flow and concomitant influence on recruitment and marine connectivity and declining water quality. These include Dusky Kob (*Argyrosomus japonicus*) which is Critically Endangered and at <1% of pristine reproductive adult biomass or breeding potential; White Steenbras (*Lithognathus lithognathus*) is Endangered at <6%; White Stumpnose (*Rhabdosargus globiceps*) Vulnerable at <22%; Spotted Grunter (*Pomadasys commersonnii*) Vulnerable at <24%; and Leervis (*Lichia amia*) Vulnerable at <14% of pristine reproductive adult biomass. Of further concern is that all endemic fish species restricted to South Africa's estuaries are threatened. These include the iconic Endangered Knysna Seahorse (*Hippocampus capensis*), the Critically Endangered Estuarine Pipefish (*Syngnathus watermayeri*), the Endangered Bot River Klipvis (*Clinus spatulatus*), and the Vulnerable Freshwater Mullet (*Pseudomyxus capensis*).

Hippocampus capensis (Figure 75) is an estuarine seahorse species endemic to three estuaries in South Africa: the Knysna, Swartvlei, and Keurbooms estuaries. Historical and anecdotal records indicate that this species could previously be found in Klein Brak, Groot Brak, Goukamma, Groot, Kromme, Kabeljous and Gamtoos estuaries (Bell et al. 2003, Lockyear et al. 2006), but surveys carried out between 2001 and 2003 could only locate individuals in the Knysna, Swartvlei, and Keurbooms estuaries (Lockyear et al. 2006). The veracity of these previous records is questionable given that all recent confirmed records have either been Thorny Seahorse *Hippocampus hystrix* or Longsnout Pipefish *Syngnathus temminckii*.

Hippocampus capensis are found at depths between 0.5-5 m in association with submerged aquatic plants including *Zostera capensis*, *Caulerpa filiformis*, *Codium extricatum*, *Halophila ovalis*, *Ruppia cirrhosa*, *Codium tenue* and *Asparagopsis taxiformis* (Teske et al. 2007; Claassens 2016), though they are most likely to be found grasping *Zostera capensis* eelgrass holdfasts (Bell et al. 2003). They also make use of artificial habitat and preferentially choose artificial Reno mattress compared to natural eelgrass (Claassens et al. 2018).

The biggest threat to the Knysna Seahorse is the continued increase in nutrient inputs from the surrounding catchments into the Knysna Estuary (Human et al. 2016), which has resulted in ongoing algal blooms (Allanson et al. 2016), that displace eelgrass habitat (Human et al. 2016). One of the major sources of nutrient input into this system is the local Waste Water Treatment Works (Human et al. 2016), and a marked change in invertebrate population structures have been found in eelgrass areas impacted by the algal bloom (Barnes 2018). In the Keurbooms Estuary, Knysna Seahorse abundances recorded were low after a freshwater flood in



Figure 75. Knysna seahorse (*Hippocampus capensis*) - Endangered B1ab(iii,iv,v)+2ab(iii,iv,v) (Source: David Harasti)

September 2018 indicating that this species is vulnerable to freshwater floods in the two smaller systems it is found in. Further, in the Swartvlei Estuary artificial mouth, a breaching event in December 2017 resulted in a high number of seahorses being stranded due to receding water levels. Note however, that the Swartvlei population is likely to have historically been boom and bust in response to natural breaching events that would have resulted in even lower low tides after breaching, similar to Bot Klipvis in the Bot and Klein Estuary. This species is assessed as Endangered because it has an estimated extent of occurrence (EOO) of 300 km², an area of occupancy (AOO) of 27 km², and is experiencing continuing decline in quality of habitat and number of mature individuals.

Emerging threats are the illegal capture and supply of Knysna Seahorses to the aquarium trade and Asian traditional medicine market (Figure 76). Additional risks from the aquarium trade are the high incidence of seahorse tuberculosis in captive bred animals and the escape or intentional release of infected and / or



Figure 76. Dried seahorses confiscated at roadblock.

hybridized Knysna Seahorse into the estuaries where they naturally occur. Dried Knysna seahorses as well as a number of other Syngnathidae that occur in South African waters have been positively identified using genetic markers, in shops selling traditional medicine in China (Chang et al. 2013). Confounding this is the frequent issuing of import and export permits by government departments despite all harvesting, possession and trade of pipefish and seahorses being prohibited by MLRA 1998 and NEMBA TOPS regulations.

Key recommendation: Additional long-term monitoring in mark recapture is needed to determine population size and trends for this species. Habitat protection, water management measures and trade restrictions need to be implemented and enforced to secure the future of this species.

Syngnathus watermeyer (Figure 77), the Estuarine Pipefish, is endemic to South Africa currently occurring in the Bushmans, Kariega, and Kasouga estuaries on the Eastern Cape coast of South Africa. Previously also occurring in the East Kleinemonde estuary but has not been found since the last survey in 1996. It is found primarily in association with the Eelgrass (*Zostera capensis*) and the aquatic macrophyte *Ruppia cirrhosa*, where it feeds almost exclusively on zooplankton (Whitfield 1995). The species undergoes large fluctuations depending on macrophyte presence or absence, and generally is only found when they are present (Sheppard et al. 2011). A flood event in the East Kleinemonde estuary in 1996 resulted in submerged *Ruppia cirrhosa* beds being flushed out to sea and the localized extinction of *S. watermeyer* (Cowley 1998).



Figure 77. Estuarine Pipefish (*Syngnathus watermeyer*) - Critically Endangered C2a(i)b (Source: Fred Fourie)

S. watermeyer depends on regular freshwater influxes, to maintain its zooplanktonic food resource (Wooldridge 2007). High freshwater abstraction in Kariega and Bushmans is having a negative influence on availability of zooplankton and causing ongoing decline to this species. The species has been listed as Critically Endangered due to a continued decline in habitat quality. It is also likely that there are less than 250 animals in total and 50 mature individuals or less in each estuarine subpopulation, with extreme fluctuations occurring linked to the availability of macrophyte habitat.

Key recommendation: Rivers in the Eastern Cape Province need to have a freshwater allocations to ensure the ecological sustainability of downstream estuaries, thereby promoting the long-term conservation of the Critically Endangered Estuarine Pipefish. As populations have declined so substantially and are too low to allow natural recolonization of unoccupied estuaries during flood events we recommend translocation is considered to areas where suitable habitat exist.

Clinus spatulatus (Figure 78) is endemic to South Africa and is known only from the Bot/Kleinmond and Klein estuaries in the south western part of Western Cape Province. Both of these estuaries are impacted by reductions in freshwater inflow, pollution, eutrophication, urbanization and agriculture. These pressures are causing ongoing decline in habitat quality. Monitoring of one of these locations the Bot/Kleinmond Estuary between 2000 and 2010 showed that this species experiences extreme fluctuations in available habitat (area of occupancy) and in the number of mature individuals,



Figure 78. Bot River Klipvis (*Clinus spatulatus*) - Endangered B1ab(iii)c(ii,iv) +2ab(iii)c(ii,iv)

linked with the opening and closing of the estuary. During this period this estuary breached four times and on each occasion, in less than 24 hours, water levels dropped at least 2 m and the habitat area available to *C. spatulatus* shrank to as little as 4% of the full estuary.

Population estimates after each breaching were significantly lower than during estuary closure. Mean population size immediately after opening events was 10% of pre-breaching values changing for example from 2.8 million fish to 10 000 individuals post-breaching (von der Heyden *et al.* 2015). Whilst these fluctuations appear to be a natural part of the species' biology, during periods of breaching when the population is low it is more vulnerable to threatening processes such as pollution eutrophication and waterborne pathogens.

Members of the family are viviparous, and therefore reproduce at a local, site-associated level, and have low dispersive ability, characteristics that can increase vulnerability to processes causing population decline. Furthermore the two subpopulations may be becoming more isolated. Connectivity and genetic exchange between the two estuaries' subpopulations occurs during large coinciding floods with a natural return period of approximately once every 10 years when their flood plumes overlap. Agricultural activities in both catchments and climate change have seen a significant reduction in the frequency, occurrence and magnitude of flood events and an increase in duration of mouth closure in recent years.

Key recommendation: Environmental flow requirements and mitigation measures to counter the threats of pollution and poorly timed artificial breaching, and negative impacts of development on the two estuaries and *C. spatulatus*, are needed. Continued research on the biology and monitoring of this species' population status and habitat quality under the umbrella of South Africa's existing estuarine fish monitoring programmes is required. Continued research on the biology and monitoring of this species' population status and habitat quality under the umbrella of South Africa's existing estuarine fish monitoring programmes is required.

The **freshwater mullet** *Pseudomyxus capensis* (Figure 79) is one of the few marine fish species that makes extensive use of the riverine environment as a nursery area (Bok 1979). Although spawning occurs at sea, *P. capensis* lives mainly in estuaries, with large numbers also making use of rivers. It is an endemic species to South Africa occurring predominantly along the eastern coastline from Kosi Bay to Table Bay but has recently been recorded in a handful of estuaries on the West Coast as far north as the Orange River indicating that it may be expanding its range in response to climate change. Previously one of the dominant species found in estuaries, this species has suffered an estimated decline of over 30% in the past 15 years due to the combined impacts of loss of freshwater habitats and gillnet fishing.



Figure 79. Freshwater mullet (*Pseudomyxus capensis*) - Vulnerable (A2cde+42cde) (Source: Corne Erasmus, DEFF)

Obstructions across rivers in the form of weirs and dams prevent the upstream migration of this facultative catadromous species. *P. capensis* naturally occupy between 100 km and 200 km of the river reaches above the estuarine zones of some of the larger Eastern Cape systems (Bok 1984), but the widespread construction of low weirs and dams on coastal rivers has reduced both the range and abundance of this species. In addition, excessive freshwater abstraction from rivers has reduced the size and number of large, deep pools in coastal rivers (Whitfield 2019). These pools are prime habitat for freshwater mullet being utilised for up to three years in the case of males and five years in females (Bruton *et al.* 1987). The decrease in availability of this habitat is inferred to have had a significant impact on the population. Further loss of freshwater habitat has come in the form of predation by piscivorous alien fish for example largemouth Bass (*Micropterus salmoides*) (Wasserman *et al.* 2011; Magoro *et al.* 2015). Typically juvenile *P. capensis* are eaten as they enter the lower river system which used to have no piscivorous fishes prior to the introduction of the alien *M. salmoides* (Weyl & Lewis 2006). An additional pressure on this species is gillnet fishing. While gillnetting on the west coast has been taking place for many years there has been a significant increase in gillnetting within this species stronghold along the South Coast, the East Coast and in KwaZulu-Natal over the past 10 years. The cancellation of fishing monitoring and enforcement contracts by DAFF since 2017 has led to a massive increase in illegal fishing.

Key recommendation: Ensuring river-estuary connectivity through the implementation of sufficient freshwater flow allocations and good water quality (i.e. limiting nutrient pollution), construction of fishways in regulated systems and the regulation of gill net fishing would allow this species to stabilise.

South Africa's Anguillid eels are most at risk. They are catadromous species with life-history stages that cross different realms and associated perils from deep freshwater pools and springs high in catchments to estuaries to the abyss where they spawn in the sea. Eels are vulnerable to pressures in all of these realms, including: flow reduction, pollution, introduced pathogens, habitat loss, fishing pressure, loss of river-estuary-sea connectivity, atmospheric ozone depletion and ultraviolet radiation, and climate change. They are apex

predators in the aquatic food chain maintaining trophic structure. Historically, they were a significant source of protein to rural communities, were sometimes taboo or had cultural significance in some areas, for example, Pondoland. Eels are still a local but important tourist drawcard in Still Bay in the Western Cape. More recently, collapse of most eel stocks in the Northern Hemisphere has seen a number of attempts to gain access to South Africa's eel for a very lucrative but short-lived and unsustainable fishery and market. To maintain the benefits

from species that are dependent on healthy ecosystems across different realms we need to identify essential linkages between realms and implement effective biodiversity management. Specifically, we need to protect key habitats (Figure 80), control harvesting/fishing pressure, manage water quantity and quality, and enhance connectivity between realms.



Figure 80. Eels in spring flowing into Goukou Estuary at Stilbaai Information Centre (Source: Lara van Niekerk)

9.4.4 Birds

Fourteen percent of estuarine bird species are threatened with extinction (Figure 81). Of particular concern is the reported loss of ~265 000 waterbirds from South African estuaries since 1980, most of which are waders from larger estuaries, especially in the Cool Temperate bioregion a decline of 68% in 40 years (see below). These declines are partly externally driven (e.g. global habitat loss), but are also closely related to estuary health, and are not mitigated by level of protection alone. Bird numbers are still on a significantly negative trajectory, emphasising the need to manage the overall decline in estuary condition, habitat loss, impact of gillnetting on birds, solid waste (plastics), hunting and human disturbances in key foraging and roosting areas.

Sixteen of South Africa's larger estuaries have been regularly monitored for birds over 20 years. Of these, 11 have experienced major declines in numbers of waterbirds (Figure 81). Some of these changes have been relatively gradual (e.g. Langebaan, uMngeni, Wildevoelplei). Those with very rapid declines had reduced occurrences of very high counts, typically of migratory waders, terns or gulls (e.g. Verlorenvlei, St Lucia, Bot/Kleinmond). Four estuaries (Eerste, Wilderness/Touws, Knysna and Kosi) had no significant change in bird numbers over time. In these estuaries, waders, gulls and terns, waterfowl and planktivorous wading birds (Lesser Flamingo) had all undergone widespread declines, and kingfishers and pelicans had declined in some. The trends for pelicans and cormorants were variable, while wading birds, piscivorous birds of prey and storks increased in most cases (Turpie *et al.* subm.).

A comparison of summer counts in the 1970s-80s with the five most recent counts for 150 estuaries which account for 94% of estuarine area (Turpie *et al.* subm.) found that estuaries on the west and south-western coasts, as well as in the north-east, have suffered the largest losses in bird numbers (Table 51, Figure 76).

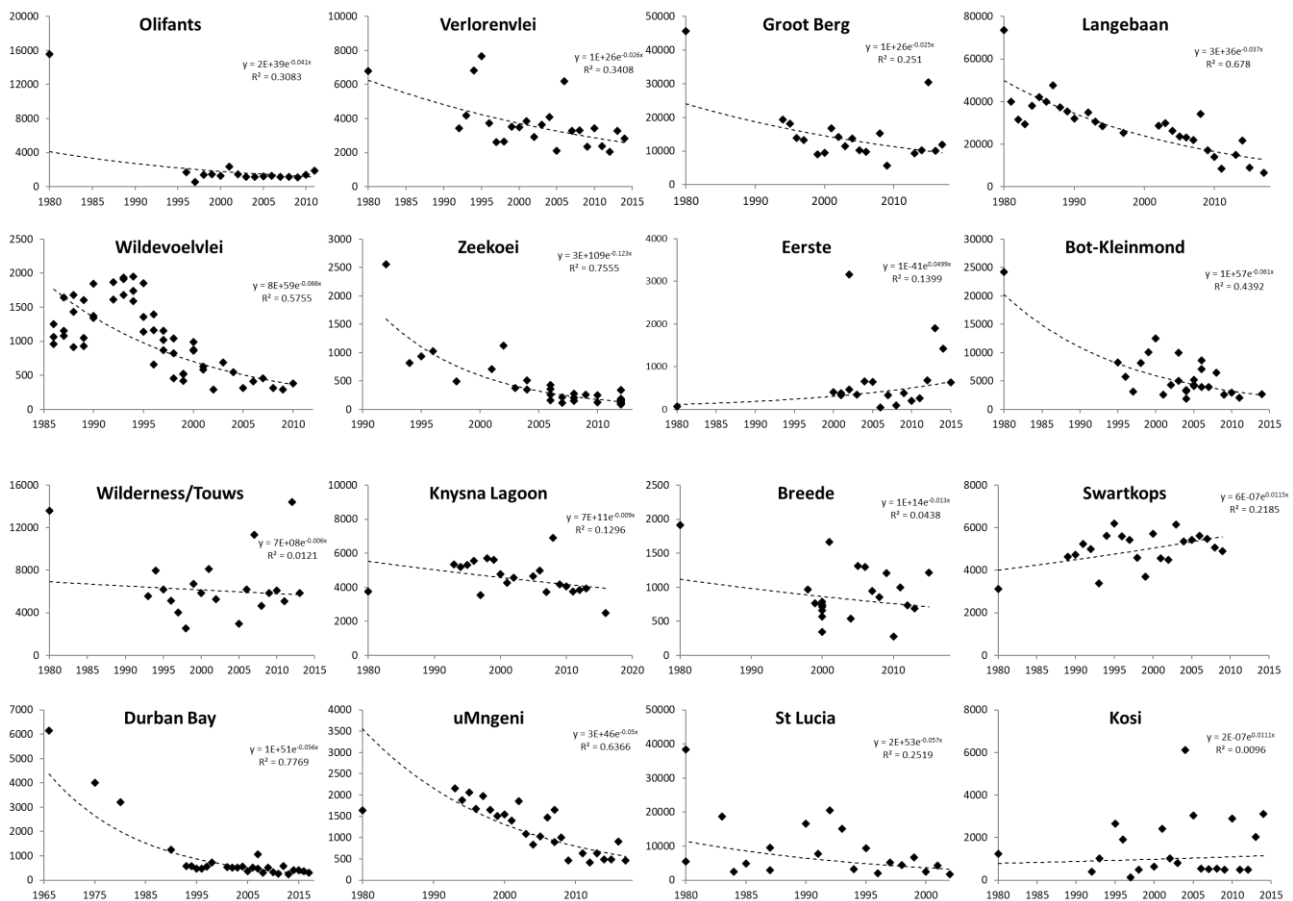


Figure 81. Changes in abundance at 16 estuaries that have been counted in at least 20 different years (Turpie *et al.* subm. based on CWAC data).

Among the larger estuaries, decreases tended to be larger than increases (resulting in average declines), while the opposite was true of smaller estuaries (resulting in average increases (Turpie *et al.* subm)). Negative changes were statistically influenced by estuary size, biogeographic zone, and the abiotic habitat score of the estuary, with estuaries with better abiotic health scores having lower changes (Figure 82). Protection status did not have a significant effect in ameliorating losses. Increases in bird numbers tended to occur in estuaries with lower levels of development.

All but one of the functional groups and nearly all the species analysed had declined overall since the 1980s (Figure 83; Turpie *et al.* subm). The largest overall decreases have been seen in the migratory birds, especially migratory waders, which have decreases by about 85% since the 1980s. Other groups that have undergone major declines include the gulls and terns, omnivorous and herbivorous water fowl (Figure 82).

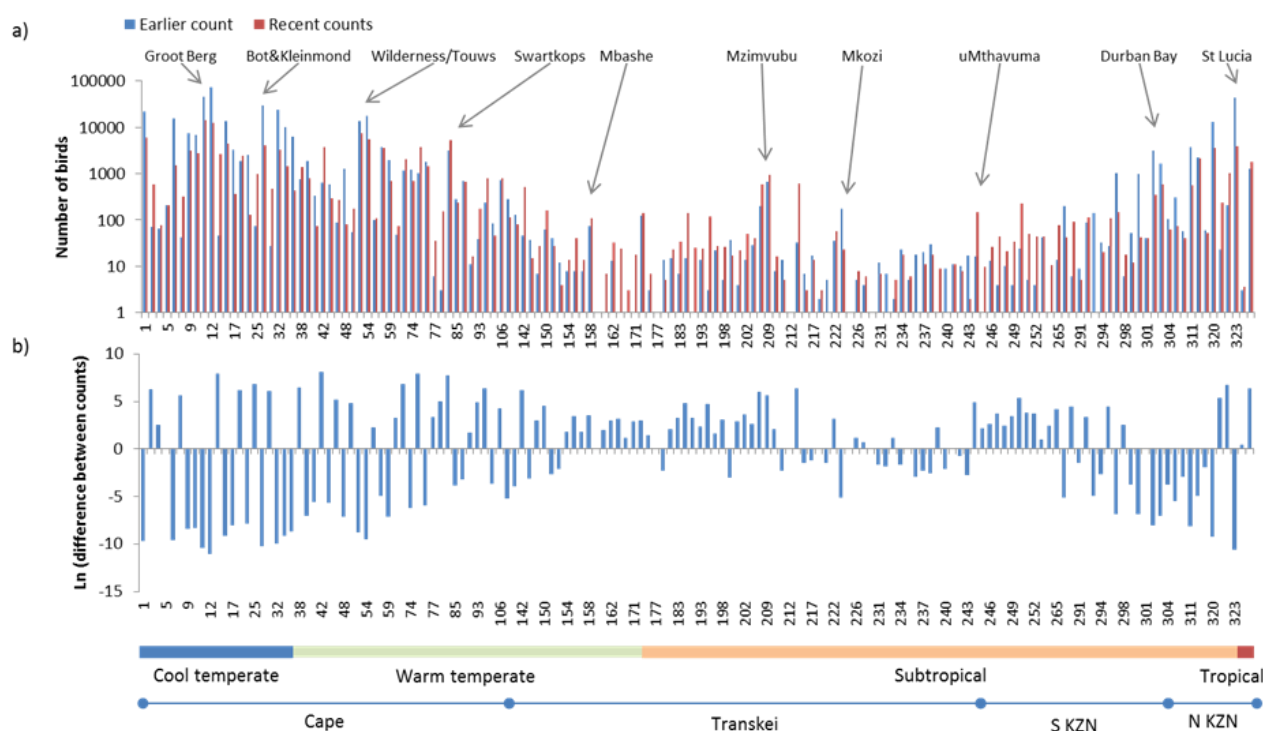


Figure 82. (a) Comparison of number of estuary birds counted for earliest count and the average of most recent 5 counts. (b) Difference in counts from earlier to recent counts $\ln(\text{difference})$. Estuaries and micro-estuaries numbered west to east with important estuaries labelled and delineation in terms of biogeographic zones and sections of coast (S KZN = South coast KwaZulu-Natal, N KZN = north coast KwaZulu-Natal). Note the log scale (Turpie *et al.* subm.).

Notable declines include the Curlew Sandpiper (-90%), Black-necked Grebe (-94%), Pink-backed Pelican (89%), Greater Flamingo (-81%), Southern Pochard (-95%), Maccoa Duck (-94%), Ruddy Turnstone (-85%), Wood Sandpiper (-89%), Marsh Sandpiper (-88%), Red Knot (-98%), Ruff (-91%), Collared Pratincole (-97%) and Mangrove Kingfisher (-80%). On the other hand, the numbers of Egyptian Goose, Swift Tern and African Jacana have almost doubled. As a result of these changes, estuarine bird composition has also changed significantly since the 1980s (Turpie & Forsythe subm). Similarity among recent counts is higher than among the earlier counts, indicating less variability in the composition across the different estuaries.

Overall, bird numbers estimated in recent counts are only 32% of the numbers recorded in the baseline counts, mostly in 1979-81. Total non-passerine waterbird numbers have decreased from approximately 390 000 to 125 000 birds (Table 51). Overall decreases were recorded in all regions apart from the former Transkei coast, where the baseline counts were much later, and the tropical estuaries. Decreases have been by far the highest in the cool temperate region (-25.7 birds/ 100 ha/ year), and have ranged from -7.9 to +8.7 birds/100 ha/year in the remaining areas listed in Table 51. The losses are catastrophic and while dominated by migratory birds, they include nearly all estuarine waterbird groups and most species. Thus, in addition to

improving the health of estuaries, it is imperative that planners and estuary managers include significant sanctuary areas that protect birds and their prey from human disturbance and exploitation.

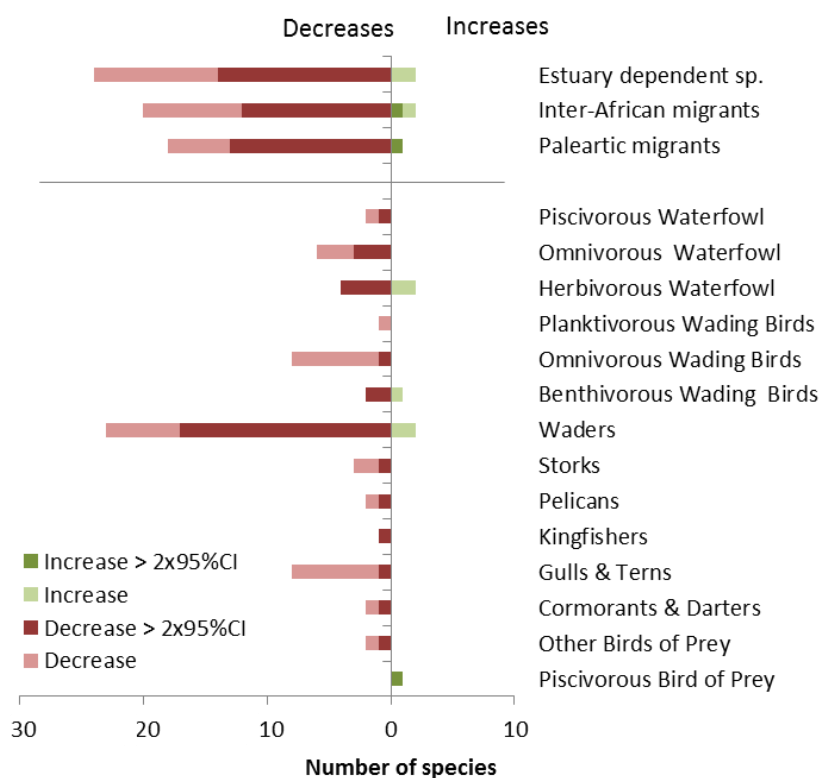


Figure 83. The number of species in different groups of estuary birds which have increased or decreased since earliest counts. Numbers in darker shade are deemed to be significant changes based on strict criteria (Turpie & Forsythe, *subm*).

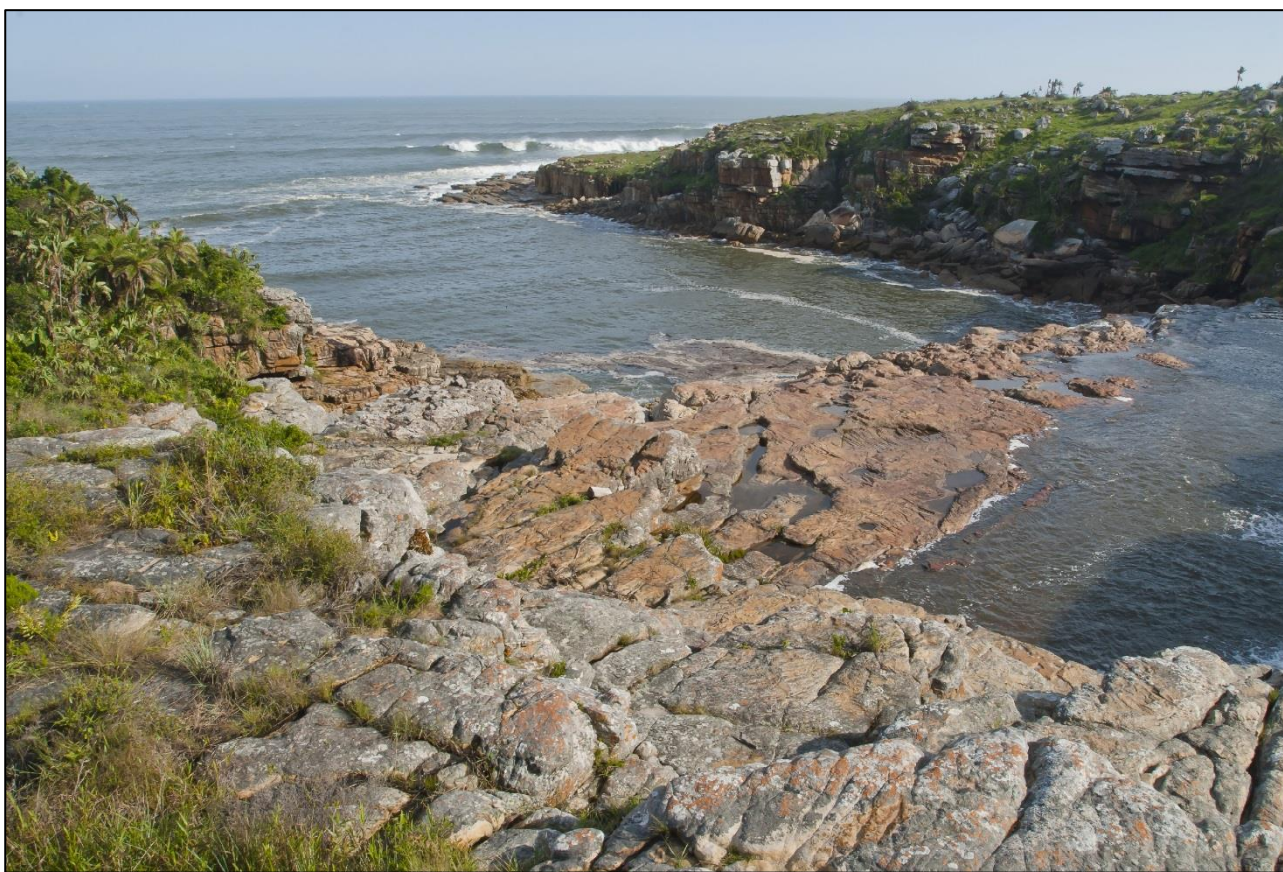
Table 51. Summary of changes in estuarine non-passerine waterbird numbers around the coast (Turpie *et al.* *subm*).

Zone	Total estuary area	% area monitored recently	Total baseline count	Average of recent counts	% of baseline
Cool temperate	22 365	98%	263 646	62 204	24%
Warm temperate (West)	14 705	81%	53 630	40 492	76%
Warm temperate (Transkei)	820	95%	440	1 152	262%
Subtropical (Transkei)	1 972	92%	1 519	3 062	202%
Subtropical (KZN south coast)	1 135	54%	2734	1 238	45%
Subtropical (KZN north coast)	50 291	96%	69 606	14 347	21%
Tropical	5 411	100%	1 249	1 811	145%
Total	96 699	94%	392 824	124 305	32%

9.5 Knowledge Gaps

Quantitative macroinvertebrate surveys from South African estuaries are scarce. This lack of monitoring was noted two decades ago (de Villiers & Hodgson 1999), and assessing contemporary assemblages from functional systems has shown little improvement in addressing large spatial gaps around the coast. Most estuaries lack even basic inventories detailing invertebrate diversity let alone detailing changes and trends from pre-coastal development and catchment influences.

Many other estuarine invertebrate and fish species may be threatened, but as yet are undetected due to lack of monitoring data being available and Red List assessments not having been conducted. South Africa has a unique fauna of invertebrates that occur in estuaries, many of which are endemic. Endemic invertebrates are priorities for inclusion in future species assessments. Further monitoring of invertebrate and fish species' response to changing estuarine conditions is required.



Mkambati Estuary mouth © Peter Chadwick

TEXT BOX 11: FISH SPECIES POPULATION GENETICS

Stock assessment of Dusky Kob shows the biomass of reproductive adults at < 2% of pristine. This is supported by there being < 500 successful breeding pairs coastwise and < 50 pairs regionally in recent years. Population bottlenecks identified have been linked to abrupt increases in fishing effort in estuaries and overfishing of juvenile and adolescent kob, drought and anomalous flood events. Hybridization is occurring between the estuarine-dependent Dusky Kob and the predominantly marine silver kob. This is only between large Dusky males and smaller silver females which mature at 110 cm and 40 cm respectively. So, it appears that silver females are more attracted to large Dusky males than to the small males of their own species or, both species are at critical levels and the probability of encounter with the opposite sex is very low but greater with a large noisy Dusky male.

Bot River Klipvis (*Clinus spatulatus*) only occur in the Bot and Klein estuaries in Walker Bay. They diverged from the marine Super Klipvis (*Clinus superciliosus*) since the last Ice Age with sea-level rise and increased isolation of Walker Bay and these two systems. Compared with the relatively stable *C. superciliosus* population, *C. spatulatus* is characterised by low genetic diversity from repeated population crashes arising from the opening and closure of these two estuaries. However, *C. spatulatus* is much more physiologically tolerant of salinity extremes, water temperature and low oxygen levels (Von der Heyden *et al.* 2015). Population genetics and genetic structure of *C. spatulatus* have also verified that the Bot or Kleinmond and Klein estuarine lakes have been functioning this way and driving this specie's evolution for millennia.

Population genetics is needed to delineate discrete stocks or populations of fish and invertebrate species, even more so in increasingly isolated estuarine ecosystems between which we are trying to maintain connectivity. It is crucial in spatial planning, stock assessment, the setting of protection levels and the implementation of appropriate management interventions. From a resource management perspective, we need to identify population bottlenecks manifest in shrinking effective population size (successful breeding pairs) and link these to the causes amongst other overexploitation, disease, drought, flood and physiological stress. This said, most estuaries are subject to some degree of isolation that varies according to the locality and characteristics of individual systems but all driving divergence. Distinct lineages often display physiological and behavioural adaptations to the habitats in which they arise which in turn drive further divergence. These discrete lineages and genetic adaptations need to be considered when setting biodiversity and conservation targets especially with regard to future climate change scenarios (Von der Heyden *et al.* 2015).

Aside from population genetics, molecular forensics is emerging as a critical tool for identifying and tracking plants and animals in the wildlife trade. Amongst other, recent confiscations of contraband indicate a thriving illicit trade for pipefishes and Seahorses (*Syngnathidae*) from within and via South Africa. Catching or possession of the entire pipefish and seahorse family is prohibited in this country. Molecular forensics helps identify these confiscated animals and species composition

points to country of origin. It also helps identify markets with the endemic Knysna Seahorse (*Hippocampus capensis*), that occurs in only three estuaries, being identified on Asian markets.

Citation: Lamberth, S.J. 2018, 'Fish Species Population Genetics' in Volume 3: Estuarine Realm', South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A



Goukou Estuary © Peter Chadwick

10. HOW VULNERABLE ARE SA ESTUARIES TO CLIMATE CHANGE?

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Climate Change

- West Coast and KZN estuaries will be most influenced from a structural and functional perspective.
- Along KZN the major driver of change is increased runoff into the numerous small, perched temporarily open/closed estuaries, resulting in more open mouth conditions, a decrease in retention time and a related decrease in primary productivity and nursery function.
- Delagoa estuarine lakes will be sensitive to increased drought conditions, reduced groundwater input, increased mouth closure and resultant loss of connectivity with catchment, sea and adjacent estuaries.
- West Coast estuaries will experience reduced freshwater input and declines in primary production and nursery function.
- Wild Coast, Eastern and Southern Cape estuaries will show shifts in mouth state, nutrient supply and salinity regime, but the most obvious impact will be the change in temperature (nearshore and land), associated species range expansions / contractions and changes in community structure.
- The effects of ocean acidification in the short term will be negligible in comparison with the terrestrial signal (e.g. eutrophication resulting from urban runoff and agricultural return flow). West Coast systems that experience regular upwelling or increased upwelling are likely to display the effects of ocean acidification first.

10.1 Introduction

Climate change is a measurable reality and South Africa is especially vulnerable to its impacts (DEA 2010, 2013). The country's people are divided along socio-economic lines with the majority depending on ecosystem services to supplement their life needs. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) stresses the importance of providing a socio-economic perspective (e.g. resource use implication) and assessing scenarios that assume no restriction on greenhouse gases (GHG) compared to assuming GHG stabilisation (Carter et al. 2007). Adaptation to environmental change is therefore central to building societal resilience in the face of change. The concept of vulnerability has become increasingly important in Climate change research (Jones and Preston 2011). The IPCC defines it vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects including climate variability and extremes (IPCC 2001, 2012, 2014). Vulnerability is a function of the character, magnitude, and rate of climatic variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC 2001). Assessing vulnerability requires an estimation of the health and functioning of an ecosystem (Carter et al. 2007). Defining and measuring geographical, spatial, temporal and social dimensions of vulnerability is however notably complex and has generated many methods (Carter et al. 2007). In South Africa however there is no standard approach or best practise guidelines (DEA 2013) which makes monitoring vulnerability and evaluating adaptation between sectors or localities particularly challenging (DEA 2017). This study aims to address this omission for the estuaries of South Africa.

Recently estuaries have been the focus of several comprehensive climate change vulnerability assessments (Day et al. 2008, 2011, Gillanders et al. 2011, Robins et al. 2016). Climate change was found to drive change in estuaries through changing oceanic circulation, modifying terrestrial climatic and hydrologic processes, ocean acidification, sea level rise, and increased sea storminess (Day et al. 2008; Day et al. 2011; Gillanders et al. 2011; Newton et al. 2014; Robins et al. 2016). These findings are supported by ongoing controlled laboratory studies and *in situ* observations on estuarine sensitivity to changes, e.g. ocean acidification and temperature (e.g. Duarte et al. 2013; Vizzini et al. 2013; Kerfahi et al. 2014; Milazzo et al. 2014; Ge et al. 2017; Rees et al. 2017; Laurent et al. 2017). More recently, downscaling the global climate model to regional scales has allowed the development of site-specific dynamic models that can assess estuary responses more systematically, e.g. increased storminess and sea level rise on estuarine processes (e.g. Brito et al. 2012; Ranasinghe et al. 2013; Prandle and Lane 2015; Duong et al. 2015 2017; Brown et al. 2016a; 2016b; House et al. 2017; Goodwin et al. 2017). These models however require data and considerable effort would be needed to apply them in South Africa's data limited estuarine environment. Key to understanding the vulnerability of South African estuaries is their physical features. They are highly variable in size, shape, degree of marine/fluviol influence and catchment characteristics (Reddering, 1988) Consequently, mouth state, water depth, salinity, temperature, turbidity and dissolved oxygen concentrations can fluctuate rapidly, both temporally and spatially (Day, 1981).

Transition zones between the biogeographical regions are shaped by oceanographic and climatic features such as currents, bathymetry and, terrestrial runoff (Figure 84). Therefore, these transitional zones vary according to El niño - La niña events and related wet-dry cycles (Dieppois et al. 2015). Freshwater inflow to estuaries is determined by climatic conditions, as well as the size and shape of the catchment, the latter controlling the magnitude and flow distribution of runoff (Reddering and Rust, 1990). The relatively small South African estuaries are wave-dominated, shallow (water depth 2–3 m) and microtidal (<2 m) (Cooper 2001). The resulting low tidal flows, coupled with comparative low freshwater inflow, results in a limited ability to maintain inlet stability (i.e. open mouth conditions). The effect of strong wave action and high sediment availability is that more than 90% of estuaries have restricted inlets, with more than 75% closing for varying periods of time when a sandbar forms across the mouth (Cooper 2001; Whitfield, 1992; the findings of this study). Overall, estuary size influences several physical characteristics including tidal flow, dependency on river inflow and associated mouth regimes. Size also acts as a predictor of community composition and abundance, with smaller systems having fewer species and lower absolute abundance (Whitfield, 1980a, 1980b). Larger estuaries also tend to have higher habitat diversity (water column and substrate) than smaller systems (Lamberth and Turpie 2003; Van Niekerk and Turpie 2012). Estuary responses to Climate change processes will vary according to estuary type. For example, large and small estuaries respond differently to major resetting events. In South Africa, large estuaries are buffered against flood scouring as they have greater storage capacity relative to flow, which translates into less loss of substrate, habitat and biota whilst smaller systems are experience a complete reset of substrate and biotic composition during a similar size event such as a 1 in 5 year flood.

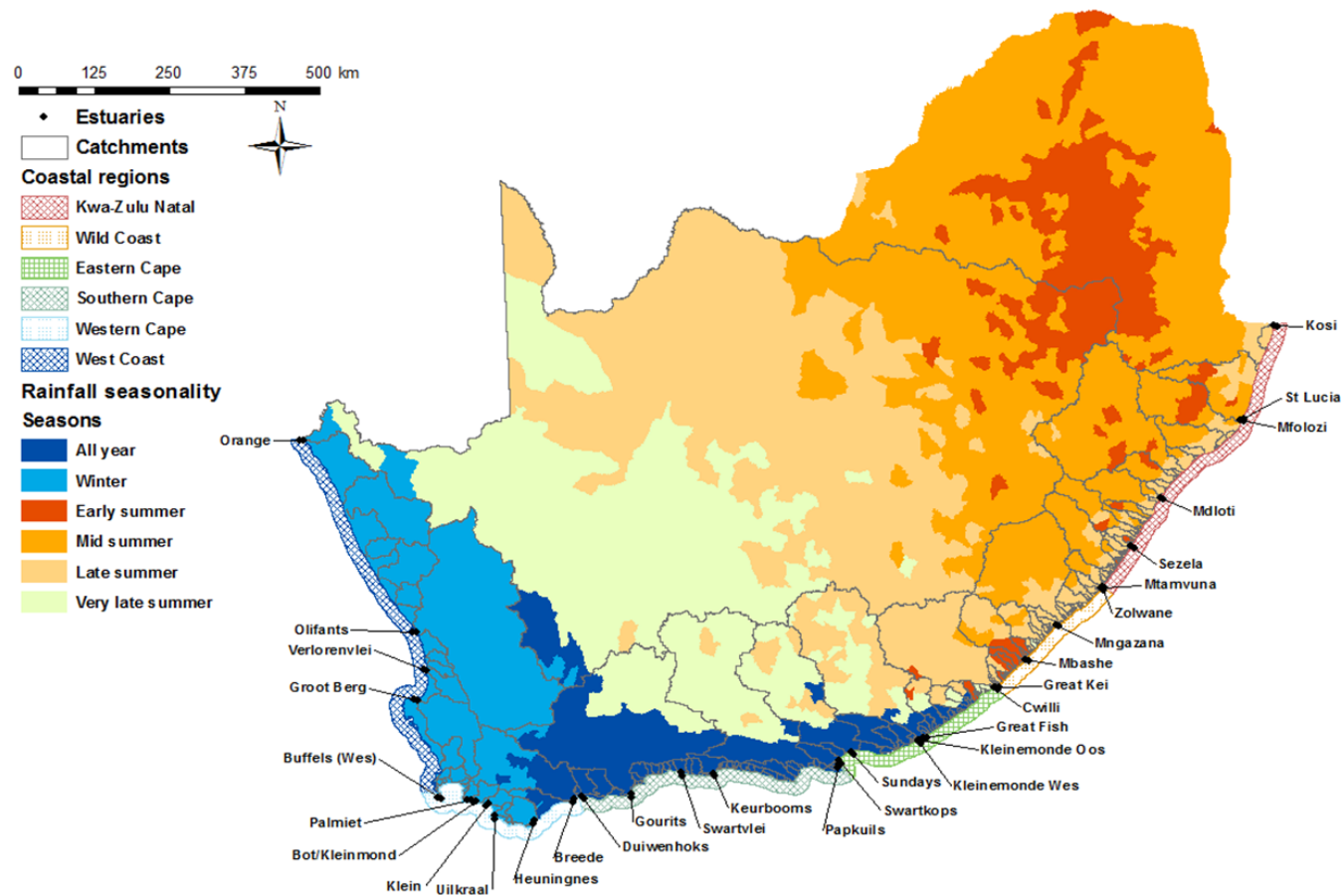


Figure 84. Map showing the six coastal regions, relative catchment size and rainfall seasonality for South Africa (Van Niekerk, 2018).

In addition, estuarine habitats are significantly degraded through freshwater reduction, habitat destruction, nutrient pollution and overexploitation of living resources, which affects related ecosystem services (e.g. nursery function). These impacts reduce the capacity of estuaries to buffer the effects of change, albeit natural or anthropogenic.

The vulnerability of South African estuaries to climate change has been recently assessed (James and Hermes 2011; James et al. 2013; SANBI 2013). This paper aims to re-explore their vulnerability in the light of their characteristics and additional data. It synthesises the projected climate change stressors with a focus on near-future (2016-2035) and mid-future (2040-2060) impacts and ranks their vulnerability on a regional scale. The paper concludes by identifying priority adaptation strategies to mitigate and manage the effects of climate change on these ecosystems.

10.2 Methods

Estuaries were subdivided into seven coastal regions that were relatively homogenous with respects to rainfall and catchment characteristics, coastal topography, beach slope, dominant mouth position when closed, and size (Table 52). A literature review identified the key climate change stressors on estuaries in the various coastal regions. The following were considered critical:

- Changing in oceanic circulation processes, including coastal temperature regimes;
- Modification of terrestrial climatic and hydrologic processes (temperature, precipitation and run-off regime shifts);
- Ocean acidification;
- Sea level rise; and
- Increase in the frequency and intensity of sea storms.

Estuaries of the six coastal regions were assessed at a broad scale to determine the potential impact on ecosystem processes and patterns based on their regional sensitivity to each stressor. A change rating (low=largely similar, medium= some change from present, high = significant change is expected) was applied to indicate where the areas of change in the near-future and mid-future.

The interaction between climate change stressors, estuarine processes and anticipated biotic response is summarised together with implications for different regions.

10.3 Key climate change stressors on South African Estuaries

10.3.1 Changing ocean circulation processes

South Africa's coastal climate is strongly influenced by two large scale ocean currents. The Agulhas Current, flowing along the east coast, is the strongest western boundary current in the southern hemisphere (Beal et al. 2011). Although it generally occurs within 20 to 50 km from the coast

(Gründlingh, 1983; Bryden et al. 2005; Goschen and Schumann, 1990; Rouault and Penven 2011) its position is influenced by offshore cyclonic meanders (referred to as “Natal Pulses”) that can force its core 200 km offshore up to 4 times per year driving localized upwelling and contributing to the dispersion and transport of pollutants or fish larvae (Bryden et al. 2005; Rouault and Penven 2011; Krug et al. 2014; Beal et al. 2015). Natal Pulses also influence the downstream variability of the current and the leakage of warm, salty water into the Atlantic. The pulses are linked to the formation of Agulhas Rings and Early Retroflexions when the current retroflects upstream of its usual location and interrupts the Agulhas Leakage (Lutjeharms and van Ballegooyen, 1988; van Leeuwen and de Ruijter 2000; Rouault et al. 2010). Most of the inter-ocean transfer of heat and salt between the Indian and Atlantic oceans is associated with the Agulhas Leakage (Gordon et al., 1987; Matano and Beier 2003). Changes in Agulhas Leakage influence the Benguela Current Large Marine Ecosystem and its coastal climate thus impacting on river run-off and estuarine dynamics. Recent work suggests that meso-scale variability in the greater Agulhas Current system has intensified with the northern Agulhas Current (north of about Coffee Bay) experiencing a strengthening of the mean current; while the southern Agulhas Current appears to be slowing down, but meandering more (Backeberg et al. 2012). Overall, stronger Agulhas Current transport has been predicted due to global warming, which will affect inshore upwelling cells as well as shelf-edge upwelling which in turn may impact coastal ecology (Backeberg et al. 2012). The impact of a stronger Agulhas Current on the retroflexion mode is still unclear. Cai et al. (2007) and Rouault et al. (2009) indicate that an increase in Agulhas Current transport will lead to stronger Agulhas Leakage with more warm Indian Ocean water passing along the southern and western coasts of South Africa. While Van Sebille et al. (2009) found that an increase in Agulhas Current transport may lead to a higher frequency of Upstream Retroflexion with a concomitant decrease in Agulhas leakage. Either way, the impact of a stronger Agulhas Current will have definitive effects on the coastal climate of South Africa. In addition, close to the coast, winds play an important role in determining the ocean temperatures through wind driven upwelling. Rouault et al. (2010) reports a cooling trend along South Africa’s south coast and in the Port Elizabeth/Port Alfred region associated with an increase in upwelling-favourable easterly winds, suggesting that the cooling trends are both due to an intensification of the Agulhas Current as well as increased upwelling favourable winds.

Greenhouse gas (GHG)- induced global warming and the ozone hole has caused an intensification and southward shift of Southern Hemisphere Sub-tropical gyres over the last 40 years (Cai 2006). On the west coast, the Benguela Current is likely to intensify and lead to more intense upwelling due to the acceleration of the Supergyre (Saenko et al. 2005; Roemich 2007).

This will induce lower sea surface temperatures in this region. Agulhas Rings sometimes drift close inshore, raising the temperature of nearshore waters and occasionally interacting with upwelling plumes, both of which have important consequences for fish recruitment including that into the nearshore and estuarine environments (Duncombe Rae et al., 1992). How robust the upwelling trends in the Benguela Upwelling System are remains unclear (Hagen et al. 2001; Lutjeharms et al. 2001; Bakun et al. 2010; Rouault et al. 2010; Dufois and Rouault 2012).

Table 52. Summary of the key physical features of South African estuaries that influence their vulnerability to climate change

BIOGEOGRAPHICAL REGION	COOL TEMPERATE	WARM & COOL TEMPERATE TRANSITION ZONE	WARM TEMPERATE		SUBTROPICAL-WARM TEMPERATE TRANSITION ZONE	SUBTROPICAL	TROPICAL-SUBTROPICAL TRANSITION ZONE
COASTAL REGION	West Coast Orange-Krom n= 18	Western Cape Buffels (Wes)-Breede n=18	Southern Cape Duiwenhoks - Papenkuils n= 39	Eastern Cape Swartkops – Cwili n=55	Wild Coast Great Kei - Umtamvuna n= 85	KwaZulu Natal iSolwane – St Lucia n = 73	Delagoa uMgobezeleni - Kosi n = 2
Coastal energy	High energy wave dominated coast						
Rainfall seasonality	Winter (Note: Orange catchment Mid/Late Summer)	Predominantly Winter	All year, peaks in spring and autumn. Very late summer in larger catchments	Late summer to All year	Late summer	Mid to Late summer, Early summer in larger catchments	Late summer
Mean annual precipitation (mm)	200 - <100	200 – 600 (mountains >1000)	200 - 800	200 – 800	400 - 800	600 – 1200	900
Dominant catchment size	Three very large catchments, rest small catchments	Small to large catchment	Small to large catchments	Small catchments interspersed with large catchments	Numerous small catchments	Numerous small catchments	Ground water fed, with little surface runoff
Coastal topography	Coastal plain	Vary from steeply incised to coastal plain	Vary from steeply incised to coastal plain	Vary from steeply incised to coastal plain	Steeply incised	Steeply incised, Coastal plain in northern parts	Coastal plain
Dominant closed mouth position	Mostly perched	Mostly not perched	Mostly not perched	Mostly not perched	Mostly not perched	Mostly perched	Mostly not perched
% Estuaries	%	%	%	%	%	%	%
• Very Large: >500 ha	33%	22%	13%	4%	0%	7%	100%
• Large: 100-500 ha	17%	17%	21%	20%	9%	10%	0%
• Medium: 50-100 ha	17%	0%	3%	16%	7%	7%	0%
• Small: 15 - 50 ha	17%	11%	13%	25%	26%	37%	0%
• Very small: <15 ha	17%	50%	51%	35%	58%	40%	0%

10.3.2 Modification of terrestrial climatic and hydrological processes

Global temperatures have increased by about 0.8 °C over the last century, in response to the enhanced greenhouse effect. However, recent climate trend analyses indicate that South Africa has been warming at more than twice the global rate over the past five decades (Jones et al. 2012; Kruger and Sekele 2012; MacKellar et al. 2014; Engelbrecht et al. 2015; Kruger & Nxumalo 2016). The largest and smallest increases in maximum air temperature have been recorded during winter and autumn, and summer respectively. Increasing air temperatures have also resulted in increasing seawater temperatures, particularly in shallow coastal areas (Rijnsdorp et al. 2010). Although the mean temperature of these waters has increased by 0.1°C per decade since the early 1970's (Schlegel et al. 2016) the trend is not uniform, with increases along the KwaZulu-Natal coast among the highest in the Western Indian Ocean (Lima and Wethey 2012). Localized areas along the west and south coasts are cooling seasonally as a result of changes in upwelling patterns (Rouault et al. 2010, Lima and Wethey 2012).

There is strong evidence of statistically significant increases in rainfall over the southern interior regions, extending from the western interior of the Eastern Cape and eastern interior of the Western Cape northwards into the central interior region of the Northern Cape (Kruger 2006; MacKellar et al. 2014). Extreme daily rainfall events have increased over these same areas.

This study is largely based on the outputs of the global climate model analysed in Assessment Report Five (AR5) and downscaled? within regional climate models and the Coordinated Regional Downscaling Experiment (CORDEX) of the World Climate Research Programme. For South Africa, projected climate change futures were derived using both statistical and dynamical downscaling techniques. The projections were developed for both low-mitigation (RCP8.5) and high-mitigation (RCP4.5) futures, and for near-future (2016-2035), mid-future (2036-2065) and far-future (2066-2099) time scales (Note: temporal time-frames vary $\pm$ 10 years between models). Examples of such model results are shown in Figure 85 and Figure 86. These projections make feasible the identification of plausible climate futures for South Africa and the identification of adaptation actions.

Climate change may also manifest itself through changes in the frequency of occurrence of severe weather events (in addition to potential changes in the long-term averages of variables such as rainfall and temperature). An increase in extreme rainfall events is projected to occur along the Southern, Eastern Cape and KwaZulu-Natal coasts during spring and summer, with a reduction in such events projected for winter and autumn (e.g. Christensen et al. 2007; Engelbrecht et al. 2009; Engelbrecht et al. 2013).

An increase in extreme rainfall events is associated with an upsurge in the frequency of occurrence of cut-off lows and more frequent occurrence of tropical-temperate cloud bands over the region (e.g. Engelbrecht et al. 2009, 2010). Tropical cyclone tracks are projected to shift northward, bringing more flood events to northern Mozambique and fewer to the Limpopo and KwaZulu-Natal provinces in South Africa (Malherbe et al. 2013). Statistical models also show an increase in extreme precipitation

events in the summer over the east coast of KwaZulu-Natal, along with an increase in rain-days for much of the country, excepting possibly the extreme west / southwest (Hewitson et al. 2005). Climate change in southern Africa will change precipitation patterns, which, in turn, will affect the quantity, quality, and seasonality of freshwater runoff to estuaries and exacerbate existing human modifications of river inflows (Alber 2002; USEPA 2009; James et al. 2013, Bunn 2016; SAWS 2017). Along the Subtropical and warm temperate biogeographical region the combination of generally wetter conditions and heavy precipitation events would result in more runoff (Figure 86). While a decrease in rainfall in the Cool Temperate bioregion, with the related minor increase in inter-annual variability, would result in a decrease in freshwater flows and an intensification of the wet-dry cycles, as shifts in precipitation are strengthened in the hydrological cycle (Hewitson and Crane 2006; Engelbrecht et al. 2009; 2011; Lumsden et al. 2009, James et al. 2013). The exception to this is the Orange River, which drains more than half of the country and with most of the catchment falling in the summer rainfall area. The frequency and magnitude of large floods are expected to increase in this system as are the intensity and duration of drought or zero-flow periods. The impact of these changes on marine and estuarine habitats and biota are likely to be significant as this catchment provides more than 75% of the flow into the sea on the west coast.

10.3.3 Sea level rise (SLR)

Recent calibrated observations from satellites show that global sea level rise over the last decade has been $3.3 \pm 0.4 \text{ mm.yr}^{-1}$ (Rahmstorf et al. 2007). The IPCC AR5 SPM 2013 (IPCC 2013; Church et al. 2013) concludes that anthropogenic warming and sea level rise will continue for centuries due to the time scales associated with climate processes and feedbacks, even if greenhouse gas concentrations are stabilised. Comparisons between approximately 30 years of South African tide-gauge records and the longer-term records elsewhere show substantial agreement with global trends (Theron 2007). Present South African sea level rise rates are approximately: west coast $+1.9 \text{ mm.yr}^{-1}$, south coast $+1.5 \text{ mm.yr}^{-1}$, and east coast $+2.7 \text{ mm.yr}^{-1}$ (Mather et al. 2009; Mather and Stretch 2012). Although recent literature (subsequent to IPCC 2007) provides a range of SLR scenarios, the best estimate (or 'central estimate/mid scenario') by 2100 is around 1 m, with a plausible worst-case scenario of 2 m and a best-case scenario (low estimate) of 0.5m. The corresponding best estimate (mid-scenario) projections for 2030 and 2050 are 0.15m and 0.35m, respectively (Pfeffer et al. 2008; Milne et al. 2009; Rossouw and Theron 2009; Nicholls and Cazenave 2010; SWIPA 2011; Theron et al. 2012; Church et al. 2013).

10.3.4 Increase in the frequency and intensity of sea storms

The IPCC predicts an increasing frequency and intensity of extreme weather events in the 21st Century (IPCC 2007). The frequency and magnitude of severe weather events such as tropical cyclones, hailstorms, droughts and floods appears to be on the increase globally (IPCC 2007).

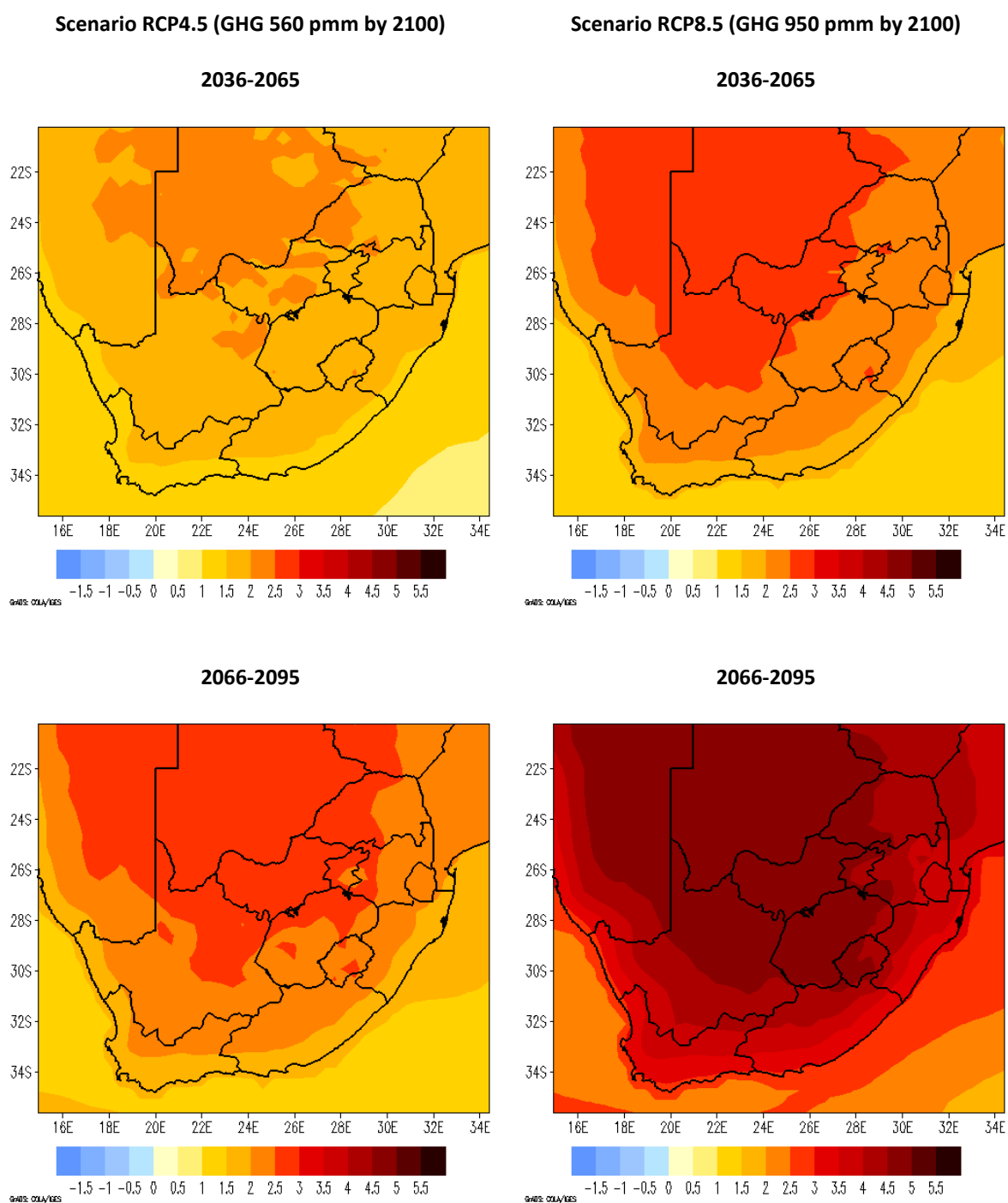


Figure 85. Annual mean near-surface temperature (°C) change from the median projected for 2036-2065 (top) and 2066-2095 (bottom), relative to present (1976-2005), under conditions of the RCP 4.5 (left) and RCP 8.5 (right) pathway.

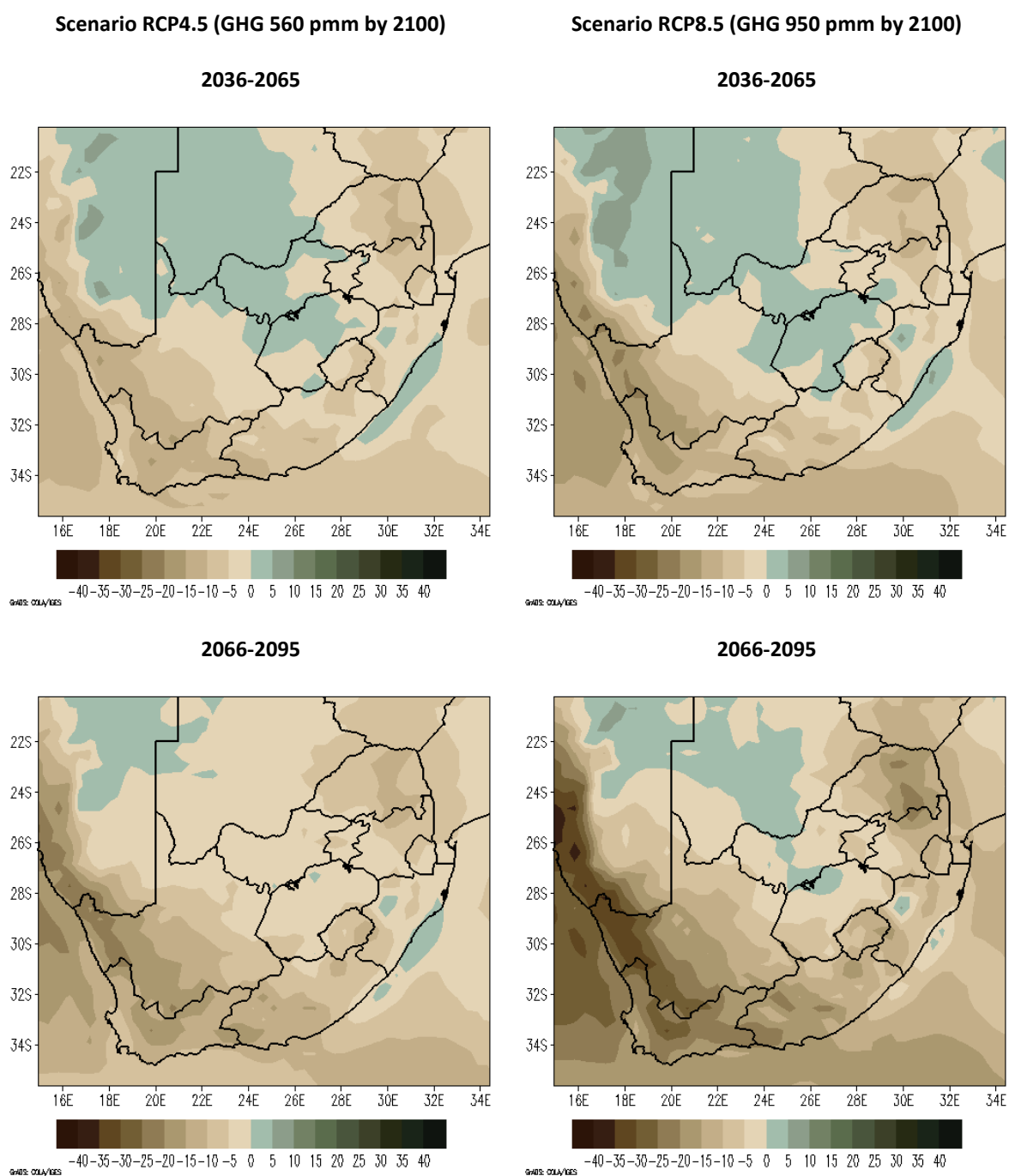


Figure 86. Annual total rainfall percentage (%) change from the median projected for 2036-2065 (top) and 2066-2095 (bottom), relative to present (1976-2005), under conditions of the RCP 4.5 (left) and RCP 8.5 (right) pathways.

In South Africa, increases in either intensity or frequency, or changes in seasonal storm intensity have been reported at a local scale albeit on a very short time-scale (Guastella and Rossouw 2012; Harris 2010). Preliminary findings indicate that there may be long-term trends in the regional metocean climate (Theron 2007). Mori et al. (2010) predicted that mean wave height might generally increase in the regions of the mid-latitudes (both hemispheres) and the Antarctic ocean, while decreasing towards the equator. Wang et al. (2004), Komar and Allan (2008) and Ruggiero et al. (2010) provide further evidence of a general wave height increase and increasing storm intensities in the Northern Hemisphere. Such changes in the regional metocean climates are expected to have significant impacts on local coastal areas. It is therefore important to investigate possible future climatic changes off the southern African coastline as well as the expected associated impacts. As can be anticipated, a more severe wave climate (or related oceanic wind climate) will result in more storm erosion, potentially more coastal sediment transport, and greater coastal impacts.

Although the South African wave-records are short, wave-data show an increase in wave height for the coast of approximately 6% during events (Theron et al. 2010). Predicted values for potential changes in oceanic wind regimes off the coast are lacking and a relatively modest increase of 10% were therefore be assumed. However, an increase of this magnitude means a 12% increase in wind stress, a 26% increase in wave height, and as much as an 80% increase in wave power (Theron 2007).

1.1.2 Coastal acidification

Fossil fuel burning and anthropogenic land-use changes have caused the atmospheric CO₂ concentrations to rise from 280 ppm to about 387 ppm globally (Le Quéré et al. 2009). The oceans have absorbed approximately 30% of these total anthropogenic carbon dioxide emissions from the atmosphere (Canadell et al. 2007; IPCC 2014). When seawater absorbs CO₂, chemical reactions occur that reduce the pH of seawater, the concentration of carbonate ions, and the saturation states of bio-minerals aragonite and calcite in a process called “ocean acidification” (Feely et al. 2010). Over the past 250 years, the pH of the ocean surface waters has decreased by about 0.1, corresponding to a 26% increase in acidity (Feely et al. 2010; IPCC 2014). By the end of this century, surface ocean pH is expected to decrease by another 0.2 to 0.4 units (Feely et al. 2004, 2009; Doney et al. 2009; IPCC 2014). Globally the aragonite saturation state from preindustrial to present has decreased below the envelope of natural variability (Hauri et al. 2013). In coastal ecosystems changes in pH may be caused by ocean acidification as well as other factors such as eutrophication, upwelling and changes in freshwater inflow (Duarte et al. 2013, Strong et al. 2013).

Southern African upwelling systems have a naturally lower pH and a considerably lower carbonate saturation state (Gruber et al. 2012). The pH levels in the Southern Benguela current range 7.60 - 8.25 depending on the season but have an annual average pH of ~8.1 (Gregor 2012). This system is predicted to have a pH of approximately 7.8 to 7.5 units by the year 2100 and an even lower pH of 7.3 to 6.7 units by the year 2300 (Caldeira and Wickett 2003). Ocean acidification will ultimately result in change in pH and oxygen in estuaries, with a related response in biotic processes such as community composition, nursery function and behavioural responses. However, natural variability in estuarine pH

should be taken into account when effects of acidification are considered. Natural fluctuation in pH may play a large role in the development of resilience in estuarine biological populations. On the other hand, it may combine with the effects of ocean acidification to produce more extreme events that result in even greater impact on the biota (Hofmann et al. 2011).

10.4 Quantification and mapping of vulnerability

10.4.1 Changing ocean circulation processes

Upwelling and biogeochemical inputs

Predicted changes in ocean circulation process such as current location and velocity will strongly influence key marine-driven biogeochemical inputs such as dissolved oxygen and nutrients, into the coastal zone. Coastal biogeochemical processes in turn, will influence permanently open, marine dominated estuaries to a larger extent than Temporarily Closed or freshwater-dominated systems. Estuaries adjacent to upwelling systems will be most affected by biogeochemical shifts linked to ocean circulation and upwelling. (Figure 87) because tidal advection of upwelled water will increase nutrient availability. This phenomenon will mostly influence the large permanently open Orange, Olifants and Groot Berg estuaries along the West Coast. In the case of the Groot Berg Estuary (situated within St Helena Bay), more frequent upwelling induced “black tides” and advection of anoxic hydrogen-sulphide waters may pose additional risk (Lamberth et al. 2010). Figure 87 indicates that there will be some change (medium) for these estuaries as well as for permanently open systems in KwaZulu-Natal and Wild Coast. An increase in shelf upwelling will increase nutrient input and primary production in the nearshore and lower reaches of open estuaries.

Temperature shifts

Estuaries, particularly the large numbers of shallow, Temporarily Closed estuaries that characterise the South African coast, will have a high vulnerability to increases in land temperatures (Figure 87). Projected increases in the average global surface atmosphere range from a low scenario of 1 to 3oC with a potential upper range of 6oC by 2100 (indicated as high in all regions on Figure 86 and Figure 88). Shallow-water aquatic systems such as rivers and estuaries will exhibit greater increases in temperature than deeper waters (Rijnsdorp et al. 2009; James et al. 2013). Larger, permanently open estuaries, will be more likely to respond to shifts in temperature primarily caused by changes in ocean currents and upwelling conditions, while the influence of terrestrial heating will be mostly confined to the upper reaches where river processes dominate. This means that estuaries will be subject to changes in the longshore coastal temperature gradient and land-sea gradient (Wooldridge and Deyzel 2012). Wooldridge and Deyzel, (2012) show that where species are at the edge of their range they can arrange themselves longitudinally according to the land-sea temperature gradient. As predicted land temperatures rise the upper reaches of temperate estuaries are likely to support more tropical species due to increased temperature gradients between estuaries and the sea. Thus, there may be a low

degree change in Subtropical KwaZulu-Natal estuaries, but a medium degree in the other regions (Figure 86).

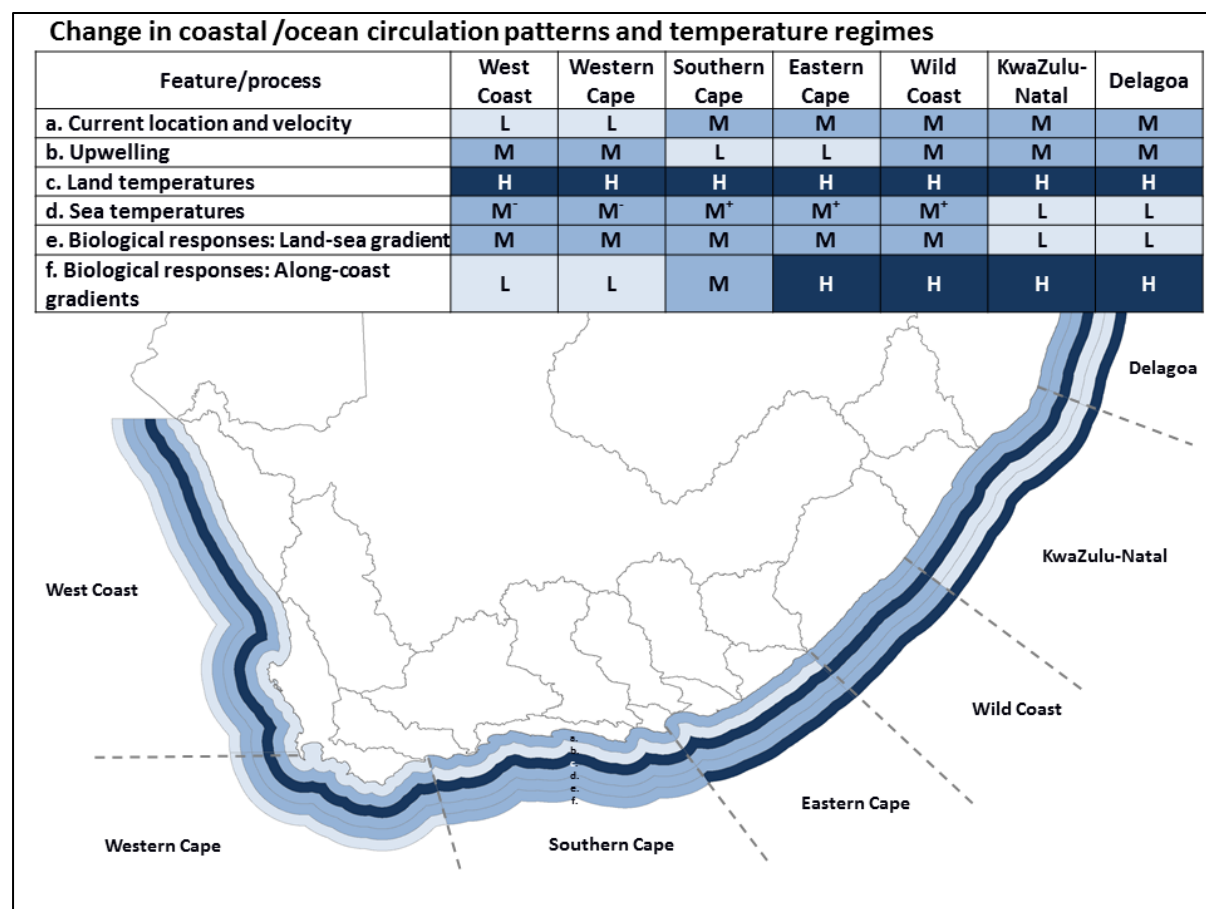


Figure 87. Regional summary of changes in ocean circulation patterns and shifts in temperature regimes and the influence on the community structure, abundance and distribution of estuarine species. Vulnerability is indicated as high/medium/low shifts from west to east with potential change a. to f. depicted by moving outward from the coast.

Higher sea surface temperatures on the east coast may result in the expansion of the Subtropical bioregion south-westwards compacting the warm temperate region against the cooling southern Benguela and expansion of Cool Temperate waters and species to the east (Blamey et al. 2015; Whitfield et al. 2016). A significant change (indicated as high) is therefore expected for Eastern Cape, Wild Coast and KwaZulu-Natal estuaries (Figure 85). Temperature will influence community composition and species distribution as well as reproduction, growth, behaviour, mortality, predator-prey and parasite-host relationships and competition for resources. Species are adapted to, and distributed within, specific environmental temperature ranges (Maree et al. 2000; Elliott 2002; Harrison and Whitfield 2006) and tend to be more stressed near the edge of their distribution (Sorte and Hoffman 2004). As temperature changes, the geographical distribution of species, depending on

their tolerances or preferences, may contract or expand, leading to new and unpredictable species interactions (Murawski, 1993; Perry et al. 2005; Clark 2006; Harley, et al. 2006; USEPA 2009, James et al. 2013).

While many species of fish in estuaries are tolerant of extreme temperatures, changes in the distribution and abundance of especially the marine species in estuaries are likely to be linked to coastal temperatures because of spawning and larval development taking place in the marine environment (James, Whitfield and Harrison 2016). For example, the distribution and abundance of mugilids in African estuaries seems to be strongly linked to coastal temperatures rather than estuarine temperatures (James, Whitfield and Harrison 2016). Thermal windows are narrow in the early life stages of fish (eggs and larvae) and widen in juveniles and young adults (Pörtner and Knust 2007; Pörtner and Peck 2010). In recent years a number of estuarine-associated Subtropical species as well as some tropical reef species have extended their ranges 200 to 1000 km south to the Warm / Cool Temperate transition zone (Lamberth et al. 2013). Furthermore, the increased occurrence of tropical fish species in estuaries along the east coast (e.g. East Kleinemonde and Mngazana) has not displaced the numbers of temperate species resulting in an increase in species richness (reviewed in James et al. 2013).

Range expansion may be accompanied by behavioural changes. Expansion of, for example, spotted grunter *Pomadasy commersonii* into the warm-cool temperate bioregion transition zone has culminated in stock separation, loss of return migration and the establishment of a spawning population in its new range (Lamberth et al. 2013). Less mobile or sessile species less able to escape or compete with encroaching species for resources, may face local or global extinction. Communities do not shift their distribution as a unit. Movement into new habitat depends on: 1) the abundance of reproductively active adults available in the original habitat and their capacity to produce young; 2) enough potential colonisers; 3) their ability to move into new habitats; 4) the survival of a viable and effective population size in the new habitat to produce succeeding generations (Kennedy et al. 2002). The loss of species from an estuary that has become too warm may reduce species diversity in the short term with recovery depending on the mobility of new colonizers, their ability to tolerate higher temperatures and their tolerance of higher salinities in the marine environment.

Changes in temperature will also affect coastal vegetation with Subtropical species moving further south, most notably the invasion of salt marsh habitats by mangroves, the latter being tropical and sub-tropical in nature and ideal indicators of global warming (Steinke, 1999; Adam 2002; Gilman et al. 2008; Hoppe-Speer et al. 2015). Introduced mangroves survive in warm temperate estuaries as far south as East London and as temperatures increase the communities will expand (Hoppe-Speer et al. 2015, 2015b; Whitfield et al. 2016). The only inhibitor of mangrove expansion appears to be the absence of suitable habitat due to the dominance of temporarily open-closed estuaries to the west. Frost may also play a role but in most cases, frost and plant cell damage are dampened in estuaries and the nearshore zone (de Lange and de Lange, 1994; Whitfield et al. 2016). Several mangrove-associated invertebrates have already shifted further than mangroves and colonised “surrogate” salt marsh and sedge habitat to the south. This includes the tropical fiddler crab *Uca annulipes* and

mangrove snail *Cerithidea decollate* in the Knysna Estuary a new southernmost limit for both genera (Hodgson and Dickens 2012; Peer et al. 2015).

10.4.2 Modification of terrestrial climatic and hydrological processes

Precipitation and freshwater inflow

In principle, all estuaries are sensitive to changes in precipitation and associated freshwater inflow. This is especially true of the relatively small estuaries, which depend on river inflow to offset the high wave energy that causes mouth closure along a relatively exposed coast (Cooper 2001, this study). The five major consequences of modifications in freshwater inflow are changes in the frequency and duration of mouth closure, the extent of saline intrusion, land-derived biogeochemical inputs (suspended solids, nutrients, POM, dissolved oxygen), sediment dynamics, and contaminant behaviour and accumulation (e.g. toxic substances). Vulnerability is high for these features for the West Coast and KwaZulu-Natal (Figure 86).

Changes in the frequency and duration of mouth closure

Temporarily closed estuaries become isolated from the sea by the formation of a sand berm across the mouth during periods of low or no river inflow. Such estuaries stay closed until their basins fill up and berms are breached by increased river flow. A foremost consequence of river flow modification, is a change in the frequency and duration of estuary mouth closure in Temporarily Closed Estuaries (Whitfield et al. 2008). In extreme cases, freshwater inflow reduction can cause permanent mouth closure or a significant flow increase can prevent the mouth from closing. Permanently or predominantly open estuaries may also experience closure and switch to being temporarily closed estuaries. Figure 88 shows that mouth closure responds to precipitation and run-off with the same response pattern around the coast for different regions.

A significant decrease in runoff along the West Coast (High) and Western Cape (medium) is likely to cause a significant increase in closed conditions in temporarily open systems along this coastline. Average flow conditions are predicted to remain largely similar along the Southern Cape (possible slight decrease) and Eastern Cape (possible slight increase) in most regional climate models (indicated by low in Figure 88) Although extreme events, such as cut-off lows, are predicted to increase this is likely to lead to only a small change in closed mouth conditions depending on the size of the system and the inflow regime (indicated by low in Figure 88). Wild Coast Temporarily Closed Estuaries are likely to show slight reductions in closed mouth conditions as a result of increased river flow. However, these flow-driven increases in open mouth state could be offset by increased sedimentation from the highly erodible, but severely degraded Wild Coast catchments (i.e. Roux et al. 2008). KwaZulu-Natal Temporarily Closed Estuaries have high vulnerability as a predicted increase in precipitation will result in estuary mouths closing less often thus reducing the periods of high productivity associated with closed-mouth conditions (indicated by high in Figure 88) (Nozais et al. 2005; Thomas et al. 2005). The

Delagoa region, which comprise estuarine lakes, will be sensitive to increase in the frequency and intensity of droughts, with Kosi likely to close again (similar to 1970s) and lake levels to become low due to reduce ground water inflow.

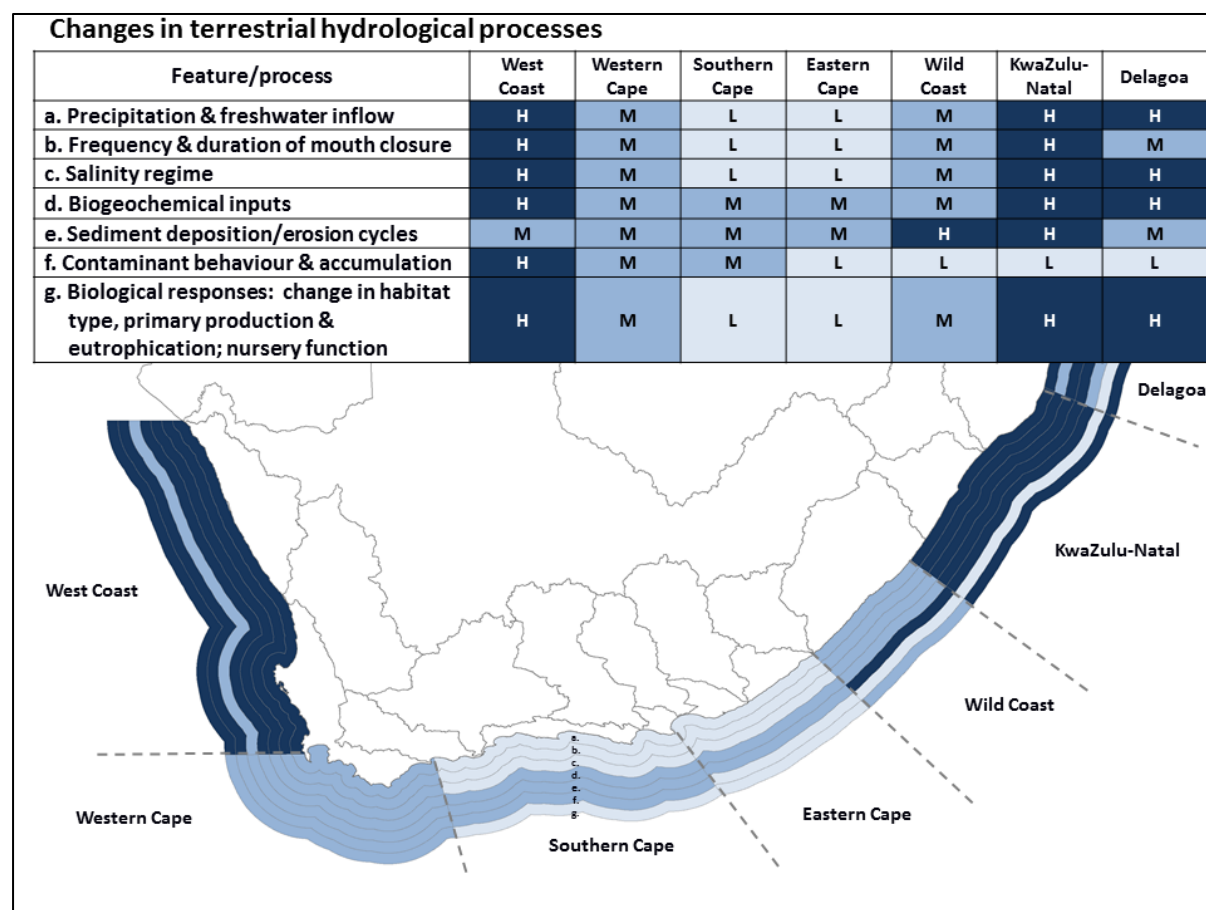


Figure 88. Regional summary of the consequences of changes in precipitation on key estuarine processes – mouth state, salinity regime, nutrient inputs, floods and sediment depositional cycles, contaminant behaviour, habitat type and nursery function.

Vulnerability is indicated as high/medium/low shifts from west to east with potential change a. to g. depicted by moving outward from the coast.

Riddin and Adams (2008, 2010 and 2012) showed that changes in the mouth state, water levels and salinity of temporarily closed estuaries result in changes in estuary habitat type in that an increase in salinity of temporarily closed estuaries result in changes in estuary habitat type in that an increase in closed mouth conditions can reduce submerged macrophyte cover and increase macroalgal cover. Associated high water levels can reduce supratidal salt marsh, reed and sedge cover. Loss of these habitats may result in bank destabilisation and erosion, while a loss of submerged macrophytes affects faunal composition and abundance and the subsequent functioning of temporarily closed estuaries. The most vulnerable regions are the West Coast and KwaZulu-Natal as indicated by the high rating in Figure 88.

Changes in mouth condition have serious ecological implications since temporarily closed estuaries represent 70% of the estuaries along the coast. For example, the Mud Prawn *Upogebia africana* has an obligatory marine phase of development during the larval stages. Estuary mouth closure, particularly for extended periods (e.g. >1 year), disrupts the life cycle and can result in local extirpation (Wooldridge and Loubser, 1996). Some demersal zooplankton species exhibit tidally-phased migratory behaviour (Schlacher and Wooldridge, 1995). Mouth closure removes the tidal signal disrupting the life cycles of these organisms. Extended mouth closure, coupled with dilution or evaporation can lead to hypo or hypersalinity respectively with impacts on biota linked to their salinity preferences or tolerances (indicated by high and medium for West Coast and Western Cape respectively in Figure 88). Reproduction may be interrupted in species that breed in estuaries, e.g. *Callichirus kraussi*, or mass mortalities may result in species unable to escape intolerable conditions (Whitfield et al. 2006). Prolonged mouth closure in temporarily closed estuaries results in low recruitment potential for juvenile marine fish and effectively prevents the emigration of adults back to sea (Vorwerk et al. 2003). During extended closure, fish populations may also decrease due to predation by other fishes, birds and mammals including humans. For example, predation by piscivorous birds reduced the Cape stumpnose *Rhabdosargus holubi* population in the West Kleinemonde Estuary by 20 to 80% over a six month period (Blaber, 1973). In severe cases, when the mouth reopens, predation will result in little or no recruitment to the adult population in the sea. Some fishes may live out their life in a closed estuary without ever having had the opportunity to breed.

Mouth closure will lead to a loss of tidal action which, in turn, will adversely affect the quantity and availability of intertidal benthic organisms to wading birds that forage mainly on intertidal mudflats (Whitfield et al. 2008). Many of these are Palaearctic migrants mouth closure can therefore impact populations globally. Other effects of reduced freshwater inflow include the loss of shallow water habitats favoured by herons, flamingos and other wading birds, and the loss of islands, which provide roosts and breeding sites safe from terrestrial predators. Under extreme climate change scenarios, increased mouth closure results in loss of connectivity with the marine environment and adjacent estuaries, increased population isolation and allopatric speciation.

Changes in the salinity regime

The degree to which seawater enters an estuary is dependent on river inflow and the bathymetry of the system, i.e. seawater penetration is often constrained by river inflow in the shallow, constricted upper reaches of South African estuaries, but penetrates and mixes with relative ease into the deeper middle reaches whilst the lower reaches are generally dominated by tidal flows. Thus the middle reaches show the most sensitivity to changes in flow (river and tidal) as they can shift from a brackish to a freshwater (increase flow) or marine (increase sea level or decrease flow) state. Flow reduction may result in a reduction, or even complete elimination, of the estuarine mixing zone (Bate and Adams 2000). If there is no freshwater input, a reverse salinity gradient may develop (Bate et al. 2002; Paterson and Whitfield 2003, James et al 2013).

Reduced freshwater inflow reduces the primary productivity of an estuary, thereby reducing the food available to juvenile fishes (Strydom and Whitfield 2000; Snow and Adams 2006). This will impact

growth, survival and production or recruitment into the adult population (Strydom 2015). Reduction in freshwater inflow into Temporarily closed estuaries may lead, paradoxically, to a reduction in salinity in many small systems. If the mouth is closed and, provided that the river inflow still exceeds evaporation and seepage losses, a progressive freshening of the estuary occurs until such time as rising water levels lead to a breaching of the berm closing the mouth, e.g. Groot Brak. The impact is an almost complete loss of marine species with only a few euryhaline estuarine and freshwater species remaining (Whitfield 2005). Mass mortalities of marine fish species occurred in the closed Bot Estuary when salinities declined to 2- 3 and temperatures to below 18°C (Bennett, 1985).

West Coast and Western Cape estuaries will show a significant increase in salinity penetration (indicated by high and medium respectively in Figure 88) in large permanently open estuaries, especially during the summer low-flow period, but some freshening (decline in average salinity) of temporarily closed estuaries is likely under increased closed mouth conditions as they will remain closed for longer periods under the influence of limited river inflow and continuous seepage losses through the berm. Southern Cape estuaries are likely to remain similar to present (indicated by low in Figure 88), but may show a limited increase in salinity penetration in some large permanently open estuaries during the low flow season. Eastern Cape systems are also predicted to remain similar to present (indicated by low in Figure 88), but could experience a slight decrease in salinity penetration in some large open estuaries due to an increase in resetting events. In the smaller Eastern Cape temporarily closed estuaries, the predicted slight increases in flow could cause an increase in open mouth conditions with a concomitant increase in average salinity depending on estuarine size and shape. The Wild Coast is likely to see some reduction in salinity penetration in permanently open systems owing to increased freshwater flows (indicated by medium in Figure 88), whilst the slight increase in open mouth state in temporarily closed estuaries may facilitate increased tidal action and related salinity penetration. Overall predicted increases in precipitation in KwaZulu-Natal are likely to dilute the average salinity in numerous small perched temporarily closed estuaries (< 10), whilst increased open states in the deeper temporarily closed estuaries and estuarine lakes will facilitate a shift to more saline conditions (10 -20). The large permanently open systems are expected to become fresher under increased flow conditions, and salinity to increase in the lakes as a results of reduce freshwater input and evaporation. However the estuarine lakes of Kwa-Zulu Natal and Delagoa region are sensitive to droughts and salinity is likely increase in the lakes as a results of reduce freshwater input and evaporation, e.g. St Lucia > 150 and Kosi 4th lake >10. A significant change is thus expected for KwaZulu-Natal estuaries (indicated by high in Figure 88).

Changes in biochemical inputs (suspended solids, nutrients, POM, dissolved oxygen)

While estuary biogeochemistry is strongly influenced by freshwater inflow and marine inputs, *in situ* hydrodynamic processes (e.g. mixing, flushing, residence time and stratification) and biogeochemical processes (e.g. flocculation, remineralisation and primary production) also play a role (Taljaard et al. 2009a; 2009b). Overall the expected changes in biochemical inputs largely follows changes in freshwater inflow, albeit median flow conditions or/and increase in floods, thus showing a high degree of change along the West Coast and Subtropical regions Figure 88). These ratings were a precautionary

aggregate of predicted responses in suspended solids (SS) (or turbidity), particulate organic matter (POM), dissolved inorganic nutrients, and dissolved oxygen, with the highest rating allocated to the combined grouping of biochemical inputs.

River inflow usually introduces suspended solids to estuaries, especially in highly erodible catchments. Therefore, estuaries situated in regions where river inflow is projected to decrease, mainly the West Coast and Western Cape, will become generally less turbid, while systems where an increase in extreme events is expected will become more turbid, mainly KwaZulu-Natal and, to some extent the Wild Coast region. Vulnerability is indicated as high for these regions (Figure 88). This, in turn, may affect important factors such as light attenuation (e.g. linked to primary production) and visibility (e.g. predator-prey relationships) that will decrease in systems becoming more turbid and increase in the less turbid systems (Whitfield, 1998; Lemley et al. 2017).

POM is affected by input from the river and *in situ* biological processes (e.g. primary production, eutrophication) and anthropogenic input (e.g. wastewater discharges and contaminated runoff) (McCallister et al. 2006; De Villiers and Thiar 2007; He et al. 2014; Lemley et al. 2017). However, changes in freshwater inflow are viewed to be the key stressor, as river inflow introduces significant amounts of POM to estuaries during high flow events. Systems situated in regions where a decrease in flow is projected, West Coast and Western Cape regions, will generally receive less catchment-derived POM, while in regions where flows and/or floods are expected to increase, mainly Delagoa, KwaZulu-Natal and to some extent the Wild Coast region POM will increase.

Nutrients in estuaries are naturally derived from river inflow, upwelling and *in situ* processes such as remineralisation and primary production (e.g. De Villiers and Thiar 2007; Taljaard et al. 2009a; Gillanders et al. 2011). Anthropogenic sources have however increased nutrient input to estuaries. And these ecosystems are no longer able to assimilate nutrient loads resulting in eutrophication (Lemley et al. 2015, 2017). Climate change driven nutrient dynamics will be superimposed on existing impacts experienced in highly impacted urban estuaries around Cape Town, Mossel Bay, Port Elizabeth and Durban, and the large permanently open systems subject to agricultural return flow (e.g. Groot Berg, Olifants, Breede, Sundays, uMfolozi). Expected change in processes and patterns will be similar to that of suspended solids and POM. Along the West Coast and Western Cape the decrease in river inflow and associated increase in water residence time will allow for more effective utilisation of nutrients that benefit *in situ* processes and thus increase primary production (Taljaard et al. 2009a; Human et al. 2015). In contrast, increased flow along the KwaZulu-Natal coastline will reduce water retention and associated increase in primary production. While the Delagoa region will see a decrease in average retention, the increase in retention under projected increased droughts is likely to impact on nutrient cycling and primary production as connectivity to the sea become constricted or disconnected.

Dissolved oxygen levels in estuaries are influenced by temperature, salinity, nutrient loading, residence time and stratification (Taljaard et al. 2009b; Gillander et al. 2011; Human et al. 2015). Increased temperature increases primary production and remineralisation rates, thus increasing

fluctuations in dissolved oxygen (Justic et al. 2007). Thus, higher temperatures (Figure 87), shifts in residence time (e.g. change mouth closure) and nutrient input will increase dissolved oxygen stress especially in the smaller temporarily closed estuaries (O'Boyle et al. 2013; Wallace et al. 2014). This is the case along the West Coast and Western Cape regions owing to the significant reduction in freshwater input. The highly enriched, smaller urban temporarily closed estuaries would be most at risk. Only small shifts in freshwater inflow is predicted for the Southern Cape and Eastern Cape regions and while some overall decline in dissolved oxygen is expected, it would not be as severe as West Coast and Western Cape. Along the Wild Coast (indicated as medium in Figure 88) the predicted increase in river inflow will somewhat offset the general increase in dissolved oxygen stress because of warming and increase primary production. In KwaZulu-Natal, increased river inflow will reduce residence time. As a result, the effects of nutrient enrichment on DO levels will be less persistent, i.e. these systems will flush more often. However the large lake systems in Delagoa region (e.g. Kosi) comprising naturally deep, highly-resident water bodies, will not benefit from this mechanism and can become enriched over time with predicted higher river inflow (indicated as high in Figure 88).

Changes in water quality will affect primary production and cause eutrophication, resulting in an overall decline in the species richness and abundance of estuarine resident taxa (indicated as high for West Coast and KwaZulu-Natal in Figure 88). For example, in the iSezela Estuary in KwaZulu-Natal, subject to chronic industrial pollution in the 1980s, a maximum of two estuarine resident fish species was recorded in the system between 1984 and 1986. Subsequent improvements in water quality resulted in an increase in the number of these fish species, recorded to a maximum of 16 species in 2001 (Whitfield, 1995; Harrison and Whitfield 2004).

Sediment deposition / erosion cycles and floods

Floods in estuaries scour sediment deposited during periods of lower flow. This accumulated sediment is from fluvial and marine origin. Soil erosion in catchments poses a major threat to estuaries, particularly those in Wild Coast and KwaZulu-Natal (see Figure 84) (Le Roux et al. 2008; Morant and Quinn, 1999). Similarly the denuding of vegetation in arid catchments (i.e. increasing the erodibility of soils) coupled with an increase in the frequency of high intensity rain events due to climate change will lead to a significant increase in the deposition of sediment in estuaries (indicated by high in Figure 88).

Whilst the Western Cape is likely to experience only small increase in flood events, the arid nature of the land and sparse land cover will make it highly vulnerable to erosion especially in areas subjected to poor land-use. Western Cape and Southern Cape estuaries fed by rivers draining Table Mountain Sandstone tend to be sediment starved, and will therefore be somewhat buffered from related effects. The Southern Cape and Eastern Cape systems will see some increase in the occurrence of flooding and substrate instability (hence indicated as medium low in Figure 88. Along the Wild Coast the predicted increase in the frequency and magnitude of flood events will, exacerbated by current land use, result in greater catchment erosion. This will lead to more infilling, changes from sandy to muddy habitats and a decline in substrate stability that changes biotic community structure. In KwaZulu-Natal's small incised estuaries, increased flooding will negatively influence substrate stability resulting in

depauperate biotic communities as there is little intertidal habitat and lower floodplain habitat available for colonization. Significant change (high) is thus expected in Wild Coast and KwaZulu-Natal estuaries (Figure 86). The Delagoa region is somewhat buffered from increase erosion due to the sandy nature of the coastal plain around it (indicated by medium rating). Large dams have the effect of capturing freshets and attenuating larger floods. The degree to which this will occur depends on the size of the dam, the capacity of the dam preceding the flood, and the size of the flood event. A less resetting events will intensify sediment deposition in estuaries and overall open water habitat. Higher temperatures, with the related increase in evaporation, will not only increase the need to build more dams but will also exacerbate the impact of existing dams on the aquatic environment (Bunn 2016). Heavily utilised catchments may therefore experience a general reduction in floods and associated sediment transport, e.g. uMgeni and Groot Brak.

Contaminant behaviour and accumulation (e.g. toxic substances)

Contaminants (e.g. metals, polyaromatic hydrocarbons, pesticides, herbicides and pathogens) are introduced through wastewater discharges, stormwater runoff, agricultural return flow and atmospheric deposition. Climate change stressors can cause changes in chemical behaviour (e.g. associated with changes in temperature, pH and oxygen), and the remobilisation and/or flushing of such contaminants (Kennedy, et al. 2002; Schiedek et al. 2007).

For example, changes in pH and dissolved oxygen may result in contaminants becoming bio-available with ripple effects on estuarine biota. Toxic substances (e.g. metal and persistent organic pollutants) adsorb onto fine sediment particles and POM, which settle as a result of a decrease in flow and/or open mouth conditions. The re-suspension and flushing of settled contaminants from estuarine systems is largely influenced by high river flows and extreme events. The predicted increases in temperature are also expected to increase the bioavailability of some toxins, but this is an area that needs further research.

Because of reduced inflow, and increased retention, West Coast and Western Cape estuaries may experience an increase in average pollutant concentrations with a high and medium vulnerability indicated in Figure 88, respectively. As water resources become more developed return flow (e.g. agriculture and wastewater) is expected to make up a larger percentage of the baseflows in especially the West Coast, Western and Southern Cape thus contributing to pollution loads. Contaminant behaviour with the exception of temperature induced aspects, is expected to remain similar to present along the Eastern Cape and the relatively pristine Wild Coast. Along the KwaZulu-Natal coast, a high number of urban estuaries (e.g. Durban, Richards Bay) are likely to experience a significant increase in the flushing of pollutants from the water column and sediment thus “buffering” against the effect climate change (indicated by a low in Figure 88)). A decrease in retention will also assist in reducing the average contaminant concentration.

10.4.3 Sea level rise

Sea level rise can either counteract the reduction in runoff to an estuary or exacerbate the effect depending on the size of the estuary, sediment availability, and wave energy near or at its mouth. In the case of small, temporarily open/closed estuaries sea level rise could assist in maintaining open mouth conditions through increasing the tidal prism, particularly if the system is sheltered from wave action and/or little sediment is available near its mouth. Alternatively, sea level rise could merely reset the level at which an estuary closes to the same relative height above mean sea-level, without significantly affecting the frequency or duration of mouth closure. However, an increase in storminess might actually increase the frequency and or duration of the mouth closure due to increased marine sediment transport into the mouth area during sea storms. Sea level rise can also dampen the barrier effect (i.e. protection) provided by submerged rocky platforms in dissipating wave action and maintaining open mouth conditions under low flows. In the case of permanently open estuaries, sea level rise may lead to an increase in saline penetration (especially in the middle reaches) and require additional freshwater inflow to maintain the present salinity gradient, i.e. it may be necessary to increase ecological flow requirements to maintain present ecological health.

West Coast and Western Cape estuaries will see a significant increase in tidal flows as the less steep topography of this region facilitates the formation of large permanently open systems (e.g. 70 km long Groot Berg Estuary). The increased tidal prisms in the medium to larger temporarily open systems will assist with maintaining open mouth conditions, and associated salinity penetration, in the face of flow reductions, but the benefits of increased sea level rise may be offset by changes in mouth protection (indicated by high in Figure 88). The net result is that the estuaries along this coastline may become more saline as salinity penetration becomes more effective. Southern Cape estuaries will also show a significant increase in tidal flows due to a gentle topography of the large estuarine lakes, bays and permanently open systems of the region. Even the smaller systems may show an increase in tidal amplitude, tidal prisms and associated salinity penetration as sediment is often limiting along this coast, thus preventing estuary berms from resetting to their potential levels. The nett result is that increased tidal prisms in medium to larger temporarily open systems and estuarine lakes will assist with maintaining open mouth conditions and longitudinal salinity gradients. Significant changes (high) are thus expected for the West Coast, Western and Southern Cape (Figure 89).

In the Eastern Cape larger permanently-open estuaries may experience a substantial increase (>1.0 m) in tidal flows, while that of the smaller systems with generally steeper topography will be similar to the present day. Increased tidal prisms in medium to larger temporarily open systems will assist with maintaining open mouth conditions and increase salinity intrusion (indicated by medium in Figure 89). The tidal amplitudes, and flows (tidal prism), of Wild Coast estuaries will remain fairly similar to present as the region has predominantly small systems with steep topography. The Delagoa estuaries, situated on the coastal plain, are also likely to see a large increase in tidal flows and related salinity penetration. However due to their restricted inlets the lakes will only see a small increase in tidal amplitude.

An increase in open mouth conditions and related salinity regimes will mostly be driven by increased inflow as tidal prisms will only increase marginally as the systems reset to a new equilibrium. Once again, the exceptions to the rule are the larger permanently open systems with floodplain areas. It is expected that estuary berm heights along the KwaZulu-Natal Coast will reset themselves to a new elevated equilibrium and so the effects of sea level rise on mouth state and tidal amplitudes in the estuaries of this region are seen as limited (Figure 89).

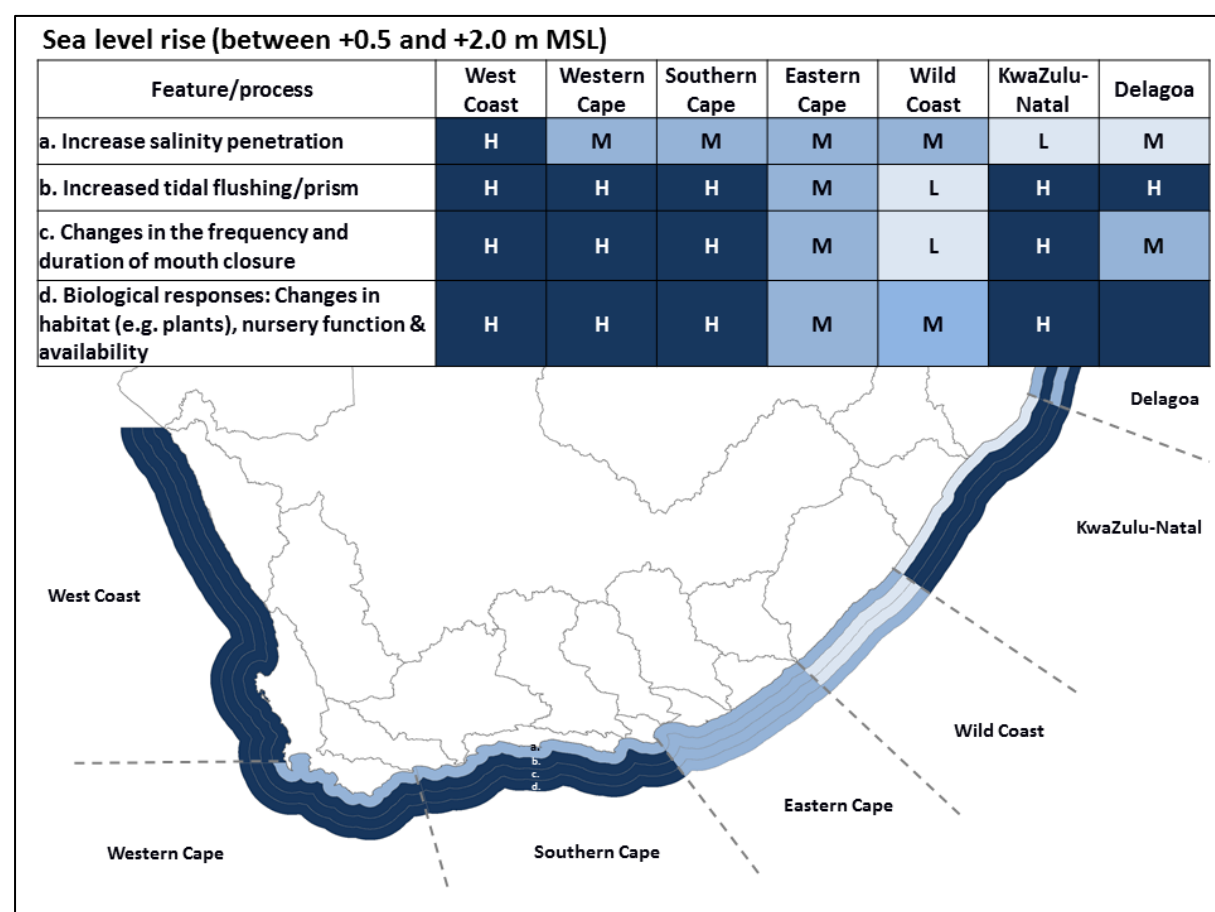


Figure 89. Regional summary of the consequences of sea level rise on key estuarine processes – salinity penetration, tidal flushing and mouth state. Vulnerability is indicated as high/medium/low shifts from west to east with potential change a. to g. depicted by moving outward from the coast.

Thus, tidal amplitudes, tidal prisms and associated salinity regimes, of the KwaZulu-Natal estuaries are likely to remain very similar to present as the region has predominantly small, perched systems with steep topography. However, the exceptions to this rule are the large estuarine lakes and bays of KwaZulu-Natal and Delagoa region, which have extensive floodplains (i.e. St Lucia Lake system comprising more than half of South Africa's estuarine area). The combination of increased tidal prisms in the estuarine lakes, together with amplified inflow, will lead to an increase in open mouth conditions and salinity penetration for these important systems. Hence, the overall high rating given

to the Kwa-Zulu-Natal region in Figure 89, notwithstanding the smaller system largely remaining similar to present. In the case of the Delgoa estuarine lakes, Kosi is predicted to close during extended drought condition (indicated by medium rating).

TEXT BOX 12: SEA-LEVEL RISE AND COASTAL SQUEEZE ON SALT MARSHES AT KNYSNA

Sea-level rise is a significant threat to salt marshes as these habitats exist within defined sections of the tidal frame. Sea-level rise will alter inundation regimes, and this can lead to significant physiological challenges for these plant species. However, under certain conditions, these habitats can respond to sea-level rise and maintain their preferred position in the tidal frame. This can be achieved through the accumulation of organic and inorganic material (to increase surface elevation), or by landward migration (the habitat shifts landward through successive plant growth).

Recent research has investigated the threat of sea-level rise to salt marshes in the Knysna Estuary (Figure 1). The potential for these salt marshes to respond to sea-level rise by increasing surface elevation is dependent on sediment supply from both fluvial and marine sources. As a result, salt marshes in the middle reaches have experienced elevation deficits over time. If gaining surface elevation is not possible, the only adaptation strategy available for salt marshes faced with rising sea-level is landward migration. At the Knysna Estuary, artificial structures are present along 20.7km of the perimeter. These structures significantly reduce the availability of adjacent areas for salt marsh migration. Furthermore, some areas that are currently occupied by salt marshes have been zoned within the South African cadastral layer as erven, indicating the potential for future development. If these areas are developed, this will result in a loss of 60ha of salt marsh (Figure 1). Developing areas adjacent to the salt marsh will therefore significantly increase coastal squeeze.

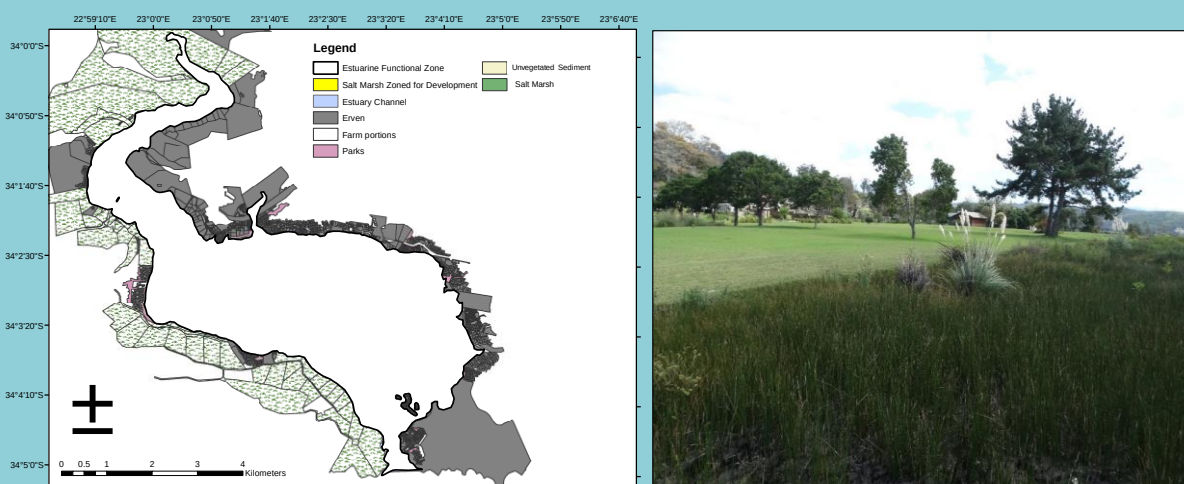


Figure 1. Development zones and salt marsh distribution in the Knysna Estuary. Yellow areas indicate existing salt marsh habitats that occur within zones allocated for future development within the South African cadastre. An example of lawn encroachment into salt marsh at Belvidere in 2018 is shown on the right.

Protecting areas for salt marsh migration should be a conservation priority, as the Knysna Estuary has been long recognized as one of the most ecologically important estuaries in South Africa.

Citation: Raw, J.L. & Riddin, T. 2019, 'Sea-Level Rise And Coastal Squeeze On Salt Marshes At Knysna' in Volume 3: Estuarine Realm. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A.

Climate change and sea level rise will intensify pressure on management agencies to implement assisted (and often premature) breaching as increasingly low-lying properties will be at risk of flooding.

The response of humans to sea level rise are often damaging to estuaries and estuarine biota, e.g. armouring the coastline with berms / dykes that prevent biological systems from adjusting naturally (i.e. inland retreat of wetlands). This could lead to the loss of salt marsh and mangroves leading to a decrease in estuarine habitat and food supply. An indirect impact is an increase in turbidity, as the fringing vegetation around an estuary no longer traps sediment. This, in turn, reduces light penetration thus causing a decrease in primary production by microalgae, whilst filter and 'tactile' feeders will benefit at the expense of 'visual' feeders (e.g. estuarine round herring *Gilchristella aestuaria* vs Cape silverside *Atherina breviceps*).

Furthermore, some mangrove and salt marsh systems may not be able to keep pace with more rapid levels of sea-level rise (see Text Box 12). Mangroves may out-compete salt marshes in Subtropical areas in response to rising sea levels (Adam 2002).

10.4.4 Increase in the frequency and intensity of sea storms

A number of small to medium sized estuaries (e.g. Groot Brak) show great sensitivity to increased wave action (e.g. DWS tidal gauge K2T004). In general, large storms at sea generate the wave conditions that close such estuaries, unless there is significant river flow to maintain the open mouth condition. An increase in storminess due to climate change would therefore increase the occurrence of mouth closure and transport more marine sediment into an estuary than at present. In the absence of freshwater inflow changes, estuaries along an exposed, sediment rich coastline such as KwaZulu-Natal would be more likely to close than estuaries that are fairly protected, or those located on marine sediment starved coastlines such as the Wild Coast. However these generalisations are tempered by aspects such as beach slope, protection against wave action and changes in freshwater inflow.

Along the West Coast and Western Cape mouth closure will increase (indicated by medium in Figure 88), but note that a number of the smaller arid systems are predominantly closed due to a lack of inflow, while larger systems such as the Olifants and Groot Berg should remain open as a result of significant tidal flows. While the steeper beach slopes along West Coast are likely to buffer against a significant increased overwash, overwash is likely to increase salinity in more the sheltered systems, with lower berms, of the Western Cape (indicated as high in Figure 88). The average berm height which is estimated between 2.5– 3.5m MSL can increase by 0.5 – 1.0 m where sediment is available as a result of increased sediment transport potential. As sediment is generally not a limiting factor along most of the Southern and Eastern Cape, increased storminess is likely to translate into increased mouth closure and an ingress of marine sediment at exposed systems (indicated by medium in Figure 88). The exception is the Tsitsikamma coastline in the Southern Cape region where there is limited sediment. Overwash events are also likely to occur more frequently especially in systems where limited marine sediment available retards, or prevents, berm growth (indicated by medium to high in Figure 88). The net result is that some of the estuaries may experience a net increase in salinity during periods of low flow or during drought years.

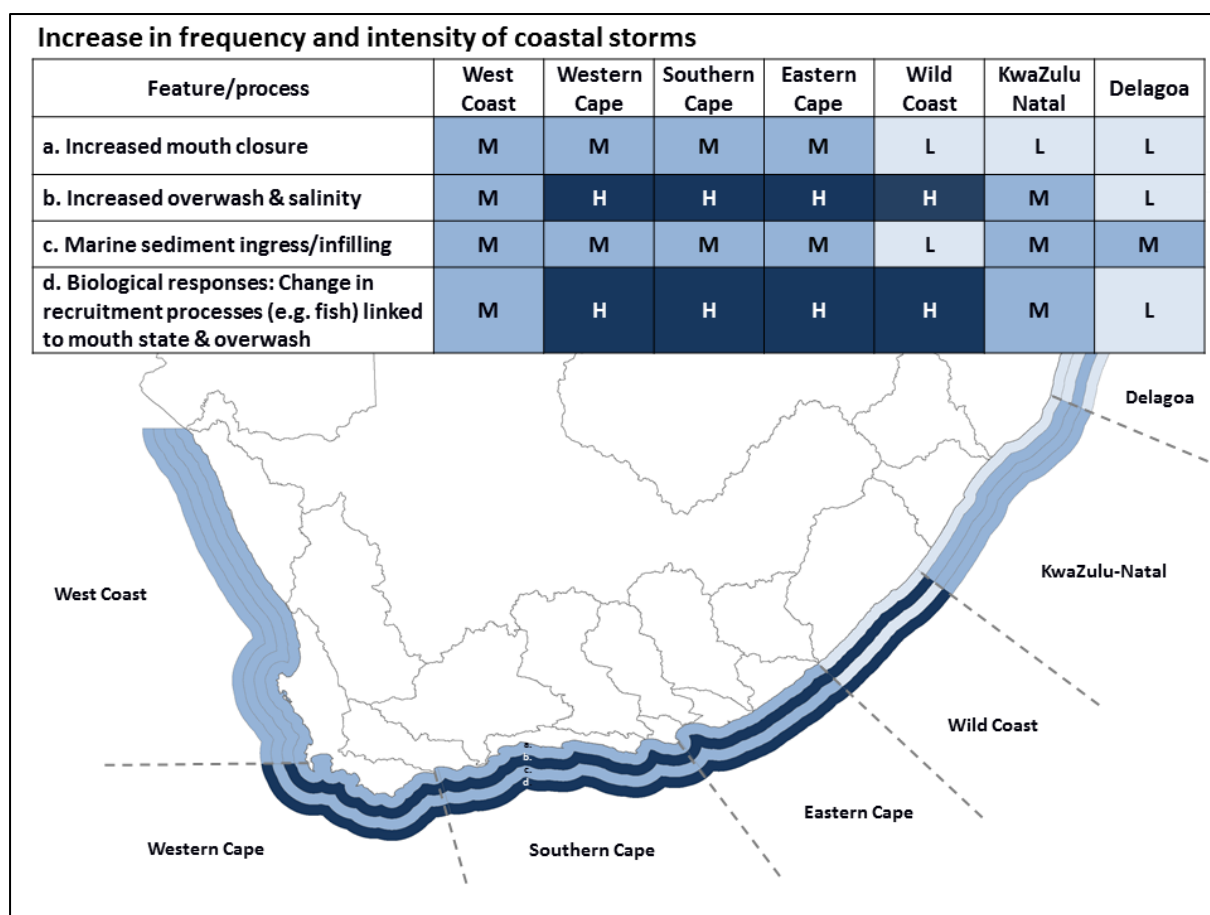


Figure 90. Regional summary of the consequences of increased frequency and intensity of sea storms on estuary mouth state, overwash and marine sediment processes.

Vulnerability is indicated as high/medium/low shifts from west to east with potential change a. to d. depicted by moving outward from the coast.

Wild Coast estuaries are mostly very sheltered with limited marine sediment availability, future mouth conditions are thus likely to be very similar to present (indicated by low in Figure 88), particularly given that a slight increase in river inflow is predicted for this region. At present average berm heights are estimated at 2.5 to 3.0 m MSL, but may rise by 0.5 – 1.0m depending on overwash, increased sediment transport potential and available sediment. KwaZulu-Natal estuaries are somewhat buffered against the potential effects of increased storminess as this coast is characteristically wave dominated, resulting in most estuaries being ‘perched’ high on the beach profile and subsequently less vulnerable to increased storminess (Figure 88). The predicted increase in closure along this coastline is also likely to be offset by increased inflow. In KwaZulu-Natal, present berm heights are relatively high at about 3 to 3.5m MSL and could build up even more by 0.5 to 1.0m by a combination of the predicted increases in overwash and sediment transport potential. The Delagoa estuarine lakes are somewhat buffered against storminess as a result of their restricted inlets and large tidal flows, indicated by medium and low ratings.

The change in biological recruitment follows the same pattern as mouth state and overwash (Figure 88). An overall predicted increase in overwash could offset some of the impacts of mouth closure along the Western and Southern Cape and increase connectivity along the Eastern Cape and Wild Coast (indicated as high on Figure 88).

In addition, to the direct effects of increased storminess on estuary mouth state, are the indirect effects on human behaviour and pressure on estuary resources utilisation. For example, increased wind speeds have resulted in a significant decline in sea-days for the commercial marine linefishery on the southern Cape coast (Augustyn et al. 2017). In an attempt to maintain fishing effort and catch levels, fishers are likely to build larger vessels (i.e. maintain fishing effort at sea) or find calmer waters elsewhere, resulting in a displacement of fishing effort into calmer estuarine waters. This has already happened in the Bot Estuary with the resultant overexploitation and user conflict.

10.4.5 Ocean acidification and estuarine pH shifts

Estuarine pH levels are strongly dependent on coastal upwelling; catchment geology and land-use; freshwater inflow; nutrient input; primary production and decomposition (Feely et al. 2010; Zeng et al. 2015; Laurent et al. 2017). Changes in land-use can result in changes in freshwater alkalinity and CO₂ fluxes up to 0.5 units (Howland et al. 2000; Aufdenkampe et al. 2011; Cia et al. 2011; Duarte et al. 2013; Zeng et al. 2015; Laurent et al. 2017). In South Africa, many rivers are acidic (e.g. pristine rivers of Western Cape Table Mountain Sandstone fynbos region have pH<6), and have saturation states for aragonite (Ω) lower than receiving ocean waters (Midgley and Schafer, 1992). However, as a result of anthropogenic interference (e.g. riparian clearing, agricultural return flow), many of these weakly buffered systems have lost their strong acidic character and pH levels can now exceed that of sea waters, e.g. Palmiet Estuary (DWA 2010). Dynamic gradients in pH and saturation states are driven by estuary mixing processes, but *in situ* metabolic processes can causing deviation from these gradients (Howland et al. 2000; Salisbury et al. 2008; Cai et al. 2011; Duarte et al. 2013; Laurent et al. 2017). The pH in estuarine habitats (e.g. mangroves, salt marshes and macroalgal beds) reveal site-specific diel, semi-diurnal and stochastic patterns of varying amplitudes as high as 1.0 unit (Spilling 2007; Hofmann et al. 2011; Wallace et al. 2014; Hendriks et al. 2014; Baumann et al. 2015). Nutrient enrichment stimulates primary production and eutrophication (e.g. phytoplankton blooms increase pH to 9.0); however once die-off occurs, organic matter is remineralized, leading to potential hypoxia and lower pH (Feely et al. 2010; Wallace et al. 2014; Zeng et al. 2015; Laurent et al. 2017). Deeper, stratified estuaries (e.g. Klein, Swartvlei, Sundays) are more vulnerable to the effects of remineralisation compared with shallower, well-mixed systems. However, shallower systems (e.g. uMdloti) are more vulnerable to large diurnal variations in pH depending on the level of nutrient loading (Baumann et al. 2015). Increased residence times are likely to exacerbate remineralisation and the lowering of pH (O'Boyle et al. 2013; Wallace et al. 2014).

The pH of surface ocean waters may decrease by 0.3-0.4 units by 2100 under the influence of rising atmospheric CO₂ levels (Caldeira and Wickett 2003). Thus, by the end of this century, ocean acidification may become the dominant process in permanently open estuaries as the acidification

process continues, especially the West Coast and Western Cape estuaries (indicated by medium in Figure 91) will be vulnerable as they are subjected to regular upwelling (Figure 87). In the smaller, temporarily open/closed estuaries of these regions, reduced inflow and longer closure may also intensify the effects of existing anthropogenic enrichment. In the KwaZulu-Natal region, and to a lesser extent the Wild Coast region, increased flows and more frequent openings in the small temporarily open/closed estuaries, may reduce the existing effects of anthropogenic enrichment through more regular flushing. Most at risk are the systems that are currently subject to significant pH shifts, i.e. smaller, temporarily open/closed systems in the urban nodes and permanently open systems receiving agricultural runoff.

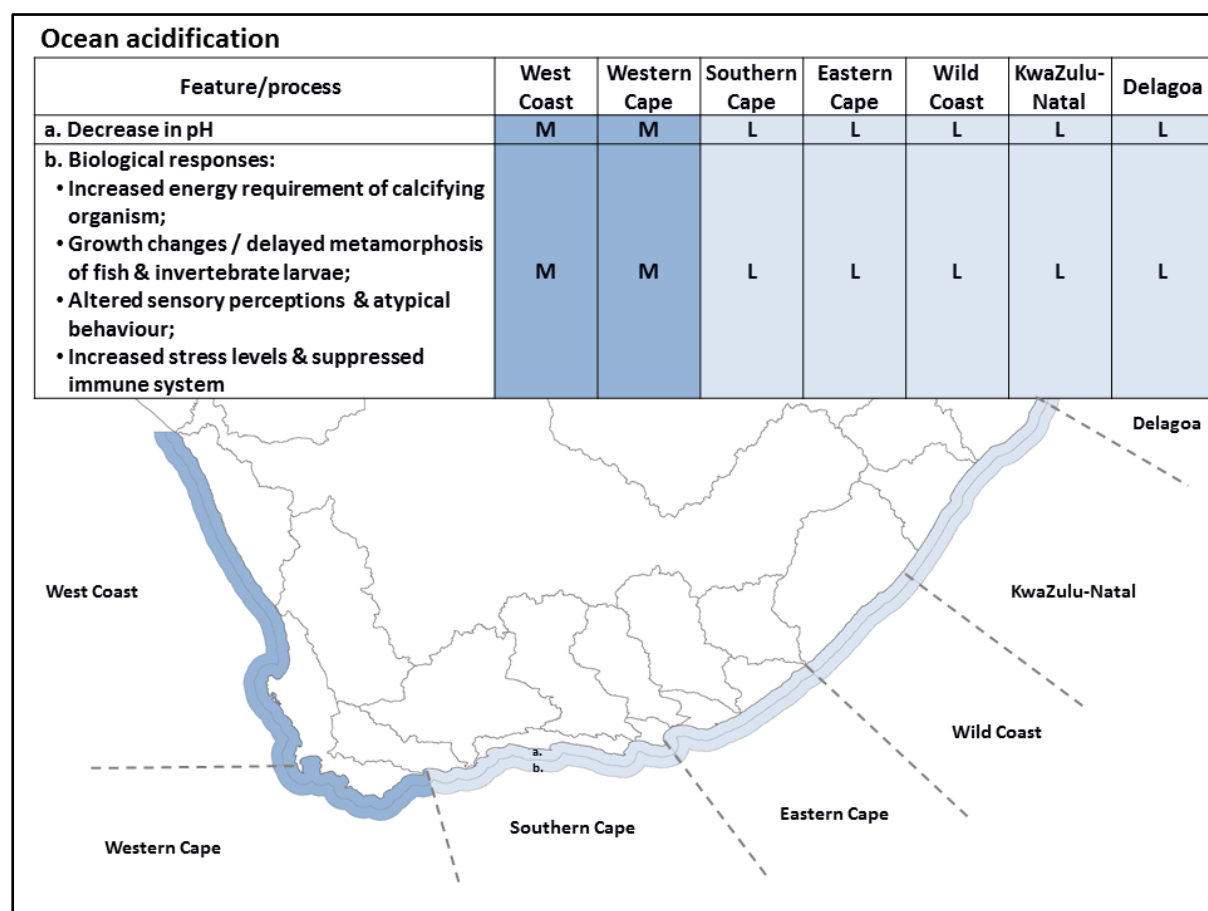


Figure 91. Regional summary of the vulnerability to ocean acidification and the possible consequences on calcifying species. Vulnerability is indicated as high/medium/low shifts from west to east with potential change a. to b. depicted by moving outward from the coast.

Lower pH will affect all calcifying organisms (indicated by medium in Figure 91), as structures made of calcium carbonate dissolve requiring more metabolic energy for an organism to maintain the integrity of its exoskeleton (Azevedo et al. 2015).

Estuarine organisms that may be affected include coralline algae, echinoderms, crustaceans and molluscs (USEPA 2009; James et al. 2013; Azevedo et al. 2015; Zeng et al. 2015). Calcifiers residing in cold water habitats such as upwelling systems are at a higher risk to ocean acidification and decreased seawater carbonate saturation, as their environment is only just supersaturated with respect to the carbonate phases they excrete (Anderson et al. 2008).

The extent of these potential impacts will depend on organisms' ability to adjust their acid–base balance as well as their ability to increase their calcification rates, whilst the ability to withstand or adapt to these changes over long periods of time would clearly be beneficial (Fabry et al. 2008). Acidification will likely impact various life stages differently as CO₂ tolerance varies between life stages of organisms (Pörtner et al. 2004). For most fish species, egg and larval phases are more sensitive to elevated CO₂ compared to the juvenile and adult stages (Ishimatsu et al. 2004). Increases in CO₂ levels may lead to hypercapnia (elevated CO₂ partial pressure) and acidosis in the blood and tissues of fishes (Pörtner et al. 2004). Ocean acidification will not only have a direct impact, but will possibly indirectly influence the ability of organisms to deal with local phenomena. Estuary-dependent species with a pelagic life-history stage will be particularly vulnerable. Slower growth and delayed metamorphosis of fish and invertebrate larvae may result in recruitment failure if these animals miss the brief recruitment window typical of most temporarily open-closed systems along the South African coastline. In some fish species, slow development and changes in the physical and chemical structure of otoliths (and other bone structure) may alter sensory perceptions and their ability to communicate, avoid danger or detect prey (indicated by medium in Figure 91) (Potts et al. 2015). Acid-induced otolith malformation led to atypical behaviour such as reliance on visual rather than sound stimuli, as well as to increased cortisol levels, stress levels and suppressed immune systems in the Sciaenid *Sciaenops ocellatus* (indicated by medium in Figure 91) (Browning et al. 2012). However, not all species will react in the same way to ocean acidification and an understanding of the process driving the different responses by fish is critical for future prediction (Potts et al. 2015).

Anomalous to the above in South African estuaries is the alkalinisation of acidic blackwater catchments (along the Western Cape and Southern Cape) brought about by riparian clearing, agricultural return flow and other bad land-use practices with some estuarine pH levels exceeding that of marine inflow (Lamberth unpublished). While, several species have enough physiological plasticity to cope with acidification, many may not be able to cope with the two extremes of acidity and alkalinity in the marine and estuarine environment.

Abrupt changes and increases in pH and other environmental extremes raise the susceptibility of fish and invertebrates to disease (Huchzermeyer and van der Waal 2012). The invasive potential of these pathogens and their vectors also increases (Conn 2014). Furthermore, the estuarine invasive potential of alien species e.g. Pacific oyster *Crassostrea gigas* may increase in response to rising pH whilst they die-off in an acidic sea (Keightley et al. 2015). However, it may be possible to mitigate the continued development and impacts of corrosive conditions by addressing and reducing the land-derived anthropogenic pressures that contribute to their formation, such as increased nutrient and sediment inputs associated with land-use change and urbanization (Kelly et al. 2011).

10.5 Summary of impact of climate change stressors on critical South African estuarine processes and variables

The interaction between climate change stressors, estuarine processes and associated biotic response are complex (Table 53). With multiple interactions which can both amplify and moderate responses. In summary, the impacts of climate change on South African estuaries include changes in: 1) Ocean circulation patterns resulting in shifts in temperature regimes and coastal connectivity; 2) Terrestrial climatic/hydrological processes forcing changes in: freshwater inflow and associated inputs; shifts in the frequency and duration of estuary mouth closure; modifications in salinity regimes; changes in biochemical inputs; changes in sediment deposition/erosion cycles including accumulation of POM; and changes in contaminant behaviour and accumulation; 3) Sea level rise and related impact on salinity regime and mouth state; and 4) Increase in frequency and intensity of coastal storms also impacting on salinity regimes and mouth state; and 5) Ocean acidification amplifying existing pH fluctuations.

Table 53. A summary of the impact of climate change stressors on critical South African estuarine processes and variables, which in turn drive a range of key biotic responses.
(Large/Small Circle = High/Medium degree of change or vulnerability)

CLIMATE CHANGE STRESSOR					KEY ESTUARINE-ASSOCIATED PROCESSES/ VARIABLES	KEY BIOTIC RESPONSES							
Ocean circulation	Climatic and hydrological	Sea level rise	Storminess	Ocean acidification		Primary production	Habitat forming plants	Eutrophication	Range contraction/expansion	Recruitment	Nursery function	Community composition	Behavioural responses
●					Coastal connectivity	●	●		●	●	●	●	●
	●				Freshwater inflow	●	●	•		●	●	●	●
	●	●	●		Mouth State	●	●			●	●	●	●
	●	●	•		Salinity regime		●	●			●	●	
●	●		•		Nutrients	●	•	●			●	●	
●	●				Temperature	•	•		●	•	•	•	●
•	●			●	Oxygen						●	●	●
●	●			●	pH						●	●	●
	●	●	●		Sediment dynamics & organic accumulation	•	●	●			•	●	
	●				Particulate Organic Matter & Suspended Solids		•	•			•		
	●				Contaminants (Toxins)			●			●	●	



10.6 Conclusion

Overall, this analysis showed that West Coast and KwaZulu-Natal estuaries will be the most influenced by climate change from a structural and functional perspective. In KwaZulu-Natal, the major driver of change is increased runoff into the numerous small, perched temporarily open/closed estuaries, resulting in more open mouth conditions, a decrease in retention time and a related decrease in primary productivity and nursery function. While along the Delagoa estuarine lakes will be sensitive to increase drought conditions and reduce groundwater input leading reduce connectivity in the form of mouth closure. Similar to KwaZulu-Natal, West Coast estuaries will also experience a decline in primary production and loss of nursery function, but as a result of reduced freshwater input. Whilst Wild Coast, Eastern and Southern Cape estuaries will show some shifts in mouth state, nutrient supply, salinity regime and ultimately production. The most obvious impacts of climate change along these coastal regions will be the change in temperature (nearshore and land), associated species range expansions / contractions and changes in community structure.

The effect of sea level rise, and related increase in tidal prisms, will be less apparent along the KwaZulu-Natal coastline, where with the exception of estuarine lakes and bays, the majority of estuaries are perched whilst it will be more apparent along the Southern and Western Cape coast with their more extended coastal floodplains. The effects of ocean acidification in the short term will be negligible in comparison with the terrestrial signal (e.g. eutrophication resulting from urban runoff and agricultural return flow). Systems subjected to regular upwelling or increased upwelling, e.g. along the West Coast are likely to display the effects of ocean acidification first. South Africa is a wave dominated coast sensitive to increased sea storminess. However highly protected (e.g. Wild Coast) or very exposed (along the KwaZulu-Natal) estuaries are less likely to change character, whereas smaller estuaries along the Western, Southern and Eastern Cape may be very sensitive to this change.

11. GOVERNMENT'S RESPONSE TO DECLINING CONDITION OF ESTUARINE ECOSYSTEMS

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Government's Response

- Good progress has been made in the management of estuaries across a number of sectors. These not insignificant gains play a critical role in maintaining and restoring estuary health and ensuring the benefits that society derives from them.
- DWS determined the ecological water requirements of nearly 40% of estuaries, with 37% of these being subject to the "Classification" of freshwater resources.
- About 18% of estuaries have Estuary Management Plans, in various stages of completion, but there is a need to clarify local level responsibilities to ensure effective implementation.
- Unfortunately, there has been a deterioration in the management of fishing pressure, but DEFF is poised to roll out slot limits and the 'prohibition of night fishing in estuaries' country wide in an effort to facilitate national stock recovery.
- Estuaries represent pressure hotspots. Unfortunately, there is a lack of long-term monitoring data to inform conflict resolution and provide for high confidence decision making.

Government responses to declining estuarine condition and productivity are assessed here as follows:

- Resource and biodiversity protection to ensure future benefits to all;
- Management and control of pressure (activities) to ensure estuarine health and productivity;
- Restoration and rehabilitation of critical ecological infrastructure and populations (or stocks);
- Cooperative governance to resolve conflicts and ensure coherent and coordinated responses;
- Strategic responses to future-proof estuaries under changing climate conditions;
- Natural Capital Accounting (NCA) as a complementary reporting system; and
- Monitoring estuarine resources.

11.1 Resource and Biodiversity Protection

Key legislation pertaining to the protection of South Africa's biodiversity and natural resources, including estuarine resources is summarised in Table 54 (Taljaard et al. 2019). The lead agent responsible for such protection in South Africa is the Department of Environment, Forestry and Fisheries (DEFF).

Table 54 Key legislation governing estuarine biodiversity protection

ACT	KEY FOCUS RELEVANT TO ESTUARIES
National Environmental Management: Biodiversity Act (Act 10 of 2004) (Biodiversity Act)	Provides for conservation of biological diversity and ecosystems, and regulates the sustainable use of biological resources
National Environmental Management: Protected Areas Act (No. 57 of 2003) (Protected Areas Act)	Provides for protection and conservation of ecologically viable areas representative of SA's biological diversity and natural land- and seascapes.
Marine Living Resources Act (Act 18 of 1998, as amended in 2000) (Marine Living Resources Act)	Provides for declaration of marine protected areas to facilitate fisheries management areas.
National Parks Act (No. 57 of 1976)	Provides for establishment and management of National Parks (some including estuaries).
World Heritage Convention Act (No. 49 of 1999)	Provides for incorporation of the World Heritage Convention into South African Law (e.g. iSimangaliso Wetland Park).
National Forests Act (No. 84 of 1998)	Promote the sustainable management and development of forests; provides for special measures for the protection of certain forests and trees (including mangroves), and promote the sustainable use of forests.

11.1.1 Increasing protection level and ecosystem resilience

The NBA 2011 developed a biodiversity plan for estuaries of South Africa by prioritising and establishing which should be assigned partial or full Estuarine Protected Area (EPA) status (Turpie et al. 2012; Van Niekerk and Turpie 2012). The National Estuary Biodiversity Plan provides the 'lens' through which all present, and future, resource allocations should be evaluated to ensure that national and international biodiversity targets are achieved.

The plan followed a systematic approach that took pattern, process and biodiversity persistence into account. While the plan has not explicitly taken social and economic costs and benefits into consideration, it used ecosystem health as a surrogate for the former. This is because estuaries where the opportunity costs of protection are likely to be high, are also likely to be heavily utilised systems that are in a lower state of health. The analysis, which included targets for habitats, species, and ecosystem type, suggested that a core set of 133 estuaries, including those already formally protected, would be required to meet South Africa's biodiversity targets. Of these, 61 should be fully protected, and 72 require partial protection.

Fully protected estuaries are taken to be full no-take areas and no/limited riparian development are mostly aimed at small systems. Partial protection allows for some resource use and could involve zonation which includes a no-take zone, or might address other pressures with other types of interventions. Both fully and partially protected estuaries should receive the associated allocation of freshwater quantity and quality to remain at a high level of functionality, i.e. A / B Category or Best Attainable State. Where estuaries are not in a good condition efforts should be made to restore functionality. Fully and partially protected estuaries can be considered 'Estuarine Protected Areas', whereas all other estuaries should be designated 'Estuarine Management Areas'. The plan recommends that all estuaries develop an Estuarine Management Plan in terms of the ICM Act (Act

24 of 2008), and these plans should take into account the results of this National Estuary Biodiversity Plan. An additional six estuaries were subsequently also highlighted as provincial conservation priorities by the relevant conservation authorities, namely Noetsie, Rooiels, aMahlongwa, uMahlongwane, uThukela, iNhlabane.

However, there has been little progress on the declaration of estuaries as protected areas, with only 13 km² (parts of Sundays and uThukela estuaries) added in nearly ten years as part of the recently declared Operation Phakisa Marine Protected Area (MPA) initiative. The Goukou, Sundays and uThukela also represent the only estuaries that have been explicitly promulgated as MPAs. An additional concern is that there are very few no-take estuaries. Measures should be explored to increase the amount of no-take areas (e.g. zonation, full closure and seasonal closures). Provincial Protected Areas Expansion Strategies need to be focussed on how to incorporate more estuarine area into formal processes aimed at increasing the protection status of important estuaries, e.g. CapeNature has included priority estuaries in the Western Cape Protected Area Expansion Strategy and intends to increase protection levels by identifying and implementing the most appropriate conservation tools for each estuary in, or adjacent, to Protected Areas over the next five to ten years, e.g. Olifants, Verlorenvlei, Groot Berg, Rooiels, Bot/Kleinmond, Palmiet, Klein, Uilkraals, Heuningnes, Breede, Goukou, Goukamma, Keurbooms.

Smaller estuaries that exist within one municipality in their entirety can also be formally protected by local government, e.g. the City of Cape Town formally protected Zand and the Diep/Rietvlei Estuary under provincial legislation that assigns this function to them.

11.1.1 Ramsar Convention

The Convention on Wetlands, called the Ramsar Convention, is a global intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The Convention entered into operation in South Africa on 21 December 1975. South Africa currently has 23 sites designated areas as Wetlands of International Importance (Ramsar Sites). Nine estuaries are listed Ramsar sites under the Ramsar Convention namely the Orange, Verlorenvlei, Langebaan, Bot/Kleinmond, Touw/Wilderness, Heuningnes, Kosi and St Lucia (including a part of uMfolozi) estuaries. Of these only Langebaan and Kosi

are in a Near Natural condition, while Bot/Kleinmond, Heuningnes and Touw/Wilderness are in a Moderate modified state. The other four systems are in a Heavily Modified condition, with the Orange Estuary listed on the 'Montreux Record' and still declining in condition. Bot/Kleinmond was designated in 2017, representing the only Ramsar site added in the last decade. Of the above listed systems, three estuaries do not have formal protection (Orange, Verlorenvlei, Bot/Kleinmond), and the national and provincial government are in the process of addressing this gap.



Whilst Ramsar site status clearly recognises the global conservation value of a site it does not provide any legal conservation status for the site. It is the responsibility of the South African Government at national and provincial level to ensure that the site receives legal conservation status.

11.1.2 Important Bird and Biodiversity Areas

Important Bird and Biodiversity Areas (IBAs), as defined by BirdLife International, constitute a global network of over 13 500 sites, of which 112 sites are found in South Africa. IBAs are sites of global significance for bird conservation, and are identified nationally through multi-stakeholder processes using globally standardised, quantitative and scientifically agreed criteria. The IBA sites are generally small enough to be entirely conserved and differ in their character, habitat or ornithological importance from the surrounding habitat. Often IBAs form part of a country's existing protected area network, and so are protected under national legislation. Nineteen estuaries form part of IBAs sites in South Africa (Table



Table 55 Important Bird and Biodiversity Areas in South Africa

ESTUARY	STATUS	BIODIVERSITY PRIORITY
Orange	Heavily	Priority
Olifants	Moderate	Priority
Verlorenvlei	Heavily	Priority
Groot Berg	Moderate	Priority
Diep/Rietvlei	Heavily	Priority
Bot/Kleinmond	Moderate	Priority
Heuningnes	Heavily	Priority
Touw/Wilderness	Moderate	Priority
Gamtoos	Near Natural	Priority
Van Stadens	Near Natural	Priority
Maitland	Near Natural	Priority
Swartkops	Heavily	Priority
Cebe	Natural	-
uMthamvuna	Near Natural	Priority
uMlalazi	Near Natural	Priority
uMhlathuze	Heavily	Priority
iMfolozi/uMsunduze	Heavily	Priority
St Lucia	Heavily	Priority
Kosi	Natural	Priority

55). Of these only seven are in a Natural or Near Natural state. All of the systems, with the exception of the Cebe Estuary, form part of the core set of estuaries identified in need of protection. In some cases IBAs also form part of Ramsar sites.

It is also critical to understand that while spatially planned conservation areas form a critical part of the overall conservation effort of specific species, the migration corridors, e.g. alternative breeding and feeding areas, also need to be taken into consideration when planning for the overall conservation of ecosystems and important species.

The management of especially recreational activities (e.g. swimming, boating, bird watching, dog walking, picnic sites, hiking and kite surfing) needs to be managed very effectively in IBAs to ensure that there is little disturbance of birds in roosting and feeding areas.

11.1.3 Increasing protection through stewardship programmes

The establishment of protected areas is a key response to change and human activity pressures on estuarine biodiversity. Protected areas are traditionally the most secure mechanisms for conserving species and ecosystems but estuarine ecological processes, which often operate over large spatial scales, are not effectively protected in protected areas e.g. land-sea connectivity. Historically, the emphasis in South African protected areas establishment was the protection of wildlife resources, charismatic species or areas, mountain catchment areas and indigenous forests. The preferred mechanisms were proclamation of state-owned land or purchase and proclamation by the state. More recently, biodiversity stewardship programmes have expanded, allowing for the proclamation of protected areas on privately owned land. In the last ten years ~ 830 00ha has been added to the protected areas estate of South Africa. Over 68% of which (564 000ha) was through biodiversity stewardship agreements (Skowno et al. 2019). This approach relies on the willingness of key land owners and has been shown to be 70 to 400x cheaper to establishment stage and 4 to 17x cheaper to manage.

Biodiversity stewardship recognises landowners as the custodians of biodiversity on their land. Stewardship is based on voluntary commitments from landowners, with a range of different types of Biodiversity Stewardship Agreements available to support conservation and sustainable resource use. Some types of Biodiversity Stewardship Agreements are formally declared as protected areas in terms of the Protected Areas Act, providing long-term security for the sites involved.

Biodiversity stewardship is particularly effective in multiple-use landscapes where biodiversity priority areas are embedded in a matrix of other land uses. A flexible range of biodiversity stewardship agreements is available that can combine biodiversity protection and sustainable resource use. It should be noted that biodiversity stewardship agreements are often confined to estuarine riparian areas and not the open water area. It is strongly recommended that there should be more engagement with biodiversity stewardship programmes to ensure that estuaries (in the form of EFZ protection) are more represented in the protected area network in the future.

11.1.4 Consideration of Critical Biodiversity Areas in planning and decision making

National legislation makes provision for identifying Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) with accompanying land-use guidelines that are compiled into Biodiversity Sector Plans. These represent the biodiversity sector's inputs to cross-sector planning and decision-making. Critical Biodiversity Areas (CBAs) are areas required to meet biodiversity targets for ecosystems, species and ecological processes, as identified in a systematic biodiversity plan. Ecological Support Areas (ESAs) play a vital role in supporting the ecological functioning of Critical Biodiversity Areas and Protected Areas and/or in delivering ecosystem services. A CBA map is a spatial plan for ecological sustainability that identifies a set of biodiversity priority areas, which, together with Protected Areas and ESAs, are needed for the long-term ecological functioning of the land and seascape s (SANBI 2017). The purpose of a plan (including map) is to guide

decision-making about where best to locate development and are designed for use by a range of sectors (e.g. land use planning, environmental authorisations, agricultural authorisations, mining authorisations, water use licencing) that impact on the use and management of natural resources. To date this has only been systematically done with the terrestrial environment. Moving forward CBAs and ESAs should be designed across land- and seascapes. Until now, terrestrial, estuarine and marine realms in South Africa (and for the most part, globally) have been working on conservation/biodiversity planning independently, which can result in a non-alignment of priorities.

The key to estuarine resilience is in maintaining ecological connectivity across the land-sea interface that defines and supports functioning of this ecotone; delineating estuary ecosystem types and their supporting habitats, such as River-Estuary Transition Zone and River-Influenced Nearshore Marine Environments, is the first step towards protecting them. Some progress has also been made in the identification of coastal and estuarine CBAs, under the Biodiversity Act with some estuaries listed as Critical Biodiversity Areas 1 (CBA1) due to their sensitivity and high productivity. This means that future development should not impair their functioning or put associated biodiversity at risk. This initial list needs to be expanded to include all important estuarine habitats and high priority systems.

11.1.5 Ecologically or Biologically Significant Marine Areas

South Africa also has a network of Ecologically or Biologically Significant Marine Areas (EBSAs) (Figure 92) which were adopted by the CBD in 2014. EBSAs were initially conceptualised as 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, soon became apparent. Through a series of regional workshops, EBSAs were identified by evaluating sites against seven criteria, and delineated within country exclusive economic zones (EEZs), in the high seas, and transboundary. Currently, 279 sites have been identified, globally.

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

Although EBSAs are not legally binding, the CBD encouraged countries to co-operate regionally, and implement 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, 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 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 (Harris et al. 2019). 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 the emerging national Marine Spatial Planning processes, it is likely that EBSAs will comprise two zones: a conservation zone, and an impact management zone.

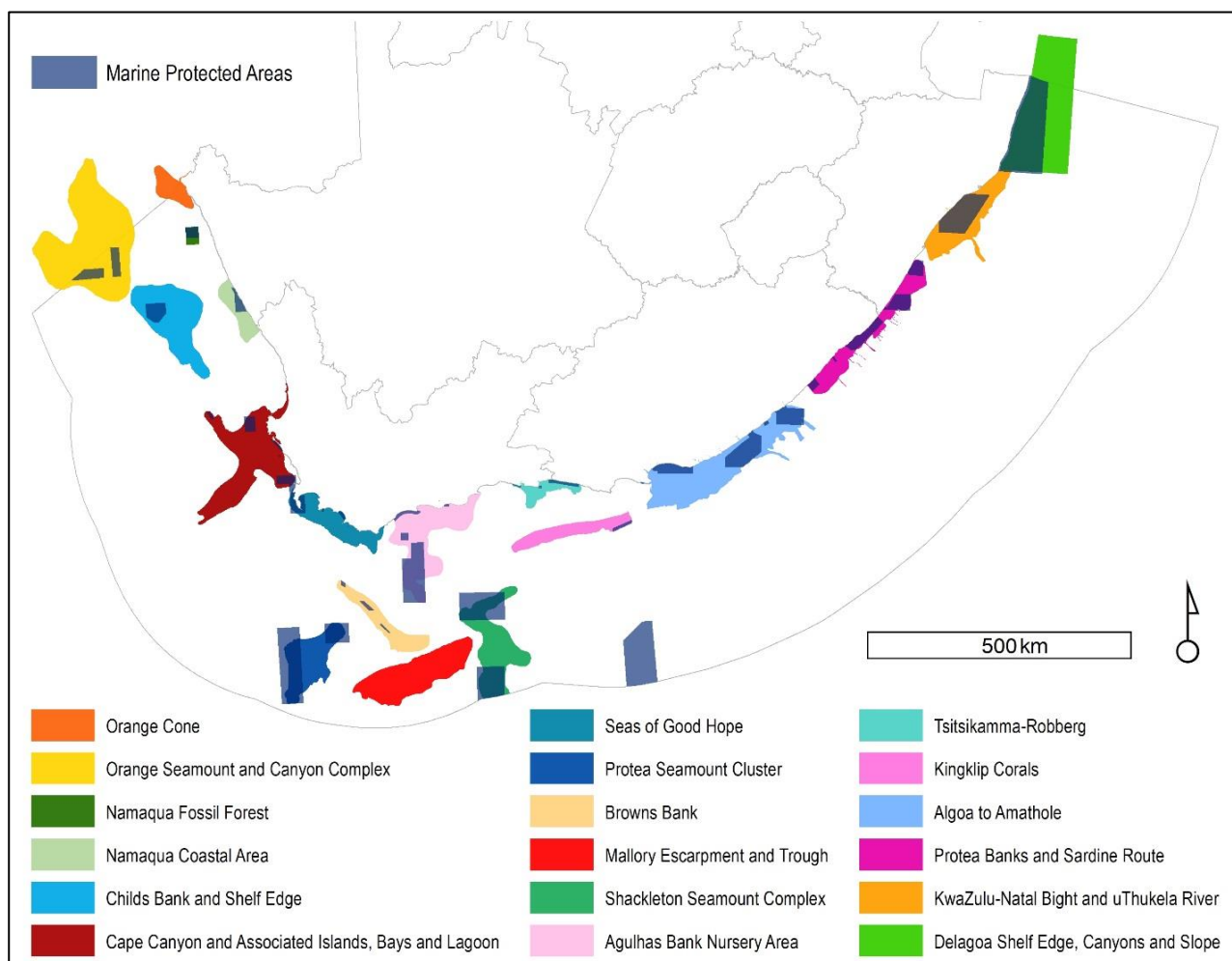


Figure 92. South African Ecologically or Biologically Significant Marine Areas.

The management objectives of these two zones align strongly with those of CBAs and ESAs respectively; therefore, the Coastal and Marine CBA Map is being put forward as 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 streamlined, single, coherent and science-based ‘ask’ from the biodiversity sector in the multi-sectoral MSP negotiations.

Although EBSAs primarily delineate important marine areas, the land-sea connection provided by an estuary sometimes underpins a lot of the associated marine biodiversity and/or ecological processes that make a site deserving of EBSA status.

Particular examples in South Africa are the Orange Cone EBSA and KwaZulu-Natal Bight and uThukela River EBSA, respectively driven to a large extent by flows from the Orange and uThukela Rivers. Therefore, in the revised delineations as part of the MARISMA project, priority estuaries are included in the new boundaries where they play a key role in land-sea connectivity and support ecological processes for marine biodiversity in adjacent coastal areas.

11.2 Management and control of key pressure

In South Africa, government responses to mitigate, manage and control pressures in estuaries, are largely regulatory, with little focus on an incentive-orientated system. Also, the legal framework is largely sectoral, spanning several government departments, as is illustrated by a brief summary of the key legislation provided in Table 56.

Table 56. Summary of legislation governing mitigation, management and control of key pressures in estuaries (including lead agents)

KEY PRESSURE CATEGORY	ACT	KEY FOCUS RELEVANT TO ESTUARIES	LEAD AGENT
WATER RESOURCE DEVELOPMENT	National Water Act (No. 36 of 1998) (Water Act)	Ensures protection of aquatic ecosystems of South Africa's water resources, including estuaries, through classification of resources and establishment of resource quality objectives.	DWS
		Classifies certain land use (e.g. activities resulting in stream-flow reduction (e.g. afforestation and crop cultivation of crops).	
POLLUTION (INCLUDING PLASTICS)	NEMA	Some waste disposal activities (e.g. effluent discharges) are specified as listed activities.	DEFF
	National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008)(ICM Act)	Prohibits incineration at sea, and controls dumping at sea, land-based pollution in the coastal, inappropriate development in coastal environment and other adverse effects on the coastal environment.	DEFF
	Water Act	The Act (section 21) identifies waste disposal (from land-based activities) as 'water uses' that require authorisation.	DWS
	National Environmental Management: Waste Act (No. 59 of 2008)	Regulates (solid) waste management to protect health and environment by providing reasonable measures for prevention of pollution and ecological degradation.	DEFF
	Marine Pollution (Control and Civil Liability) Act (No. 6 of 1981)	Provides for prevention and combating pollution in marine environment from oil and other harmful substances.	Dept. of Transport (prevention) DEFF (combating)
	National Health Act (No. 61 of 2003)	Delegates responsibility for environmental health (e.g. water quality for recreation) to metropolitan and district municipalities.	Dept. of Health Municipalities
EXPLOITATION OF LIVING RESOURCES	Marine Living Resources Act	Governs utilisation, conservation and management of marine living resources.	DEFF
	Biodiversity Act	Regulates control and management of alien invasive species. Controls harvest, use, trade of selected species e.g. seahorses & pipefish (TOPS regulations under NEMBA).	DEFF
	Conservation of Agricultural Resources Act (No. 43 of 1983)	Provides for conservation of natural agricultural resources and protection of vegetation.	DALRRD
LAND-USE & URBAN DEVELOPMENT	Disaster Management Act (No. 57 of 2002)	Provides for integrated and co-ordinated disaster management policy (including disaster management related to climate change). Also Governs artificial breaching of estuary mouths in urban settings (once approval has been granted under NEMA).	Provinces/ Municipalities
	Local Government: Municipal Systems Act (Act 32 of 2000)	Provides for integrated development planning intended to encompass and harmonise planning over various sectors.	Dept. of Provincial & Local Government & Municipalities

KEY PRESSURE CATEGORY	ACT	KEY FOCUS RELEVANT TO ESTUARIES	LEAD AGENT
	Spatial Planning and Land Use Management Act (No. 16 of 2013)	Provides for a framework to govern planning permissions and approvals, sets parameters for new developments and provides for different lawful land uses.	Dept. of Rural Development and Land Reform/ Provinces/ Municipalities
	National Environmental Management Act (No. 107 of 1998) (NEMA)	Specifies listed activities in sensitive areas (including EFZs) that require environmental authorisation before they may proceed. Some waste disposal activities and infrastructural developments (e.g. altering watercourse) are classified as 'water use' that require authorisation.	DEFF & Provincial Departments of Environmental Affairs
	ICM Act	Ensures that development and the use of natural resources within the coastal zone is socially and economically justifiable and ecologically sustainable.	DEFF
	Water Act	Classifies certain infrastructural developments (e.g. altering watercourse) as 'water use' that require authorisation.	DWS
	Sea-shore Act (No. 21 of 1935)	Regulating, operating and legalisation process of jetties, slipways and other structures along the seashore, including estuaries.	Provinces
	Municipal Bylaws	Urban drainage (stormwater management) is the responsibility of municipalities for which bylaws need to be promulgated.	Municipalities
	National Ports Act (No. 12 of 2005)	Provides for management of commercial ports (in estuaries), including environmental matters.	Dept. of Transport (DoT) (through TNPA)
MINING	Mineral and Petroleum Resources Development Act (No. 28 of 2002)	Regulates mining including management of mining impacts on environment.	DMRE
ALIEN INVASIVE SPECIES	Biodiversity Act	Regulates control and management of alien invasive species, including estuarine environments.	DEFF
	Conservation of Agricultural Resources Act (No. 43 of 1983)	Provides for conservation of natural agricultural resources and protection of vegetation.	DALRRD
	Agricultural Pests Act, 1983 (Act 36 of 1983)	Provides for measures to combat agricultural pests and prevent their introduction.	DALRRD

11.2.1 Flow modification

In total, 56 estuaries have been identified as being affected by Very High to High flow modification pressures. These systems need to become priorities for both DWS and Management Authorities for future interventions, especially concerning the provision of adequate seasonal baseflows (see Appendix D for complete list). In accordance with the National Water Act (1998), ecological water requirements (EWRs) must be determined for all water resources (including estuaries). The water resource 'Classification' process and the associated 'setting of Resource Quality Objectives (RQOs)' is one of the critical tools that, if prioritized according to

environmental flow requirements, can be used to effectively ensure estuarine resource or ecosystem protection. Over the past 10 years substantial progress has been made in assessing ecological water requirements of estuaries, with 40% of the country's estuaries covered (Van Niekerk et al. 2019b). In addition, the Classification and ROQs allocation processes has been completed for 37% of systems. A concern, however, is that many of these assessments have been done at the 'Desktop' level, and therefore of very low confidence. This unfortunately may result in overestimation, but more importantly an underestimation of freshwater allocations to estuaries.

The 'Classification' process also seems to view existing water resource use as sacrosanct, while other forms of resource use, e.g. fishing or pollution, are treated as negotiables. To reach a truly balanced distribution of estuarine benefits even existing lawful uses may need to be redistributed through compulsory licensing mechanisms, e.g. returning some baseflows to ensure estuarine production. At present the Water Act does not recognise river-influenced nearshore marine ecosystems as a 'water resource'. As a result, the flow requirement processes exclude freshwater allocations to these critically important estuarine-associated ecosystems, with knock-on effects to estuaries, e.g. limited spawning habitat (subtidal fluvial fans) for White Steenbras. Concern also exists around ensuring ecosystem functionality to meet globally committed biodiversity protection targets and their associated freshwater flow requirements as conservation priorities are still simply viewed as 'another water user' in a catchment, rather than their freshwater allocations being given a higher priority to sustain the fabric of life and associated ecosystem services.

Currently, EWR and Classification studies are providing baseline information on estuarine pressures and health to the NBA, State of the Environment reporting and Natural Capital Accounting processes. It also provides important information and targets for local estuary management planning. Moving forward it is important that other avenues for assessment are developed to ensure continuous updating of estuary health assessments. In some cases Municipal and Provincial Coastal Committees can be used to generate the required data and information on pressures once a reporting framework have been developed. Also imperative is the development of reporting processes and frameworks for updates to Statistics South Africa (STATS SA), thereby ensuring a regulated flow of information.

11.2.2 Pollution

Overall, 94 estuaries were identified as being under Very High or High pollution pressures. These systems need to become management priorities for future interventions by DWS, DEFF and local government, with nutrient pollution mainly originating from wastewater disposal, agricultural return flow and urban stormwater runoff (see Appendix D for complete list). Of high concern, is the rapid escalation of pressures associated with municipal wastewater (sewage) disposal and sewage spills, especially in the coastal urban centres (e.g. Cape Town, Port Elizabeth, East London and Durban). As a result of rapid urbanisation and poor infrastructure maintenance, municipal wastewater treatment works (WWTW) and pump stations are no longer able to cope with high sewage volumes. Even if the treatment plants can treat effluent to legal standards (e.g. General Standards), the volumes of effluent are simply too large to remain within the assimilative capacity of the relatively small estuaries. In some cases, lack of human and financial resources as well as frequent vandalism and cable theft, also cause malfunctioning of WWTW infrastructure resulting in untreated waste entering

sensitive estuarine systems. Misperception between government departments caused by overlapping mandates in terms of the management and control of land-derived wastewater disposal to estuaries (i.e. DEFF under the ICM Act, DWS under the Water Act) hamper effective, focussed and timeous government responses to mitigate these pressures. The mandates of provincial government, protected area authorities and municipalities (district and local) in incident responses also appears unclear.

The dominant vector of pollution in rural areas is nutrient enrichment from agricultural return flows (typically introduced through excessive application of fertilisers). However, very little information is available on the effects of other toxic substances (e.g. organic compounds from herbicides and pesticides) which are also likely to be entering estuaries, but are not measured due to the costs of monitoring such parameters. In accordance with national legislation (e.g. National Water Act and ICM Act) any discharge of effluent that originates from land into a water resource or into coastal waters requires general authorisation or a coastal waters discharge permit (DEA 2014 & 2019). The development of infrastructure related to effluent discharges may also trigger listed activities under the NEMA EIA Regulations and thus subject to an Environmental Impact Assessment (EIA). Further, South Africa's new regulations pertaining to coastal waters discharge permits states that no new wastewater discharges will be allowed into estuaries (DEA 2019b). DEFF: Oceans and Coasts must report every three years on the status of effluent discharged into coastal waters and its impact on the coastal environment. To be able to accurately assess this pollution pressure on estuaries, it is critical that the Department insist that owners of existing WWTWs (or industries) disposing of wastewater provide them with actual monitoring data on volumes and composition of effluent (and not having to rely on licence agreements). Indeed, this should be a requirement in coastal water discharge permits (DEA 2019b). In addition, the volumes of waste discharges just above estuaries also needs to be reflected as a coastal impact, regardless of jurisdictional boundaries.

In terms of both the ICM Act and National Water Act, urban (and industrial) stormwater runoff also fits the definition of land-derived wastewater or effluent. Contaminated runoff contains an array of pollutants posing serious threat to ecosystems, including toxic substances (such as metals, petroleum hydrocarbons and persistent organic pollutants). However, unlike point sources (e.g. WWTW discharges) these diffuse sources of pollution are extremely difficult to identify, regulate or control at end-of pipe; and should rather focus on identifying interventions at source. Management of urban stormwater resides with local authorities (Constitution (Act No.108 of 1996)), which municipalities typically manage using by-laws. Estuaries are being overwhelmed by contaminated stormwater runoff (and plastic pollution) resulting from rapid urbanisation along banks and adjacent catchments. Traditional approaches to managing pollution sources require urgent re-thinking. Adams et al., 2019 recommended more stringent and technologically innovative guidelines are needed to address this growing pressure.

Solid waste should be disposed of in licensed landfill sites, regulated NEMA under the Waste Management Act and licensed by the mandated authorities of DEFF (in terms of hazardous waste facility) and Provinces (general waste facility). Inappropriate solid waste disposal, e.g. littering due to the lack of waste collection services at informal settlements, is having a serious impact on the coastal zone (e.g. ingesting of plastic by and entanglement of marine animals, beach closures, and deteriorating aesthetic values in general). Solid waste disposal and collection sites are also often the source of plastic pollution into estuaries, harming

estuarine ecology and eroding the social benefits that can be derived from estuaries, e.g. tourism opportunities. The impact of littering, a diffuse source of solid waste (plastic pollution), is being targeted through the Source to Sea initiative and the Working for the Coast Programme and related activities such as annual participation in the International Coastal Clean-up campaign (DEA 2019a). In addition, it is strongly recommended that a census be conducted of solid waste disposal and collection sites near, or in, estuaries, to assess their impact and identify possible mitigation measures to elevate pollution pressure, e.g. Seekoei (Cape Town), Nenga (Coffee Bay) and uMgeni (Durban) impact. Focused efforts are also required in addressing the most problematic plastic products as well as growing the recycling economy.

Finally, greater effort is necessary to implement root cause responses, ameliorative actions and ensure that compliance monitoring is taking place. Poor legal compliance and lack of enforcement contributes significantly to deteriorating water quality in estuaries – however, particularly encouraging is the recent intention by DWS to establish an Anti-Pollution Task Team which will deal with escalating incidents of pollution as well as conduct a nation-wide assessment of the status of water quality throughout the value chain and not just at source. Co-operation and collaboration between government departments and stakeholders through sharing of resources ideally needs to take place in order combat this growing pressure that threatens the ecological resilience and health of South Africa's estuaries. Healthy functional estuaries support the cultural, aesthetic, commercial, recreational and subsistence activities and values upon which we depend.

11.2.3 Exploitation of living resources

In relation to over-exploitation, 61 estuaries were identified as being subject to Very High to High fishing pressure. These systems need to become management priorities for future interventions by DEFF and the relevant management authorities, such as the ban on night fishing and effective compliance thereof (see Appendix D for complete list). It needs to be understood that unlike the ocean where habitats and species aggregations are spatially distributed along the entire coast, the relatively small estuarine space can be easily and intensively targeted (or “mined”) by fishers leading to a high risk of stock depletion due to intensive fishing pressure.

Over the last 10 years, high fishing pressure has resulted in some estuarine-dependent fish species showing no signs of stock recovery, with some experiencing further decline to critical levels (<1% of pristine) and at risk of population extirpation. Total extinction of endemic species is becoming a real possibility. For example, Dusky Kob *Argyrosomus japonicus*, are at less than 1% of historical spawner biomass with an effective population size (successful breeders) estimated at less than 500 pairs countrywide, 50 to 100 pairs in the Western Cape (Mirimin et al. 2015). In response to this, and the fact that more than 50% of large reproductive adults are caught at night, a ban on night fishing was introduced at the Breede Estuary to protect both adolescents and breeding adults as well as to enhance nursery function. Initially there was significant resistance (and still is in isolated instances) to this measure, it is proving so successful that the approach will be rolled out to all other estuaries in the country over the next few years. Similarly, a prohibition on targeting and catching sharks and rays in the Breede Estuary has shown promise in controlling trophy fishing for these species. It is suggested that either a ban or catch-and-release of these, should also be rolled out countrywide.

In addition, no commercial fishing is allowed in estuaries with the exception being the Olifants and Langebaan estuaries that have a commercial gillnetting fishery. Commercial gillnetting was removed from the Groot Berg Estuary in 2001. No night-time fishing is allowed in the Zand Estuary (CCT) but this was implemented as a public safety measure rather than as a fisheries control measure. With the exception of the traditional Kosi trap fishery and bait harvesters in the Knysna and Swartkops estuaries, small-scale fishers in all systems are not allowed to sell their estuarine catch. In spite of ongoing compliance initiatives on a number of large estuaries, e.g. Groot Berg and Goukou, there is a lack of national scale compliance and enforcement capacity with regards to fish catch monitoring in estuaries. In addition, the integrity of estuarine protected areas is being eroded by both sanctioned and unlawful fishing in these areas. In many instances, fishing effort is now five times higher inside than outside restricted areas, e.g. estuaries in the Dwesa-Cwebe Marine Protected Area (MPA) and Nature Reserve.

Multiple interventions are required to avoid further decline in fish health. These include protection of freshwater inflow, restoration of water quality, reduction in fishing effort and avoidance of mining, infrastructure development and crops in the EFZ. The first priority is the implementation of the (ministerially approved) prohibition on fishing at night in all estuaries in South Africa. Implementation of amended bag and slot limits (minimum and maximum sizes) for priority species - Dusky Kob, Dusky Steenbras, Spotted Grunter, Leervis and Elf. Regularly update stock assessments of the afore mentioned species. Consideration should also be given to testing rotational time area closures in pilot estuaries. Escalating gill net poaching is responsible for at least half the catch in South Africa's important estuary fish nursery areas. This has resulted in recruitment and growth overfishing and collapse of the six most economically and socially important species in estuaries and the sea. The most severely impacted are small scale coastal fisheries. There needs to be a coordinated campaign to eradicate this destructive fishing method. This includes national government support (financial and logistical) to provincial management authorities. There is much scope for the improvement and resourcing of fisheries compliance monitoring and enforcement efforts, more so an urgency with the recent gazettement of the new 'Operation Phakisa' MPAs.

11.2.4 Land-use and urban development

A total of 84 estuaries are subject to severe land-use and development pressure. Urgent management interventions are required to evaluate how ecological functionality can be restored and if restoration is possible of key habitats (see Appendix D for complete list). Land-use change requires a range of management responses to manage ongoing degradation.

The Department of Environment, Forestry and Fisheries (DEFF and previously known as DEA) is the lead agent for NEMA that provides for co-operative environmental governance through the establishment of national environmental management principles and procedures, and for their incorporation into decisions affecting the environment. The NEMA emphasizes co-operative governance and assists in ensuring that the environmental and related rights in the Constitution are protected. The Act states that sensitive, vulnerable, highly dynamic or stressed ecosystems (such as estuaries) require specific attention in management and planning procedures, especially where subjected to significant human resource usage and development. Various activities listed in the NEMA Environmental Impact Assessment ('EIA') Regulations (which came into

effect on 2 August 2010) have a bearing on activities within the coastal zone and require environmental authorisation before they can proceed. The EIA Regulations are especially pertinent to estuaries as many estuaries are situated within rapidly expanding development nodes along the South African coast and are under tremendous development pressure. Depending on the activity and/or applicant, DEFF, DMRE or the provincial competent authority will be responsible for assessing applications for environmental authorisation. In terms of GNR 327 (Listing Notice 1) a Basic Assessment must be conducted; and in terms of GNR 325 (Listing Notice 2) an EIA must be conducted. GNR 324 (Listing Notice 3) identifies activities in sensitive areas (including the estuarine functional zone limited to the 5m topographical contour) that also require environmental authorisation before they may proceed. Particularly in KwaZulu-Natal there is the realisation that the current EFZ delineation is inadequate and that a new EFZ area must be legislated before even more estuarine habitat is compromised.

The Department of Cooperative Governance Traditional Affairs (CoGTA) is the lead agent for the Municipal Systems Act. The Act deals with Integrated Development Planning (IDPs), and municipalities are mandated to prepare and to update IDPs regularly. An IDP is intended to encompass and harmonise planning over a range of sectors such as water, transport, land use and environmental management linked to municipal mandates. It requires each local authority to adopt a single, inclusive plan for the development of the municipality. Chapter 5 of the Act deals with integrated development planning that sets the social and economic objectives for an area. The Municipal Planning and Performance Management Regulations (Government Notice R.796, 24 August 2001) promulgated in terms of this Act describe the content requirements of IDPs. The regulations, for example state that Spatial Development Framework (SDF), reflected in the municipality's IDP, must 'contain a strategic assessment of the environmental impact of the spatial development framework'. It is envisaged that all municipal functions listed in the associated Estuary Management Plans (EMPs) are nested in local IDPs to ensure wise sustainable development, use and biodiversity protection. Estuary Zonation Plans (including the EFZ delineation) should also be incorporated into the SDFs of local or district municipalities to guide sustainable development amongst other things. There is no reporting framework for how effectively, if at all, municipal mandated estuary related activities are addressed in the various IDPs and SDFs in coastal municipalities. It is recommended that an oversight function on the effective nesting of EMPs into IDPs be added in DEFF and provincial authorities.

The Department of Agriculture, Land Reform and Rural Development (DALRRD) is the lead agent for the Conservation of Agricultural Resources Act (CARA). The objectives of CARA are to provide for the conservation of the natural agricultural resources of South Africa by: 1) maintenance of the production potential of land; 2) combating and prevention of erosion and weakening or destruction of water sources; and 3) the protection of vegetation and the combating of weeds and invader plants. At present this Act does not explicitly support estuary management as evidenced by agriculture being one of the main sectors responsible for land use change in EFZs. Guidelines need to be developed on how to mitigate the impact of agriculture on estuaries given their sensitivity to agriculture focussing on: agricultural return flow, drainage structures within the EFZ, spaying of herbicides and pesticides, grazing of salt marsh, browsing of mangroves, burning of reeds, livestock stock and dairy farming impacts and the need for buffer zones, and crops and fields within the EFZ. The latter can result in pressure to artificially breach estuary mouths, if agricultural land becomes back-flooded.

The Department of Mineral Resources and Energy (DMRE) is the lead agent for the Mineral and Petroleum Resources Development Act (No. 28 of 2002). South Africa's mineral wealth is comparable to its outstanding biodiversity (Norman and Whitfield, 2006). Therefore, as in the ocean, in order to make the most of the mineral resources while not compromising South Africa's natural and associated cultural heritage, careful spatial planning (MSP), monitoring and management of mining operations is essential to avoid and mitigate the worst of the impacts. The Mining and Biodiversity Guidelines, published in 2013, summarise the range of impacts on biodiversity typically associated with mining and list some possible mitigations to moderate the impact of mining. Ideally, no mining activities should occur within the EFZ of estuaries. However, there has been little constructive engagement around estuaries and the governance of this space. Sand and diamond mining have severe impacts on estuaries and are largely unregulated with a significant amount of illegal activity not being adequately addressed. Also of concern is that many salt-works are closing down without any decommissioning guidelines or rehabilitation plans in place. The decline in condition of these sheltered artificial habitats can be linked to the significant drop in bird numbers in some estuaries e.g. Swartkops.

Given the irreversibility of the impact of mining and the substantial threat it poses to estuarine ecosystems and the coast in general, a sector specific engagement is urgently needed to ensure ongoing estuarine functionality, productivity and a sustainable flow of benefits (e.g. coastal protection) to local coastal communities. A strategic assessment of the spatial extent and associated impacts on mining on estuaries and the coast is urgently needed, i.e. 'Mining SEA for South Africa's estuaries'. Also required is a national scale 'estuary and coastal sediment budget analysis' guiding the sustainable rate of sand extraction from the different systems.

11.2.5 Mouth manipulation

Overall 45 estuaries were subjected to some form of mouth manipulation, with 17 systems deemed under severe pressure. Inlet manipulation is an outcome of South African coastal legislation not recognising back-flooding areas as being part of the estuary functional zone, i.e. 'estuary space' is not confined to below the highwater mark as defined in legislation. Consequently, inappropriate low-lying developments and land-use (e.g. urban infrastructure, golf courses or agricultural activities) within the flooding zones, and inundated under closed inlet conditions, are being protected at the cost of the natural environment. It is of critical importance that the legal definition of an estuary in South Africa be adjusted in the ICM and Water Acts to include back-flooding areas and incorporate the EFZ. Precautionary principles need to apply in the development of estuary setback and management lines to ensure that future development does not take place in low lying areas which will necessitate artificial breaching of the estuary mouth as a flood risk mitigation measure. The updated EFZ delineation in parts of the country extend beyond the 5m contour, this poses the risk of further estuarine habitat being compromised as the EIA regulations defines the EFZ as up to the 5m contour. This conflicting definition needs to urgently resolve to fit the ecological boundary.

In the Western Cape, the development of estuary 'Mouth Management Plans' have become the norm for estuaries under artificial breaching pressure, and once agreement has been reached on the need for regular breaching, a 'Maintenance Management Plan' is developed under NEMA for formal approval by the provincial authority. The actual breaching activity by the relevant management authority, which includes the

digging of a breaching channel, is then governed by the pre-approved mouth Maintenance Management Plan. It is recommended that this proactive management approach be adapted and adopted at a national level. Mouth Management Plans should urgently be developed for all systems that are under artificial breaching pressure, or require regular breaching, to assess if breaching is a necessity (investigate socio-economic imperative for breaching) and if so, how to do it with the least amount of ecological impact to ensure the benefits derived from estuaries, e.g. nursery function, are equitably distributed to all users not just riparian owners.

11.2.6 Biological invasions

Biological invasions represent a major threat to biodiversity. Many species have been transported by humans (either accidentally or intentionally) to areas where they are not naturally present, and on reaching such areas, some species, due to lack of natural predators or competitors, have become invasive and have spread across natural ecosystems, threatening indigenous species and habitats and reducing the ability of ecosystems to deliver vital services. These biological invasions often have direct negative impacts on the wellbeing of many people, and in particular threaten rural livelihoods.

In the past, South Africa has dealt with invasive species by ad hoc, often piecemeal, legislation (Van Wilgen & Wilson 2017). Recently, there has been a more coordinated sector-specific approach. Regulations under CARA were promulgated to govern the management of certain (listed) invasive plant species ('weeds'), while the Agricultural Pests Act (Act 36 of 1983) provides for measures to combat agricultural pests and prevent their introduction. In 2014, a set of regulations was promulgated under the Biodiversity Act, by which the management of biological invasions is to be governed. These regulations govern the import of new alien species, place existing alien species into several categories and specify how these species are to be controlled or managed. One of the requirements contained in these regulations is for SANBI to produce regular status reports. The Act also gives effect to ratified international agreements relating to biodiversity binding on the Republic, including the Convention on Biological Diversity (CBD) that requires the prevention, control or eradicate of 'alien species which threaten ecosystems, habitats or species'. Other relevant conventions include the International Plant Protection Convention, which requires signatory countries to reduce the risks of pests of plants from either leaving or entering the country. From a marine and estuarine perspective, the UN Convention on the Law of the Sea obliges signatory parties to prevent, reduce and control the intentional or accidental introduction of species to the marine environment where they may have significant harmful effects. The International Convention for the Control and Management of Ship's Ballast Water and Sediments imposes obligations to prevent, minimise, and ultimately eliminate the transfer of harmful aquatic organisms and pathogens through the control and management of ship's ballast water and sediments.

Pathway-based control measures focus on reducing the risk of introducing damaging species (i.e. the actual mechanism by which species arrive, rather than specific species themselves). For example, organisms can be introduced by ships through several pathways (as stowaways in ballast water, in cargo containers, on the hull of the ship, or in the luggage of crew or passengers). In South Africa, intentional introductions are currently managed through a permitting system. Species require import permits that are based on a risk assessment reviewed by the Alien Species Risk Analysis Review Panel (ASRAR P) and DEFF. For air traffic, inspections are

currently only carried out at O.R. Tambo International Airport, where permit compliance is checked, illegal imports are intercepted, and the luggage of tourists and cargo is searched. Occasional joint operations are also carried out at a limited number of other entry points. These inspections need to become the norm at all entry points.

For shipping, the Marine Draft Ballast Water Bill aims to reduce the risk of the unintentional introduction of alien marine species through the release of ship ballast water. Other control measures focus on potential agricultural pests (e.g. phytosanitary inspections at border posts) or threats to human health (e.g. spraying the interior of aircrafts to eradicate insect disease vectors). The DALRRD regulates and monitors the importation of agricultural goods. Departments such as DALRRD and SARS-Customs are present at other ports of entry and sometimes identify instances of non-compliance and alert DEFF biosecurity.

SANBI, in collaboration with the DST–NRF Centre of Excellence for Invasion Biology at Stellenbosch University, recently published South Africa's first national report on the status of invasive species (Van Wilgen & Wilson 2017). The report is the first such country-level assessment anywhere in the world that focuses specifically on biological invasions. The report is structured around four aspects: pathways of introduction and dispersal; the number, distribution and impact of individual species; species richness and abundance of alien species in defined areas; and their impact in those areas and the effectiveness of interventions – how effective the regulations and control measures are in reducing the problem. The impact on estuaries was not explicitly highlighted, but to some degree captured in the terrestrial, freshwater aquatic and marine realm discussions.

Thus, from an estuarine perspective, the understanding of the current extent and severity of invasions, the impacts of the invasions on biodiversity, and how to predict and prevent further invasions is not adequate. In turn, ignorance of the legislation is ubiquitous through all government agencies responsible for implementation. Where understanding exists, regulations are often selectively applied. Focused monitoring and control of invasive species, introduction pathways, distribution and abundance is urgently required to better predict, understand and manage biological invasions in estuaries.

Invasive alien plants

Overall 103 estuaries (High to Medium pressure) were highlighted as in need of measures to control invasive alien plants, including manual harvesting, eradication in the catchment and reducing nutrient input. Invasive plant species are characterised by a rapid growth rate and higher tolerance to environmental stress that enables the competitive displacement of native pioneer species. Early detection is key to their eradication. A good example of this is the complete eradication by 2017/18 of Smooth cordgrass *Spartina alterniflora* from the Groot Brak Estuary as plants were first observed in 2004 by local residents. Due to its rapid growth and large underground biomass, the species can change open, intertidal mudflats into dense, monospecific marshes (Adams et al. 2016). Although there were delays in initial control efforts, the threat posed by *S. alterniflora* was evident and SANBI Invasive Species Programme oversaw the process. Progress was enhanced by enthusiastic and supportive local stakeholders, organized in the form of the local residents' association and Groot Brak Estuary management forum highlighting the role local communities can play in early detection and eradication. Research is needed to document and understand the spread of alien invasive plants in South African estuaries.

Exotic aquatic macrophytes are generally found in fresher upper reaches of estuaries (Adams et al. 1999). Low freshwater input and nutrient enrichment promote their growth thus highlighting the importance of managing these pressures. Aquatic invasive plants result in a loss of ecosystem services, e.g. decreasing species diversity, forming a homogenous habitat, and disrupting aquatic food webs (Adams et al. 2019). Despite biological control programmes, Water Hyacinth, *Eichhornia crassipes* still remains the worst aquatic weed in South Africa (Coetzee and Hill 2012). Currently control programmes utilise a range of methods (biocontrol agents, manual, mechanical or herbicide control), but will be only successful if nutrient management strategies are also implemented under CARA, NWA and ICM. Moreover, clear protocols and procedures are needed on the most environmentally effective clearing methods which could be pursued for particular species and in particular systems.

Long-term eradication from estuaries will only be possible if supported by catchment clearing programmes such as the 'Working for Water' and 'Working for Wetlands' natural resource management programmes to prevent re-infestation after floods.

Alien invasive or extralimital fish

Overall, 58 estuaries were considered under severe pressure from invasive or extralimital fish, and thus in need of management intervention. The development of protocols and procedures for the early detection, risk assessment and management of invasive alien fish and invertebrate species are essential. For example, certain invasive alien fish species can act as a barrier to migratory species (eels and freshwater mullet) and influence the species composition and abundance of species, many of which are commercially important, in the river-estuarine interface. Very little is known about invasive fauna in South Africa's estuaries. There is an urgent need to have a census on the occurrence of invasive alien species in different estuaries and the potential environmental impact of these on both the ecosystem function and the value derived from the estuary in question. All invasive species (freshwater, marine and estuarine) should be included in the census.

Overall very little has been done about managing freshwater aquatic and estuarine invasive faunal species. Managing invasive fish without harming other indigenous biota is often not possible, and there are conflicting opinions about the need for, and type of interventions. Management objectives range from the extirpation of alien fish from waterbodies where possible; the prevention of spread to uninvaded areas; and the early detection of new incursions (Van Wilgen & Wilson 2017). Monitoring of Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora exports, uptake of export quotas, and implementation of non-detriment findings is also 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.

11.2.7 Recreational activities

Recreational use of estuaries should be reviewed for each site, with a view to reducing disturbance and limiting impacts on the estuarine environment and its birdlife, especially where the estuary falls within an IBA, a site of global significance for the conservation of birds and their habitats. Estuary Management Plans, including zonation plans, should incorporate concepts that reduce human-bird conflict. When zoning,

providing facilities, and managing the use of facilities, the source, range and intensity of potential impacts should be taken into account, as well as methods to manage these impacts that address short and long term responses by birds.

The appropriate zoning of an estuary for recreational use and the corresponding implementation and enforcement of sound by-laws is key. Sensitive habitats with high bird numbers and/ or threatened species should be zoned to reflect their conservation importance, such as at the Berg River estuary where the larger areas of intertidal mudflat are zoned as conservation areas, and entry is prohibited, or as in the example of the estuaries within the Cape Whale Coast IBA, where there are declared bird sanctuaries.

Estuaries are popular birding destinations, so the potential for disturbance is likely to be greater. Furthermore, bird watching is increasing as a global recreational activity. Consequently, the relative effects on birds, particularly where approached on foot, or where observers spend a considerable amount of time viewing birds from vantage points within the natural habitat, requires further investigation at estuaries. At many sites, sensitive areas can still be enjoyed by employing the use of facilities such as walkways and bird hides.

Disturbance seems to be more intense when activities are dispersed within the habitats, or not practiced on predictable paths. For example, boats outside the established channels elicit stronger responses in birds. In the same way, people and dogs going off-track enlarge the perturbation area, increasing the consequences of disturbance. Therefore, where appropriate, paths or channels should be designated and defined for recreational use, to help reduce disturbance.

Where zonation allows for high disturbance activities such as kite-surfing, water-skiing, and the use of jet skis, care must be taken to ensure sufficient buffering of the more sensitive areas, including the estuarine shoreline. Kite-surfing for example has been demonstrated to have adverse effects on birdlife, even when confined to designated channels, disturbing for example, neighbouring roost, foraging and nesting sites. Not all activities are appropriate to all estuaries. Creation of additional or alternative habitat, away from disturbance centres, such as the creation of floating wetlands or islands may allow certain species to escape areas of high intensity recreational activity, but it is probable that not all species will benefit from such actions; similarly, not being able to use the preferred habitat will likely come at a cost, and should be avoided.

Estuary managers may need to reduce the use of some areas all the time or at critical times, such as during bird nesting and fledging, limit the number of users to small groups e.g. enforce limits on boat numbers, and/or limit the types of activities particularly those that are likely to have greater impacts. Even relatively 'low' impact activities such as walking or canoeing where visitors do not deliberately disturb animals can have negative effects on birds, ranging from changes in physiology to reduced reproductive success, and need to be managed accordingly e.g. prohibiting access to areas with known roost sites, or to areas with nesting birds during the breeding season.

The changing conditions of estuaries (mouth open/closed, water levels low/high) can make zonation for recreational use more difficult, but the recommendation should always be to zone according to the area's highest conservation value. For example, when the mouth is open and water levels are low, areas of intertidal

mudflat can support important numbers of migrant waders, and warrant protection through appropriate zonation, despite the fact that those same areas may support fewer bird numbers when water levels are high. Changes to the permissible recreational use of that area under different conditions may then be at the management authority's discretion.

Recreational activities need to be managed and the zonation of activities enforced by the relevant management authority, so that disturbance is reduced and biodiversity safeguarded, while making the most of the recreational potential of each estuary. There is limited research on the disturbance impacts of a number of increasing recreational activities on birds, such as kite-surfing, jet-skiing and horse-riding, and further study should be encouraged.

11.2.8 Status of government responses in terms of the management and control of key pressures on South African estuaries

To provide a succinct evaluation of the status of government responses in terms of the management and control of key pressures on South African estuaries, an overview provided in Table 57. This qualitative assessment, largely aim at assisting with prioritisation of management responses going forward. The table depict the assessment of the status of existing legislation, as well as availability of supporting norms and standards (here defined as regulations, protocols, strategies, guidelines and methods) and the response status is rated (depicted as Good = Large green circle; Average = medium orange circle; Weak = small red circle). Weak responses indicate the need for urgent intervention. Finally, successes in terms of implementation and compliance (also including appropriate monitoring initiatives) across the various activities are assessed.

Table 57. Status assessment of government's responses to mitigate, manage and control key pressures and associated activities in estuaries (adapted from Taljaard et al. 2019)

PRESSURE /ACTIVITY		STATUS OF GOVERNMENT RESPONSE		
		Legislation	Norms & Standards	Implementation & Compliance
FLOW MODIFICATION	Surface water abstraction (i.e. run-of river abstraction, large dam & weir development, hydro-electrical schemes, transfer schemes)	●	●	●/●
	Return flow (wastewater & agriculture)	●	●	●
	Alien vegetation infestation in catchment	●	●	●
	Groundwater abstraction	●	●	●
	Plantations	●	●	●
	Hardening of the catchment & storm water	●	●	●
POLLUTION	Wastewater disposal	●	●	●
	Agricultural return flow	●	●	●
	Urban stormwater runoff	●	●	●
	Solid waste (litter and plastics)	●	●	●

PRESSURE /ACTIVITY		STATUS OF GOVERNMENT RESPONSE		
		Legislation	Norms & Standards	Implementation & Compliance
	Oil pollution (from shipping affecting estuaries)	●	●	●
EXPLOITATION OF LIVING RESOURCES	Recreational fishing	●	●	●
	Commercial fishing	●	●	●
	Small-scale / subsistence	●	●	●
	Traditional/ artisanal	●	●	●
	Illegal gillnetting	●	●	●
	Alien fish species	●	●	●
	Ornamental (pet) fish collection	●	●	●
	Bait collection	●	●	●
	Traditional medicine including <i>muti</i> trade	●	●	●
	Aquaculture	●	●	●
LAND-USE & URBAN DEVELOPMENT	Urban development (housing, resorts, hotels)	●	●	●
	Transport infrastructure (roads, bridges and culverts)	●	●	●
	Riparian infrastructure (fences and low-lying developments)	●	●	●
	In-stream infrastructure (jetties and boat launching sites)	●	●	●
	Agriculture (croplands & clearing)	●	●	●
	Livestock grazing/browsing of riparian zone	●	●	●
	Harvesting housing material (reeds/sedges & mangroves)	●	●	●
	Mining (including instream sandmining)	●	●	●
	Salt works	●	●	●
	Power-boating and water-skiing	●	●	●
	Kite and wind surfing	●	●	●
MANIPULATION OF INLETS	Artificial breaching	●	●	●
	Mouth stabilisation/ canalisation	●	●	●
	Inlet diversion	●	●	●
ALIEN INVASIVE PLANTS	Ornamental garden plants (pathway)	●	●	●
	Agriculture (pathway)	●	●	●
	Plantations (escapees)	●	●	●
	Ornamental fish trade & garden water features (pathway)	●	●	●
IN VA SIV E	Introduction for food security	●	●	●

PRESSURE /ACTIVITY		STATUS OF GOVERNMENT RESPONSE		
		Legislation	Norms & Standards	Implementation & Compliance
	Introduction for sport fishing			
	Release of ornamental fish			
	Aquaculture			

What is clear from Table 57 is that overall South Africa has a well-defined and strong legislative framework, with less well developed supporting norms and standards. However what is deeply concerning is that across most sectors implementation and compliance is sorely lacking.

11.3 Restoration and biodiversity requirements for novel ecosystems

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’, recognising that ‘there has never been a more urgent need to restore damaged ecosystems than now’. Restoration efforts would also contribute to achieving the UN Sustainable Development Goals, 2030 Agenda for Sustainable Development, and other targets set out by international conventions and agreements.

However, restoration and/or rehabilitation of degraded or novel ecosystems (highly transformed estuaries) have not been systematically dealt with in South Africa. This assessment set out to consolidate the various outputs from a range of studies into one integrated summary to guide restoration efforts moving forward by highlighting systems under severe pressure in need of key sectorial interventions.

An analysis of present state (PES) versus desired state (REC) indicates that about a quarter of estuaries do not meet biodiversity targets. Overall about 43% of estuaries need some restoration or protection of base flows, while about 5% require some increase in flood allocation (Figure 93). From a pollution perspective, 42% of estuaries need an improvement in catchment river water quality, while an additional 28% require a reduction in the input of stormwater and agricultural drainage from the flood plain, and 14% require wastewater reduction measures. Nearly 39% of estuaries require restoration or rehabilitation of the estuarine floodplain or adjacent wetlands. Overall 39% of systems require removal of invasive alien vegetation, while 20% of estuaries need investigation into the possible eradication of alien or extra-limital fish. Overall, 32% of estuaries should be targeted for the reduction of fishing pressure. Mouth Mananget practises (artificial breaching) need to be re-evaluated, and improved on where possible, for 15% of estuaries. A minimum of 14% of estuaries need management of recreational activities to reduce impacts on birds. Nearly 13% of estuaries need restoration or rehabilitation of mining impacts. About 4% of systems need mangrove harvesting to be controlled, while 3% need the implementation of cattle exclusion zones and an additional 2% need measures to control grazing.

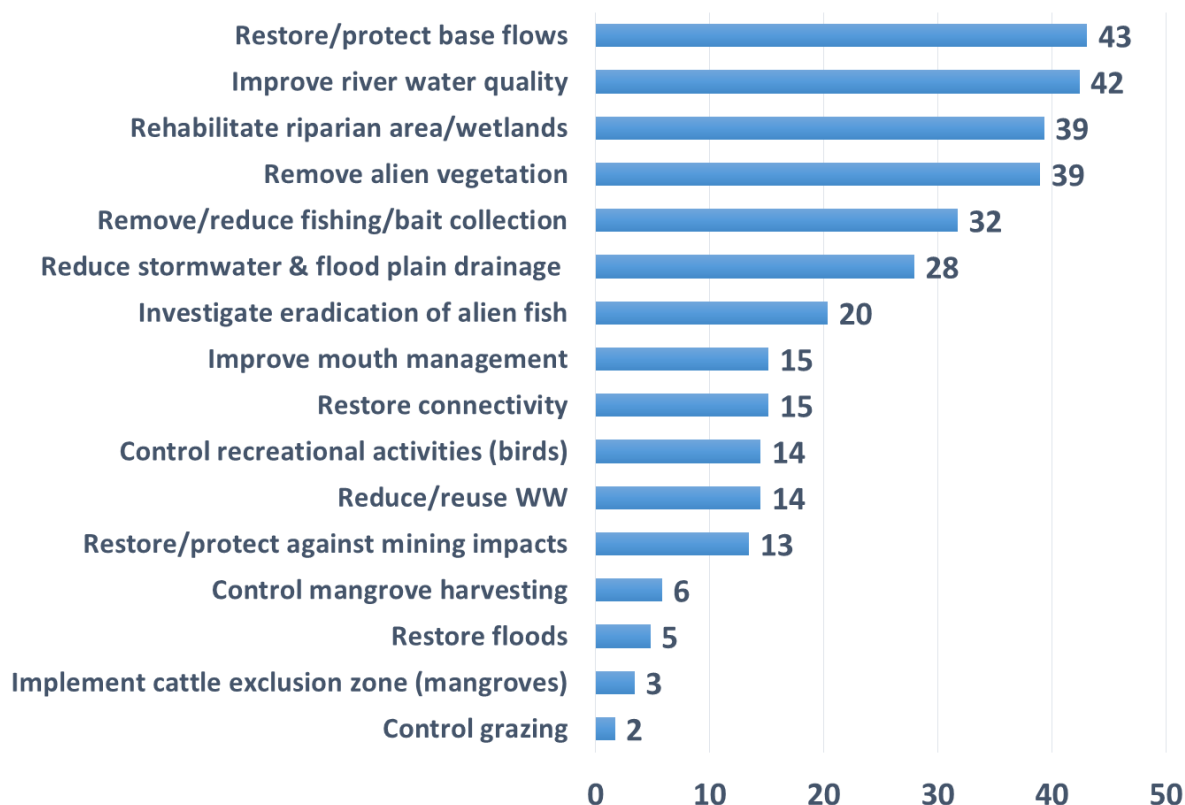


Figure 93. A summary of restoration interventions required in estuaries to address decline in condition.

It would also not be remiss to stress that at present South Africa's most important estuarine system, the Greater St Lucia Lake system, is undergoing a tremendous restoration effort to restore estuarine functionality. Lessons learned from this and other restoration processes will inform future management and restoration efforts of estuaries across the country.

National-scale deterioration in water quality and quantity threatens estuarine species and habitat diversity. Impacts include seagrass habitat that have been lost from Knysna Estuary due to macroalgal blooms, the rampant spread of alien invasive aquatic plants in the small KZN estuaries and the occurrence of persistent microalgal blooms in the upper reaches of estuaries receiving agricultural return flow. Improvement in water quality of the most cost effective restoration measure for aquatic systems such as estuaries. Research is needed to investigate the role of salt marshes in maintaining water quality and delivering ecosystem services (e.g. water purification). Studies have commenced at Swartkops Estuary on heavy metal bioavailability and uptake. The magnitude, frequency and type of HABs are increasing in South Africa and an understanding is needed on their autecology, seasonal dynamics and mechanisms facilitating their persistence.

Transdisciplinary approaches to aquatic ecosystem restoration are important, i.e. a socio-ecological systems approach to restoration through action research should be adopted. There are opportunities to implement a circular, regenerative economic approach to restoring estuary health with a focus on water quality

management. Globally, there is a call to action as the UN has announced a ‘Decade of Restoration (2021-2030)’ that includes wetlands. Reducing nutrient inputs whilst culturing a harvestable resource as a restoration activity would significantly improve estuary health in South Africa. This provides for the opportunity to develop a ‘National Restoration Programme’ for estuaries. Redesigning severely degraded systems to maximise estuarine fish nursery function could be a useful tool for the recovery of overexploited resources, e.g. Eerste Estuary, Durban Bay.

The Berg River Improvement Plan aims to address water quality concerns in the Berg River (including the estuary) and has a vision of improving water quality of water of the Berg River to an acceptable quality and quantity for sustainable farming, industrial development, human consumption and recreation, as well as ecological health. However, the Berg Estuary with its expansive floodplain marshes is unique nationally and must also be prioritised for rehabilitation. Agricultural impacts pose a serious threat to the state of the estuary. Restoration of the extensive salt marsh at Orange Estuary is also needed to halt ongoing decline of this system. Salt marsh restoration interventions are also required at the Klein Brak Estuary which is subject to severe habitat fragmentation. In some cases restoration intervention needs to take the form of infilling of old drainage channels to raise the water table such as on the Bitou floodplain at Keurbooms Estuary.

Urban estuaries such as Zand provide important ecosystem services and their health and productivity can be improved through a range of restoration interventions, e.g. the mouth is opened to increase salinity, control the spread of pondweed and prevent harmful algal blooms.

11.4 Responses pertaining to Integrated Management Systems

The ICM Act (2008) aims to establish an integrated coastal and estuarine management system in South Africa embedded in the ethos of cooperative governance with supporting norms, standards and policies for management and conservation of the coastal zone whilst ensuring ecologically sustainable development. Key progress was the promulgation of the National Estuarine Management Protocol (NEMP) and the roll out of the Estuary Management Planning framework and the provision of resources, both human and funding, to sustain this effort. At present there are over 50 Estuary Management Plans, in various stages of completion, being developed as part of the implementation of the ICM Act, with the Western Cape and the Northern Cape being the two provinces (with financial support from DEFF) which have largely implemented such a process on most of the estuaries in their jurisdiction. In addition conservation bodies such as SANParks and CapeNature have also embraced the process as a legislative measure for community engagement, integrative planning and cooperative governance. For example, the Western Cape Estuary Management Framework and Implementation Strategy has produced 33 Estuary Management Plans, 12 Mouth Management Plans, guidelines (erosion, watercraft use, structures in the littoral active zone and dune management); and a draft bylaw on watercraft use in estuaries. In addition, an Implementation Plan and Strategy is being developed using an ‘estuary tool’ to address the key threats through prioritised management interventions (informed by the NBA and social inputs) in the Western Cape estuaries.

The EMP process also includes the establishment of Estuary Advisory Forums which form the vital communication platform between coastal communities and the various government departments that play

a role in estuarine management. It is strongly recommended that this best practice process be formalised as part of future regulation under the ICM Act. A National Estuary Management Course (a registered short learning programme of the Nelson Mandela University) has been ongoing since 2008. This allows for transfer of knowledge across the science-policy-practice continuum. More than 350 resource managers, students, conservers, and local stakeholders have attended the course in all four coastal provinces.

The Intergovernmental Relations Framework Act (No. 13 of 2005) provides for the ministerial political (MINMEC) and technical (MINTEC) structures that ensure policy and strategy coherence between the three spheres of government. MINMEC and MINTEC have replaced the role of the National Coastal Committee. Working Group 8 coordinates Oceans and Coastal Management in South Africa and is facilitated by the Chief-Director: Integrated Coastal Management of the Oceans and Coasts Branch of DEFF. The group is attended by key national departments/agencies and representatives from the metropolitans and provincial lead agents for ICM. Working Group 8 feeds into the MINTECH and ultimately to MINMEC. Between 2014 and 2017 a **National Estuaries Management Task Group** (an advisory body to Working Group 8) also served as an additional focal group that assisted with the coordinates and fostered cooperation in estuarine management and planning at a national scale. This, now defunct, Task Group provided government authorities (and other key role-players) with a platform to coordinate resource planning across all sectors and optimised the use of limited estuarine resources. **It is strongly recommended that National and Provincial Estuary Working Groups be re/established to provide scientific and technical support to the National, Provincial and Municipal Coastal Committees**, e.g. Western Cape Estuaries Programme Task Team. Provincial Estuary Working Groups will facilitate more effective coordination and cooperation in estuarine resource planning across estuaries in a province or municipal area. Estuary Advisory Forums are the ideal communication hub that can be used to prioritise and integrate management actions and disseminate information at the local scale. These communication platforms may become advisory committees for the Municipal and Provincial Coastal Committees. For example, in the Western Cape, an annual estuary advisory /coastal committee calendar is developed each year that plans for meetings across all platforms on a quarterly basis. Local level estuary meetings take place prior to the Municipal Coastal Committees and Provincial Coastal Committee meetings. This results in issues tabled at a local level being addressed at a provincial level within a short time period. All issues, as well as proposed actions, are recorded at each governance level. This provides for good communication and transparent decision making. Representatives from national government departments participate at a provincial level or when specific detailed feedback is needed at a local level.

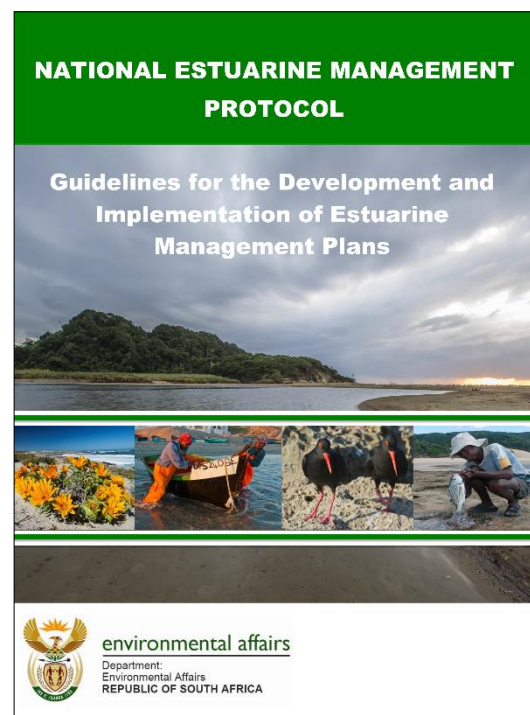
Implementation (including compliance and enforcement) of national legislation linked to the protection and sustainable use of estuarine ecosystems and the species that exist within these systems, largely resides at provincial and local level through the delegation or appointment of state bodies such as the South African National Parks Board (SANParks), provincial departments (responsible for conservation and environment) and local authorities. An uncoordinated approach has resulted in fragmented and inefficient estuarine management. In addition, there are uncertainties at local level over which government departments or agencies are mandated to enforce the various laws or respond to certain incidents affecting estuaries and, finally, there is limited enforcement capacity to enforce these laws and regulations (Van Niekerk & Taljaard 2003). The judgement handed down by the Supreme Court of Appeal in the matter between David Willoughby Abbott v Overstrand Municipality and others (99/2015) [2010] ZASCA 68 (20 May 2016) ('the

Abbott judgement') has resulted in disparity between the spheres of government on the interpretation and understanding of the roles and responsibilities of organs of state as prescribed by the relevant statutes. After considering both the 'Abbott judgement' and the subsequent legal advice, the DEFF concur with the Court's finding that there are constitutional shortcomings with the assignment of powers (paragraph 5.1) under the NEMP. The Court considered it to be inconsistent with section 156 (1)(b) of the Constitution as it was not provided for in legislation and it did not comply with the conditions in section 156(4) of the Constitution. There was no agreement from the municipalities, confirming that the function of estuarine management would most effectively be managed at local government level and that the municipalities have capacity to perform that function.

It must be noted that the 'non-assignment' of functions is in terms of the NEMP and refers to the development and coordination of the implementation of EMP actions that is assigned to the 'Responsible Management Authorities'. The EMP strives to converge all existing functions in estuaries to achieve the overall objective of integrated environmental management in these high use, high value environments.

Local municipalities are tasked in the NEMP to oversee the overall coordination and ensure that all organs of state are fulfilling their respective functions (as per their mandate). These are the only additional functions assigned to municipalities through the NEMP. The original mandates assigned to local government in terms of the Constitution and the ICM Act are still in effect. The national and provincial government are working together to provide legal certainty about the roles of local government in estuary management to reaffirm the importance of local municipalities involvement in estuary management. The DEFF is in the process of redrafting the NEMP in a manner that would delegate many of these functions to the provinces, which in turn may delegate it to a 'willing' municipality.

It is envisaged that relevant aspects of all Estuary Management Plans be nested into Coastal Management Programmes and local IDPs to ensure wise use and biodiversity protection. Estuary Zonation plans (including the EFZ) should also be incorporated into the SDFs of local or district municipalities to guide sustainable development and use. The Municipal Planning and Performance Management Regulations (Government Notice R.796, 24 August 2001) promulgated in terms of this Act describe the content requirements of IDPs. The Regulations, for example state that the Spatial Development Framework (SDFs), reflected in the municipality's IDP, must 'contain a strategic assessment of the environmental impact of the spatial development framework'. Each municipality also needs to develop an environmental over-layer which needs to reflect estuaries as areas of high conservation value as well as providing migratory corridors to a range of species.



South Africa has a strong policy and legislative framework with regards to estuary protection and management. Significant progress has been made in the management of estuaries across a number of sectors (Figure 94). However, it becomes very clear that resource and biodiversity protection is lagging, with measures at low levels (<10%), with the exception of 37% of estuaries having some limited overlap with protect areas. Urgent measures are required across the spectrum of responses to ensure a network of healthy and productive estuaries.

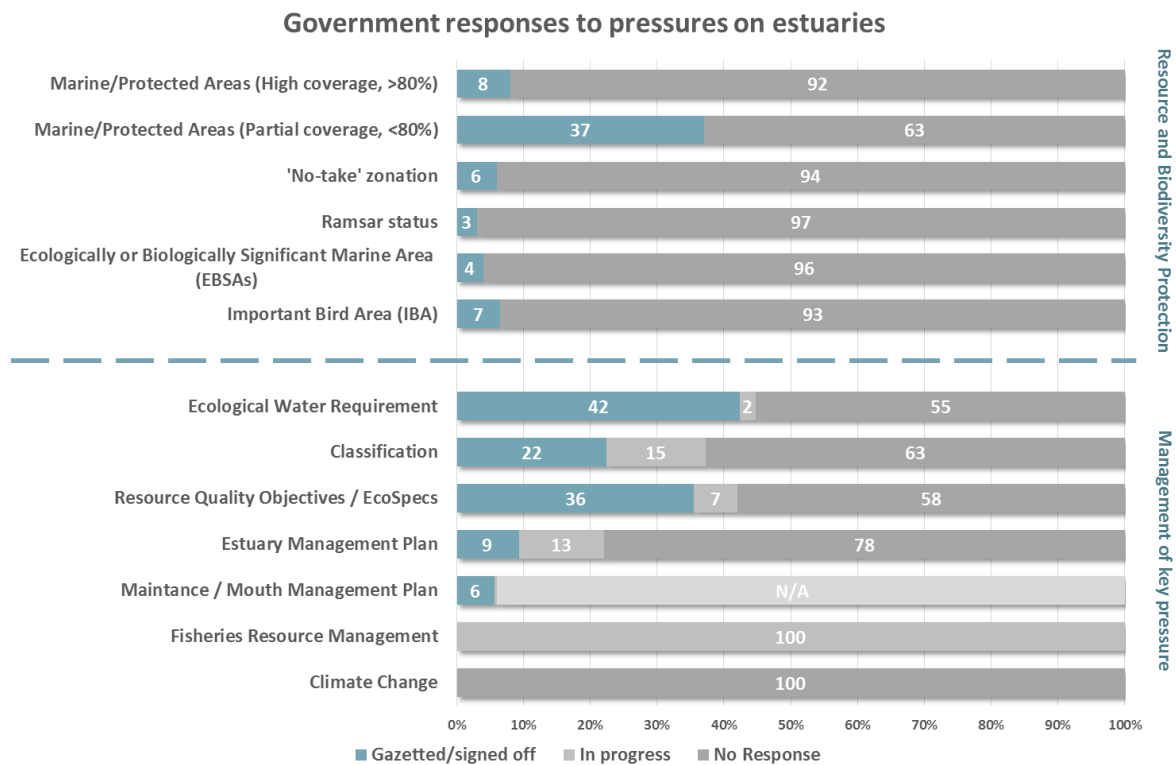


Figure 94. Summary of government's responses (express as % estuaries) pertaining to biodiversity protection and implementation of integrated management systems

11.5 Future-proof estuaries under changing climate conditions

South Africa's Third National Communication under the United Nations Framework Convention on climate change (UNFCCC) indicates that climate change could have significant impacts on estuary structure and functioning. Anticipated changes in precipitation and runoff will cause: (i) modifications in the extent of saline water intrusion; (ii) changes in the frequency and duration of mouth closure (iii) decreases or increases in nutrients fluxes; and (iv) changes in the magnitude and frequency of floods and related sediment deposition/erosion cycles. Increased storminess and flooding will increase the occurrence of disasters at a number of systems, for example, Groot Brak, Wilderness and Swartvlei estuaries. Other anticipated impacts include changes in the dilution and or flushing of pollutants, rising water temperatures, and associated changes in estuarine biota.

Climate change impacts highlighted above and sea level rise will increase the pressure on management agencies to implement assisted (and often premature) estuary mouth breaching, as increasingly properties will be below the level of the sand berm near the mouth. The response of humans to sea level rise may take the form of actions destructive to estuaries, such as armouring the coastline with berms or dykes that will prevent biological systems from adjusting naturally (e.g. by inland retreat of wetlands). Climate change will therefore not only increase the risks to estuary ecosystems, but also to the human communities and associated infrastructure and land-use surrounding them. Estuarine management is therefore also likely to become more complex and conflicted over time.

Accelerated climate change is one of many pressures acting on estuaries and should be viewed as an additional form of anthropogenic stress in an already stressed ecosystem. It is necessary to understand the potential amplification of variability that climate change may have on existing freshwater resources, potential impact on estuarine and marine production, as well as the harvesting of resources in the marine and estuarine environments. It is thus necessary to integrate Climate change and non-climate change threats in planning and management interventions. Climate change should be seen as a catalyst to fast-track sustainable resource allocation processes, e.g. allocations of environmental flows (Bunn 2016).

The ability to predict the response of estuaries to climate change and to plan mitigation and adaptation strategies is still hindered by a lack of good prediction tools and the lack of a fundamental understanding of many of the effects of climate variability on the physical, chemical and biological characteristics (Meyer et al. 1999; Thompson et al. 2014). We are limited by the availability of both data (e.g. long-term flow data, temperature data, mouth conditions, wave height, and species data) and models (e.g. flow changes, linking hydrological regimes to ecosystem processes and large-scale ocean current changes).

At the same time, this uncertainty around forecasting change should not be an obstacle to understanding and developing adaptation mechanisms to reduce the effects of climate change on estuarine resources. Accurate forecasting is not obligatory to begin the process of adapting to climate change, as major trends are often evident enough for meaningful actions to be planned and implemented. Priority adaptation and mitigation strategies to consider for future Estuarine Management Plans (a legal requirement in South Africa) are discussed below and summarised in Figure 95.

To accommodate projected changes in estuarine functioning and production as a result of changes in ocean circulation and terrestrial climatic processes it is important to reduce fishing and other harvesting pressures to sustainable levels to allow for resilience to natural and anthropogenic resetting events. Marine Protected Areas (MPAs) are producing larger, healthier fish with higher thermal tolerances and resilience (Potts et al. 2017). The current network of estuarine and marine protected areas needs to be expanded to cover all bioregions and estuarine types.

In addition, it is important to preserve coastal connectivity to ensure recruitment from healthy neighbouring systems in the event of natural/man-made disasters. In order to accommodate sea storms and sea level rise the estuarine functional zone (i.e. estuary floodplain and supporting habitats) must be protected from developments to increase resilience to extreme flooding (and allow for lateral channel movement), negate the need for premature artificial breaching, and prevent coastal squeeze of estuarine habitats. Areas where

salt marsh can expand inland in response to rising sea level need to be identified and prioritised for protection. Future setback/ management/flood lines determinations should include sea level rise (+0.5 to +2.0 m) and projected increase in flood magnitudes.

The determination and implementation of estuarine environmental flow requirements is critical in ensuring health and productivity in the face of change in the hydrological processes. Environmental flow requirement studies should therefore include projected 'climate change operational scenarios' to determine future catchment yields and ecological requirements. The duration and extent of future droughts needs to be explicitly evaluated and planned for in arid countries such as South Africa. Catchment connectivity is critical to ensuring adaptation to future climate shifts, therefore structures such as dams, bridges and weirs should ideally not be planned in, or near, estuaries. Urgent interventions are needed to curb nutrient loading to ensure resilience during the low flow season as reduced baseflow and an increase in water retention time can lead to hypoxia / anoxia. It is essential that Departments responsible for aspects of estuary management ensure that the freshwater quantity and quality needed to sustain the estuaries are included in the DWS classification processes and RQOs. There needs to be continued pressure applied to DWS to ensure that climate change scenarios are included in the classification scenarios. It needs to be understood that the negotiations for freshwater resources within the classification process are not the sole responsibility of DWS. Departments such as DEFF and conservation entities play a vital role in this process by providing the ecosystem and species requirements for freshwater that can then be evaluated against water use requirements in the catchment.

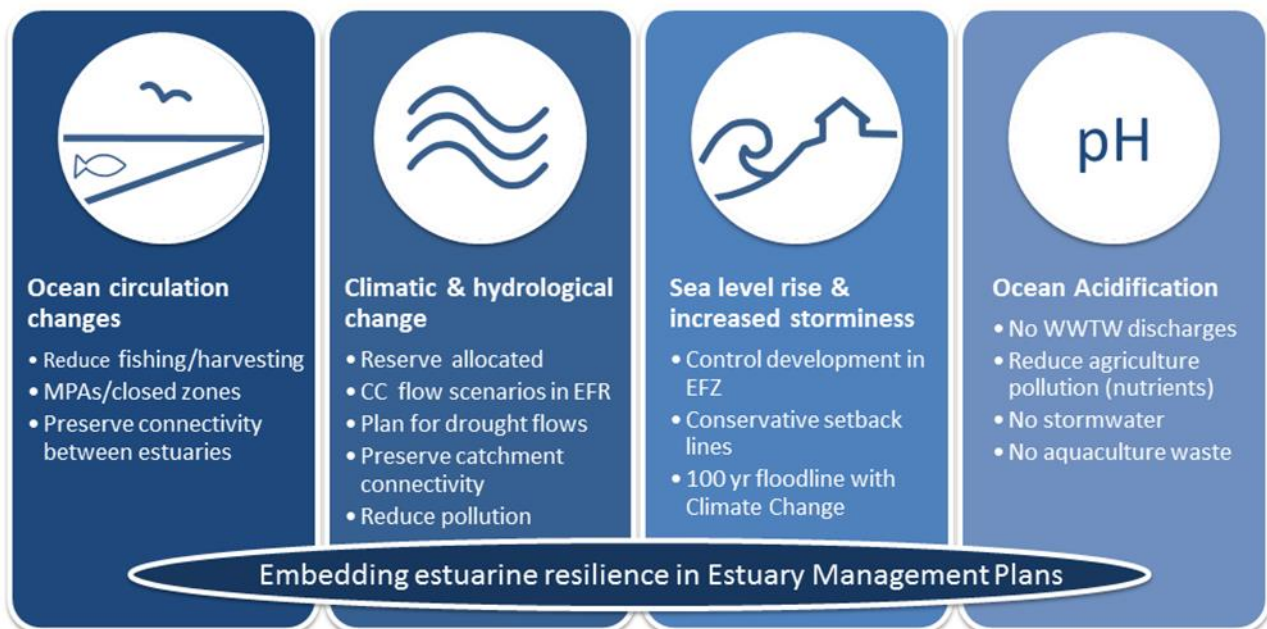


Figure 95. Embedding estuarine resilience to climate change by incorporating predicted effects of climate change into current planning and managed approaches (Van Niekerk 2018).

TEXT BOX 13: THE QUANTIFICATION OF BLUE CARBON IN SOUTH AFRICAN ESTUARIES

Coastal habitats including mangroves, salt marshes and seagrasses have been recognized for their high productivity and biodiversity. Recently interest has shifted towards their carbon storage ability where the term 'blue carbon' refers to the carbon stored in the soil, living and non-living above and belowground biomass. In South Africa, blue carbon habitats occur in sheltered estuaries where at present, little is known about their carbon storage. This research only exists for terrestrial systems, estimated as part of the South African National Carbon Sink Assessment (DEA, 2015; Turpie et al., 2017). The paucity of this dates prompted the present study, which is a component of a larger study on the response of blue carbon habitats to climate change. This study was the first to quantify and compare the carbon storage of blue carbon habitats in South Africa using the Intergovernmental Panel for climate change (IPCC, 2013) guidelines which were outlined in the coastal blue carbon manual (Howard et al., 2014). The guidelines identified two tiers of assessment for the accurate quantification of blue carbon, namely the Tier 1 and 2 assessment methods. The Tier 1 involves national based estimates of blue carbon using area cover data per estuary (ha) multiplied by the global average default values for carbon stocks (to 1 m depth). The Tier 2 assessment includes site-specific *in situ* measurements of carbon storage in the sediment and biomass of all the different habitat types and this was done at the Nxaxo Estuary in the Eastern Cape.

Results from the Tier 1 assessment at Nxaxo Estuary reported the carbon stocks to be 3667, 2782 and 4.32 Mg C for the mangroves, salt marshes and seagrasses respectively. The site-specific Tier 2 assessment for sediment carbon storage was 1140, 28.55 and 0.06 Mg C for mangroves, salt marshes and seagrasses respectively.



Figure 1: An example of a sediment core collected using a Polyvinyl chloride (PVC) corer, extracting a subsample from the core using a syringe and a sediment core extracted from a mangrove plot using a Russian Peat Corer at the Nxaxo Estuary for the Tier 2 assessment. (Photos: S. Mbense and J. Raw)

These results indicated that the Tier 1 assessment overestimates the amount of carbon stored in habitats especially for mangroves and salt marshes as the values were higher than those obtained in the Tier 2 assessment.

Our study therefore demonstrated the importance of site and species-specific data, especially for ecosystems in the warm temperate regions since the global averages are extrapolated from blue carbon studies done in tropical and subtropical countries. We also found that carbon storage for salt marshes, seagrasses and mangroves was lower than the global means and values reported from other studies. This is potentially due to slower growth and productivity at latitudinal limits for mangroves, and a drier climate and coarse-grained sediment for seagrasses

and salt marshes. These factors have been linked to the decreased preservation of carbon and low storage capacity.

The carbon stock data from this study will be used to calculate carbon sequestration and determine the potential emissions reductions of these habitats. At present, South African policy has not directly addressed the value of carbon in coastal wetlands and research is underway to explore the opportunities for participation in carbon trading, offset schemes and payments for other ecosystems services provided by these unique ecosystems.

Citation: Mbense, S, Adams, J.B., Rajkaran, A, Johnson, J-L, Raw, J 2019. 'The quantification of blue carbon in South African estuaries in South African Estuary' in Volume 3: Estuarine Realm. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A

Sediment extraction from rivers and estuaries are also a critical climate change consideration as unsustainable extraction rates will reduce the volume of sediment which reaches the coast and replenishes estuaries and beaches. Given the increasing frequency and intensity of flood and storm events and further predicted sea-level rise impacts, an eroding riparian area and shrinking beach profile (due to less sand reaching the coast) poses worrisome implications for coastal development and beach tourism.

Eutrophication resulting from nutrient pollution can also severely amplify the potential ocean acidification signal. It is therefore critical that current sources of nutrient pollution in estuaries be addressed and no additional future inputs planned, i.e. no additional Waste Water Treatment Works (WWTW) discharges; improved agricultural practises and urban agricultural return flow; improved stormwater infrastructure and pre-treatment stormwater; and no marine aquaculture effluent or waste discharges should be allowed in high retention environments such as estuaries. Recycling of wastewater or marine outfalls should become the norm.

In summary, it is essential that climate change, and the projected effects thereof, be integrated into current plans and policies dealing with management and governance of estuaries, specifically, the fishing, water and coastal management sectors. Current planning tools need to focus on integration of the synergistic effects of global change. In addition, adaptation includes adjusting to situations, developing coping strategies and impact responses. Adaptation may be behavioural or involve mitigation efforts such as engineering solutions. This requires an adaptive management approach that is supported by monitoring and frequent review.

11.6 Natural Capital Accounting (NCA) as a complementary reporting system

In 2012 the United Nations (UN) launched the System of Environmental-Economic Accounting (SEEA), the first international statistical framework for measuring the environment and its relationship to economic and human activity. The framework is based on internationally agreed accounting concepts in terms of gathering and organising information in a consistent manner that enables integration with socio-economic information such as the System of National Accounts (UN 2014a; TEEB 2013). Specifically the SEEA EEA method (UN 2014b; UNEP 2017) includes the measurement of extent of ecosystem types, their condition, flows of ecosystem services provided by such ecosystems, and the estimated value (or benefit) to communities, governments and businesses (based on either market transactions or non-market valuation). These parameters can be measured in physical and/or monetary terms (Figure 96).

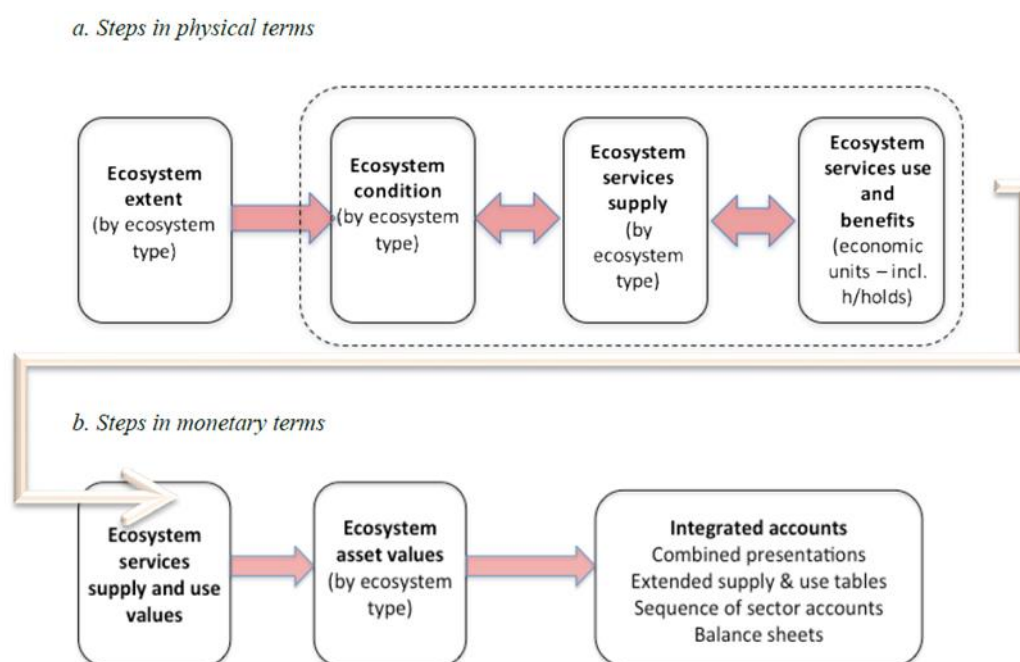


Figure 96. Steps in ecosystem accounting (Source: UNEP 2017).

Ecosystem accounting provides a means of quantifying and tracking change in natural capital, and associated ecosystem services over time. This is intended to inform a range of policy, planning and decision-making processes relating to the management of ecosystems and the use of ecosystems services, and to enable links to be made between the measurement of ecosystems and the measurement of the economy (Van der Velde 2016). Ecosystem accounts can support strategic decision making about natural resources management and about trade-offs between different ecosystem services. They can also provide a powerful set of information and indicators for measuring and reporting on sustainable development. Ecosystem accounting also can be applied at different scales for different purposes. For example, at national and international levels, accounts can be used for raising awareness, monitoring progress or setting priorities. At the provincial or local scales, accounts can be used to inform resource allocation, restoration or to evaluate policies and programmes. Currently the UN is in the process of rolling out experimental ecosystem accounting in various countries, including South Africa (SEEA EEA) (UN 2014b; UNEP 2017). The CSIR is in the process of adapting the NBA 2018 data into this format.

11.7 Monitoring of estuarine resources

A significant constraint to change detection in estuaries is the lack of long-term measured data on South African estuaries. One of the challenges that has led to this situation is the existence of a range of mandated Departments involved in estuary management and therefore monitoring. However, some progress has been made since the NBA 2011. An analysis of current monitoring initiatives by DWS, DEFF, conservation and provincial authorities, SAEON, ADU, ORI, CSIR and coastal universities showed that:

- < 17% of estuaries have continuous water level recording data (<http://www.dwa.gov.za/Hydrology/>);
- < 10% of coastal catchments are well gauged for freshwater inflow but with a bias towards large river systems, i.e. little to no information on small catchments (<http://www.dwa.gov.za/Hydrology/>);
- there is a lack of information on estuary topography and bathymetry (estuary size and shape). Historical datasets from the 1990s cover less than 15% of estuaries in Cape Regions (CSIR);
- water quality monitoring stations in inflowing rivers and long-term data on estuaries are scarce, but most large catchments do have some monitoring data available (http://www.dwa.gov.za/iwqs/wms/data/WMS_pri_txt.asp)
- < 12% of estuaries have some ongoing *in situ* water quality monitoring (i.e. salinity, temperature, turbidity and oxygen), with a smaller subset also having nutrients collected and analysed.
- There is a lack of information on the quantity and quality of urban stormwater runoff and toxic substances flowing into estuaries.
- < 30 % of estuaries have some sediment composition and quality information (see Text Box 14 for new initiative to address this gap).
- There is a lack of reliable national-scale long-term biological data sets (e.g. national bird counts date from the 1980s, e.g. Underhill and Cooper 1984) and national fish surveys date from the 1990s (e.g. Council for Scientific and Industrial Research (CSIR), unpublished data; Harrison 2000, 2005).
 - >40% of estuarine habitat have been spatially mapped and verified, while 100% have area estimates available.
 - < 20% of estuaries have regular monitoring of the state of estuarine fish resources with a focus on the larger estuaries that supports fisheries or are in protected areas (DEFF, SANParks, NPA)
 - <20% of estuaries have Co-ordinated Waterbird Counts (CWAC) counts that monitors fluctuations in bird numbers, but these do represent most of the larger estuaries that are most important to birds (ADU).
 - Regional data sets are being collected on the invertebrates of KZN (Subtropical region), similarly DEFF is collecting data on some systems in the Northern, Western and Eastern Cape (Cool and Warm Temperate region).

Up-to-date national-scale field surveys of the abiotic (topography, bathymetry and sediment structure) and biotic components (plants, invertebrates and fish and bird) is urgently needed. National surveys were last carried out in the early 1980 and 1990s. These surveys urgently need to be repeated in a once-off effort that is comparable with the earlier surveys. Towards this it is recommended that DEFF expands its current fish (and invertebrate) monitoring surveys to also include a representative sample of small and large estuary types across biogeographical regions (where no such datasets presently exists, e.g. in protected areas).

Towards this, SAEON is including long term ecological research on estuaries as part of the Shallow Water Coastal Marine Infrastructure Initiative (SMCRI) (see Figure 97). SMCRI is one of 13 large Research Infrastructures developed as part of the South African Research Infrastructure Roadmap. SMCRI was

established in 2016 to develop an array of instruments and physical research platforms around the coast of South Africa to collect long-term data for scientific research on vulnerability of the coastal zone to climate and global change. SMCRI is building on the suite of observatories, sentinel site and research platforms already established and maintained by the National Research Foundation's (NRF) South African Environmental Observation Network (SAEON) and the South African Institute for Aquatic Biodiversity (SAIAB).

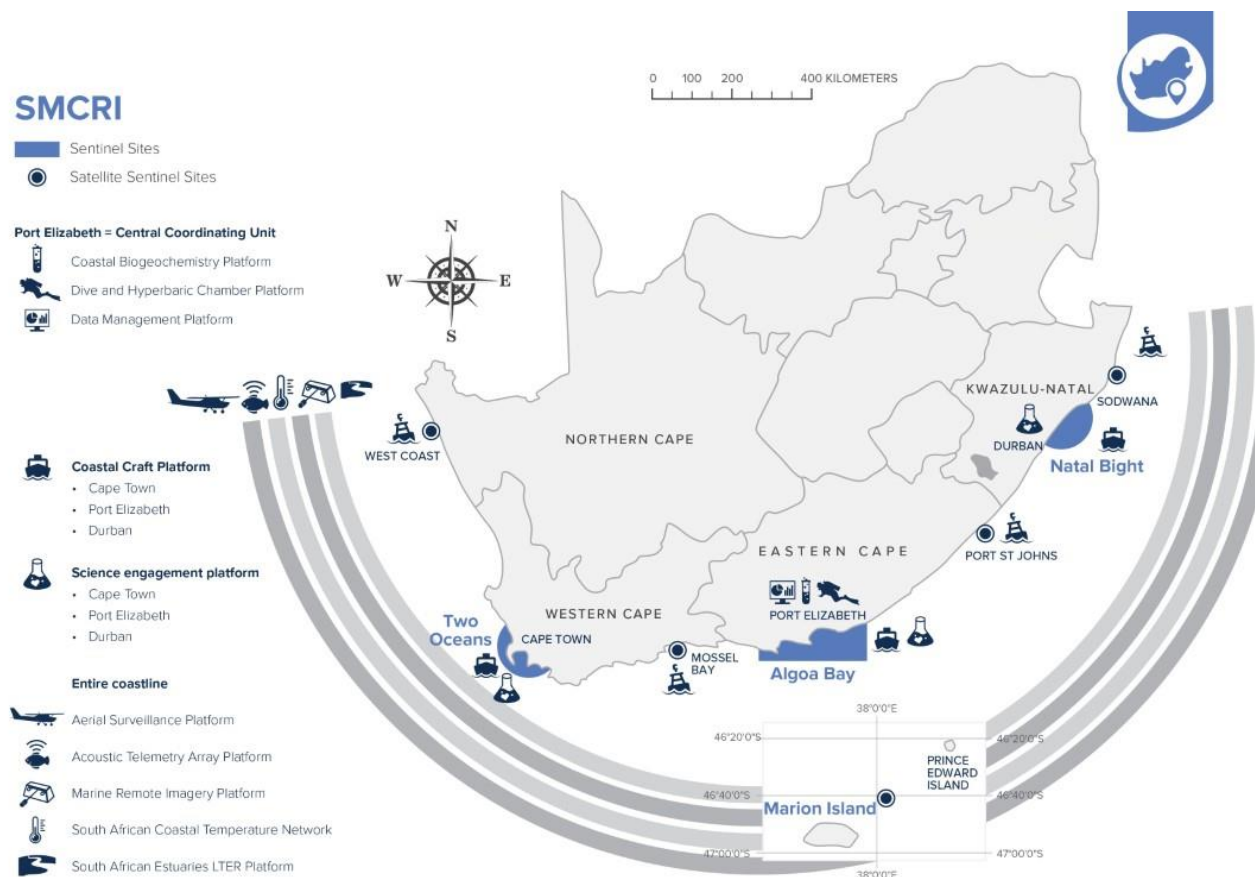


Figure 97. Shallow Water Coastal Marine Infrastructure Initiative (SMCRI) Sentinel and Satellite Sentinel Sites.

Currently, the **National Estuary Monitoring Programme** implemented by DWS is under resourced (Cilliers and Adams 2016). This multi-tier, multi-parameter (include biotic and abiotic components) programme is based on current best practice and with sufficient funding, and support from other organs of state, could go a long way in addressing data deficiencies in future NBA assessments. Funding is urgently required to support this programme.

It is further recommended that the **DEFF Oceans and Coasts National Water Quality Monitoring Programme**, **SMCRI** and **DWS National Estuary Monitoring Programme** developed an integrated approach moving forward with regards to estuaries. However, it is critical that full accreditation of all parameters monitored in estuaries be achieved before results are widely distributed, as analytical techniques for

estuarine water and sediment quality often vary greatly from freshwater and even marine techniques. In the past inappropriate techniques have led to over and/or under detection of pollutant levels in estuaries, with cascading effects in stakeholder interactions. Until such time it is strongly recommended that samples taken from polluted systems be analysed by a fully accredited laboratory to ensure the relevant documentation is in order to support permit conditions and/or any legal measures required to address pollution.

Chapter 4 of the ICM Act also places responsibility on the Provinces to ensure integrated and strategic management of estuaries. As a first step towards developing a platform for future monitoring, an observer programme funded by the KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs (EDTEA) has been established which involves field trips to all 76 KZN estuaries at least once per year to collect various data on estuarine state, including biophysical condition, habitat information, pressures and threats. These are integrated and spatially represented as a visual and interactive tool (i.e. CoastKZN: www.coastkzn.co.za) to assist managers on the ground. A citizen science programme has also been linked with a particular focus on estuary mouth status and invasive species in estuaries.

11.8 Recommendations to address ongoing decline in estuary condition.

The ongoing decline in estuary condition, high number of threatened estuarine ecosystem types, and low protection levels emphasise the need for strategic interventions across multiple sectors to restore estuarine health and protect benefits to people. To avoid further compromising of the benefits derived from estuaries a 9-point Strategic Estuarine Management Framework needs to be developed focusing on implementation and compliance across key sectors – including freshwater allocation, fish and other living resource use, water quality management, land-use planning, agriculture and mining. Complex ecosystems, such as estuaries, require an integrated approach to address the ongoing decline in condition. To be effective all actions and programmes need to be integrated into one coordinated framework with regular feedback to ensure implementation. Key actions that should be addressed in the **Strategic Estuarine Management Framework** should be:

1. Increase estuarine protection levels and share the benefits of estuarine protected areas equitably among coastal communities. The development of the NBA 2011 National Estuary Biodiversity Plan was the first step towards this. The DEFF, in collaboration with SANBI and DWS, should lead the implementation of the National Estuary Biodiversity Plan (or any revisions that may stem from it). This should include the setting of short- to medium-term targets for Estuarine Protected Areas, e.g. 10% of all ecosystem types will be formally protected by 2025. However, the integrity of existing estuarine protected areas (including no-take MPAs) is being compromised by both sanctioned and illegitimate fishing in these areas. Estuaries are first and foremost a national asset providing and sustaining fisheries resources throughout South African coastal waters, not just on a local scale. Over-allocating fishing rights to local fisheries is compromising the benefits to communities on a national scale throughout the coast. This practise has to be reviewed and reversed to ensure an equitable and sustainable sharing of coastal resources by all communities dependent upon them. An additional tool in the biodiversity protection arsenal is the identification of Estuary Critical Biodiversity Areas (CBAs) and Ecological Supporting Areas (ESAs) that are integrated across land and seascapes (project in progress to address this). These need to be embedded in local planning and EIA processes. Salt marsh,

seagrass and mangrove habitats require greater protection, with a strategy for especially mangrove protection urgently needed to prevent further loss. Apart from improving the overall health of estuaries, planners and managers also need to include sanctuary areas that are large enough to protect birds and their prey from human disturbance and exploitation.

2. Complete ecological water requirements and classification of all estuaries within five years and implement flow requirements within two years of their classification. This process is likely to require a two-tiered approach in which the findings of the NBA 2018 form the basis for allocation on a national level in the 'classification' of water resources in terms of the National Water Act. While more detailed ecological water requirement studies will be needed for water-stressed catchments or biodiversity priority areas, there is also an urgent need for strategic assessments (such as the National Water Resources Strategy) to take cognisance of estuarine flow requirements which are often substantially higher than the flow requirements of the river entering the estuary. This little recognised fact leads to national- and catchment- scale water resource plans that over-estimate the water resources available for development, thus compromising the ecosystem processes that coastal communities depend upon. This includes the recognition, determination and allocation of the freshwater requirements of nearshore river-dependent marine ecosystems by DWS in consultation with DEFF.
3. Stock or population recovery of fish and invertebrate resources must be facilitated by reducing fishing pressure, increased compliance, ensuring adequate freshwater inflow, decreasing nutrient pollution, managing noise pollution and boating activity. DEFF is poised to roll out ministerial approved slot limits and the 'night fishing ban' country wide in an effort to facilitate national stock recovery. Efforts are also in progress to restore compliance along the KZN coastline.
4. A comprehensive 'Pollution Reduction Strategy' is needed for estuaries. Municipal wastewater treatment works (WWTW) and pump stations are no longer able to cope with high sewage volumes. Even if effluent is treated to legal standards, effluent volumes are too high to remain within the assimilative capacity of estuaries. In response, South Africa's new coastal waters discharge regulations state that no new wastewater discharges will be allowed into estuaries. This regulation needs to be enforced. While existing WWTWs should evaluate options for reuse and recycle or ocean outfalls. In addition, agricultural best practise guidelines needs to be developed, and implemented, by the DALRRD in consultation with DWS and DEFF, to reduce agricultural return flow and other agricultural impacts. Estuaries are being overwhelmed by contaminated stormwater runoff from rapid urbanisation in their environs. Traditional approaches to managing stormwater require urgent re-thinking as technologically innovative guidelines are needed to address this growing pressure. A census of solid waste disposal and collection sites near, or in, estuaries, is required to assess their impact and identify possible mitigation measures. The impact of littering should then be systematically targeted through the 'Source to Sea' initiative' and the 'Working for the Coast Programme'. Poor legal compliance and lack of enforcement contributes significantly to deteriorating water quality in estuaries. The recently established DWS Anti-Pollution Task Team is set to deal with the escalating incidents of pollution in rivers. A similar unit must be established in DEFF for the coast and estuaries. Healthy functional estuaries support the cultural, aesthetic, commercial, recreational and subsistence benefits upon which coastal communities depend.

5. South Africa's Estuarine Lakes are in crisis. This group of estuaries has seen extensive infrastructure development in the EFZ, substantial flow reduction, nutrient pollution, overfishing (especially gillnetting) and are subjected to artificial breaching / mouth manipulation. In addition, the lakes are highly vulnerable to climate change. These impacts have reduced their ability to provide key services such as flood regulation, nutrient cycling, nursery habitat, and have compromised recreational and tourism values. To ensure future climate change resilience, a long-term 'Estuarine Lakes Programme' is needed to restore habitat, improve water quantity and quality, reduce pressure on resources and increase protection levels. The Lake St Lucia Estuary Restoration Programme represents the start of such a programme.
6. Strengthen the National Estuary Management Protocol to ensure cooperative governance between lead authorities, and to facilitate the development and implementation of Estuary Management Plans. The current focus on enabling local estuary management (e.g. bottom-up approach to land-use), should also be broadened in scope to actively facilitate pro-active strategic resource use managed between national and provincial departments (e.g. top-down approach to regional water and fisheries resource allocation). Mechanisms to ensure that compliance to policy and regulations becomes the norm, need to be investigated, funded and implemented. Ensure that the legal definition of estuaries in South Africa includes the biophysically defined EFZ (as defined in NBA 2018). NEMA EIA Regulations (2010) identifies the EFZ as a sensitive area that requires environmental authorisation before a development may proceed. It is important that the more inclusive NBA 2018 delineation be assimilated into the Integrated Coastal Management (ICM) Act and the National Water Act, both of which need to recognise the value of the estuarine 'floodplain' and the hazard of (back) flooding to development within this zone. Formal protection and adopting the EFZ as a 'setback line' is a key mechanism to halt the creeping decline in habitat condition.
7. Extractive activities, such as mining, need to be carefully examined to ensure that ecological, social, economic and access issues are addressed in a sustainable manner. This is especially the case for mining, in and around estuaries that has disproportionally large ecological impacts with often little economic or social benefits to the diversity of estuarine beneficiaries enjoying their services, e.g. nursery function, coastal protection, tourism. A strategic assessment of the spatial extent and associated impacts on of mining on estuaries and the coast is urgently needed, i.e. 'Mining SEA for South Africa's estuaries' that includes an analysis of estuarine and coastal sediment budgets.
8. Invest in solutions to restore estuarine ecological infrastructure to strengthen climate resilience and sustain ecosystem services. There is a pressing need for a 'National Estuary Restoration Programme' that focuses on degraded and novel systems, with an emphasis on the larger systems of high biodiversity importance and the socially important urban systems. Here an opportunity exists for flagship programmes that could be developed in a collaborative manner between government agencies and civil society. Opportunities also exist for Blue Carbon trading and Ecosystem-based adaptation (EbA) interventions moving forward.
9. Estuaries represent pressure hotspots, making collection of long-term monitoring data a priority to inform conflict resolution and provide for high-confidence decision making. For example, current ecological flow requirements are mostly done at a low-confidence desktop level due to lack of long-

term datasets. While some new data is being collected on larger systems, very little data is being collected on the numerous smaller estuaries. This results in poor decision making and hinders maximising the benefits that flow from estuaries. National-scale field surveys of South African estuaries were last carried out in the early 1980s and 1990s. Up-to-date field surveys of abiotic (topography, bathymetry and sediment structure) and biotic components (plants, invertebrates, fish and birds) are in urgent need of being repeated in a once-off effort that is comparable with earlier surveys. For example, DEFF: Fisheries Research should expand the estuary fish and fisheries monitoring programme to the entire coastline. This includes the monitoring of invasive alien and extralimital plants, invertebrates and fish, and the inclusion of estuaries into national detection and eradication programmes. Fund and implement the National Estuary Monitoring Programme initiated by DWS, this multi-tier, multi-parameter (including biotic and abiotic components) programme is based on current best practice and with sufficient funding, and support from other organs of state, could go a long way in addressing data deficiencies. This may require that the programme be integrated into the DEFF Oceans and Coasts National Water Quality Monitoring Programme. The NBA 2018 Estuaries Management and Monitoring Register was developed to foster institutional collaboration and the sharing of management and monitoring resources and datasets (Van Niekerk et al. 2019). It enables the cross linking of estuary condition or present ecological state (PES), desired condition or recommended ecological category (REC), management initiatives (Estuary Management Plans and Freshwater allocation) with monitoring activities. This register tracks the various ongoing data collection efforts occurring along the coast in order to optimise resources and ensure that critical issues are addressed. It also identifies gaps where ongoing pressures are degrading systems that provide critical ecosystem services and/or form part of the core set of priority systems in need of formal protection to achieve biodiversity targets.

10. Address critical knowledge gaps that limit the assessment of estuarine biodiversity and decision making for a sustainable oceans economy. Action research is needed on restoration, pollutants (herbicides, pesticides, pharmaceuticals and plastics), noise and light pollution, population genetics, climate change impacts, estuarine connectivity, recruitment studies of fish and invertebrates, invasive species and resource economics.

The United Nations Decade of Ecosystems Restoration 2021-2030 makes restoration and protection of critical ecosystems an imperative at a global scale. This call to arms, aims to scale up the restoration of degraded ecosystems to combat the climate crisis and enhance food security and biodiversity. It also presents a host of funding opportunities through climate finances instruments (e.g. Blue Carbon trading), Ecosystems-based Adaptation (EbA) global funds, and national debt restructuring mechanisms which will be highly supportive of a South African Strategic Estuarine Management Framework.

TEXT BOX 14: INITIATING A NATIONAL COASTAL MONITORING PROGRAMME

The DEFF Oceans and Coasts National Water Quality Monitoring Programme, an Operation Phakisa: Ocean Economy initiative, seeks to co-ordinate the current monitoring initiatives in terms of the sampling protocol (frequency, standardizing sampling methods and analysis) and addressing the limitations to the existing coastal monitoring initiatives. The main objective is to measure and report on a regular basis on the status and trends of the condition of marine and coastal waters (not only estuaries) and in a manner that supports strategic management decision in the context of their fitness for use for coastal waters. This is also aimed at determining baselines by looking at historical and current monitoring data in order to set site specific thresholds.

The first step will be the establishment of a fully South African National Accredited Systems (SANAS) accredited National Pollution Laboratory (NPL) to be hosted at the Walter Sisulu University. Currently, the laboratory is operational, working towards accreditation. The end point will be easy access to standardized monitoring results using a publicly accessible database, i.e. Oceans and Coasts Information System (OCIMS).

Currently, sixteen pilot sites have been selected in the Eastern Cape, Northern Cape and KwaZulu-Natal. The idea is to progressively increase the number sites in each province, including the Western Cape, so that there can be representative sites for the entire coastline. The NPL is currently doing quarterly water sampling and analysis on the pilot sites focusing on microbial, physicochemical analysis, toxicity testing and heavy metals. In order to have an accurate baseline, once accreditation is achieved for relevant parameters, the frequency needs to be increased to monthly.



Plate 1: Technician at the National Pollution



The DEFF has employed 34 unemployed graduates as coastal monitors distributed throughout the four coastal provinces. Their duties include, but are not limited to co-ordinating the collection of monitoring data and providing data and information needed for the implementation of coastal management programmes and supporting plans, i.e. Estuary Management Plans.

Plate 2: Water quality sampling at Qholora Estuary in the

Citation: Matoti, A. Initiating a National Coastal Monitoring Programme 2019. South African Estuary. Volume 3: Estuarine Realm. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A

12. KEY FINDINGS AND RECOMMENDATIONS

12.1 Key findings and messages

South Africa has 290 estuaries and 42 micro-estuaries which have been classified into 22 estuarine ecosystem types and 3 micro-estuary types. This represents a high diversity of estuary types stemming from our diverse climatic, oceanographic and geological drivers. Some ecosystem types and estuarine species only occur in South Africa, with some species confined to a few systems.

Estuaries are 'super' ecosystems. Although they constitute less than 2% of South Africa's territory, these highly productive ecosystems contribute R 4.2 billion per annum to the South African economy. They are focal points for development, tourism and recreation, as well as important for supporting biodiversity, livelihoods and marine fisheries. However, the development of estuaries and their catchments has come at a cost of about R700 million per annum in terms of lost fishery benefits as well as unknown costs to society from the overexploitation of resources and loss of biodiversity. This has reduced the diversity of benefits delivered by estuaries as well as the diversity of beneficiaries enjoying their services. Moving forward, development and resource use needs to be balanced to ensure the equitable sharing of benefits derived from these highly productive systems. Estuaries provide warm, shallow and calm waters along our rugged, wave-exposed coast, and are highly productive thanks to inputs of nutrients from both the land and sea. These characteristics together with their scenic appeal make them focal points for recreation and tourism, as well as important for supporting biodiversity, livelihoods and marine fisheries. Just over 70% of this value is manifest in property and tourism value as a result of the use of the amenities that they provide. However, the development of estuaries and their catchment areas has come at a cost of about R700 million per annum in terms of lost fishery benefits as well as unknown costs to society from the overexploitation of resources and loss of biodiversity. This has reduced the diversity of benefits being delivered by estuaries as well as the diversity of beneficiaries enjoying their services. The protection and rehabilitation of estuaries through the implementation of ecological water requirements and protecting the estuarine functional zone and its structural habitat from poorly planned coastal development is critical for maintaining resilience and enhancing future estuary benefits.

The Estuarine Functional Zone (EFZ) has been expanded to include estuarine habitats omitted from previous delineations (e.g. swamp forest, estuarine shores). This is important to ensure that all estuarine ecotones are captured in the delineation and considered in estuarine planning, monitoring and management. By doing this we ensure that all estuarine processes are protected by South Africa's environmental legislation (e.g. NEMA, ICM Act). In addition **interconnected riverine, wetland and marine ecosystem types that support estuarine functioning were delineated and embedded in the national map of South Africa ecosystems.** The recognition of the connectivity between these ecosystems is essential for integrated management. In future effective cross-sectoral management of these connected ecosystem types are required to secure their ecosystem health and associated benefits.

A third of South Africa's freshwater flow no longer reaches the coast, with present inflows down from 36 900 to 24 800 million cubic metres per annum. Twenty percent of estuaries are significantly impacted (Very High or High) by freshwater flow reduction, especially the large permanently open systems in the Cool Temperate biogeographic region, e.g. Orange, Groot Berg and Olifants estuaries. A further 14% of South African estuaries are moderately impacted (Medium) by reduced flow modification, with the highest proportion in the Cool Temperate (33%) and Warm Temperate (14%) regions. This affects estuary-marine connectivity (mouth state), estuarine productivity, water quality, sedimentary processes, invertebrate and fish recruitment, and nursery function. To avoid further compromising the benefits of these super ecosystems a Strategic Estuarine Management Plan - including freshwater allocation, fish resource use, water quality management and land-use planning - must be developed and implemented.

There has been a significant increase in pollution pressure in estuaries, e.g. 840 million litres of waste water daily flow into estuaries, with deteriorating water quality driving change on regional scales. Thus, about 33% of estuaries are under severe (Very High and High) pollution pressure, with the majority of those located in the cool temperate (63%), followed by the subtropical (39%) and warm temperate (18%) regions. This reduces ecosystem resilience and nursery function, kills invertebrates and fish; and makes estuaries vulnerable to invasive species, parasites, pathogens and diseases (e.g. *Tirebia* and EUS) threatening human health, wellbeing and food security. **Poor water quality is also impacting on estuarine resilience to natural stresses such as droughts and climate change over longer time scales.** Furthermore, declining water quality threatens habitat diversity such as loss of seagrass habitat in Knysna (macroalgal blooms), the increase in alien invasive aquatic plants in small KZN estuaries, and the persistent algal blooms in the upper reaches of systems with agricultural return flow. Maintaining and restoring water quality in estuaries requires reducing or recycling waste water, compliance with DWS & DEFF waste water discharge policies, innovative engineering solutions to stormwater management, improved agricultural practises (e.g. prudent application of agricultural fertilisers and pesticides).

Over 3 730 t of fish is caught annually in contrast with 3030 tons in 2011, with 21% of estuaries subjected to High or Very High fishing pressure. Up until a decade ago, excessive pressure or fishing effort was mostly confined to three large estuaries in the Cool Temperate region and one in the Tropical region. Since then, there's been a substantial increase in fishing effort in estuaries elsewhere on the coast especially in the subtropical and tropical bioregions. The latter was exacerbated by the effective open-access to resources that arose with the collapse of fisheries compliance in KwaZulu-Natal. Nowadays, severe to excessive fishing pressure occurs in 15% of cool-temperate estuaries as opposed to 23% and 100% of subtropical and tropical systems respectively. Countrywide, there's been a two-fold increase in estuaries subject to Medium fishing pressure with only 60% of systems under low fishing pressure as opposed to 80% in the previous assessment period. These two changes are almost entirely attributable to the increase in fishing pressure in the warm temperate and subtropical bioregions. Less than one percent of estuaries are not under some (low) fishing pressure as few have national, provincial or municipal protection or 'no-take' status. In addition, the integrity of estuarine protected areas is being eroded by both sanctioned and unlawful fishing in these areas. In many instances, fishing effort is now five times higher inside than outside restricted areas, e.g. estuaries in the Dwesa-Cwebe Marine Protected Area (MPA) and Nature Reserve.

Overall, 29% of South African estuaries are subject to severe (High and Very High) habitat modification pressure from land-use and development, mostly in the Cool Temperate (63%) and Subtropical (34%) regions. Less than 10% of all estuaries in South Africa are under no pressure from development, most of these being confined to national, provincial or municipal protected areas. Some of the more notable impacts include changes to erosion/depositional cycles, direct habitat loss during construction, changes to flow velocity and circulation patterns, reduced tidal prism, premature mouth closure, smothering of submerged habitats by excessive sedimentation, increased turbidity, reduced primary production, destruction of riparian and instream habitats and biota, contamination and associated poor water quality. To provide a broad indication of the degree of intactness of the EFZ the 2014, SANBI land cover data was disaggregated into natural and modified classes (artificial water bodies, urban (built-up) areas, mining, plantations and agriculture (croplands). The land cover data indicate that overall about 84% of the EFZ still have relative natural land cover. Agriculture (in the form of croplands) were responsible for about 10% of land cover change, while urban areas comprise about 4% of change in land-use. Mining, plantations and artificial water bodies contributed 0.8%, 0.6% and 0.2% of land cover change. The mining data does not reflect the many sand mining activities in estuaries.

Agriculture in Subtropical estuaries is mainly sugarcane farming. In the Warm Temperate estuaries floodplains were intensively cultivated in the 1950s to 1970s but then left fallow, for example in the Keiskamma and Great Fish estuaries. Cattle grazing or browsing of these areas and growth of alien plants are now common on these fallow areas. In the Cool Temperate systems floodplain areas are also prone to agricultural development (e.g. grain and fodder, fruit orchards, vineyards) and grazing by sheep and cattle. In addition farmers often set reeds alight in the hope of improving grazing. Harvesting of plants are also common in some estuaries. Targeted species are *Juncus kraussii* (Ncema Grass) and *Phragmites australis* (Common Reed). They are used for traditional crafts. Mangroves in some estuaries such as uMkomazi, Mngazana and Nxaxo-Ngqusi are also targeted, mainly for construction purposes. Browsing of mangroves by cattle are a key concern. Formal protection and adopting the EFZ as a 'setback line' is a key mechanism to halt the creeping decline in habitat condition

The mouths of only 15% of South African estuary are artificially manipulated, but these estuaries represent more than 60% of the total estuarine habitat in the country. Artificial breaching at lower levels is causing premature closure, reduced marine connectivity and the accumulation of marine sediments in the lower reaches. This reduces estuarine productivity and nursery function, but increases flood risks to coastal communities in the long term. There is a need to generate awareness of the systemic consequences of artificial breaching at low water levels. Artificial breaching is a listed activity that should only be allowed under exceptional circumstances that are guided by a national breaching policy.

The small-scale mining of sand, diamonds and heavy minerals is causing permanent habitat destruction in about 12% of estuaries, with especially low-value sand mining impacting on critical habitats, estuary hydrodynamics, sediment structure (grain size) and depleting sediment reservoirs needed to replenish physical habitat after scouring by floods. Ultimately resulting in the deepening of estuaries and the loss of meandering channels and sheltered backwater areas that provide refuge to estuarine biota from floods and large predators. This loss of physical structure increases the vulnerability of estuaries to floods and lengthens the recovery period between floods, i.e. post-flood sediment deposition rates are significantly reduced. This

reduction in sediment reservoirs also have knock on effects for the replenishment of beaches and foredunes that plays a critical role in coastal protection. Strategic spatial planning is required to find the balance between natural resource exploitation and the ability of living resources to replenish themselves. At present data are lacking to assist with such endeavours on a national scale.

Alien, extralimital or translocated fish occur in 25 % of South Africa's estuaries. There are 22 species recorded to date with one to nine per system. All are freshwater species that with the exception of Mozambique tilapia (*Orichromis mossambicus*) and Rainbow Trout (*Oncorhynchus mykiss*), are intolerant of salty water and confined to the headwaters of estuaries. It's here that they may become an impenetrable barrier to the upstream movement of eggs, larvae and juveniles of estuary-dependent fish and catadromous eels. Four of the aliens are voracious predators of eggs and larvae, eight are predominantly piscivores and two habitat altering. Many of these are also vectors of disease such as Epizootic Ulcerative Syndrome (EUS). Further invasions can be dampened by stricter import controls and management of the aquarium trade and aquaculture industry. Barring poisoning, existing populations can be controlled by directed and innovative fishing to the benefit of local communities.

A third of estuaries have invasive terrestrial plants occurring within the estuarine functional zone. While aquatic invasive species occur at 23 estuaries in the country. In total 70 invasive plant species were reported. Invasive *Acacia* species, particularly Rooikrans (*Acacia cyclops*), and *Eucalyptus* trees were abundant along the Cool and Warm Temperate coastline. Kikuyu grass (*Pennisetum clandestinum*), classified as NEMBA Category 1b in protected areas and wetlands, was also prevalent. A greater diversity of invasive alien plant species occur along the subtropical KwaZulu-Natal coastline. Dominant tree species include Brazilian Pepper Tree (*Schinus terebinthifolius* Raddi), *Casuarina equisetifolia* and *Sesbania punicea*. The urbanised estuaries of KwaZulu-Natal are highly disturbed and often the riparian vegetation consists only of invasive alien plants. Although there has been implementation of a biological control programme, Water Hyacinth (*Eichhornia crassipes*), still remains the worst aquatic weed in South Africa displacing rare submerged macrophyte species. Eradication programmes are urgently needed to address this growing concern.

More than 60% of SA estuaries are relatively healthy, but this amounts to only 22% of total estuarine extent, comprised mostly of small estuaries. More than 63% of estuarine area is significantly modified with important ecological processes under severe pressures that reduce productivity, food security, fisheries livelihood, property values and recreational enjoyment. Multiple interventions are required to avoid further decline in health. These include protection of freshwater inflow, restoration of water quality, reduction in fishing effort and avoidance of mining, infrastructure development and crops in the EFZ.

The estuarine realm is the most threatened of all realms in South Africa, both for the number of ecosystem types and for area. About 86% of estuary types are threatened with 9% Critically Endangered, 45% Endangered and 32% Vulnerable. By area, 99% are threatened with 3% Critically Endangered, 74% Endangered and 22% Vulnerable. This emphasises the need for strategic interventions across multiple sectors to restore estuarine health and protect benefits to people. To avoid further compromising of the benefits of these ecosystems a Strategic Estuarine Management Plan – including freshwater allocation, fish resource use, water quality management and land-use planning – must be developed and implemented.

South Africa's 12 Estuarine Lakes are in crisis with all four types threatened. This includes St Lucia, Kosi, uMgobezeleni, iNhlabane, uMhlathuze/Richards Bay, Touw/Wilderness, Swartvlei, Klein, Bot/Kleinmond, Heuningnes, Seekoeivlei and Verlorenvlei. This group of estuaries has seen extensive infrastructure development in the EFZ, substantial flow reduction, nutrient pollution, over fishing (especially gillnetting) and are subjected to artificial breaching / mouth manipulation. In addition, the lakes are highly vulnerable to climate change. These impacts have reduced their ability to provide key services such as flood regulation, nutrient cycling, nursery habitat, and have compromised recreational and tourism values. To ensure future climate change resilience, a strategic programme is needed to restore habitat, improve water quantity and quality, reduce pressure on resources and increase protection levels.

Estuaries are under protected in South Africa with only 18% of ecosystem types and 1% of estuarine area well protected. Since 2011 the situation has worsened with a loss of protection caused by removal of no-take restrictions and developing commercial fisheries in Marine protected Areas (MPAs). This said, several under protected ecosystem types can advance to Well Protected solely with improved management of fishing and water quality. For example, 32% of types and 10% of area can be well protected if fishing effort in just 3 estuaries are better controlled – Langebaan, Knysna and Kosi.

Salt marsh, seagrass and mangrove habitats require greater protection. Mangroves no longer occur in 10 Subtropical estuaries and nearly 30% of salt marsh habitat has been lost as a result of poor land-use practices, flow reduction and related mouth closure, direct harvesting and cattle grazing. Priority systems for habitat diversity protection are the Groot Berg, Knysna, Mngazana, uMlalazi, St Lucia and Kosi estuaries. Especially the Berg Estuary with its expansive floodplain marshes is unique and must be prioritised for rehabilitation and protection, while greater protection of the endangered seagrass (*Zostera capensis*) and large intertidal salt marshes areas of Knysna Estuary is also needed. A strategy for mangrove protection is also urgently needed to prevent further loss.

Several estuarine-dependent fish species are threatened by overfishing (especially gill-netting), declining water quality, and reduced flows with their concomitant influence on recruitment and marine connectivity. For example, Dusky Kob (*Argyrosomus japonicus*) (Critically endangered at < 1% of pristine reproductive adult biomass), White Steenbras (*Lithognathus lithognathus*) (Endangered at < 6%), and Leervis (*Lichia amia*) (vulnerable at < 14%). Many more threatened estuarine invertebrate and fish species may be going undetected. Stock or population recovery must be facilitated by reducing fishing pressure (e.g. nationwide prohibition on fishing at night in estuaries, estuarine protected areas), increased compliance, ensuring adequate freshwater inflow, decreasing nutrient pollution, managing noise pollution and boating activity.

More than 265 000 waterbirds have been lost from our estuaries, most of which are waders and from larger estuaries, especially in the cool temperate region. Birds are regularly monitored in 94% of the national estuarine area, with much of this area having been monitored since the 1970s or 80s. Over this time period, we estimate that the overall numbers of non-passerine waterbirds has declined to just 32% of the numbers present in 1979-81. These changes have been largely externally driven by hunting and habitat loss in the Northern Hemisphere, but are also significantly related to estuary health, and are not mitigated by level of protection. In nearly all the well-monitored estuaries, bird numbers are still on a significantly negative

trajectory. Apart from improving the health of estuaries, planners and estuary managers need to include significant sanctuary areas that protect birds and their prey from human disturbance and exploitation.

South Africa's successful eradication of the highly invasive Cordgrass (*Spartina alterniflora*) from the Groot Brak Estuary. This species is habitat transforming and would have spread to adjacent estuaries if not for the quick eradication. Early warning systems and quick intervention for invasive species are our best protection.

Good progress has been made in the management of estuaries across a number of sectors. The DWS has determined the ecological water requirement of nearly 40% of estuaries, with 37% of these being subjected to the 'Classification' of freshwater resources. In addition 11% of estuaries have developed Estuary Management Plans, but there is a need to clarify local level responsibilities to ensure effective implementation. These not insignificant gains plays a critical role in maintaining and restoring estuary health and ensuring the benefits that society derive from them. These measures are also proactive in that they set management objectives for estuarine resources on the strategic level through the engagement of society in the decision making process. Unfortunately, there have been a deterioration in the management of fishing pressure, but DEFF is poised to roll out slot limits and the 'night fishing ban' country wide in an effort to facilitate national stock recovery.

NBA Estuaries management and monitoring register was developed to foster institutional collaboration and the sharing of management and monitoring resources and datasets (Van Niekerk *et al.* 2019). It enables the cross linking of estuary condition (PES), desired condition (REC or TEC), management initiatives (Estuary Management Plans and Freshwater allocations) with monitoring activities. The register track the various ongoing data collection efforts occurring along the coast in order to optimise resources and ensure that critical issues are addressed. It also identify gaps where ongoing pressures are degrading systems that provide critical ecosystem services and/or form part of the core set of priority systems in need of formal protection to achieve biodiversity targets. The register serve as input to regional/national assessment studies such as the NBA, DWS water resource classification and the identification of climate change adaptation priorities.

Estuaries represent pressure hotspots, unfortunately there is a lack of long-term monitoring data to inform conflict resolution and provide for high confidence decision making, e.g. ecological flow requirements are mostly done at a low confidence desktop level due to lack of long term data on river inflow (< 10% of coastal catchments), water level/mouth state (< 15%), bathymetry, water quality, biological responses (e.g. national bird counts date from the 1980s, e.g. Underhill & Cooper 1984) and national fish surveys date from the 1990s (e.g. Council for Scientific and Industrial Research (CSIR), unpublished data; Harrison 2000; 2005). While some new data is being collected on larger systems, very little data is being collected on the numerous smaller estuaries. This results in poor decisions making and hinders maximising the benefits that flow from estuaries.

12.2 Priority actions

- **Reduce pressure on invertebrate and fish living resources.** The first priority is the implementation of the (ministerially approved) prohibition on fishing at night in all estuaries in South Africa. Implementation of amended bag and slot limits (minimum and maximum sizes) for priority species - Dusky Kob, Dusky Steenbras, Spotted Grunter, Leervis and Elf. Regularly update stock assessments of the afore mentioned species. Consideration should also be given to testing rotational time area closures in pilot estuaries. Escalating gill net poaching is responsible for at least half the catch in South Africa's important estuary fish nursery areas. This has resulted in recruitment and growth overfishing and collapse of the six most economically and socially important species in estuaries and the sea. The most severely impacted are small scale coastal fisheries. There needs to be a coordinated campaign to eradicate this destructive fishing method. This includes national government support (financial and logistical) to provincial management authorities.
- **Share benefits of estuaries and estuarine protected areas equitably among coastal communities.** The integrity of estuarine protected areas (including wetland parks and nature reserves and no-take MPAs) is being compromised by both sanctioned and illegitimate fishing in these areas. In many instances, fishing effort is now five times higher inside rather than outside protected areas. Estuaries are first and foremost a national asset providing and sustaining fisheries resources throughout South African coastal waters, not just on a local scale. Over-allocating fishing rights to local fisheries is compromising the benefits to communities on a national scale throughout the coast. This practise has to be reviewed and reversed to ensure an equitable and sustainable sharing of coastal resources by all communities dependent upon them.
- **Protect and restore the health of South Africa's estuarine lakes.** South Africa's estuarine lakes are all facing disproportionately high pressure, and need to be managed in a more holistic manner. They are important national biodiversity assets, which often pay the price for inappropriate short-term local-level decision-making. The iSimangaliso Wetland Park Authority has initiated measures to combine the uMfolozi with Lake St Lucia with funding support from the Global Environment Facility (GEF) in order to restore the health of the greater ecosystem. Similar efforts needs to be directed towards the other lake systems. A programme of action needs to be developed to halt further decline in condition, focussing on integrated management and building the lakes resilience to climate change. Key intervention include: protection of freshwater inflow (surface and groundwater), removing/preventing waste discharges into estuarine lakes, improving quality of agricultural return flow, reducing/removing fishing pressure, and controlling/prohibiting new development in EFZ. To reverse ongoing sedimentation and associated increase in the long-term flood risk to low lying properties, artificial breaching should also not occur at lower level than pre-established.
- **Increase protection levels through the implementation of the National Estuary Biodiversity Plan.** The development of the National Estuary Biodiversity Plan was the first step in the planning process. The DEFF, in collaboration with SANBI and DWS, should lead the implementation of the National Estuary Biodiversity Plan. This should include the setting of protected area targets for Estuarine Protected Areas in the short to medium-term, e.g. 5% of all ecosystem types will be formally

protected by 2020 and 20% of all ecosystem types will have Estuary Management Plans by 2020. This also requires the integration of the National Estuary Biodiversity Plan in strategic processes such as the classification of water resources led by the DWS and the upcoming revision of the National Protected Area Expansion Strategy led by DEFF.

- **Respond rapidly to emerging invasive species.** The successful eradication of Smooth cordgrass *Spartina alterniflora* from the Groot Brak showed the importance of developing protocols and procedures for the early detection, risk assessment and management of invasive alien species. For example, certain invasive alien fish species can act as a barrier to migratory species (eels and freshwater mullet) and influence the species composition and abundance of species, many of which are commercially important, in the river-estuarine interface.
- **Ensure that the legal definition of estuaries in South Africa includes the estuarine functional zone.** The NEMA EIA Regulations (2010) identifies the estuarine functional zone as a sensitive area that requires environmental authorisation before a development may proceed. It is important that this consideration is also taken up by the ICM Act and the National Water Act, both of which need to recognise the value of the estuarine floodplain and the threat of (back) flooding within this zone.
- **Complete ecological water requirements and classification of all estuaries within five years and implement flow requirements within two years of their classification.** This process is likely to require a two-tiered approach in which the findings of the NBA 2011 and/or 2018 form the basis for allocation on a national level in the classification of water resources in terms of the National Water Act. While more detailed ecological water requirement studies will be needed for water-stressed catchments or biodiversity priority areas, there is also an urgent need for strategic assessments (such as the National Water Resources Strategy) to take cognisance of estuarine flow requirements which are often substantially higher than the flow requirements of the river entering the estuary. This little recognised fact leads to national and catchment scale water resource plans that over-estimate the water resources available for development, thus compromising the ecosystem processes that coastal communities depend upon.
- **Up-to-date field surveys of the abiotic (topography, bathymetry and sediment structure) and biotic components (plants, invertebrates and fish and bird) of estuaries:** National scale field surveys on South African estuaries were last carried out in the early 1980 and 1990s. These surveys urgently need to be repeated in a once-off effort that is comparable with the earlier surveys.
- **Strengthen the National Estuary Management Protocol** to ensure cooperative governance between the lead authorities that manage estuaries and roll out the development and implementation of Estuary Management Plans in terms of the ICM Act. In addition to its current focus on enabling local estuary management (e.g. bottom-up approach to land use), the Protocol should also be broadened in scope to actively facilitate pro-active strategic resource management between lead national and provincial departments (e.g. top-down approach to regional water and fisheries resource allocation).
- **Fund and implement the National Estuary Monitoring Programme** initiated by DWS, this multi-tier, multi-parameter (include biotic and abiotic components) programme is based on current best

practice and with sufficient funding, and support from other organs of state, could go a long way in addressing data deficiencies in future NBA assessments.

- **Development integrated, cross sectorial strategic resource allocation plan for estuaries** that will ensure alignment between sectoral objectives for estuaries on a national or provincial scale. Using the 2018 NBA as departure point, the plan should be developed in consultation with lead authorities (DEFF, SANBI and DWS) and assist with facilitating the co-operative governance between the lead agents. Once in place, it should serve as the 'blue print' for a number of key sectoral resource plans and processes at various levels of governance, e.g. allocation of water resources or Total Allowable Catch in coastal fisheries. Long-term, pro-active and cross sectorial planning is key to ensuring climate change resilience and the equitable sharing in estuarine benefits by coastal communities, now and into the future.

12.3 Data gaps

While significant progress were made in quantifying freshwater flow modification, waste water input and the mapping estuarine habitat since 2011, the following data gaps remain a key concern:

- **Refine estuary ecosystem types:** The NBA 2018 reclassified South Africa's estuaries. However, data on bathymetry, sediment structure, mouth state and water quality (turbidity and salinity) would aid in the development of a hierarchical classification and conceptual or numerical models to determine the general sensitivity of the different ecosystem types to pressures.
- **Taxonomic surveys of the invertebrates in all South African estuaries:** There is no up-to-date national dataset for South African estuarine invertebrates. Invertebrate data were last collated at a national scale more than a decade ago and little effort has been made to address this. Future assessments and biodiversity plans cannot be refined without filling this gap in a systematic manner.
- **Taxonomic surveys of the plants in all South African estuaries:** Taxonomic revision of salt marsh species should be supported and funded so that macrophyte species lists can be updated for all estuaries. From these data, sites of rare and threatened species can be identified.
- **Invasive Species:** With the exception of plants, very little is known about invasive species in South Africa's estuaries. There is an urgent need to have a census on the occurrence of invasive alien species in different estuaries and the potential environmental impact of these on both the ecosystem function and the value derived from the estuary in question. All invasive species (freshwater, marine and estuarine) should be included in the census.
- **The value of estuaries in South Africa:** There is very little national scale data available on the value of estuaries. As this is one of the key requirements for communicating the relevance of estuaries to coastal communities, and the country as a whole, this lack of data hinders the ability to motivate for rational decision-making.
- **Climate change:** Climate change has the potential to change the processes and functioning of South Africa's estuaries dramatically. Large and local scale climate models are becoming better at accurately predicting the drivers of change in the future. The estuarine research community needs

to make this one of their research priorities over the next decade to facilitate better adaptation strategies and ensure ecosystem resilience.

- **Sediment data:** Very little information is available on the sediment structure of South Africa's estuaries. This is a significant data gap as grain size distribution and the mud:sand ratios influence biodiversity patterns. The lack of sediment information also makes it very difficult to assess environmental change in relation to some of the major pressures such as dam development and sand mining.
- **Mapping the 3-dimensional nature of South Africa's estuaries:** Detailed systematic topographical and bathymetrical surveys are needed for all South Africa's estuaries. Cross-sectional survey data are available for less than a third of the estuaries in the country and most cases these datasets are over 20 years old. Most planning processes (e.g. ecological water requirement studies, Estuary Management Plans, setback lines, spatial development plans) are of low confidence as they lack this basic information. Assessment of change (sedimentation, erosion sensitivity to flow modifications, structural developments) is therefore mostly inferred from pressure data. Improved planning and assessments urgently require a significant effort to address these basic data requirements.
- **Up-to-date surveys of the fish and bird fauna of estuaries:** National scale surveys on fish and birds in all South African estuaries were last carried out in the early 1980s. These surveys urgently need to be repeated in a once-off effort that is comparable with the earlier surveys.

12.4 Research Priorities

- **The impact of herbicides, pesticides and pharmaceuticals is poorly understood in estuaries:** Of special concern is the combined impact of long-residence times, higher temperatures and salt-freshwater gradients on toxic substances in the water column and sediment.
- **Noise and light pollution are emerging pressures that are poorly understood:** Initial findings are that these pressures increase stress, reduce productivity and impact on the benefits that flow from estuaries, e.g. some fish experience slower growth, behaviour changes and lower reproductive potential. Research is needed to guide the development of policy to restrict activities (e.g. boating) that cause these pressures.
- **Connectivity and regional importance:** In the case of a network of small systems that collectively comprises significant estuarine area in a region, the functional gap(s) forming as a result of poor condition systems along a coast is worrying e.g. KwaZulu-Natal south coast. Unfortunately, no scientific support is available to guide planners to deal with the consequences for estuarine connectivity. The health of individual estuaries matters as it contributes to overall resilience of the network of estuaries along a coast. The science however, is lacking in understanding the degree to which the health of adjacent estuaries influences each other. Mark and recapture, telemetry and genetic studies will assist in 'making the case for estuarine connectivity' and the development of appropriately informed guidelines for regional resource allocation and estuarine resource management.

- **Taxonomic surveys of plants, invertebrates and fish in South African estuaries:** The taxonomic revision of salt marsh species should be supported and funded so that macrophyte species lists can be updated for all estuaries. From these data, sites of rare and endangered species can be identified. There is no national dataset or specimen voucher system for the *South African estuarine invertebrates*. This significant data gap was identified more than a decade ago but little effort has been made on a national scale to address this deficiency. Future assessment and biodiversity plans cannot refine on present findings without filling this gap in a systematic manner.
- **Invasive fish species as a barrier to connectivity.** The spread of invasive freshwater predatory fish acts as a barrier to migratory species (e.g. eels and freshwater mullet) and compete with estuarine-associated species in the river-estuary interface. This aspect needs further investigation to quantify the extent of the problem.
- **Climate change:** Climate change has the potential to change the processes and functioning of South Africa's estuaries dramatically. Large and local scale climate models are becoming better at accurately predicting the drivers of change in the near and far future. The estuarine community is urged to make this one of their research priorities over the next decade to facilitate better adaptation strategies and ensure ecosystem resilience.
- **Population genetics studies:** To allow for more detailed biodiversity planning in the future it is important that detailed *population genetics studies* be done on plants, invertebrates and fish to ensure the correct biodiversity protection measures. Preliminary findings indicate that there is a higher degree of isolation than is assumed for the less mobile species (such as plants). This work needs to be done systematically for the higher taxa as well.
- **Recruitment studies of fish and invertebrates:** Recruitment studies are urgently required to ensure sound strategic planning of estuarine biodiversity and resource allocation. While fisheries management measures have become more stringent over the last decade, the stock status of a number of exploited species have stayed the same or declined even further. Recruitment studies would shed light on an important bottle-neck in resource recovery plans, and identify estuaries of conservation and management importance.
- **Nursery function of exploited and collapsed fish species:** Recent work has indicated that while most estuaries serve as nurseries, some of the more sediment rich ones are associated with 'sediment deltas' in the nearshore environment which serves as nurseries for some collapsed stock species such as Dusky Kob. It is important that these systems be identified and their nursery function qualified to ensure sustainable resource utilisation into the future. Future biodiversity plans should also include these systems explicitly to align management and conservation priorities.

12.5 Recommendations for next NBA

Based on lessons learned during the NBA 2018 process, as well as aspects addressed in lesser detail than we would have liked, the following recommendations are made with reference to future NBAs:

- **National Health Assessment:** The method (based on ecological water requirement method under the Water Act) followed for the National Health Assessment proved a valuable assessment framework for evaluating ecosystem change on a national scale. It is recommended that this same approach be followed for future NBAs, but with an emphasis on improved pressure data (especially hydrology, catchment land-use and pollution aspects) and biological data. This process should commence 3 years before the next cycle of the NBA.
- **Climate change:** While climate change was addressed on a broad-scale from a process perspective, more detailed work is needed to understand its impact on the functioning and biodiversity of South Africa's estuaries. A better understanding of this threat will greatly enhance our ability to take the necessary management steps and appropriate water supply decisions. It is strongly recommended that this becomes a major thrust of the next NBA.
- **Maximise the value of estuaries in South Africa:** Time and funding constraints prevented this NBA assessment process to adequately define and value the benefits society derive from South Africa's estuaries. Future NBA studies should strive to address this aspect in more detail.
- **National biodiversity planning:** While not essential to future NBA assessments, the existing proposed National Estuaries Biodiversity Plan should be periodically reviewed in the light of new pressure information, improved classification/typing; improved ecosystems services data, policy changes and development initiatives. The NBA provides a perfect national platform for the coherent roll-out of biodiversity initiatives.
- **Time-line and project integration:** The high degree of interaction among the core team members added value and facilitated integration between the various realms (marine, estuarine, rivers and land). While this aspect may slow down the overall delivery time, it provides for significant knowledge transfer, learning opportunities, and ultimately a better product. In addition, a longer time frame allows for the engagement of domain specialists at time-scales more suitable for smaller individual research projects and scientific curiosity.

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APPENDIX A: ESTUARY AND MICRO-SYSTEM ECOSYSTEM CLASSIFICATION

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Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
1	Orange	Cool Temperate	Estuary	Large Fluvially Dominated	Large Fluvially Dominated	16°27'28.0943"	28°38'8.6783"	NBA 2012, CSIR NRIO List 1981
2	Holgat	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	16°43'15.6792"	28°58'43.946"	CSIR NRIO List 1981
3	Kwagganap	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	16°59'55.90"	29°31'23.02"	NBA 2018 river list
4	Buffels	Cool Temperate	Estuary	Arid Predominantly Closed	Arid Predominantly Closed	17°3'2.26"	29°40'38.17"	NBA 2012, CSIR NRIO List 1981
5	Swartlinterjies	Cool Temperate	Estuary	Arid Predominantly Closed	Arid Predominantly Closed	17°15'33.22"	30°15'47.49"	Northern Cape Government
6	Spoeg	Cool Temperate	Estuary	Arid Predominantly Closed	Arid Predominantly Closed	17°21'31.4280"	30°28'21.691"	NBA 2012, CSIR NRIO List 1981
7	Bitter	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	17°26'34.6020"	30°35'53.476"	CSIR NRIO List 1981
8	Groen	Cool Temperate	Estuary	Arid Predominantly Closed	Arid Predominantly Closed	17°34'35.6268"	30°50'48.472"	NBA 2012, CSIR NRIO List 1981
9	Brak	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	17°43'47.2440"	31°5'55.9355"	CSIR NRIO List 1981
10	Sout (Noord)	Cool Temperate	Estuary	Arid Predominantly Closed	Arid Predominantly Closed	17°50'54.2831"	31°14'41.207"	NBA 2012, CSIR NRIO List 1981
11	Cool Temperate 1	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18° 2'2.49"	31°29'51.35"	NBA 2018
12	Olifants	Cool Temperate	Estuary	Predominantly Open	Predominantly Open	18°11'13.6283"	31°42'3.7583"	NBA 2012, CSIR NRIO List 1981
13	Sandlaagte	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°13'29.03"	31°45'32.94"	CSIR NRIO List 1981
14	Jakkals	Cool Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	18°18'48.2976"	32°5'4.70759"	NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
15	Wadrift	Cool Temperate	Estuary	Arid Predominantly Closed	Arid Predominantly Closed	18°19'30.9719"	32°12'16.509"	NBA 2012, CSIR NRIO List 1981
16	Verlorenvlei	Cool Temperate	Estuary	Estuarine Lake	Estuarine Lake	18°19'59.4263"	32°18'57.319"	NBA 2012, CSIR NRIO List 1981
17	Papkuils	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°17'8.68"	32°37'33.97"	CSIR NRIO List 1981
18	Groot Berg	Cool Temperate	Estuary	Predominantly Open	Predominantly Open	18°8'37.9860"	32°46'11.096"	NBA 2012, CSIR NRIO List 1981
19	Cool Temperate 2	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	17°54'31.39"	32°46'56.77"	NBA 2018 river list
20	Paternosterbaai	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	17°54'1.52"	32°48'8.96"	CSIR NRIO List 1981
21	Bok (Noord)	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	17°58'26.11"	32°59'44.60"	Western Cape Government
22	Langebaan	Cool Temperate	Estuary	Estuarine Lagoon	Estuarine Lagoon	18° 1'18.97"	33° 5'50.36"	CSIR NRIO List 1981, Berg Classification
23	Dwars (Noord)	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°13'39.38"	33°24'15.98"	CSIR NRIO List 1981
24	Dwars (Suid)	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°15'46.92"	33°26'12.16"	CSIR NRIO List 1981
25	Modder	Cool Temperate	Micro-system	Micro-estuary	Micro-estuary	18°18'24.45"	33°29'5.12"	CSIR NRIO List 1981
26	Cool Temperate 3	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°19'29.19"	33°30'59.67"	NBA2018
27	Jacobsbaai	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°19'27.45"	33°31'12.44"	CSIR NRIO List 1981
28	Lêerbaai	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°19'4.72"	33°32'14.11"	CSIR NRIO List 1981
29	Bok (Suid)	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°20'2.33"	33°34'8.79"	CSIR NRIO List 1981
30	Cool Temperate 4	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°21'8.74"	33°34'39.97"	CSIR NRIO List 1981
31	Silwerstroom	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°21'21.74"	33°34'53.79"	Berg Classification
32	Sout (Suid)	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°26'36.59"	33°42'49.07"	Berg Classification
33	Springfontein	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°22'26.03"	33°36'27.56"	Berg Classification
34	Diep/Rietvlei	Cool Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	18°28'55.7148"	33°53'23.654"	NBA 2012, CSIR NRIO List 1981
35	Sout (Wes)	Cool Temperate	Estuary	Large Temporarily Closed	Predominantly Open	18°28'17.7095"	33°54'28.925"	NBA 2012, CSIR NRIO List 1981
36	Disa	Cool Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	18°21'16.2000"	34°2'47.0075"	NBA 2012, CSIR NRIO List 1981
37	Goeiehoop	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°21'10.15"	34°5'47.91"	CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
38	Wildevoolvlei	Cool Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	18°20'35.8332"	34°7'38.6796"	NBA 2012, CSIR NRIO List 1981
39	Bokramspruit	Cool Temperate	Micro-system	Micro-estuary	Micro-estuary	18°19'57.6335"	34°8'3.65999"	NBA 2012, CSIR NRIO List 1981
40	Schuster	Cool Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	18°22'15.2651"	34°12'7.3619"	NBA 2012, CSIR NRIO List 1981
41	Krom	Cool Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	18°22'42.2436"	34°13'51.391"	NBA 2012, CSIR NRIO List 1981
42	Olifantsbos	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°22'58.31"	34°15'26.47"	CSIR NRIO List 1981
43	Booskraal	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°23'46.66"	34°17'14.50"	CSIR NRIO List 1981
44	Buffels (Wes)	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	18°27'42.4151"	34°19'5.6532"	NBA 2012, CSIR NRIO List 1981
45	Elsies	Cool Temperate	Micro-system	Micro-estuary	Micro-estuary	18°25'53.3495"	34°9'37.5083"	NBA 2012, CSIR NRIO List 1981
46	Silwermyr	Cool Temperate	Estuary	Large Temporarily Closed	Small Temporarily Closed	18°26'20.1227"	34°7'57.9467"	NBA 2012, CSIR NRIO List 1981
47	Zand	Cool Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	18°28'35.4000"	34°6'22.9823"	NBA 2012, CSIR NRIO List 1981
48	Zeekoei	Cool Temperate	Estuary	Estuarine Lake	Predominantly Open	18°30'17.7623"	34°5'54.3083"	NBA 2012, CSIR NRIO List 1981
49	Eerste	Cool Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	18°45'13.4028"	34°4'43.7771"	NBA 2012, CSIR NRIO List 1981
50	Lourens	Cool Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	18°48'39.0347"	34°6'0.18719"	NBA 2012, CSIR NRIO List 1981
51	Cool Temperate 5	Cool Temperate	Micro-system	Micro-estuary	Micro-estuary	18°50'8.69"E	34° 7'39.74"S	NBA2018
52	Sir Lowry's Pass	Cool Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	18°51'53.6220"	34°9'20.0160"	NBA 2012, CSIR NRIO List 1981
53	Steenbras	Cool Temperate	Estuary	Small Fluvially Dominated	Small Fluvially Dominated	18°49'9.88319"	34°11'41.348"	NBA 2012, CSIR NRIO List 1981
54	Rooiels	Cool Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	18°49'15.7620"	34°17'44.786"	NBA 2012, CSIR NRIO List 1981
55	Buffels (Oos)	Cool Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	18°49'46.3259"	34°20'20.209"	NBA 2012, CSIR NRIO List 1981
56	Palmiet	Cool Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	18°59'38.9075"	34°20'43.584"	NBA 2012, CSIR NRIO List 1981
57	Bot/Kleinmond	Cool Temperate	Estuary	Estuarine Lake	Estuarine Lake	19°5'.49.6751"	34°22'6.3516"	NBA 2012, CSIR NRIO List 1981
58	Onrus	Cool Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	19°10'43.2912"	34°25'7.1472"	NBA 2012, CSIR NRIO List 1981
59	Mossel	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	19°16'21.25"	34°24'29.86"	CSIR NRIO List 1981
60	Klein	Cool Temperate	Estuary	Estuarine Lake	Estuarine Lake	19°17'53.3723"	34°25'14.354"	NBA 2012, CSIR NRIO List 1981
61	Uilkraals	Cool Temperate	Estuary	Predominantly Open	Large Temporarily Closed	19°24'27.4859"	34°36'27.176"	NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
62	Haelkraal	Cool Temperate	Micro-system	Micro-estuary	Micro-estuary	19°31'40.91"	34°40'35.89"	Beede/Gourits Classification
63	Ratel	Cool Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	19°44'47.4216"	34°46'15.668"	NBA 2012, CSIR NRIO List 1981
64	Drie vlietjies	Cool Temperate	Micro-system	Micro-outlet	Micro-outlet	19°46'23.85"	34°45'49.47"	Beede/Gourits Classification
65	Heuningnes	Warm Temperate	Estuary	Estuarine Lake	Predominantly Open	20°7'9.28560"	34°42'53.244"	NBA 2012, CSIR NRIO List 1981
66	Klipdrifsfontein	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	20°43'52.7951"	34°27'6.8616"	NBA 2012, CSIR NRIO List 1981
67	Papkuils	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	20°52'1.08"	34°27'22.49"	CSIR NRIO List 1981
68	Breede	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	20°50'43.1951"	34°24'26.762"	NBA 2012, CSIR NRIO List 1981
69	Duiwenhoks	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	21°0'4.25520"	34°21'54.107"	NBA 2012, CSIR NRIO List 1981
70	Goukou	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	21°25'24.6972"	34°22'42.067"	NBA 2012, CSIR NRIO List 1981
71	Gouritz	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	21°53'9.25440"	34°20'43.227"	NBA 2012, CSIR NRIO List 1981
72	Blinde	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	22°0'46.6092"	34°12'39.060"	NBA 2012, CSIR NRIO List 1981
73	Tweekuilen	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	22°6'42.11"	34°9'5.51"	CSIR NRIO List 1981, Gourits WMA study
74	Gericke	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	22°6'37.50"	34°8'38.35"	CSIR NRIO List 1981, Gourits WMA study
75	Hartenbos	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	22°7'32.8152"	34°6'54.4032"	NBA 2012, CSIR NRIO List 1981
76	Klein Brak	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	22°8'54.9096"	34°5'34.5480"	NBA 2012, CSIR NRIO List 1981
77	Groot Brak	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	22°14'21.4511"	34°3'26.1144"	NBA 2012, CSIR NRIO List 1981
78	Rooi	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	22°17'3.51"	34°3'3.31"	CSIR NRIO List 1981
79	Maalgate	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	22°21'15.9803"	34°3'15.8039"	NBA 2012, CSIR NRIO List 1981
80	Gwaing	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	22°26'2.90039"	34°3'23.2883"	NBA 2012, CSIR NRIO List 1981
81	Skaapkop	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	22°29'55.83"	34° 2'11.21"	CSIR NRIO List 1981
82	Meul	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	22°32'35.86"	34°0'49.26"	CSIR NRIO List 1981
83	Cool Temperate 6	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	22°32'56.40"	34°0'18"	NBA 2018
84	Kaaimans	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	22°33'25.4015"	33°59'52.130"	NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
85	Touw/Wilderness	Warm Temperate	Estuary	Estuarine Lake	Estuarine Lake	22°34'52.0571"	33°59'44.728"	NBA 2012, CSIR NRIO List 1981
86	Swartvlei	Warm Temperate	Estuary	Estuarine Lake	Estuarine Lake	22°47'46.5215"	34°1'53.4576"	NBA 2012, CSIR NRIO List 1981
87	Goukamma	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	22°56'56.8859"	34°4'37.7795"	NBA 2012, CSIR NRIO List 1981
88	Knysna	Warm Temperate	Estuary	Estuarine Bay	Estuarine Bay	23°3'41.2308"	34°4'57.7416"	NBA 2012, CSIR NRIO List 1981
89	Noetsie	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	23°7'44.9543"	34°4'49.0872"	NBA 2012, CSIR NRIO List 1981
90	Grooteiland	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°12'34.55"	34°5'9.14"	CSIR NRIO List 1981
91	Kranshoek	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°13'30.21"	34°5'11.69"	CSIR NRIO List 1981
92	Crooks	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°14'44.74"	34°5'28.92"	CSIR NRIO List 1981
93	Piesang	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	23°22'43.5431"	34°3'37.6740"	NBA 2012, CSIR NRIO List 1981
94	Keurbooms	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	23°22'41.4732"	34°2'59.4599"	NBA 2012, CSIR NRIO List 1981
95	Matjies	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	23°28'12.6552"	34°0'7.07399"	NBA 2012, CSIR NRIO List 1981
96	Brak	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°31'48.00"	33°59'50.00"	CSIR NRIO List 1981
97	Sout (Oos)	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	23°32'11.5548"	33°59'22.207"	NBA 2012, CSIR NRIO List 1981
98	Groot (Wes)	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	23°34'9.04799"	33°58'54.411"	NBA 2012, CSIR NRIO List 1981
99	Helpmekaars	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°35'57.52"	33°58'48.34"	CSIR NRIO List 1981
100	Klip	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°37'1.35"	33°58'42.35"	CSIR NRIO List 1981
101	Bloukrans	Warm Temperate	Estuary	Small Fluvially Dominated	Small Fluvially Dominated	23°38'50.8884"	33°58'46.721"	NBA 2012, CSIR NRIO List 1981
102	Witels	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°42'8.13"	33°59'18.40"	CSIR NRIO List 1981
103	Lottering	Warm Temperate	Estuary	Small Fluvially Dominated	Small Fluvially Dominated	23°44'9.41999"	33°59'43.836"	NBA 2012, CSIR NRIO List 1981
104	Elandsbos	Warm Temperate	Estuary	Small Fluvially Dominated	Small Fluvially Dominated	23°46'4.59120"	34°0'12.6467"	NBA 2012, CSIR NRIO List 1981
105	Geelhoutbos	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°47'8.37"	34°0'22.68"	CSIR NRIO List 1981
106	Kleinbos	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°48'46.99"	34°0'42.70"	CSIR NRIO List 1981
107	Storms	Warm Temperate	Estuary	Small Fluvially Dominated	Small Fluvially Dominated	23°54'10.7568"	34°1'15.5064"	NBA 2012, CSIR NRIO List 1981
108	Bruglaagte	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°56'12.23"	34°1'34.57"	CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
109	Langbos	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	23°58'25.39"	34°1'58.79"	CSIR NRIO List 1981
110	Sanddrif	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	24°0'17.79"	34°2'13.07"	CSIR NRIO List 1981
111	Elands	Warm Temperate	Estuary	Small Fluvially Dominated	Small Fluvially Dominated	24°4'44.7096"	34°2'38.3387"	NBA 2012, CSIR NRIO List 1981
112	Groot (Oos)	Warm Temperate	Estuary	Small Fluvially Dominated	Small Fluvially Dominated	24°11'42.0683"	34°3'35.6219"	NBA 2012, CSIR NRIO List 1981
113	Eerste	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	24°14'39.96"	34°4'41.99"	CSIR NRIO List 1981
114	Klipdrif (Wes)	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	24°16'28.50"	34°5'16.61"	CSIR NRIO List 1981
115	Boskloof	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	24°17'41.06"	34°5'31.74"	CSIR NRIO List 1981
116	Kaapsedrif	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	24°23'13.49"	34°6'20.95"	CSIR NRIO List 1981
117	Tsitsikamma	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	24°26'17.9736"	34°8'8.13480"	NBA 2012, CSIR NRIO List 1981
118	Klipdrif (Oos)	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	24°38'13.3764"	34°10'20.521"	NBA 2012, CSIR NRIO List 1981
119	Slang	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	24°39'13.3271"	34°10'26.864"	NBA 2012, CSIR NRIO List 1981
120	Kromme	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	24°50'33.8208"	34°8'34.6811"	NBA 2012, CSIR NRIO List 1981
121	Seekoei	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	24°54'38.6748"	34°5'12.0119"	NBA 2012, CSIR NRIO List 1981
122	Warm Temperate 1	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	24°55'19.17"	34° 4'6.66"	NBA 2018
123	Kabeljous	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	24°55'57.0108"	34°0'31.7051"	NBA 2012, CSIR NRIO List 1981
124	Gamtoos	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	25°2'4.97040"	33°58'13.529"	NBA 2012, CSIR NRIO List 1981
125	Van Stadens	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	25°13'13.2455"	33°58'13.994"	NBA 2012, CSIR NRIO List 1981
126	Maitland	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	25°17'31.0271"	33°59'16.933"	NBA 2012, CSIR NRIO List 1981
127	Baakens	Warm Temperate	Estuary	Small Temporarily Closed	Predominantly Open	25°37'48.0468"	33°57'49.427"	NBA 2012, CSIR NRIO List 1981
128	Papkuils	Warm Temperate	Estuary	Small Temporarily Closed	Predominantly Open	25°36'49.9896"	33°55'2.2548"	NBA 2012, CSIR NRIO List 1981
129	Swartkops	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	25°37'58.9619"	33°51'58.481"	NBA 2012, CSIR NRIO List 1981
130	Coega (Ngqurha)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	25°41'26.6604"	33°47'43.368"	NBA 2012, CSIR NRIO List 1981
131	Sundays	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	25°51'13.4100"	33°43'18.609"	NBA 2012, CSIR NRIO List 1981
132	Boknes	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	26°35'10.5396"	33°43'37.822"	NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
133	Bushmans	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	26°39'49.0392"	33°41'41.697"	NBA 2012, CSIR NRIO List 1981
134	Kariega	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	26°41'11.0364"	33°40'57.975"	NBA 2012, CSIR NRIO List 1981
135	Grant's	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	26°42'10.872"	33°40'10.412"	EC Cons Plan
136	Kasouga	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	26°44'7.07280"	33°39'14.741"	NBA 2012, CSIR NRIO List 1981
137	Salt	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	26°52'55"	33°36'54"	Whitfield & Baliwe 2013
138	Kowie	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	26°54'5.88240"	33°36'13.053"	NBA 2012, CSIR NRIO List 1981
139	Rufane	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	26°56'8.97719"	33°34'50.995"	NBA 2012, CSIR NRIO List 1981
140	Riet	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°0'49.8671"	33°33'40.330"	NBA 2012, CSIR NRIO List 1981
141	West Kleinemonde	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°2'46.1471"	33°32'28.845"	NBA 2012, CSIR NRIO List 1981
142	East Kleinemonde	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°2'57.5699"	33°32'20.493"	NBA 2012, CSIR NRIO List 1981
143	Klein Palmiet	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	27°7'30.5795"	33°30'25.257"	NBA 2012, CSIR NRIO List 1981
144	Great Fish	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	27°8'26.4624"	33°29'42.820"	NBA 2012, CSIR NRIO List 1981
145	Old Woman's	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°8'53.0520"	33°28'57.975"	NBA 2012, CSIR NRIO List 1981
146	Thatshana	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	27°11'11.80"	33°27'47.74"	CSIR NRIO List 1981
147	Mpekweni	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°13'52.2336"	33°26'16.843"	NBA 2012, CSIR NRIO List 1981
148	Mtati (Mthathi)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°15'32.6591"	33°25'22.360"	NBA 2012, CSIR NRIO List 1981
149	Mgwalana	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°16'27.1704"	33°24'46.886"	NBA 2012, CSIR NRIO List 1981
150	Bira (Bhirha)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°19'33.7116"	33°23'1.5360"	NBA 2012, CSIR NRIO List 1981
151	Gqutywa	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°21'29.0844"	33°21'45"	NBA 2012, CSIR NRIO List 1981
152	Ngculura (Ngculurha)	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°22'4.49760"	33°21'29.077"	NBA 2012, CSIR NRIO List 1981
153	Blue Krans	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	27°22'36.7139"	33°21'15.771"	NBA 2012, CSIR NRIO List 1981
154	Freshwater Poort	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	27°24'50.4287"	33°20'6.1763"	EC Cons Switch names
155	Mtana	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°25'55.7940"	33°19'6.9779"	NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
156	Keiskamma	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	27°29'28.4388"	33°16'53.328"	NBA 2012, CSIR NRIO List 1981
157	Shwele-Shwele	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	27°31'19.3584"	33°15'36.460"	CSIR NRIO List 1981
158	Nqinisa	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°31'40.5696"	33°15'9.8603"	NBA 2012, CSIR NRIO List 1981
159	Kiwane (Khiwane)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°32'35.4012"	33°14'53.887"	NBA 2012, CSIR NRIO List 1981
160	Tyolomnqa	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°35'0.31560"	33°13'32.779"	NBA 2012, CSIR NRIO List 1981
161	Shelbertsstroom	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°36'56.3903"	33°12'25.527"	NBA 2012, CSIR NRIO List 1981
162	Lilyvale	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°38'12.8723"	33°11'34.270"	NBA 2012, CSIR NRIO List 1981
163	Ross' Creek	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°39'27.6192"	33°10'36.325"	NBA 2012, CSIR NRIO List 1981
164	Ncera (Ncerha)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°40'5.54160"	33°10'12.417"	NBA 2012, CSIR NRIO List 1981
165	Mlele	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°40'47.8631"	33°9'34.963"	NBA 2012, CSIR NRIO List 1981
166	Mcantsi	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°42'7.11719"	33°8'.43.832"	NBA 2012, CSIR NRIO List 1981
167	Gxulu	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°43'53.3675"	33°7'8.0579"	NBA 2012, CSIR NRIO List 1981
168	Goda	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°46'30.1188"	33°6'3.9239"	NBA 2012, CSIR NRIO List 1981
169	Hlozi	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°48'42.7788"	33°5'8.1491"	NBA 2012, CSIR NRIO List 1981
170	Hickman's	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°50'22.8767"	33°4'14.984"	NBA 2012, CSIR NRIO List 1981
171	Mvubukazi	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	27°50'33.7163"	33°4'11.9964"	CSIR NRIO List 1981
172	Ngqenga	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	27°51'53.5968"	33°3'22.7988"	CSIR NRIO List 1981
173	Buffalo	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	27°54'58.7448"	33°1'36.476"	NBA 2012, CSIR NRIO List 1981
174	Blind	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°55'39.6983"	33°00'25"	NBA 2012, CSIR NRIO List 1981
175	Hlaze (iHlanze)	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	27°56'57.6816"	32°59'21.231"	NBA 2012, CSIR NRIO List 1981
176	Nahoon	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	27°57'6.13439"	32°59'11.176"	NBA 2012, CSIR NRIO List 1981
177	Qinira (Quinirha)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	27°57'53.3987"	32°58'27.130"	NBA 2012, CSIR NRIO List 1981
178	Gqunube	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	28°2'5.63639"	32°56'1.9535"	NBA 2012, CSIR NRIO List 1981
179	Kwesani	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	28°02'13"	32°55'51"	Whitfield & Baliwe 2013

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
180	Kwelerha (Kwelerha)	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	28°4'37.2072"	32°54'26.495"	NBA 2012, CSIR NRIO List 1981
181	Bulura (Bulurha)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°5'36.2076"	32°53'28.805"	NBA 2012, CSIR NRIO List 1981
182	Stromatolite	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	28°06'32"	32°51'43"	Whitfield & Baliwe 2013
183	Cunge	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°6'37.5263"	32°51'39.157"	NBA 2012, CSIR NRIO List 1981
184	Cintsa	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°7'1.35839"	32°49'53.155"	NBA 2012, CSIR NRIO List 1981
185	Cefane	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°8'.13.5528"	32°48'34.070"	NBA 2012, CSIR NRIO List 1981
186	Kwenxura (Kwenxurha)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°9'5.71680"	32°47'55.589"	NBA 2012, CSIR NRIO List 1981
187	Nyara (Nyarha)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°10'55.2611"	32°47'6.8279"	NBA 2012, CSIR NRIO List 1981
188	Sandy bottom	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	28°13'04"	32°46'34"	Whitfield & Baliwe 2013
189	Imtwendwe (Mtwendwe)	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°14'13.1135"	32°46'12.133"	CSIR NRIO List 1981
190	Haga-haga	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°15'11.4659"	32°45'42.901"	CSIR NRIO List 1981
191	Palm Tree	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	28°16'15"	32°45'20"	Whitfield & Baliwe 2013
192	Mtendwe	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°17'9.04920"	32°44'26.836"	NBA 2012, CSIR NRIO List 1981
193	Black Rock	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	28°17'18"	32°44'17"	Whitfield & Baliwe 2013
194	Quko	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°18'34.3367"	32°43'32.303"	NBA 2012, CSIR NRIO List 1981
195	Morgan	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°20'38.5691"	32°42'30.949"	NBA 2012, CSIR NRIO List 1981
196	Cwili	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°22'25.4531"	32°41'27.214"	NBA 2012, CSIR NRIO List 1981
197	Great Kei	Warm Temperate	Estuary	Large Fluvially Dominated	Large Fluvially Dominated	28°23'9.47040"	32°40'47.593"	NBA 2012, CSIR NRIO List 1981
198	Gxara (Gxarha)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°23'56.8679"	32°39'58.168"	NBA 2012, CSIR NRIO List 1981
199	Gqwara	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	28°24'45.07"	32°39'30.25"	Whitfield & Baliwe 2013
200	Ngogwane	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°25'17.91"	32°38'55.31"	NBA 2012, CSIR NRIO List 1981
201	Qolora (Qolorha)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°26'5.79"	32°37'47.70"	NBA 2012, CSIR NRIO List 1981
202	Ncizele	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°26'16.68"	32°37'42.50"	NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
203	Timba	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°26'45.16"	32°37'31.65"	NBA 2012, CSIR NRIO List 1981
204	Mbokotwana	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	28°27'17.44"	32°37'20.21"	CSIR NRIO List 1981
205	Kobonqaba (Khobonqaba)	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	28°29'25.2924"	32°36'28.209"	NBA 2012, CSIR NRIO List 1981
206	Nxaxo/Ngqusi	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°31'34.5323"	32°35'5.0315"	NBA 2012, CSIR NRIO List 1981
207	Masiminana	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	28°33'16.55"	32°33'5.19"	CSIR NRIO List 1981
208	Cebe	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°35'8.97719"	32°31'16.273"	NBA 2012, CSIR NRIO List 1981
209	Gqunqe	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°35'22.2396"	32°31'7.6836"	NBA 2012, CSIR NRIO List 1981
210	Zalu	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°36'11.2572"	32°30'9.5183"	NBA 2012, CSIR NRIO List 1981
211	Ngqwara (Ngqwarha)	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°36'50.6016"	32°29'39.138"	NBA 2012, CSIR NRIO List 1981
212	Sihlontweni	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°38'41.3627"	32°28'52.957"	NBA 2012, CSIR NRIO List 1981
213	Nebelele	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°39'21.3480"	32°27'45.575"	NBA 2012, CSIR NRIO List 1981
214	Qora (Qhorha)	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	28°40'24.4740"	32°26'46.932"	NBA 2012, CSIR NRIO List 1981
215	Warm Temperate 2	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	28°41'4.61"	32°26'19.03"	NBA2018
216	Jujura (Jujurha)	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°41'38.2596"	32°25'51.960"	NBA 2012, CSIR NRIO List 1981
217	Ngadla	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°42'31.2515"	32°25'6.0599"	NBA 2012, CSIR NRIO List 1981
218	Warm Temperate 3	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	28°43'2.29"	32°24'41.13"	
219	Shixini	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	28°43'31.8467"	32°24'11.163"	NBA 2012, CSIR NRIO List 1981
220	Beechamwood	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°45'7.48439"	32°22'29.492"	NBA 2012, CSIR NRIO List 1981
221	Kwazlelitsha (Kwazwedala)	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°45'29.4371"	32°22'12.151"	CSIR NRIO List 1981
222	Kwa-Goqo	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°45'41.4539"	32°21'59.050"	NBA 2012, CSIR NRIO List 1981
223	Ku-Nocekedwa	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°46'40.0655"	32°20'55.766"	NBA 2012, CSIR NRIO List 1981
224	Nqabara/Nqabarana	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	28°47'25.1915"	32°20'22.970"	NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
225	Gume	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	28°48'58.97"	32°19'15.01"	CSIR NRIO List 1981
226	Ngomane	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	28°49'32.38"	32°18'48.76"	CSIR NRIO List 1981
227	Ngomane (East)	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°49'46.22"	32°18'18.95"	EC Cons Plan
228	Ngoma/Kobule	Warm Temperate	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°50'14.3195"	32°18'4.1868"	NBA 2012, CSIR NRIO List 1981
229	Dwesana	Warm Temperate	Micro-system	Micro-estuary	Micro-estuary	28°52'27"	32°16'56"	CSIR NRIO List 1981
230	Mendu	Warm Temperate	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°52'40.0332"	32°16'51.297"	NBA 2012, CSIR NRIO List 1981
231	Mendwana	Warm Temperate	Estuary	Predominantly Open	Predominantly Open	28°53'3.25679"	32°16'8.1336"	NBA 2012, CSIR NRIO List 1981
232	Warm Temperate 4	Warm Temperate	Micro-system	Micro-outlet	Micro-outlet	28°53'24.33"	32°15'45.67"	Whitfield & Baliwe 2013
233	Mbashe	Subtropical	Estuary	Large Fluvially Dominated	Large Fluvially Dominated	28°54'6.84359"	32°14'59.946"	NBA 2012, CSIR NRIO List 1981
234	Ku-Mpenzu	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°54'51.9012"	32°14'37.777"	NBA 2012, CSIR NRIO List 1981
235	Ku-Bhula (Mbhanyana)	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°55'40.8108"	32°13'41.185"	NBA 2012, CSIR NRIO List 1981
236	Dakana	Subtropical	Micro-system	Micro-estuary	Micro-estuary	28°56'17.94"	32°13'13.91"	CSIR NRIO List 1981
237	Subtropical 1	Subtropical	Micro-system	Micro-outlet	Micro-outlet	28°56'35.68"	32°12'48.22"	
238	Kwa-Suku	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°56'48.78"	32°12'19.06"	CSIR NRIO List 1981
239	Ntlonyane	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°57'23.9832"	32°11'40.930"	NBA 2012, CSIR NRIO List 1981
240	Nyumbazana	Subtropical	Micro-system	Micro-estuary	Micro-estuary	28°57'42.26"	32°11'16.22"	CSIR NRIO List 1981
241	Nkanya	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	28°58'29.4888"	32°10'39"	NBA 2012, CSIR NRIO List 1981
242	Sundwana	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	28°58'55.1280"	32°10'24.330"	NBA 2012, CSIR NRIO List 1981
243	Xora	Subtropical	Estuary	Predominantly Open	Predominantly Open	28°59'44.1059"	32°9.'31.082"	NBA 2012, CSIR NRIO List 1981
244	Bulungula	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	29°0.'41.4647"	32°8.'16.828"	NBA 2012, CSIR NRIO List 1981
245	Ku-Amazimuzama	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°2'0.17159"	32°6.'53.729"	NBA 2012, CSIR NRIO List 1981
246	Subtropical 2	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°02'46"	32°6'23"	Whitfield & Baliwe 2013
247	Nqakanqa	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°3'44.7119"	32°5'55.1003"	NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
248	Mdikana	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°4'9.60240"	32°5'18.9023"	NBA 2012, CSIR NRIO List 1981
249	Mncwasa	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	29°4'33.8772"	32°4.'57.741"	NBA 2012, CSIR NRIO List 1981
250	Lubanzi	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°5'10.83"	32°4'28.38"	CSIR NRIO List 1981
251	Mhlalane	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°5'14.87"	32°3'50.23"	CSIR NRIO List 1981
252	Mhlahlane	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°5'59.9"	32°3'6.119"	EC Cons Switch names
253	Mpako	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°6'27.7019"	32°2.'24.853"	NBA 2012, CSIR NRIO List 1981
254	Mtonjane	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°6'43.31"	32°1'59.85"	Whitfield & Baliwe 2013
255	Subtropical 3	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°7'30"	32°1'14"	Whitfield & Baliwe 2013
256	Subtropical 4	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°7'46"	32°1'1"	Whitfield & Baliwe 2013
257	Subtropical 5	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°8'13"	31°59'44"	Whitfield & Baliwe 2013
258	Ku-Bomvu	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°8'56.27"	31°59'19.46"	CSIR NRIO List 1981, EC Cons
259	Nenga	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°9'6.51600"	31°59'7.7460"	NBA 2012, CSIR NRIO List 1981
260	Mapuzi	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	29°10'7.37759"	31°58'11.812"	NBA 2012, CSIR NRIO List 1981
261	Mtata	Subtropical	Estuary	Predominantly Open	Predominantly Open	29°11'1.52880"	31°57'10.666"	NBA 2012, CSIR NRIO List 1981
262	Thsani	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°12'31.8960"	31°56'41.855"	NBA 2012, CSIR NRIO List 1981
263	Mdumbi	Subtropical	Estuary	Predominantly Open	Predominantly Open	29°12'58.6763"	31°55'53.220"	NBA 2012, CSIR NRIO List 1981
264	Subtropical 6	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°13'29"	31°55'30"	Whitfield & Baliwe 2013
265	Subtropical 7	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°13'37"	31°55'25"	Whitfield & Baliwe 2013
266	Subtropical 8	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°13'40"	31°55'8"	Whitfield & Baliwe 2013
267	Subtropical 9	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°14'03"	31°54'44"	Whitfield & Baliwe 2013
268	Subtropical 10	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°14'12"	31°54'30"	Whitfield & Baliwe 2013
269	Lwandilana	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°14'38.1300"	31°53'46.312"	NBA 2012, CSIR NRIO List 1981
270	Lwandile	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	29°14'51.1296"	31°53'27.401"	NBA 2012, CSIR NRIO List 1981
271	Subtropical 11	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°15'41"	31°52'46"	Whitfield & Baliwe 2013

Outlet ID West to East	Estuary name	Biogeographical region	Estuary catogory	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
272	Subtropical 12	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°15'45"	31°52'27"	Whitfield & Baliwe 2013
273	Subtropical 13	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°15'44"	31°52'13"	Whitfield & Baliwe 2013
274	Mtakatye	Subtropical	Estuary	Predominantly Open	Predominantly Open	29°16'12.8892"	31°51'33.371"	NBA 2012, CSIR NRIO List 1981
275	Subtropical 14	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°17'27"	31°50'26"	Whitfield & Baliwe 2013
276	Hluleka	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°18'13.0032"	31°49'38.668"	NBA 2012, CSIR NRIO List 1981
277	Mnenu	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	29°19'48.3239"	31°48'27.223"	NBA 2012, CSIR NRIO List 1981
278	Mtonga	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	29°20'53.8475"	31°47'35.739"	CSIR NRIO List 1981
279	Subtropical 15	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°21'13"	31°46'50"	Whitfield & Baliwe 2013
280	Subtropical 16	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°21'14"	31°46'8"	Whitfield & Baliwe 2013
281	Mpande	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	29°21'25.7148"	31°45'44.096"	NBA 2012, CSIR NRIO List 1981
282	Sinangwana	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°22'11.6183"	31°45'1.7928"	NBA 2012, CSIR NRIO List 1981
283	Ndluzula	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°23'13.99"	31°44'28.08"	CSIR NRIO List 1981
284	Mngazana	Subtropical	Estuary	Predominantly Open	Predominantly Open	29°25'22.2996"	31°41'31.837"	NBA 2012, CSIR NRIO List 1981
285	Mngazi	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	29°27'47.2824"	31°40'37.862"	NBA 2012, CSIR NRIO List 1981
286	Tyityane	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°29'29.66"	31°40'5.43"	CSIR NRIO List 1981
287	Ntloloba	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°30'3.59"	31°39'33.81"	CSIR NRIO List 1981
288	Gxwaleni	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°30'24.8148"	31°39'19.706"	CSIR NRIO List 1981
289	Bulolo	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°31'3.89639"	31°39'2.4515"	NBA 2012, CSIR NRIO List 1981
290	Mtumbane	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°31'13.7316"	31.°38'52.306"	NBA 2012, CSIR NRIO List 1981
291	Mzimvubu	Subtropical	Estuary	Large Fluvially Dominated	Large Fluvially Dominated	29°32'59.7443"	31°37'52.107"	NBA 2012, CSIR NRIO List 1981
292	Mnenga	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°34'5.42"	31°37'0.66"	CSIR NRIO List 1981
293	Ntupeni	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°34'27"	31°36'47"	CSIR NRIO List 1981
294	Ntlupeni	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°34'52.419"	31°36'32.263"	NBA 2012, CSIR NRIO List 1981
295	Manzana	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°36'4.16"	31°36'1.38"	CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
296	Nkodusweni	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	29°36'29.39"	31°35'39.42"	NBA 2012, CSIR NRIO List 1981
297	Gugu	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°36'58.63"	31°35'6.44"	CSIR NRIO List 1981
298	Subtropical 17	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°37'39"	31°34'39"	Whitfield & Baliwe 2013
299	Subtropical 18	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°37'39"	31°34'35"	Whitfield & Baliwe 2013
300	Mntafufu	Subtropical	Estuary	Predominantly Open	Predominantly Open	29°38'15.8244"	31°33'45.068"	NBA 2012, CSIR NRIO List 1981
301	Subtropical 19	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°38'47"	31°33'22"	Whitfield & Baliwe 2013
302	Subtropical 20	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°39'05"	31°33'17"	Whitfield & Baliwe 2013
303	Ingo	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°39'38.90"	31°32'56.92"	CSIR NRIO List 1981
304	Ntyivini	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°40'3.39"	31°32'41.01"	CSIR NRIO List 1981
305	Dakane	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°40'43.51"	31°32'6.49"	CSIR NRIO List 1981
306	Mzintlava	Subtropical	Estuary	Predominantly Open	Predominantly Open	29°41'23.2475"	31°31'21.518"	NBA 2012, CSIR NRIO List 1981
307	Mguga	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°41'51.93"	31°30'45.14"	CSIR NRIO List 1981
308	Subtropical 21	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°42'26.88"	31°30'12.20"	NBA 2018
309	Subtropical 22	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°42'54.95"	31°29'39.81"	NBA 2019
310	Mzimpunzi	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°43'23.1816"	31°28'47.852"	NBA 2012, CSIR NRIO List 1981
311	Kwanyambalala	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°44'3.07"	31°28'5.0245"	CSIR NRIO List 1981
312	Mbotyi	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°44'3.56"	31°28'0.624"	NBA 2012, CSIR NRIO List 1981
313	Subtropical 23	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°45'17"	31°27'4"	Whitfield & Baliwe 2013
314	Mkozi	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°45'41.6663"	31°26'54.722"	NBA 2012, CSIR NRIO List 1981
315	Myekane	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°45'55"	31°26'47"	Eastern Cape Conservation Plan
316	Sikatsha	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°46'6"	31°26'42"	CSIR NRIO List 1981
317	Sitatsha	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°46'17.00"	31°26'37.98"	CSIR NRIO List 1981
318	Cutweni	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°47'12.44"	31°26'18.65"	CSIR NRIO List 1981
319	Mjihlelo	Subtropical	Micro-system	Waterfall outlet	Waterfall outlet	29°47'53.83"	31°26'9.95"	CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
320	Subtropical 24	Subtropical	Micro-system	Waterfall outlet	Waterfall outlet	29°48'9"	31°26'8"	Whitfield & Baliwe 2013
321	Subtropical 25	Subtropical	Micro-system	Waterfall outlet	Waterfall outlet	29°48'32"	31°26'4"	Whitfield & Baliwe 2013
322	Mlambomkulu	Subtropical	Micro-system	Waterfall outlet	Waterfall outlet	29°49'18.66"	31°26'0.84"	CSIR NRIO List 1981
323	Lupatana	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°51'5.32440"	31°25'23.811"	NBA 2012, CSIR NRIO List 1981
324	Mkweni	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	29°52'22.20"	31°24'12.27"	NBA 2012, CSIR NRIO List 1981
325	Subtropical 26	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°52'44"	31°23'51"	Whitfield & Baliwe 2013
326	Subtropical 27	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°52'49"	31°23'49"	Whitfield & Baliwe 2013
327	Maviti	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°53'41.28"	31°23'26.23"	CSIR NRIO List 1981
328	Tezana	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°54'21.46"	31°22'31.97"	CSIR NRIO List 1981
329	Magogo	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°55'10.02"	31°22'1.24"	CSIR NRIO List 1981
330	Subtropical 28	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°55'37"	31°21'38"	Whitfield & Baliwe 2013
331	Kilroe Beach	Subtropical	Micro-system	Micro-estuary	Micro-estuary	29°55'45.53"	31°21'34.37"	CSIR NRIO List 1981
332	Mbaxeni	Subtropical	Micro-system	Waterfall outlet	Waterfall outlet	29°56'19.92"	31°21'3.61"	CSIR NRIO List 1981
333	Msikaba	Subtropical	Estuary	Predominantly Open	Predominantly Open	29°58'3.74"	31°19'9.20"	NBA 2012, CSIR NRIO List 1981
334	Subtropical 29	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°58'53.996"	31°18'55.226"	Whitfield & Baliwe 2013
335	Butsha	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°59'5.303"	31°18'46.317"	CSIR NRIO List 1981
336	Kwanondindwa	Subtropical	Micro-system	Micro-outlet	Micro-outlet	29°59'22.606"	31°18'37.066"	CSIR NRIO List 1981
337	Daza	Subtropical	Micro-system	Waterfall outlet	Waterfall outlet	29°59'50.39"	31°18'20.76"	NBA 2012, CSIR NRIO List 1981
338	Mgwegwe	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°0.'40.9140"	31°17'15.554"	NBA 2012, CSIR NRIO List 1981
339	Mkambati	Subtropical	Micro-system	Waterfall outlet	Waterfall outlet	30°1'26.14"	31°16'27.98"	CSIR NRIO List 1981
340	Mgwetyana	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°2'22.9775"	31°15'42.454"	CSIR NRIO List 1981
341	Subtropical 30	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°02'42"	31°15'4"	Whitfield & Baliwe 2013
342	Mtentu	Subtropical	Estuary	Predominantly Open	Predominantly Open	30°2'46.5539"	31°14'55.885"	NBA 2012, CSIR NRIO List 1981
343	Subtropical 31	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°03'08"	31°14'31"	Whitfield & Baliwe 2013

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
344	Subtropical 32	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°03'24"	31°14'26"	Whitfield & Baliwe 2013
345	Sikombe	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°4'9.86160"	31°13'19.333"	NBA 2012, CSIR NRIO List 1981
346	Kwanyana	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°6'17.6615"	31°11'10.791"	NBA 2012, CSIR NRIO List 1981
347	Mtolane	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°7'37.1135"	31°9'34.8192"	CSIR NRIO List 1981
348	Mnyameni	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°8'1.60800"	31°9'7.67520"	NBA 2012, CSIR NRIO List 1981
349	Subtropical 33	Subtropical	Micro-system	Micro-estuary	Micro-estuary	30°8'33.86"	31°8'42.80"	CSIR NRIO List 1981
350	Mpahlangana	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°9'36.5831"	31°7'27.9768"	NBA 2012, CSIR NRIO List 1981
351	Mpahlane	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°9'53.4240"	31°7'9.99840"	NBA 2012, CSIR NRIO List 1981
352	Mzamba	Subtropical	Estuary	Predominantly Open	Predominantly Open	30°10'26.3999"	31°6'31.8600"	NBA 2012, CSIR NRIO List 1981
353	Mtentwana	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°11'15.1979"	31°5'17.8763"	NBA 2012, CSIR NRIO List 1981
354	uMthavuna	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°11'37.2984"	31°5'4.27200"	KZN province, NBA 2012, CSIR NRIO List 1981
355	iSolwane	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°12'17.352"	31°4'31.418"	KZN province, NBA 2012, CSIR NRIO List 1981
356	Subtropical 34	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°12'45.311"	31°4'10.312"	Bate et al., 2016
357	Subtropical 35	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°12'56.961"	31°4'1.814"	Bate et al., 2016
358	Subtropical 36	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°13'10"	31°3'52"	Whitfield & Baliwe 2013
359	Subtropical 37	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°13'30.259"	31°3'34.718"	Bate et al., 2016
360	iSandlu	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°13'44.6087"	31°2'33.4319"	KZN province, NBA 2012, CSIR NRIO List 1981
361	uMbhoiyibhoi	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°14'8.16359"	31°2'4.77599"	KZN province, NBA 2012, CSIR NRIO List 1981
362	Subtropical 38	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°14'16.684"	31°1'52.257"	Bate et al., 2016
363	Subtropical 39	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°14'48"	31°1'17"	Whitfield & Baliwe 2013
364	uMuntongazi	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°15'24.5915"	31°0'41.1732"	KZN province, NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
365	iKhandalendlovu	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°16'9.45480"	30°59'50.625"	KZN province, NBA 2012, CSIR NRIO List 1981
366	Subtropical 40	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°16'31.976"	30°59'20.309"	Bate et al., 2016
367	Subtropical 41	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°16'35.101"	30°59'17.513"	Bate et al., 2016
368	Subtropical 42	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°16'37.979"	30°59'10.318"	Bate et al., 2016
369	Subtropical 43	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°16'41.844"	30°58'52.637"	Bate et al., 2016
370	iMpenjani	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°17'2.78160"	30°58'25.348"	KZN provincial, NBA 2012, CSIR NRIO List 1981
371	uMhlangomkhulu (South) (Umhlangankulu)	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°18'11.0699"	30°56'43.490"	KZN province, NBA 2012, CSIR NRIO List 1981
372	iKhaba	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°18'32.3604"	30°56'9.4776"	KZN province, NBA 2012, CSIR NRIO List 1981
373	Subtropical 44	Subtropical	Micro-system	Micro-estuary	Micro-estuary	30°19'9"	30°55'26"	Whitfield & Baliwe 2013
374	iMbizana	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°20'5.22239"	30°54'31.103"	KZN province, NBA 2012, CSIR NRIO List 1981
375	Subtropical 45	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°20'13"	30°54'19"	Whitfield & Baliwe 2013
376	Subtropical 46	Subtropical	Micro-system	Micro-estuary	Micro-estuary	30°20'44"	30°53'47"	Whitfield & Baliwe 2013
377	iMvutshini	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°20'49.6895"	30°53'38.684"	KZN province, NBA 2012, CSIR NRIO List 1981
378	iBilanhlonhlo	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°20'56.1479"	30°53'24.687"	KZN province, NBA 2012, CSIR NRIO List 1981
379	uVuzana	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°21'32.2415"	30°52'42.254"	KZN province, NBA 2012, CSIR NRIO List 1981
380	iKongeni	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°22'21.8495"	30°51'41.288"	KZN province, NBA 2012, CSIR NRIO List 1981
381	Subtropical 47	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°22'45.842"	30°51'18.67"	Bate et al., 2016

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
382	uVunguza	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°23'43.1303"	30°50'11.345"	KZN province, NBA 2012, CSIR NRIO List 1981
383	Subtropical 48	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°24'13.3344"	30°49'39.4427"	Bate et al.
384	oHlangeni	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°24'20.1168"	30°49'12.810"	KZN province, NBA 2012, CSIR NRIO List 1981
385	Subtropical 49	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°24'47"	30°48'16"	Whitfield & Baliwe 2013
386	Subtropical 50	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°24'57"	30°48'4"	Whitfield & Baliwe 2013
387	Subtropical 51	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°25'3"	30°47'54"	Whitfield & Baliwe 2013
388	Subtropical 52	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°25'16"	30°47'38"	Whitfield & Baliwe 2013
389	iZotsha	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°25'25.1687"	30°47'22.322"	KZN province, NBA 2012, CSIR NRIO List 1981
390	iBhobhoyi	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°26'21.2531"	30°46'14.509"	KZN province, NBA 2012, CSIR NRIO List 1981
391	Subtropical 53	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°26'38.346"	30°45'50.7276"	Bate et al., 2016
392	uMbango	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°26'51.6084"	30°45'27.745"	KZN province, NBA 2012, CSIR NRIO List 1981
393	uMzimkhulu	Subtropical	Estuary	Predominantly Open	Predominantly Open	30°27'29.8800"	30°44'23.398"	KZN province, NBA 2012, CSIR NRIO List 1981
394	Subtropical 54	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°28'38.0639"	30°43'1.596"	Bate et al., 2016
395	uMthente	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°28'54.1019"	30°42'34.534"	KZN province, NBA 2012, CSIR NRIO List 1981
396	uMhlangomkhulu (North) (Mhlangamkhulu)	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°29'54.0420"	30°41'17.394"	KZN province, NBA 2012, CSIR NRIO List 1981
397	Subtropical 55	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°30'11.2679"	30°40'59.34"	Bate et al., 2016
398	Subtropical 56	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°30'27.612"	30°40'44.2919"	Bate et al., 2016
399	iDombe	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°30'37.5335"	30°40'20.863"	KZN province, NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
400	Subtropical 57	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°30'49.7159"	30°39'56.16"	Bate et al., 2016
401	Subtropical 58	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°30'53.568"	30°39'51.084"	Bate et al., 2016
402	iKhoshwana	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°31'2.27280"	30°39'37.137"	KZN province, NBA 2012, CSIR NRIO List 1981
403	Subtropical 59	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°31'38.3519"	30°38'56.112"	Bate et al., 2016
404	Subtropical 60	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°31'44.616"	30°38'48.4799"	Bate et al., 2016
405	Subtropical 61	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°32'6.4679"	30°38'26.1239"	Bate et al., 2016
406	iNjambili	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°32'11.5223"	30°38'13.938"	KZN province, NBA 2012, CSIR NRIO List 1981
407	Subtropical 62	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°32'46.392"	30°37'12.972"	Bate et al., 2016
408	uMzumbe	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°32'52.0116"	30°36'50.133"	KZN province, NBA 2012, CSIR NRIO List 1981
409	Subtropical 63	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°34'7.14"	30°35'24.8352"	Bate et al., 2016
410	uMhlabashana	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°34'17.0363"	30°35'4.1208"	KZN province, NBA 2012, CSIR NRIO List 1981
411	Subtropical 64	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°34'25.7232"	30°34'47.4888"	Bate et al., 2016
412	Subtropical 65	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°34'37"	30°34'25"	Whitfield & Baliwe 2013
413	uMhlangwa	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°34'59.6459"	30°33'38.926"	KZN province, NBA 2012, CSIR NRIO List 1981
414	Subtropical 66	Subtropical	Micro-system	Micro-estuary	Micro-estuary	30°35'46"	30°32'43"	Whitfield & Baliwe 2013
415	uMfazezala	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°36'25.4339"	30°31'54.534"	KZN province, NBA 2012, CSIR NRIO List 1981
416	uMakhosi	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°36'36.8496"	30°31'33.085"	KZN province, NBA 2012, CSIR NRIO List 1981
417	Subtropical 67	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°36'50.3352"	30°31'13.062"	Bate et al., 2016
418	Subtropical 68	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°37'2"	30°31'2"	Whitfield & Baliwe 2013

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
419	uMnamfu	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°37'28.9991"	30°30'30.272"	KZN province, NBA 2012, CSIR NRIO List 1981
420	uMthwalume	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°38'8.16000"	30°29'6.6300"	KZN province, NBA 2012, CSIR NRIO List 1981
421	Subtropical 69	Subtropical	Micro-system	Micro-estuary	Micro-estuary	30°38'30.7716"	30°28'28.2216"	Bate et al., 2016
422	uMvuzi	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°38'51.4104"	30°28'11.276"	KZN province, NBA 2012, CSIR NRIO List 1981
423	iFafa	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°39'13.0068"	30°27'24.073"	KZN province, NBA 2012, CSIR NRIO List 1981
424	Subtropical 70	Subtropical	Micro-system	Micro-estuary	Micro-estuary	30°39'39"	30°26'33"	Whitfield & Baliwe 2013
425	Subtropical 71	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°40'2"	30°26'7"	Whitfield & Baliwe 2013
426	uMdesingane	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°40'17.7275"	30°25'33.772"	KZN province, NBA 2012, CSIR NRIO List 1981
427	iSezela	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°40'39.8747"	30°24'54.046"	KZN province, NBA 2012, CSIR NRIO List 1981
428	uMkhumbane	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°40'58.2060"	30°24'20.185"	KZN province, NBA 2012, CSIR NRIO List 1981
429	Subtropical 72	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°41'42.1079"	30°23'18.9455"	Bate et al., 2016
430	Subtropical 73	Subtropical	Micro-system	Micro-estuary	Micro-estuary	30°42'4"	30°22'39"	Whitfield & Baliwe 2013
431	iNkomba	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°43'13.3608"	30°21'10.357"	KZN province, NBA 2012, CSIR NRIO List 1981
432	uMuziwezinto	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°42'32.9219"	30°22'3.5075"	KZN province, NBA 2012, CSIR NRIO List 1981
433	uMzimayi	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°43'38.3448"	30°20'47.292"	KZN province, NBA 2012, CSIR NRIO List 1981
434	Rocky Bay	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°44'4.695"	30°20'1.7045"	KZN province
435	Subtropical 74	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°44'19.2552"	30°19'27.0804"	Bate et al., 2016
436	Subtropical 75	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°44'36.1248"	30°18'44.8703"	Bate et al., 2016

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
437	Subtropical 76	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°44'58.6248"	30°17'59.8919"	Bate et al., 2016
438	uMphambanyoni	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°45'33.4655"	30°16'49.432"	KZN province, NBA 2012, CSIR NRIO List 1981
439	aMahlongwa	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°45'50.1336"	30°16'8.8968"	KZN province, NBA 2012, CSIR NRIO List 1981
440	Subtropical 77	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°46'54"	30°14'36"	Whitfield & Baliwe 2013
441	Subtropical 78	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°47'6.3996"	30°14'21.1559"	Bate et al., 2016
442	uMahlongwane	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°47'37.4424"	30°13'30.478"	KZN province, NBA 2012, CSIR NRIO List 1981
443	Subtropical 79	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°47'53"	30°12'50"	Whitfield & Baliwe 2013
444	uMkhomazi	Subtropical	Estuary	Predominantly Open	Predominantly Open	30°48'13.9248"	30°12'9.3203"	KZN province, NBA 2012, CSIR NRIO List 1981
445	iNgane	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°49'1.67159"	30°10'43.824"	KZN province, NBA 2012, CSIR NRIO List 1981
446	uMgababa	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°49'50.6171"	30°9'20.4120"	KZN province, NBA 2012, CSIR NRIO List 1981
447	Subtropical 80	Subtropical	Micro-system	Micro-outlet	Micro-outlet	30°49'55.65"	30°9'0.4176"	Bate et al., 2016
448	uMsimbazi	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°50'51.5724"	30°7'46.2863"	KZN province, NBA 2012, CSIR NRIO List 1981
449	iLovu	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°51'27.2700"	30°6'19.5552"	KZN province, NBA 2012, CSIR NRIO List 1981
450	Subtropical 81	Subtropical	Micro-system	Micro-estuary	Micro-estuary	30°51'43.308"	30°5'40.553"	Whitfield & Baliwe 2013
451	aManzanamtoti	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	30°52'23.7395"	30°4'40.9152"	KZN province, NBA 2012, CSIR NRIO List 1981
452	aManzimtoti	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°53'4.71480"	30°3'30.8159"	KZN province, NBA 2012, CSIR NRIO List 1981
453	iZimbokodo	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	30°56'12.4367"	30°0'34.9524"	KZN province, NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
454	iSipingo	Subtropical	Estuary	Predominantly Open	Predominantly Open	30°57'4.53959"	29°59'45.229"	KZN province, NBA 2012, CSIR NRIO List 1981
455	Durban Bay	Subtropical	Estuary	Estuarine Bay	Estuarine Bay	31°3.'45.0288"	29°51'58.085"	KZN province, NBA 2012, CSIR NRIO List 1981
456	uMngeni	Subtropical	Estuary	Predominantly Open	Predominantly Open	31°2.'33.4031"	29°48'30.585"	KZN province, NBA 2012, CSIR NRIO List 1981
457	uMhlanga	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	31°6.'5.30279"	29°42'10.832"	KZN province, NBA 2012, CSIR NRIO List 1981
458	uMdloti	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	31°7.'44.9328"	29°39'2.1348"	KZN province, NBA 2012, CSIR NRIO List 1981
459	Subtropical 82	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°8'49.3476"	29°37'33.4272"	Bate et al., 2016
460	Subtropical 83	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°09'37"	29°36'33"	Whitfield & Baliwe 2013
					Micro-o			
						31°10'11.6651"	29°35'39.4403"	Bate et al., 2016
461	Subtropical 84	Subtropical	Micro-system	Micro-outlet	utlet			
462	uThongathi	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	31°11'5.58600"	29°34'24.275"	KZN province, NBA 2012, CSIR NRIO List 1981
463	Subtropical 85	Subtropical	Micro-system	Micro-estuary	Micro-estuary	31°12'27.8963"	29°33'1.9079"	Bate et al., 2016
464	Subtropical 86	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°14'8.3832"	29°30'24.3431"	Bate et al., 2016
465	Subtropical 87	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°14'25.3248"	29°30'4.7052"	Bate et al., 2016
466	Subtropical 88	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°14'36.402"	29°29'50.064"	Bate et al., 2016
467	Subtropical 89	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°16'4.1772"	29°28'21.1908"	Bate et al., 2016
468	Subtropical 90	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°16'15.8555"	29°28'7.1507"	Bate et al., 2016
469	Subtropical 91	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°16'28.8372"	29°27'52.6968"	Bate et al., 2016
470	uMhlali	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	31°16'41.4119"	29°27'36.575"	KZN province, NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
471	Bob's Stream	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	31°17'41.0496"	29°26'16.717"	CSIR NRIO List 1981
472	uSetheni	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	31°18'10.4544"	29°25'45.667"	KZN province, NBA 2012, CSIR NRIO List 1981
473	Subtropical 92	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°19'2"	29°24'38"	Whitfield & Baliwe 2013
474	Subtropical 93	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°19'4"	29°24'34"	Whitfield & Baliwe 2013
475	Subtropical 94	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°19'27"	29°24'14"	Whitfield & Baliwe 2013
476	uMvoti	Subtropical	Estuary	Large Fluvially Dominated	Large Fluvially Dominated	31°20'5.47439"	29°23'30.775"	KZN province, NBA 2012, CSIR NRIO List 1981
477	uMdlotane	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	31°22'25.7844"	29°21'8.6507"	KZN province, NBA 2012, CSIR NRIO List 1981
478	iNonoti	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	31°24'25.4880"	29°19'7.8852"	KZN province, NBA 2012, CSIR NRIO List 1981
479	iZinkwazi	Subtropical	Estuary	Large Temporarily Closed	Large Temporarily Closed	31°26'36.5207"	29°16'53.724"	KZN province, NBA 2012, CSIR NRIO List 1981
480	uThukela	Subtropical	Estuary	Large Fluvially Dominated	Large Fluvially Dominated	31°30'3.62160"	29°13'27.310"	KZN province, NBA 2012, CSIR NRIO List 1981
481	aMatigulu/iNyoni	Subtropical	Estuary	Predominantly Open	Predominantly Open	31°38'40.3872"	29°5'1.30559"	KZN province, NBA 2012, CSIR NRIO List 1981
482	iSiyaya	Subtropical	Estuary	Small Temporarily Closed	Small Temporarily Closed	31°45'47.2968"	28°58'0.7716"	KZN province, NBA 2012, CSIR NRIO List 1981
483	uMlalazi	Subtropical	Estuary	Predominantly Open	Predominantly Open	31°49'22.8971"	28°56'40.995"	KZN province, NBA 2012, CSIR NRIO List 1981
484	Subtropical 95	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°53'27.9096"	28°55'28.5887"	Bate et al., 2016
485	Subtropical 96	Subtropical	Micro-system	Micro-outlet	Micro-outlet	31°54'8.9064"	28°55'18.0767"	Bate et al., 2016
486	uMhlathuze	Subtropical	Estuary	Estuarine Lake	Predominantly Open	32°2'59.9675"	28°50'55.949"	KZN province, NBA 2012, CSIR NRIO List 1981
487	Richards Bay	Subtropical	Estuary	Estuarine Lake	Estuarine Bay	32°5'51.9611"	28°48'51.138"	KZN province, NBA 2012, CSIR NRIO List 1981

Outlet ID West to East	Estuary name	Biogeographical region	Estuary category	Natural estuary type	Present transformed functional estuary type	East DD MM SS	South DD MM SS	Project/ origin of dataset/name
488	iNhlabane	Subtropical	Estuary	Estuarine Lake	Small Temporarily Closed	32°15'25.6247"	28°39'41.061"	KZN province, NBA 2012, CSIR NRIO List 1981
489	iMfolozi/ uMsunduze	Subtropical	Estuary	Large Fluvially Dominated	Large Fluvially Dominated	32°25'30.1836"	28°23'21.390"	KZN province, NBA 2012, CSIR NRIO List 1981
490	St Lucia	Subtropical	Estuary	Estuarine Lake	Estuarine Lake	32°25'29.0243"	28°22'57.226"	KZN province, NBA 2012, CSIR NRIO List 1981
491	uMgobezeleni	Tropical	Estuary	Estuarine Lake	Estuarine Lake	32°40'50.1419"	27°32'22.390"	KZN province, NBA 2012, CSIR NRIO List 1981
492	Kosi	Tropical	Estuary	Estuarine Lake	Estuarine Lake	32°52'50.8404"	26°53'42.626"	KZN province, NBA 2012, CSIR NRIO List 1981

APPENDIX B: SUMMARY OF SOUTH AFRICA'S ESTUARINE HABITAT

Est ID	Estuary Name	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds and sedges	Mangroves	Sand/mud banks	Open water	Rocks	Swamp forest	Macroalgae	Total Habitat
1	Orange	144.0	626.9	1.0	316.8	0.0	135.7	605.4	0.0	0.0	1 817.0	3 646.8
2	Buffels	0.0	0.3	0.0	6.4	0.0	1.6	1.7	0.0	0.0	0.0	10.0
3	Swartlintjies	0.0	45.6	0.0	0.0	0.0	2.9	3.7	0.0	0.0	0.0	52.2
4	Spoeg	0.0	31.3	0.0	0.9	0.0	0.0	1.2	0.0	0.0	0.0	33.4
5	Groen	0.0	12.0	0.0	1.0	0.0	10.0	8.0	0.0	0.0	0.0	31.0
6	Sout (Noord)	0.0	141.0	0.0	0.0	0.0	56.6	74.3	0.0	0.0	0.0	271.9
7	Olifants	96.6	909.5	47.7	60.1	0.0	77.0	227.9	5.5	0.0	0.0	1 424.2
8	Jakkals	0.0	47.3	0.0	0.0	0.0	13.1	1.2	0.0	0.0	0.0	61.6
9	Wadrikt	0.0	177.5	0.0	0.0	0.0	15.3	263.8	0.0	0.0	0.0	456.6
10	Verlorenvlei	0.0	20.9	0.0	518.4	0.0	1.2	1 061.2	0.0	0.0	0.0	1 601.7
11	Groot Berg	1 182.4	3 226.2	206.0	1 909.9	0.0	150.9	821.7	0.0	0.0	0.0	7 497.1
12	Langebaan	791.7	556.9	85.8	123.6	0.0	9.2	4 017.1	0.0	0.0	0.0	5 584.3
13	Diep/Rietvlei	53.0	105.6	0.0	318.6	0.0	0.0	205.1	0.0	0.0	0.0	682.3
14	Sout (Wes)	0.0	0.0	0.0	17.9	0.0	0.0	50.7	0.0	0.0	0.0	68.6
15	Disa	0.0	0.0	0.0	17.2	0.0	2.5	1.4	0.0	0.0	0.0	21.1
16	Wildevoolvlei	0.0	49.2	0.0	7.7	0.0	172.3	25.3	0.0	0.0	0.0	254.5
17	Schuster	0.0	0.0	0.0	0.1	0.0	0.0	0.5	0.0	0.0	0.0	0.6
18	Krom	0.0	0.0	0.0	1.4	0.0	0.0	7.3	0.0	0.0	0.0	8.7
19	Silwermyr	0.0	0.2	2.0	2.2	0.0	2.0	0.1	0.0	0.0	0.0	6.5
20	Zand	11.6	0.0	0.0	36.9	0.0	1.1	103.6	0.0	0.0	0.0	153.1
21	Zeekoei	0.0	0.0	0.2	56.4	0.0	1.5	205.5	0.1	0.0	0.0	263.7
22	Eerste	0.0	0.0	0.0	6.3	0.0	6.2	8.9	0.0	0.0	0.0	21.3
23	Lourens	0.0	0.0	0.0	0.6	0.0	0.0	1.3	0.0	0.0	0.0	1.9
24	Sir Lowry's Pass	0.0	0.0	0.0	0.0	0.0	1.7	1.2	0.0	0.0	0.0	3.0
25	Steenbras	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	1.9
26	Rooiels	1.2	1.9	0.0	2.8	0.0	1.2	2.8	0.0	0.0	0.0	9.9
27	Buffels (Oos)	0.0	0.0	0.0	0.8	0.0	0.4	1.7	0.6	0.0	0.0	3.5
28	Palmiet	0.1	0.0	0.0	0.0	0.0	11.0	21.4	0.5	0.0	0.0	33.0
29	Bot/ Kleinmond	0.0	117.8	46.1	301.6	0.0	8.2	1 072.8	0.0	0.0	0.0	1 546.5
30	Onrus	0.0	0.0	0.0	6.6	0.0	1.9	2.6	0.0	0.0	0.0	11.1
31	Klein	7.9	208.5	202.5	106.9	0.0	164.2	703.9	4.3	0.0	0.0	1 398.2
32	Uilkraals	50.1	23.1	1.4	5.6	0.0	46.0	21.0	0.0	0.0	0.0	147.2
33	Ratel	0.0	0.0	0.0	0.6	0.0	0.0	3.4	0.0	0.0	0.0	4.0
34	Heuningnes	16.2	942.4	10.2	1 155.0	0.0	43.4	907.9	0.0	0.0	0.0	3 075.0
35	Klipdriffontein	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.6
36	Brede	20.5	29.6	6.0	229.2	0.0	136.0	1 367.8	0.0	0.0	0.0	1 789.0
37	Duiwenhoks	35.0	0.0	0.0	3.1	0.0	15.9	102.1	0.4	0.0	0.0	156.5
38	Goukou	57.0	0.0	5.0	21.0	0.0	35.0	206.0	0.0	0.0	0.0	324.0
39	Gouritz	14.4	123.4	0.0	4.6	0.0	10.9	203.7	6.1	0.0	0.0	363.1
40	Blinde	0.0	0.0	0.0	0.9	0.0	1.9	2.6	0.0	0.0	0.0	5.4
41	Tweekuilen											0.0
42	Gericke											0.0
43	Hartenbos	47.0	0.0	0.0	9.0	0.0	1.0	42.0	0.0	0.0	0.0	99.0
44	Klein Brak	17.0	322.0	3.0	18.0	0.0	49.0	98.0	0.0	0.0	2.0	509.0
45	Groot Brak	13.0	26.6	0.0	2.5	0.0	29.9	33.1	0.0	0.0	0.0	105.1
46	Maalgate	0.0	0.0	0.0	0.0	0.0	6.9	10.6	10.5	0.0	0.0	28.0
47	Gwaing	0.0	0.0	0.0	0.6	0.0	2.7	5.5	0.2	0.0	0.0	9.0
48	Kaaimans	0.0	0.0	0.0	0.2	0.0	8.1	0.8	0.1	0.0	0.0	9.2
49	Touw/ Wilderness	42.3	0.0	4.0	227.9	0.0	0.0	21.1	0.0	0.0	0.0	295.3

Est ID	Estuary Name	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds and sedges	Mangroves	Sand/mud banks	Open water	Rocks	Swamp forest	Macroalgae	Total Habitat
50	Swartvlei	0.0	91.4	219.4	167.1	0.0	133.4	630.9	0.0	0.0	0.0	1 242.1
51	Goukamma	1.5	5.2	0.0	4.1	0.0	0.2	7.2	0.0	0.0	0.0	18.2
52	Knysna	551.9	133.0	353.0	37.8	0.0	265.5	945.5	0.0	0.0	0.0	2 286.7
53	Noetsie	0.0	0.0	0.0	4.5	0.0	2.6	6.3	0.0	0.0	0.0	13.4
54	Piesang	1.5	1.5	0.0	6.5	0.0	0.0	9.9	0.0	0.0	0.0	19.4
55	Keurbooms	72.2	41.8	88.7	146.3	0.0	166.3	159.4	0.0	0.0	0.0	674.7
56	Matjies	0.0	0.0	0.0	0.0	0.0	1.7	0.6	0.5	0.0	0.0	2.8
57	Sout (Oos)	0.4	1.0	0.1	0.0	0.0	2.1	4.0	1.2	0.0	0.0	8.8
58	Groot (Wes)	0.0	3.5	0.0	0.3	0.0	0.8	3.0	0.6	0.0	0.0	8.2
59	Bloukrans	0.0	0.0	0.0	0.0	0.0	2.6	1.1	0.0	0.0	0.0	3.7
60	Lottering	0.0	0.0	0.0	0.0	0.0	0.4	1.7	0.0	0.0	0.0	2.0
61	Elandsbos	0.0	0.0	0.0	0.0	0.0	3.0	2.1	0.0	0.0	0.0	5.1
62	Storms	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	0.0	0.0	12.1
63	Elands	0.0	0.0	0.0	0.0	0.0	1.7	5.8	0.0	0.0	0.0	7.5
64	Groot (Oos)	0.0	0.0	0.0	1.5	0.0	0.9	8.7	0.0	0.0	0.0	11.1
65	Tsitsikamma	0.0	0.0	0.0	1.5	0.0	0.5	4.5	0.0	0.0	0.0	6.5
66	Klipdrif (Oos)	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.6
67	Slang	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
68	Kromme	18.1	77.2	34.0	13.0	0.0	89.7	189.3	0.0	0.0	0.0	421.2
69	Seekoei	0.0	8.5	18.5	26.4	0.0	22.8	77.9	12.6	0.0	0.0	166.7
70	Kabeljous	0.0	10.5	21.5	8.6	0.0	0.0	77.4	0.0	0.0	0.0	117.9
71	Gamtoos	92.9	80.8	5.1	40.9	0.0	92.1	189.4	0.0	0.0	0.0	501.3
72	Van Stadens	0.0	0.0	0.0	5.7	0.0	1.1	17.4	0.0	0.0	0.0	24.2
73	Maitland	0.0	0.0	0.0	4.5	0.0	0.3	11.4	2.5	0.0	0.0	18.7
74	Baakens	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75	Papkuils	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
76	Swartkops	209.2	338.2	44.7	4.5	0.0	177.0	135.0	0.0	0.0	0.0	908.6
77	Coega (Ngqurha)	0.0	18.5	1.2	4.3	0.0	0.0	2.3	0.0	0.0	0.0	26.3
78	Sundays	0.0	19.4	0.0	31.5	0.0	118.4	314.0	0.0	0.0	0.0	483.3
79	Boknes	0.0	1.5	0.5	6.0	0.0	0.5	6.5	0.0	0.0	0.0	15.0
80	Bushmans	118.3	0.0	39.8	20.9	0.0	0.0	161.9	0.0	0.0	0.0	340.9
81	Kariega	36.1	15.1	3.3	0.0	0.0	24.9	135.9	0.8	0.0	0.0	216.0
82	Grant's											0.0
83	Kasouga	0.0	20.9	0.0	2.5	0.0	0.1	27.4	2.3	0.0	0.0	53.2
84	Kowie	35.2	26.5	8.2	6.4	0.0	29.7	129.5	0.0	0.0	0.0	235.4
85	Rufane	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.8
86	Riet	0.0	3.9	0.0	1.2	0.0	0.9	3.1	0.0	0.0	0.0	9.1
87	West Kleinemonde	35.5	32.1	8.2	4.1	0.0	0.8	19.2	8.4	0.0	0.0	108.3
88	East Kleinemonde	3.4	14.0	14.5	1.0	0.0	11.6	14.5	0.1	0.0	0.0	59.1
89	Great Fish	133.0	65.0	0.0	17.0	0.0	3.0	150.0	0.0	0.0	0.0	368.0
90	Old Woman's	0.0	0.0	0.0	14.2	0.0	0.1	10.7	0.2	0.0	0.0	25.1
91	Mpekweni	0.0	0.7	1.6	21.0	0.0	13.2	63.4	15.1	0.0	0.0	114.9
92	Mtati (Mthathi)	0.0	9.2	3.2	26.2	0.0	1.5	180.2	21.1	0.0	0.0	241.3
93	Mgwalana	0.0	23.8	1.1	48.8	0.0	5.3	154.3	9.6	0.0	0.0	242.9
94	Bira (Bhirha)	0.0	7.1	5.3	15.2	0.0	18.0	122.5	0.0	0.0	0.0	168.0
95	Gqutywa	0.0	1.2	2.5	3.8	0.0	4.5	38.1	1.6	0.0	0.0	51.6
96	Ngculura (Ngculurha)	0.0	0.0	0.0	0.7	0.0	1.2	0.5	0.0	0.0	0.0	2.4
97	Mtana	0.0	2.5	2.5	1.3	0.0	0.2	7.1	2.2	0.0	0.0	15.7
98	Keiskamma	210.4	91.3	12.0	103.9	0.0	49.2	277.8	0.0	0.0	0.0	744.5
99	Nqinisa	0.0	0.0	0.0	2.3	0.0	0.1	9.1	1.2	0.0	0.0	12.7
100	Kiwane (Khiwane)	0.0	0.0	3.6	4.6	0.0	0.2	9.0	1.6	0.0	0.0	18.8
101	Tyolomnqa	17.8	10.5	0.2	21.6	0.5	20.6	85.7	1.2	0.0	0.6	158.6
102	Shelbertsstroom	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5
103	Lilyvale	0.0	0.0	0.0	0.5	0.0	0.0	1.8	0.0	0.0	0.0	2.3

Est ID	Estuary Name	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds and sedges	Mangroves	Sand/mud banks	Open water	Rocks	Swamp forest	Macroalgae	Total Habitat
104	Ross' Creek	0.0	0.0	0.2	0.1	0.0	0.0	1.0	0.0	0.0	0.0	1.3
105	Ncera (Ncerha)	0.0	2.9	1.0	0.9	0.0	6.7	16.9	0.0	0.0	0.0	28.4
106	Mlele	0.0	0.4	0.0	0.5	0.0	0.0	2.7	0.0	0.0	0.0	3.6
107	Mcantsi	0.0	0.5	0.0	4.0	0.0	0.5	4.0	0.0	0.0	0.0	9.0
108	Gxulu	1.0	11.9	0.0	0.6	0.0	4.0	31.0	0.0	0.0	0.0	48.5
109	Goda	0.0	1.9	0.0	1.1	0.0	0.6	13.6	0.0	0.0	0.0	17.2
110	Hlozi	0.0	0.0	0.0	0.3	0.0	0.0	0.4	0.0	0.0	0.0	0.7
111	Hickman's	0.0	0.8	0.0	0.4	0.0	0.0	3.1	0.0	0.0	0.0	4.3
112	Buffalo	0.0	0.1	0.0	0.2	0.0	0.0	97.7	0.0	0.0	0.0	98.0
113	Blind	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.5
114	Hlaze (iHlanze)	0.0	0.1	0.0	0.7	0.0	0.0	0.7	0.0	0.0	0.0	1.5
115	Nahoon	3.0	0.0	2.3	0.2	1.6	10.9	49.6	0.0	0.0	2.6	70.2
116	Qinira (Quinirha)	16.8	5.7	0.0	15.2	0.0	0.0	34.4	0.0	0.0	0.0	72.1
117	Gqunube	3.7	2.2	0.8	0.4	0.0	6.3	40.0	0.0	0.0	0.0	53.4
118	Kwelerera (Kwelerha)	9.3	7.2	2.3	0.3	0.5	4.4	26.6	0.0	0.0	0.0	50.6
119	Bulura (Bulurha)	2.8	5.6	0.4	2.7	0.0	4.6	19.4	0.0	0.0	0.0	35.5
120	Cunge	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4
121	Cintsa	7.0	7.1	0.0	1.0	0.0	1.6	12.6	0.0	0.0	0.0	29.3
122	Cefane	28.1	21.4	0.0	1.9	0.0	8.8	22.5	0.0	0.0	0.0	82.7
123	Kwenxura (Kwenxurha)	0.0	3.3	0.0	2.6	0.0	5.0	18.2	0.0	0.0	0.0	29.1
124	Nyara (Nyarha)	1.1	6.3	0.0	0.6	0.0	1.7	7.4	0.0	0.0	0.0	17.1
125	Imtwendwe (Mtwendwe)	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3
126	Haga-haga	0.0	0.3	0.0	0.4	0.0	1.4	1.3	0.0	0.0	0.0	3.4
127	Mtendwe	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2
128	Quko	3.9	0.0	0.0	1.2	0.0	0.1	31.0	0.0	0.0	0.0	36.2
129	Morgan	0.0	2.0	0.0	1.0	0.0	1.0	20.0	0.0	0.0	0.0	24.0
130	Cwili	0.0	0.0	0.0	0.6	0.0	0.0	0.6	0.0	0.0	0.0	1.2
131	Great Kei	5.8	6.2	0.0	12.3	0.5	8.7	189.4	0.0	0.0	0.0	222.9
132	Gxara (Gxarha)	0.0	1.9	0.0	6.3	0.0	1.5	14.2	0.0	0.0	0.0	23.9
133	Ngogwane	0.0	0.0	0.0	2.4	0.0	2.1	4.7	0.0	0.0	0.0	9.1
134	Qolora (Qolorha)	0.0	0.0	0.0	8.7	0.0	1.2	7.4	5.6	0.0	0.0	22.9
135	Ncizele	0.0	0.0	0.0	1.2	0.0	0.0	5.4	0.0	0.0	0.0	6.6
136	Timba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
137	Kobonqaba (Khobonqaba)	2.3	4.5	1.0	2.4	0.5	4.6	11.1	0.0	0.0	0.0	26.4
138	Nxaxo/ Ngqusi	2.4	8.6	0.3	4.7	9.5	6.6	124.3	0.0	0.0	11.2	167.5
139	Cebe	0.0	0.0	0.0	7.6	0.0	1.4	7.5	0.0	0.0	0.0	16.5
140	Gqunqe	0.0	0.0	0.0	9.2	0.0	0.9	7.9	0.0	0.0	0.0	17.9
141	Zalu	0.0	0.0	0.0	5.2	0.0	0.0	7.1	0.0	0.0	0.0	12.4
142	Ngqwara (Ngqwarha)	0.0	2.3	0.0	4.7	0.0	2.1	10.2	0.0	0.0	0.0	19.4
143	Sihlontweni	0.0	0.0	0.0	2.6	0.0	0.1	8.4	0.0	0.0	0.0	11.0
144	Nebelele	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
145	Qora (Qhorha)	0.0	1.0	8.5	5.7	0.0	10.2	65.2	0.0	0.0	0.0	90.6
146	Jujura (Jujurha)	0.0	0.0	0.1	1.2	0.0	0.1	3.5	0.0	0.0	0.0	4.8
147	Ngadla	0.0	0.0	0.0	5.2	0.0	0.0	8.7	0.0	0.0	0.0	13.9
148	Shixini	0.0	0.0	0.0	5.6	0.0	5.2	11.2	0.0	0.0	0.0	22.1
149	Beechamwood	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
150	Kwazlelitsha (Kwazwedala)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
151	Kwa-Goqo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
152	Ku-Nocekedwa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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153	Nqabara/ Nqabarana	0.1	0.0	1.2	4.6	11.8	4.6	89.5	0.0	1.2	0.0	113.1
154	Ngomane (East)											0.0
155	Ngoma/ Kobule	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
156	Mendu	0.0	0.0	0.0	9.5	0.0	0.0	14.3	0.0	0.0	0.0	23.8
157	Mendwana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
158	Mbashe	4.2	0.0	1.5	13.5	9.2	6.7	89.2	0.0	4.8	0.0	129.1
159	Ku-Mpenzu	0.0	0.0	0.0	4.3	0.0	1.2	6.5	1.3	0.0	0.0	13.4
160	Ku-Bhula (Mbhanyana)	0.0	0.0	0.0	2.7	0.0	0.0	2.6	2.3	0.0	0.0	7.6
161	Kwa-Suku	0.0	0.0	2.3	7.6	0.0	0.0	8.2	0.0	0.0	0.0	18.1
162	Ntlonyane	0.0	0.0	0.0	8.0	0.0	3.9	29.5	0.0	0.0	0.0	41.3
163	Nkanya	0.0	0.0	0.0	7.4	0.0	0.1	7.5	0.5	0.0	0.0	15.5
164	Sundwana	0.0	0.0	0.0	2.3	0.0	0.0	4.3	0.0	0.0	0.0	6.6
165	Xora	0.1	13.0	2.6	10.1	25.5	17.1	91.5	0.0	0.0	0.0	159.9
166	Bulungula	0.1	2.3	0.0	4.7	0.0	2.5	8.9	0.0	0.0	0.0	18.5
167	Ku- Amanzimuzama	0.0	0.0	0.0	1.2	0.0	1.1	1.4	0.0	0.0	0.0	3.7
168	Nqakanqa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
169	Mdikana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
170	Mncwasa	0.0	0.0	0.0	3.7	0.0	0.2	15.4	0.0	0.0	0.0	19.2
171	Mpako	0.0	0.0	0.0	5.1	0.0	1.0	7.4	0.0	0.0	0.0	13.5
172	Nenga	0.0	0.0	0.0	2.1	0.0	2.2	5.7	0.0	0.0	0.0	10.0
173	Mapuzi	0.0	0.0	0.0	7.5	0.0	0.0	8.5	0.0	0.0	0.0	15.9
174	Mtata	27.3	21.0	0.0	6.2	31.5	5.6	102.4	0.0	0.0	0.0	194.1
175	Thsani	0.0	0.0	0.0	1.2	0.0	0.0	2.8	0.0	0.0	0.0	4.0
176	Mdumbi	4.0	8.2	0.1	7.9	5.0	13.9	45.6	0.0	0.0	0.0	84.6
177	Lwandilana	0.0	0.0	0.0	2.4	0.0	0.1	7.2	0.0	0.0	0.0	9.7
178	Lwandile	0.0	0.0	0.0	7.4	0.0	2.4	12.4	0.0	0.0	0.0	22.2
179	Mtakatye	2.7	0.0	0.0	0.0	9.9	0.0	0.0	0.0	0.0	0.0	12.6
180	Hluleka	0.0	0.0	0.0	2.4	0.0	4.1	8.5	0.0	0.0	0.0	14.9
181	Mnenu	0.0	0.0	0.0	44.0	0.0	0.1	46.4	0.0	0.0	0.0	90.5
182	Mtonga	0.0	0.0	0.0	15.6	0.0	1.2	15.4	0.0	0.0	0.0	32.2
183	Mpande	0.0	0.0	0.0	6.7	0.0	0.5	7.8	0.0	0.0	0.0	15.0
184	Sinangwana	0.0	0.0	0.0	7.4	0.0	0.0	5.8	0.0	0.0	0.0	13.2
185	Mngazana	5.9	5.4	2.0	11.4	149.3	87.9	76.4	0.0	7.8	0.0	346.1
186	Mngazi	0.0	0.0	0.0	4.6	0.0	0.0	12.5	0.0	0.0	0.0	17.1
187	Gxwaleni	0.0	0.0	0.0	5.6	0.0	0.0	4.5	0.0	0.0	0.0	10.1
188	Bulolo	0.0	0.0	0.0	6.3	0.0	0.0	6.3	0.0	0.0	0.0	12.6
189	Mtumbane	0.0	0.0	0.0	5.4	0.0	0.1	5.4	0.0	0.0	0.0	10.9
190	Mzimvubu	0.1	0.0	0.0	16.0	0.0	26.0	345.0	0.0	5.0	0.0	392.1
191	Ntlupeni											0.0
192	Nkodusweni	0.0	0.0	0.0	4.7	0.0	5.5	22.4	0.0	0.0	0.0	32.6
193	Mntafufu	14.0	0.0	0.0	1.5	12.0	0.8	7.7	0.0	0.5	0.0	36.4
194	Ingo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
195	Mzintlava	0.1	0.0	0.0	3.1	1.7	2.9	14.4	0.0	0.4	0.0	22.6
196	Mzimpunzi	0.0	0.0	0.0	1.4	0.0	0.6	3.1	0.0	0.0	0.0	5.1
197	Kwanyambalala											0.0
198	Mbotyi	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.6
199	Mkozi	0.0	0.0	0.0	0.5	0.0	0.1	2.1	0.0	0.0	0.0	2.7
200	Sikatsha											0.0
201	Lupatana	0.0	0.0	0.0	0.2	0.0	0.2	2.7	0.0	0.5	0.0	3.6
202	Mkweni	0.0	0.0	0.0	0.3	0.0	0.2	5.2	0.0	1.3	0.0	7.0
203	Msikaba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
204	Mgwegwe	0.0	0.0	0.0	0.2	0.0	0.8	3.4	0.0	4.5	0.0	8.8
205	Mgwetyana	0.0	0.0	0.0	0.3	0.0	0.6	2.5	0.0	0.0	0.0	3.3

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206	Mtentu	0.1	0.0	0.0	4.8	0.6	8.1	35.0	0.0	3.7	0.0	52.2
207	Sikombe	0.0	0.0	0.0	0.3	0.0	0.8	9.2	0.0	1.2	0.0	11.5
208	Kwanyana	0.0	0.0	0.0	0.7	0.0	0.1	6.3	0.0	0.0	0.0	7.1
209	Mtolane	0.0	0.0	0.0	0.0	0.0	0.1	1.2	0.0	0.0	0.0	1.3
210	Mnyameni	7.4	0.0	0.0	8.5	5.0	2.3	17.1	0.0	0.0	0.0	40.3
211	Mpahlanganyana	0.0	0.0	0.0	0.7	0.0	0.1	3.0	0.0	0.0	0.0	3.9
212	Mpahlane	0.0	0.0	0.0	0.7	0.0	0.3	3.0	0.0	0.0	0.0	3.9
213	Mzamba	1.7	0.0	0.0	24.1	0.3	4.0	37.9	0.0	4.7	0.0	72.7
214	Mtentswana	0.0	0.0	0.0	0.0	0.0	1.2	10.2	0.0	0.0	0.0	11.4
215	uMthavuna	0.0	0.0	0.0	7.1	1.0	11.6	76.9	0.0	0.1	0.0	96.7
216	iSolwane	0.0	0.0	0.0	0.0	0.0	2.0	0.3	0.0	0.0	0.0	2.3
217	iSandlu	0.0	0.0	0.0	3.3	0.0	3.0	4.0	0.0	0.3	0.0	10.5
218	uMbhoyibhoyi	0.0	0.0	0.0	3.0	0.0	1.0	1.1	0.0	0.0	0.0	5.1
219	uMuntongazi	0.0	0.0	0.0	0.0	0.0	3.0	0.8	0.0	3.0	0.0	6.8
220	iKhandalendlovu	0.0	0.0	0.0	3.9	0.0	1.0	1.1	0.0	5.2	0.0	11.2
221	iMpenjani	0.0	0.0	0.0	4.3	0.0	6.1	12.2	0.0	6.0	0.0	28.6
222	uMhlangomkhulu (South) (Umhlangankulu)	0.0	0.0	0.0	4.0	0.0	1.5	5.8	0.0	4.0	0.0	15.3
223	iKhaba	0.0	0.0	0.0	1.1	0.0	0.3	2.6	0.0	1.1	0.0	5.1
224	iMbizana	0.0	0.0	0.0	12.0	0.0	1.0	12.4	0.0	3.0	0.0	28.4
225	iMvutshini	0.0	0.0	0.0	0.0	0.0	3.0	0.9	0.0	0.0	0.0	3.9
226	iBilanhlonhlo	0.0	0.0	0.0	0.6	0.0	0.3	2.6	0.0	1.1	0.0	4.6
227	uVuzana	0.0	0.0	0.0	4.5	0.0	1.0	0.6	0.0	0.0	0.0	6.1
228	iKongeni	0.0	0.0	0.0	4.0	0.0	1.0	1.4	0.0	0.3	0.0	6.7
229	uVunguza	0.0	0.0	0.0	0.0	0.0	6.0	1.1	0.0	0.0	0.0	7.1
230	oHlangeni	0.0	0.0	0.0	8.0	0.0	4.0	3.6	0.0	0.0	0.0	15.6
231	iZotsha	0.0	0.0	0.0	13.0	0.0	4.0	7.3	0.0	5.0	0.0	29.3
232	iBhobhoyi	0.0	0.0	0.0	9.0	0.0	4.0	1.3	0.0	0.0	0.0	14.3
233	uMbango	0.0	0.0	0.0	8.0	0.0	2.0	0.9	0.0	2.0	0.0	12.9
234	uMzimkhulu	0.0	0.0	0.0	18.0	0.0	11.0	73.9	0.0	15.0	0.0	117.9
235	uMthente	0.0	0.0	0.0	5.0	0.0	1.0	8.0	0.0	4.5	0.0	18.5
236	uMhlangomkhulu (North) (Mhlangamkulu)	0.0	0.0	0.0	69.9	0.0	0.0	30.0	0.0	0.2	0.0	100.1
237	iDombe	0.0	0.0	0.0	6.3	0.0	2.7	1.7	0.0	9.0	0.0	19.7
238	iKhoshwana	0.0	0.0	0.0	10.0	0.0	1.0	1.2	0.0	6.0	0.0	18.2
239	iNjambili	0.0	0.0	0.0	1.5	0.0	1.0	1.7	0.0	6.3	0.0	10.5
240	uMzumbe	0.0	0.0	0.0	5.0	0.0	15.0	15.8	0.0	0.0	0.0	35.8
241	uMhlabashana	0.0	0.0	0.0	4.0	0.0	1.5	2.3	0.0	11.5	0.0	19.3
242	uMhlungwa	0.0	0.0	1.5	7.0	0.0	4.0	3.0	0.0	1.0	0.0	16.5
243	uMfazela	0.0	0.0	0.0	7.5	0.0	1.0	2.1	0.0	5.0	0.0	15.6
244	uMakhosi	0.0	0.0	0.0	3.5	0.0	2.0	2.5	0.0	7.0	0.0	15.0
245	uMnamfu	0.0	0.0	0.0	6.0	0.0	3.0	1.3	0.0	4.0	0.0	14.3
246	uMthwalume	0.0	0.0	0.0	4.0	0.0	10.0	24.8	0.0	0.0	0.0	38.8
247	uMvuzi	0.0	0.0	0.0	15.0	0.0	2.0	0.8	0.0	0.0	0.0	17.8
248	iFafa	0.0	0.0	1.5	6.1	0.0	0.7	19.5	0.0	6.6	0.0	34.4
249	uMdesingane	0.0	0.0	0.5	6.0	0.0	0.3	0.4	0.0	0.0	0.0	7.1
250	iSezela	0.0	0.0	0.0	18.0	0.0	1.0	9.0	0.0	0.0	0.0	28.0
251	uMkhumbane	0.0	0.0	0.0	7.0	0.0	5.0	0.3	0.0	0.0	0.0	12.3
252	iNkomba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
253	uMuziwezinto	0.0	0.0	0.0	14.0	0.0	4.0	7.0	0.0	4.5	0.0	29.5
254	uMzimayi	0.0	0.1	0.0	0.7	0.0	0.6	0.5	0.0	2.8	0.0	4.7
255	Rocky Bay	0.0	0.2	0.0	0.2	0.0	0.0	0.2	0.0	0.3	0.0	0.9
256	uMphambanyoni	0.0	0.0	0.0	3.0	0.0	7.0	2.3	0.0	0.3	0.0	12.6
257	aMahlongwa	0.0	0.0	0.0	7.0	0.0	1.0	5.9	0.0	0.0	0.0	13.9

Est ID	Estuary Name	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds and sedges	Mangroves	Sand/mud banks	Open water	Rocks	Swamp forest	Macroalgae	Total Habitat
258	uMahlongwane	0.0	0.0	3.0	5.0	0.0	2.0	6.8	0.0	4.0	0.0	20.8
259	uMkhomazi	0.0	0.0	0.0	4.0	1.0	9.0	64.0	0.0	10.0	0.0	88.0
260	iNgane	0.0	0.0	0.0	3.0	0.0	4.0	1.4	0.0	0.0	0.0	8.4
261	uMgababa	0.0	0.0	0.0	39.0	0.0	0.7	19.4	0.0	2.6	0.0	61.7
262	uMsimbazi	0.0	0.0	0.0	12.0	0.0	3.0	13.2	0.0	0.0	0.0	28.2
263	iLovu	0.0	0.0	0.0	19.0	0.0	5.0	10.5	0.0	5.0	0.0	39.5
264	aManzanamtoti	0.0	0.0	0.0	0.1	0.0	1.3	1.7	0.0	6.5	0.0	9.6
265	aManzimtoti	0.0	0.0	0.0	5.0	0.0	7.0	6.7	0.0	2.5	0.0	21.2
266	iZimbokodo	0.0	0.0	0.0	8.0	0.0	2.5	7.2	0.0	0.0	0.0	17.7
267	iSiphingo	0.0	3.0	0.0	2.0	3.8	1.0	0.8	0.0	16.0	0.0	26.6
268	Durban Bay	0.0	0.0	8.0	2.0	13.4	37.0	1 080.0	0.0	5.0	0.0	1 145.4
269	uMngeni	8.4	0.0	1.0	2.0	26.5	8.5	55.8	0.0	0.5	0.0	102.6
270	uMhlanga	0.0	0.0	0.0	69.9	0.0	0.7	12.0	0.0	0.2	0.0	82.8
271	uMdloti	0.0	0.0	0.0	10.0	0.0	7.3	33.0	0.0	7.8	0.0	58.1
272	uThongathi	0.0	0.0	0.0	17.2	0.0	2.8	13.9	0.0	3.4	0.0	37.3
273	uMhlali	0.0	0.0	0.0	6.0	0.0	8.0	21.0	0.0	7.0	0.0	42.0
274	Bob's Stream	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
275	uSetheni	0.0	0.0	0.0	0.3	0.0	2.0	1.1	0.0	4.0	0.0	7.4
276	uMvoti	0.0	0.0	0.0	87.0	0.0	6.0	16.0	0.0	2.0	0.0	111.0
277	uMdlotane	0.0	0.0	0.7	6.0	0.0	0.0	6.4	0.0	12.3	0.0	25.4
278	iNonoti	0.0	0.0	2.5	2.5	0.0	3.0	18.0	0.0	1.0	0.0	27.0
279	iZinkwazi	0.0	0.0	0.0	39.5	0.0	0.0	20.4	0.0	11.3	0.0	71.2
280	uThukela	0.0	0.0	0.0	40.0	0.0	20.6	72.5	0.0	0.3	0.0	133.3
281	aMatigulu/ iNyoni	3.4	49.5	0.0	99.0	0.0	88.1	214.3	0.0	0.0	0.0	454.3
282	iSiyaya	0.6	0.0	0.1	2.7	0.0	0.2	2.2	0.0	3.7	0.0	9.5
283	uMlalazi	42.0	34.4	0.0	43.0	60.7	45.0	140.0	0.0	104.0	0.0	469.1
284	uMhlathuze	60.0	0.0	28.5	205.0	761.5	90.0	679.0	0.0	0.0	0.0	1 824.0
285	Richards Bay	69.9	0.0	0.0	309.0	171.0	531.0	869.0	0.0	16.0	0.0	1 965.9
286	iNhlabane	0.0	0.0	1.1	333.9	0.0	0.0	5.2	0.0	0.3	0.0	340.5
287	iMfolozi/ uMsunduze	0.0	0.0	0.0	1 607.2	78.2	0.0	90.0	0.0	1 683.1	0.0	3 458.5
288	St Lucia	250.0	700.0	431.5	7 225.8	209.5	0.0	32 533.9	0.0	17.4	0.0	41 368.1
289	uMgobezeleni	0.0	0.0	22.6	117.0	0.0	0.5	80.0	0.0	416.7	0.0	636.8
290	Kosi	58.0	229.0	652.0	127.0	71.0	23.0	3 367.0	0.0	869.0	0.0	5 396.0

APPENDIX C: ESTUARY PRESSURE ASSESMENT

#	NAME	East DD MM SS	South DD MM SS	Cumulative	Flow	Pollution	Habitat loss	Fishing Effort	Artificial Breaching	Invasive Aliens: Plants	Invasive Aliens: Fish	Natural MAR (MCM)	Present MAR (MCM)	WW volume	Fish Catches (t)
1	Orange	16°27'28.0943"	28°38'8.6783"	H	VH	H	H	L	U	M	M	10 833.0	4 142.9	0	5.0
2	Buffels	17°3'2.26"	29°40'38.17"	H	VH	VH	VH	L	U	H	N	9.3	6.7	0	0.1
3	Swartlintjies	17°15'33.22"	30°15'47.49"	L	L	L	M	N	0	0	N	0.2	0.2	0	0.0
4	Spoeg	17°21'31.4280"	30°28'21.691"	L	M	L	L	N	0	0	N	1.1	0.2	0	0.0
5	Groen	17°34'35.6268"	30°50'48.472"	L	M	L	L	N	0	L	N	0.5	0.4	0	0.0
6	Sout (Noord)	17°50'54.2831"	31°14'41.207"	VH	VH	L	VH	N	0	0	N	1.5	1.5	0	0.0
7	Olifants	18°11'13.6283"	31°42'3.7583"	M	M	H	H	VH	0	H	VH	1 070.1	715.0	418	121.1
8	Jakkals	18°18'48.2976"	32°5'4.70759"	H	VH	H	H	L	U	0	N	3.5	2.5	0	0.1
9	Wadriest	18°19'30.9719"	32°12'16.509"	VH	VH	H	VH	L	0	0	N	13.3	9.8	0	0.0
10	Verlorenvlei	18°19'59.4263"	32°18'57.319"	H	VH	VH	H	M	U	0	H	52.2	40.2	0	10.0
11	Groot Berg	18°8'37.9860"	32°46'11.096"	M	M	VH	H	VH	M	M	VH	916.0	520.4	130 000	511.0
12	Langebaan	18° 1'18.97"	33° 5'50.36"	L	L	L	L	VH	0	0	N	0.0	0.0	0	206.0
13	Diep/Rietvlei	18°28'55.7148"	33°53'23.654"	H	M	VH	VH	L	L	M	H	63.3	51.1	57 000	8.0
14	Sout (Wes)	18°28'17.7095"	33°54'28.925"	VH	VH	VH	VH	L	?	0	N	31.1	27.5	0	0.1
15	Disa	18°21'16.2000"	34°2'47.0075"	VH	VH	VH	VH	L	0	M	H	15.2	14.6	0	0.1
16	Wildevölvlei	18°20'35.8332"	34°7'38.6796"	H	M	VH	H	L	0	H	L	2.1	1.8	9 500	0.1
17	Schuster	18°22'15.2651"	34°12'7.3619"	L	M	L	L	L	?	0	N	2.6	2.5	0	0.0
18	Krom	18°22'42.2436"	34°13'51.391"	L	L	L	L	L	0	0	N	7.0	6.8	0	0.0
19	Silwermyr	18°26'20.1227"	34°7'57.9467"	VH	H	H	VH	L	L	0	H	3.8	3.6	0	0.1
20	Zand	18°28'35.4000"	34°6'22.9823"	H	L	VH	VH	M	L	M	VH	21.7	19.8	0	20.0
21	Zeekoei	18°30'17.7623"	34°5'54.3083"	VH	H	VH	VH	L	Y	H	VH	22.3	20.4	116 640	0.1
22	Eerste	18°45'13.4028"	34°4'43.7771"	VH	VH	VH	VH	L	Y	H	H	104.6	87.1	205 630	0.1
23	Lourens	18°48'39.0347"	34°6'0.18719"	H	L	VH	VH	L	Y	H	VH	66.3	59.2	0	0.1
24	Sir Lowry's Pass	18°51'53.6220"	34°9'20.0160"	VH	M	VH	VH	L	?	M	N	0.1	0.1	0	0.1
25	Steenbras	18°49'9.88319"	34°11'41.348"	L	VH	L	L	L	0	M	L	33.7	26.3	0	0.2
26	Rooiels	18°49'15.7620"	34°17'44.786"	L	L	L	L	L	0	M	N	8.6	8.6	0	0.1
27	Buffels (Oos)	18°49'46.3259"	34°20'20.209"	L	M	L	L	L	0	H	N	9.7	9.4	0	0.1
28	Palmiet	18°59'38.9075"	34°20'43.584"	M	M	M	H	L	0	M	H	256.3	163.7	0	0.2

#	NAME	East DD MM SS	South DD MM SS	Cumulative	Flow	Pollution	Habitat loss	Fishing Effort	Artificial Breaching	Invasive Aliens: Plants	Invasive Aliens: Fish	Natural MAR (MCM)	Present MAR (MCM)	WW volume	Fish Catches (t)
29	Bot/Kleinmond	19°5.'49.6751"	34°22'6.3516"	M	M	H	L	VH	L	M	H	47.0	87.4	1 000	70.0
30	Onrus	19°10'43.2912"	34°25'7.1472"	H	H	VH	H	L	Y	M	H	9.6	7.3	0	0.1
31	Klein	19°17'53.3723"	34°25'14.354"	M	L	H	M	VH	L	H	H	53.4	40.9	400	80.0
32	Uilkraals	19°24'27.4859"	34°36'27.176"	H	VH	VH	H	M	Y	M	L	39.3	29.4	1 000	2.1
33	Ratel	19°44'47.4216"	34°46'15.668"	L	L	M	L	L	M	0	N	4.7	4.7	0	0.1
34	Heuningnes	20°7'9.28560"	34°42'53.244"	H	M	M	H	M	L	M	VH	41.6	36.9	0	10.0
35	Klipdriffontein	20°43'52.7951"	34°27'6.8616"	L	L	L	L	L	0	0	N	0.2	0.2	0	0.0
36	Breede	20°50'43.1951"	34°24'26.762"	L	M	L	L	H	0	H	VH	1 785.0	1 034.0	0	80.0
37	Duiwenhoks	21°0'4.25520"	34°21'54.107"	M	H	M	H	H	0	M	H	94.2	72.3	0	20.0
38	Goukou	21°25'24.6972"	34°22'42.067"	M	H	H	M	H	0	M	H	102.8	77.0	2 200	13.0
39	Gouritz	21°53'9.25440"	34°20'43.227"	M	VH	M	VH	H	0	M	VH	628.8	446.0	0	20.0
40	Blinde	22°0'46.6092"	34°12'39.060"	M	H	H	L	L	0	H	N	1.2	0.9	0	0.1
41	Tweekuilen	22°6'42.11"	34°9'5.51"	VH	H	VH	VH	L	0	0	N	35.6	34.4	0	0.1
42	Gericke	22°6'37.50"	34°8'38.35"	VH	H	VH	H	L	0	0	N	0.3	0.2	0	0.1
43	Hartenbos	22°7'32.8152"	34°6'54.4032"	H	M	VH	H	L	L	M	H	4.6	2.8	10 000	2.1
44	Klein Brak	22°8'54.9096"	34°5'34.5480"	M	H	M	H	M	0	H	H	53.4	40.4	90	10.0
45	Groot Brak	22°14'21.4511"	34°3'26.1144"	H	M	H	VH	M	L	H	H	36.8	16.3	0	10.0
46	Maalgate	22°21'15.9803"	34°3'15.8039"	L	H	L	L	L	0	H	N	26.6	16.0	0	0.1
47	Gwaing	22°26'2.90039"	34°3'23.2883"	M	L	VH	L	L	?	H	H	43.5	32.6	7 931	0.1
48	Kaaimans	22°33'25.4015"	33°59'52.130"	L	H	L	L	N	0	H	N	35.7	28.8	0	4.0
49	Touw/Wilderness	22°34'52.0571"	33°59'44.728"	M	L	L	L	N	L	M	L	29.7	25.2	0	170.0
50	Swartvlei	22°47'46.5215"	34°1'53.4576"	L	L	L	M	N	L	M	M	83.2	56.6	0	170.0
51	Goukamma	22°56'56.8859"	34°4'37.7795"	L	L	M	L	M	P	M	H	57.5	48.8	0	4.1
52	Knysna	23°3'41.2308"	34°4'57.7416"	L	L	H	L	H	0	0	H	83.2	68.0	6 500	70.4
53	Noetsie	23°7'44.9543"	34°4'49.0872"	L	L	L	L	L	?	M	N	4.4	4.4	0	0.2
54	Piesang	23°22'43.5431"	34°3'37.6740"	H	H	M	H	L	U	H	N	5.2	3.4	0	7.2
55	Keurbooms	23°22'41.4732"	34°2'59.4599"	L	L	L	M	L	0	M	H	232.0	215.0	0	23.4
56	Matjies	23°28'12.6552"	34°0'7.07399"	L	L	L	L	L	0	0	N	5.1	4.3	0	0.1
57	Sout (Oos)	23°32'11.5548"	33°59'22.207"	L	L	L	L	L	0	0	N	11.2	10.1	0	0.5
58	Groot (Wes)	23°34'9.04799"	33°58'54.411"	L	L	L	L	L	0	M	L	12.8	11.1	0	5.8
59	Bloukrans	23°38'50.8884"	33°58'46.721"	L	L	L	L	L	0	0	N	40.1	39.3	0	1.0
60	Lottering	23°44'9.41999"	33°59'43.836"	L	L	L	L	L	0	0	N	18.5	16.8	0	0.2
61	Elandsbos	23°46'4.59120"	34°0'12.6467"	L	L	L	L	L	0	0	N	27.2	24.7	0	0.2
62	Storms	23°54'10.7568"	34°1'15.5064"	L	L	L	L	L	0	0	N	54.1	47.9	0	0.1

#	NAME	East DD MM SS	South DD MM SS	Cumulative	Flow	Pollution	Habitat loss	Fishing Effort	Artificial Breaching	Invasive Aliens: Plants	Invasive Aliens: Fish	Natural MAR (MCM)	Present MAR (MCM)	WW volume	Fish Catches (t)
63	Elands	24°4'44.7096"	34°2'38.3387"	L	L	L	L	L	0	0	N	52.2	46.9	0	0.1
64	Groot (Oos)	24°11'42.0683"	34°3'35.6219"	L	L	M	L	L	0	0	N	47.0	44.1	0	0.1
65	Tsitsikamma	24°26'17.9736"	34°8'8.13480"	L	M	M	L	L	0	0	N	19.9	13.3	0	1.8
66	Klipdrif (Oos)	24°38'13.3764"	34°10'20.521"	L	L	H	M	L	0	0	N	32.9	18.6	0	0.1
67	Slang	24°39'13.3271"	34°10'26.864"	M	L	VH	H	L	0	0	N	5.1	4.6	0	0.1
68	Kromme	24°50'33.8208"	34°8'34.6811"	H	VH	VH	H	H	0	0	H	123.0	37.0	0	22.1
69	Seekoei	24°54'38.6748"	34°5'12.0119"	H	H	H	VH	L	Y	M	L	20.3	11.4	0	1.0
70	Kabeljous	24°55'57.0108"	34°0'31.7051"	M	M	M	M	L	0	H	H	11.5	9.7	0	2.0
71	Gamtoos	25°2'4.97040"	33°58'13.529"	L	M	M	H	H	Y	M	VH	388.8	265.5	0	19.3
72	Van Stadens	25°13'13.2455"	33°58'13.994"	L	M	L	L	L	0	H	N	17.2	15.6	0	2.1
73	Maitland	25°17'31.0271"	33°59'16.933"	L	M	M	L	L	0	H	N	12.9	11.7	0	0.1
74	Baakens	25°37'48.0468"	33°57'49.427"	VH	H	VH	VH	L	0	0	N	4.1	3.6	0	0.1
75	Papkuils	25°36'49.9896"	33°55'2.2548"	VH	H	VH	VH	L	0	0	N	2.9	2.9	47 200	0.1
76	Swartkops	25°37'58.9619"	33°51'58.481"	H	VH	VH	VH	H	0	H	H	97.6	79.2	0	46.7
77	Coega (Ngqurha)	25°41'26.6604"	33°47'43.368"	VH	H	L	VH	L	0	0	H	10.1	8.6	0	10.0
78	Sundays	25°51'13.4100"	33°43'18.609"	M	M	VH	H	H	0	H	H	273.0	260.0	0	9.0
79	Boknes	26°35'10.5396"	33°43'37.822"	M	VH	M	L	L	0	0	L	14.4	14.4	0	0.3
80	Bushmans	26°39'49.0392"	33°41'41.697"	L	L	L	M	H	0	0	H	42.9	36.8	2 000	11.5
81	Kariega	26°41'11.0364"	33°40'57.975"	M	VH	L	M	M	0	0	N	21.7	15.6	1 000	0.2
82	Grant's	26°42'10.872"	33°40'10.412"	M	H	M	M	L	0	0	N	0.0	0.0	0	0.0
83	Kasouga	26°44'7.07280"	33°39'14.741"	L	L	L	L	L	0	0	N	4.3	4.3	0	2.2
84	Kowie	26°54'5.88240"	33°36'13.053"	M	L	L	H	H	0	M	H	31.8	30.3	1 800	6.0
85	Rufane	26°56'8.97719"	33°34'50.995"	M	H	L	M	L	0	0	N	1.2	1.1	0	0.1
86	Riet	27°0'49.8671"	33°33'40.330"	L	L	L	L	L	0	0	N	0.0	0.0	0	0.1
87	West Kleinemonde	27°2'46.1471"	33°32'28.845"	L	L	L	L	L	0	0	N	6.0	5.5	0	2.2
88	East Kleinemonde	27°2'57.5699"	33°32'20.493"	L	L	M	L	L	0	0	N	2.9	2.7	0	2.0
89	Great Fish	27°8'26.4624"	33°29'42.820"	M	L	H	L	H	0	M	VH	513.3	463.3	0	30.0
90	Old Woman's	27°8'53.0520"	33°28'57.975"	M	M	H	M	L	0	0	N	1.1	0.9	0	0.1
91	Mpekweni	27°13'52.2336"	33°26'16.843"	L	M	L	L	M	0	0	N	2.4	2.1	0	2.2
92	Mtati (Mthathi)	27°15'32.6591"	33°25'22.360"	L	M	L	L	L	0	0	N	6.0	5.1	0	3.0
93	Mgwalana	27°16'27.1704"	33°24'46.886"	L	M	L	L	L	0	0	N	9.7	8.2	0	3.5
94	Bira (Bhirha)	27°19'33.7116"	33°23'1.5360"	L	M	L	L	L	0	0	N	12.0	10.0	0	8.5
95	Gqutywa	27°21'29.0844"	33°21'45"	L	L	L	L	L	0	0	N	3.5	3.0	0	0.2

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96	Ngculura (Ngculurha)	27°22'4.49760"	33°21'29.077"	L	M	L	L	L	0	0	N	0.6	0.6	0	0.1
97	Mtana	27°25'55.7940"	33°19'6.9779"	L	L	L	L	L	0	0	N	1.1	0.9	0	2.1
98	Keiskamma	27°29'28.4388"	33°16'53.328"	L	L	M	M	H	0	0	H	138.9	108.3	0	66.7
99	Nqinisa	27°31'40.5696"	33°15'9.8603"	L	L	L	L	L	0	0	N	1.2	1.2	0	0.1
100	Kiwane (Khiwane)	27°32'35.4012"	33°14'53.887"	L	L	L	L	L	0	0	N	5.3	5.3	0	2.0
101	Tyolomnqa	27°35'0.31560"	33°13'32.779"	L	L	L	L	H	0	0	N	35.6	34.5	0	40.0
102	Shelbertsstroom	27°36'56.3903"	33°12'25.527"	L	L	M	L	L	0	M	N	0.6	0.6	0	0.1
103	Lilyvale	27°38'12.8723"	33°11'34.270"	L	L	M	L	L	0	0	N	1.1	1.0	0	0.1
104	Ross' Creek	27°39'27.6192"	33°10'36.325"	L	L	L	L	L	0	0	N	0.6	0.5	0	0.1
105	Ncera (Ncerha)	27°40'5.54160"	33°10'12.417"	L	L	L	L	L	0	0	N	11.0	10.2	0	2.3
106	Mlele	27°40'47.8631"	33°9'34.963"	L	L	M	L	L	0	0	N	2.0	1.9	0	0.1
107	Mcantsi	27°42'7.11719"	33°8'43.832"	L	L	L	L	L	0	0	N	2.8	2.6	0	0.1
108	Gxulu	27°43'53.3675"	33°7'8.0579"	L	L	L	M	L	0	0	N	15.6	14.5	0	3.2
109	Goda	27°46'30.1188"	33°6'3.9239"	L	L	M	L	L	0	0	N	6.2	5.8	0	1.0
110	Hlozi	27°48'42.7788"	33°5'8.1491"	L	L	H	L	L	0	0	N	1.7	1.6	0	0.1
111	Hickman's	27°50'22.8767"	33°4'14.984"	L	L	M	L	L	0	0	N	1.4	1.3	0	0.1
112	Buffalo	27°54'58.7448"	33°1'36.476"	H	VH	M	M	H	0	0	VH	96.0	18.7	0	60.0
113	Blind	27°55'39.6983"	33°00'25"	H	H	VH	M	L	0	0	N	0.7	1.1	0	0.1
114	Hlaze (iHlanze)	27°56'57.6816"	32°59'21.231"	H	VH	VH	L	L	0	0	N	0.3	0.8	0	0.1
115	Nahoon	27°57'6.13439"	32°59'11.176"	M	M	H	M	H	0	H	H	38.2	27.1	0	7.4
116	Qinira (Quinirha)	27°57'53.3987"	32°58'27.130"	L	L	M	L	M	0	0	N	8.4	8.3	0	2.0
117	Gqunube	28°2'5.63639"	32°56'1.9535"	L	L	L	L	M	0	0	H	34.1	32.1	0	7.7
118	Kwelera (Kwelerha)	28°4'37.2072"	32°54'26.495"	L	L	L	L	H	0	0	L	34.8	32.8	0	8.0
119	Bulura (Bulurha)	28°5'36.2076"	32°53'28.805"	L	L	L	L	H	0	0	N	3.7	3.5	0	2.0
120	Cunge	28°6'37.5263"	32°51'39.157"	L	L	L	L	L	0	M	N	0.3	0.3	0	0.1
121	Cintsa	28°7'1.35839"	32°49'53.155"	L	L	L	M	M	0	0	N	4.0	3.8	0	7.0
122	Cefane	28°8'13.5528"	32°48'34.070"	L	L	L	L	M	0	0	N	4.0	3.2	0	6.2
123	Kwenxura (Kwenxurha)	28°9'5.71680"	32°47'55.589"	L	L	L	L	M	0	0	N	16.9	16.6	0	7.0
124	Nyara (Nyarha)	28°10'55.2611"	32°47'6.8279"	L	L	L	L	L	0	0	N	4.3	4.3	0	0.2
125	Imtwendwe (Mtwendwe)	28°14'13.1135"	32°46'12.133"	L	L	L	L	L	0	0	N	1.1	1.0	0	0.1

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126	Haga-haga	28°15'11.4659"	32°45'42.901"	L	L	L	L	L	0	0	N	2.1	2.1	0	1.0
127	Mtendwe	28°17'9.04920"	32°44'26.836"	L	L	L	L	L	0	0	N	1.4	1.4	0	0.1
128	Quko	28°18'34.3367"	32°43'32.303"	L	L	L	L	L	0	0	N	17.2	16.9	0	3.8
129	Morgan	28°20'38.5691"	32°42'30.949"	L	L	L	L	H	0	0	H	2.7	2.7	0	7.8
130	Cwili	28°22'25.4531"	32°41'27.214"	L	L	L	L	L	0	0	H	1.2	1.2	0	0.1
131	Great Kei	28°23'9.47040"	32°40'47.593"	M	VH	L	L	H	0	0	VH	954.9	649.3	670	40.0
132	Gxara (Gxarha)	28°23'56.8679"	32°39'58.168"	L	L	M	L	L	0	0	N	3.4	3.4	0	2.3
133	Ngogwane	28°25'17.91"	32°38'55.31"	L	L	M	L	L	0	0	N	0.8	0.8	0	0.1
134	Qolora (Qolorha)	28°26'5.79"	32°37'47.70"	L	L	L	L	L	0	0	N	8.9	8.7	0	1.7
135	Ncizele	28°26'16.68"	32°37'42.50"	L	L	L	L	L	0	0	N	1.0	1.0	0	0.1
136	Timba	28°26'45.16"	32°37'31.65"	L	L	L	L	L	0	0	N	0.4	0.3	0	0.1
137	Kobonqaba (Khobonqaba)	28°29'25.2924"	32°36'28.209"	L	L	L	M	L	0	0	N	36.2	35.5	0	6.0
138	Nxaxo/Ngqusi	28°31'34.5323"	32°35'5.0315"	L	L	L	M	H	0	M	N	23.3	22.8	0	9.0
139	Cebe	28°35'8.97719"	32°31'16.273"	L	L	L	L	L	0	0	N	5.7	5.6	0	2.4
140	Gqunqe	28°35'22.2396"	32°31'7.6836"	L	L	L	L	L	0	0	N	7.0	6.8	0	2.4
141	Zalu	28°36'11.2572"	32°30'9.5183"	L	L	L	L	L	0	0	N	1.7	1.7	0	1.5
142	Ngqwara (Ngqwarha)	28°36'50.6016"	32°29'39.138"	L	L	L	L	L	0	0	N	5.2	5.1	0	2.4
143	Sihlontlweni	28°38'41.3627"	32°28'52.957"	L	L	L	L	L	0	0	N	2.2	2.2	0	1.5
144	Nebelele	28°39'21.3480"	32°27'45.575"	L	L	M	L	L	0	0	N	1.1	1.0	0	0.1
145	Qora (Qhorha)	28°40'24.4740"	32°26'46.932"	L	L	L	L	H	0	0	N	78.5	72.0	0	21.0
146	Jujura (Jujurha)	28°41'38.2596"	32°25'51.960"	L	L	L	L	L	0	0	N	11.3	10.3	0	1.3
147	Ngadla	28°42'31.2515"	32°25'6.0599"	L	L	L	L	L	0	0	N	1.6	1.5	0	1.5
148	Shixini	28°43'31.8467"	32°24'11.163"	L	L	L	L	M	0	0	N	42.3	41.0	0	5.0
149	Beechamwood	28°45'7.48439"	32°22'29.492"	L	L	L	L	L	0	0	N	0.5	0.5	0	0.1
150	Kwazlelitsha (Kwazwedala)	28°45'29.4371"	32°22'12.151"	L	L	L	L	L	0	0	N	0.6	0.6	0	0.1
151	Kwa-Gogo	28°45'41.4539"	32°21'59.050"	L	L	L	L	L	0	0	N	1.0	1.0	0	0.1
152	Ku-Nocekedwa	28°46'40.0655"	32°20'55.766"	L	L	L	L	L	0	0	N	1.1	1.1	0	0.1
153	Nqabara/Nqabarana	28°47'25.1915"	32°20'22.970"	L	L	L	L	M	0	M	N	76.4	75.9	0	16.8
154	Ngomane (East)	28°49'46.22"	32°18'18.95"	L	L	L	M	L	0	0	N	0.0	0.0	0	0.1
155	Ngoma/Kobule	28°50'14.3195"	32°18'4.1868"	L	L	L	L	L	0	0	N	6.3	6.2	0	1.0

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156	Mendu	28°52'40.0332"	32°16'51.297"	L	L	L	L	M	0	0	N	5.2	5.1	0	2.0
157	Mendwana	28°53'3.25679"	32°16'8.1336"	L	L	L	L	M	0	0	N	1.4	1.3	0	0.1
158	Mbashe	28°54'6.84359"	32°14'59.946"	L	L	L	L	VH	0	0	H	801.8	817.7	0	25.0
159	Ku-Mpenzu	28°54'51.9012"	32°14'37.777"	L	L	L	L	L	0	0	N	0.8	0.7	0	0.1
160	Ku-Bhula (Mbhanyana)	28°55'40.8108"	32°13'41.185"	L	L	L	L	M	0	0	N	8.9	8.6	0	0.2
161	Kwa-Suku	28°56'48.78"	32°12'19.06"	L	L	L	L	M	0	0	N	0.7	0.7	0	0.1
162	Ntlonyane	28°57'23.9832"	32°11'40.930"	L	L	L	L	M	0	0	N	13.6	13.2	0	0.5
163	Nkanya	28°58'29.4888"	32°10'39"	L	L	L	L	L	0	0	N	2.5	2.4	0	0.1
164	Sundwana	28°58'55.1280"	32°10'24.330"	L	L	L	L	L	0	0	N	0.8	0.8	0	0.0
165	Xora	28°59'44.1059"	32°9'31.082"	L	L	L	L	H	0	M	N	53.0	50.4	0	7.0
166	Bulungula	29°0'41.4647"	32°8'16.828"	L	L	L	L	L	0	M	N	7.6	7.5	0	0.2
167	Ku-Amanzimuzama	29°2'0.17159"	32°6'53.729"	L	L	L	L	L	0	0	N	1.6	1.6	0	0.0
168	Nqakanqa	29°3'44.7119"	32°5'55.1003"	L	L	L	L	L	0	0	N	0.8	0.8	0	0.0
169	Mdikana	29°4'9.60240"	32°5'18.9023"	L	L	L	L	L	0	0	N	0.2	0.2	0	0.0
170	Mncwasa	29°4'33.8772"	32°4'57.741"	L	L	M	L	L	0	0	N	26.9	26.5	0	2.0
171	Mpako	29°6'27.7019"	32°2'24.853"	L	L	M	L	M	0	0	N	21.7	21.6	0	0.5
172	Nenga	29°9'6.51600"	31°59'7.7460"	M	L	M	H	M	0	0	N	9.1	9.0	0	0.1
173	Mapuzi	29°10'7.37759"	31°58'11.812"	L	L	M	L	L	0	0	N	5.5	5.5	0	0.1
174	Mtata	29°11'1.52880"	31°57'10.666"	M	M	H	M	H	0	M	VH	392.2	319.0	0	5.5
175	Thsani	29°12'31.8960"	31°56'41.855"	L	L	M	L	L	0	0	N	0.5	0.5	0	0.1
176	Mdumbi	29°12'58.6763"	31°55'53.220"	L	L	L	L	H	0	M	N	36.6	35.5	0	5.0
177	Lwandilana	29°14'38.1300"	31°53'46.312"	L	L	L	L	L	0	0	N	1.4	1.4	0	0.1
178	Lwandile	29°14'51.1296"	31°53'27.401"	L	L	L	L	L	0	0	N	3.4	3.3	0	1.0
179	Mtakatye	29°16'12.8892"	31°51'33.371"	L	L	L	L	H	0	M	N	63.4	61.7	0	5.2
180	Hluleka	29°18'13.0032"	31°49'38.668"	L	L	L	L	L	0	0	N	4.3	4.2	0	0.1
181	Mnenu	29°19'48.3239"	31°48'27.223"	L	L	L	L	M	0	0	N	19.7	19.2	0	6.0
182	Mtonga	29°20'53.8475"	31°47'35.739"	L	L	L	L	L	0	0	N	4.0	3.9	0	0.1
183	Mpande	29°21'25.7148"	31°45'44.096"	L	L	L	L	L	0	0	N	4.5	4.4	0	0.1
184	Sinangwana	29°22'11.6183"	31°45'1.7928"	L	L	L	L	L	0	0	N	11.5	11.2	0	1.0
185	Mngazana	29°25'22.2996"	31°41'31.837"	L	L	L	M	H	0	0	N	49.3	47.8	0	6.7
186	Mngazi	29°27'47.2824"	31°40'37.862"	L	L	L	L	H	0	0	N	84.3	84.0	0	6.0
187	Gxwaleni	29°30'24.8148"	31°39'19.706"	L	L	L	L	L	0	0	N	1.6	1.6	0	0.1
188	Bulolo	29°31'3.89639"	31°39'2.4515"	L	L	L	M	M	0	0	N	1.6	1.6	0	0.1

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189	Mtumbane	29°31'13.7316"	31.°38'52.306"	L	L	L	M	L	0	0	N	1.0	1.0	0	0.0
190	Mzimvubu	29°32'59.7443"	31°37'52.107"	L	L	H	L	H	0	M	VH	2 665.6	2 552.0	0	35.2
191	Ntlupeni	29°34'52.419"	31°36'32.263"	L	L	L	L	L	0	0	N	3.8	3.8	0	0.0
192	Nkodusweni	29°36'29.39"	31°35'39.42"	L	L	L	L	L	0	0	N	8.2	8.1	0	1.0
193	Mntafufu	29°38'15.8244"	31°33'45.068"	L	L	L	L	H	0	H	N	44.5	43.8	0	4.1
194	Ingo	29°39'38.90"	31°32'56.92"	L	L	L	L	L	0	0	N	0.0	0.0	0	0.1
195	Mzintlava	29°41'23.2475"	31°31'21.518"	L	L	L	L	H	0	0	N	69.8	67.0	0	3.8
196	Mzimpunzi	29°43'23.1816"	31°28'47.852"	L	L	L	L	L	0	0	N	9.2	8.5	0	0.1
197	Kwanyambalala	29°44'3.07"	31°28'5.0245"	L	L	L	L	H	0	0	N	4.2	3.9	0	0.1
198	Mbotyi	29°44'3.56"	31°28'0.624"	L	L	L	L	H	0	0	N	11.1	10.3	0	2.0
199	Mkozi	29°45'1.6663"	31°26'54.722"	L	L	L	L	L	0	0	N	15.7	14.6	0	0.0
200	Sikatsha	29°46'6"	31°26'42"	L	L	L	L	L	0	0	N	0.0	0.0	0	0.0
201	Lupatana	29°51'5.32440"	31°25'23.811"	L	L	L	L	L	0	0	N	7.0	6.5	0	0.0
202	Mkweni	29°52'22.20"	31°24'12.27"	L	L	L	L	L	0	0	N	18.4	17.0	0	0.0
203	Msikaba	29°58'3.74"	31°19'9.20"	L	L	L	L	H	0	M	N	212.4	199.3	0	3.2
204	Mgwegwe	30°0'40.9140"	31°17'15.554"	L	L	L	L	L	0	0	N	1.2	1.2	0	0.1
205	Mgwetyana	30°2'22.9775"	31°15'42.454"	L	L	L	L	L	0	0	N	1.8	1.8	0	0.1
206	Mtentu	30°2'46.5539"	31°14'55.885"	L	L	L	L	H	0	M	H	157.0	145.4	0	4.5
207	Sikombe	30°4'9.86160"	31°13'19.333"	L	L	L	L	L	0	0	N	6.8	6.8	0	1.0
208	Kwanyana	30°6'17.6615"	31°11'10.791"	L	L	L	L	L	0	0	N	4.0	3.9	0	0.1
209	Mtolane	30°7'37.1135"	31°9'34.8192"	L	L	L	L	L	0	0	N	1.8	1.8	0	0.1
210	Mnyameni	30°8'1.60800"	31°9'7.67520"	L	L	L	L	M	0	0	N	45.9	44.8	0	3.5
211	Mpahlanyana	30°9'36.5831"	31°7'27.9768"	L	L	L	L	M	0	0	N	1.1	1.0	0	0.1
212	Mpahlane	30°9'53.4240"	31°7'9.99840"	L	L	L	L	M	0	0	N	2.7	2.5	0	0.1
213	Mzamba	30°10'26.3999"	31°6'31.8600"	L	L	L	L	H	0	M	N	67.4	62.8	0	3.7
214	Mtentwana	30°11'15.1979"	31°5'17.8763"	M	L	VH	M	L	0	0	N	1.3	1.2	0	0.1
215	uMthavuna	30°11'37.2984"	31°5'4.27200"	L	L	L	L	H	P	M	L	275.2	239.5	0	6.2
216	iSolwane	30°12'17.352"	31°4'31.418"	L	L	L	L	L	0	M	N	2.2	2.3	0	0.1
217	iSandlu	30°13'44.6087"	31°2'33.4319"	M	L	L	M	L	p	M	N	5.1	5.0	0	0.5
218	uMbhoiyibhoiyi	30°14'8.16359"	31°2'4.77599"	L	L	L	L	L	0	M	N	1.0	1.0	0	0.2
219	uMuntongazi	30°15'24.5915"	31°0'41.1732"	L	L	H	M	L	0	0	N	7.0	7.3	250	0.0
220	iKhandalendlovu	30°16'9.45480"	30°59'50.625"	L	L	M	L	L	0	M	N	1.5	1.6	0	0.3
221	iMpenjani	30°17'2.78160"	30°58'25.348"	M	L	M	H	M	P	M	N	23.6	23.8	602	1.3

#	NAME	East DD MM SS	South DD MM SS	Cumulative	Flow	Pollution	Habitat loss	Fishing Effort	Artificial Breaching	Invasive Aliens: Plants	Invasive Aliens: Fish	Natural MAR (MCM)	Present MAR (MCM)	WW volume	Fish Catches (t)
222	uMhlangomkhulu (South) (Umlhangankulu)	30°18'11.0699"	30°56'43.490"	M	L	VH	M	L	?	0	N	2.9	2.9	0	0.7
223	iKhaba	30°18'32.3604"	30°56'9.4776"	M	L	VH	H	L	p	H	N	3.1	3.1	0	0.4
224	iMbizana	30°20'5.22239"	30°54'31.103"	L	L	M	M	M	?	M	H	36.3	35.5	0	1.5
225	iMvutshini	30°20'49.6895"	30°53'38.684"	L	L	H	M	L	?	M	N	1.7	1.6	0	0.2
226	iBilanhlonhlo	30°20'56.1479"	30°53'24.687"	M	L	H	VH	L	U	M	N	5.0	5.0	0	0.3
227	uVuzana	30°21'32.2415"	30°52'42.254"	M	L	VH	M	L	0	M	N	1.0	1.0	0	0.2
228	iKongeni	30°22'21.8495"	30°51'41.288"	VH	VH	VH	VH	M	U	0	H	1.9	4.8	4 998	0.3
229	uVunguza	30°23'43.1303"	30°50'11.345"	L	L	VH	L	L	0	M	N	27.8	28.9	2 738	0.0
230	oHlangeni	30°24'20.1168"	30°49'12.810"	M	L	VH	H	M	U	0	N	9.3	9.8	700	0.6
231	iZotsha	30°25'25.1687"	30°47'22.322"	L	L	H	M	M	U	M	N	15.7	16.2	0	1.3
232	iBhobhoyi	30°26'21.2531"	30°46'14.509"	L	L	H	M	L	0	0	N	8.2	8.1	123	0.3
233	uMbango	30°26'51.6084"	30°45'27.745"	VH	VH	VH	VH	L	0	0	N	3.0	7.3	9 000	0.1
234	uMzimkhulu	30°27'29.8800"	30°44'23.398"	L	L	L	L	VH	U	0	N	1 452.5	1 175.1	0	11.3
235	uMthente	30°28'54.1019"	30°42'34.534"	M	M	H	H	L	0	0	N	12.1	11.1	0	0.7
236	uMhlangomkhulu (North) (Mhlangamkulu)	30°29'54.0420"	30°41'17.394"	M	H	H	M	L	0	H	N	2.1	1.7	0	0.4
237	iDombe	30°30'37.5335"	30°40'20.863"	H	H	M	H	L	P	H	N	4.6	3.9	0	0.4
238	iKhoshwana	30°31'2.27280"	30°39'37.137"	M	L	VH	H	L	?	0	N	2.1	2.0	250	0.3
239	iNjambili	30°32'11.5223"	30°38'13.938"	M	VH	M	M	L	0	M	H	6.5	4.9	0	0.2
240	uMzumbe	30°32'52.0116"	30°36'50.133"	M	L	M	VH	L	0	M	N	58.5	52.8	0	0.8
241	uMhlabashana	30°34'17.0363"	30°35'4.1208"	L	L	H	M	L	?	M	N	6.5	6.5	411	0.4
242	uMhlungwa	30°34'59.6459"	30°33'38.926"	M	L	M	H	L	0	M	N	5.8	5.7	0	1.2
243	uMfazezala	30°36'25.4339"	30°31'54.534"	M	L	H	H	M	0	0	N	2.8	2.6	0	0.6
244	uMakhosi	30°36'36.8496"	30°31'33.085"	M	L	M	M	L	0	0	N	3.2	3.0	0	0.6
245	uMnamfu	30°37'28.9991"	30°30'30.272"	M	L	H	M	M	0	0	N	3.1	2.9	0	0.3
246	uMthwalume	30°38'8.16000"	30°29'6.6300"	M	L	M	M	M	0	M	N	57.6	41.8	0	0.5
247	uMvuzi	30°38'51.4104"	30°28'11.276"	M	L	M	M	M	0	0	N	1.6	1.5	0	0.3
248	iFafa	30°39'13.0068"	30°27'24.073"	M	M	M	H	M	U	M	N	46.4	37.6	0	1.8
249	uMdesingane	30°40'17.7275"	30°25'33.772"	H	L	VH	VH	M	0	0	N	2.0	2.0	0	0.1
250	iSezela	30°40'39.8747"	30°24'54.046"	M	L	VH	H	M	P	0	N	3.9	3.9	698	0.5
251	uMkhumbane	30°40'58.2060"	30°24'20.185"	M	L	H	H	M	0	0	N	3.8	3.5	0	0.3
252	iNkomba	30°43'13.3608"	30°21'10.357"	M	L	H	H	L	0	0	N	0.7	0.7	0	0.0
253	uMuziwezinto	30°42'32.9219"	30°22'3.5075"	M	M	H	H	M	U	0	N	23.2	20.1	0	0.8

#	NAME	East DD MM SS	South DD MM SS	Cumulative	Flow	Pollution	Habitat loss	Fishing Effort	Artificial Breaching	Invasive Aliens: Plants	Invasive Aliens: Fish	Natural MAR (MCM)	Present MAR (MCM)	WW volume	Fish Catches (t)
254	uMzimayi	30°43'38.3448"	30°20'47.292"	M	H	H	M	M	0	0	N	6.1	4.5	0	0.2
255	Rocky Bay	30°44'4.695"	30°20'1.7045"	H	H	H	M	M	0	M	N	0.0	0.0	0	0.0
256	uMphambanyoni	30°45'33.4655"	30°16'49.432"	M	L	H	H	M	0	0	N	60.1	55.5	1 605	0.3
257	aMahlongwa	30°45'50.1336"	30°16'8.8968"	M	L	H	M	M	P	M	N	13.8	13.2	0	8.1
258	uMahlongwane	30°47'37.4424"	30°13'30.478"	M	L	H	H	M	0	M	N	2.7	2.9	2 000	0.8
259	uMkhomazi	30°48'13.9248"	30°12'9.3203"	M	M	M	VH	VH	P	M	H	1 077.7	926.1	1 000	11.8
260	iNgane	30°49'1.67159"	30°10'43.824"	M	L	M	H	L	0	M	N	3.8	4.3	0	2.0
261	uMgababa	30°49'50.6171"	30°9'20.4120"	M	M	M	H	H	0	M	N	10.6	9.6	0	2.7
262	uMsimbazi	30°50'51.5724"	30°7'46.2863"	L	L	M	H	H	0	M	N	10.0	10.3	0	2.2
263	iLovu	30°51'27.2700"	30°6'19.5552"	M	H	M	H	VH	U	M	N	119.1	82.5	0	3.4
264	aManzanamtoti	30°52'23.7395"	30°4'40.9152"	VH	H	VH	H	L	U	M	L	2.8	6.6	4 763	0.4
265	aManzimtoti	30°53'4.71480"	30°3'30.8159"	H	M	VH	VH	L	L	M	L	5.3	6.7	0	0.6
266	iZimbokodo	30°56'12.4367"	30°0'34.9524"	VH	H	VH	VH	L	P	M	N	31.5	53.5	33 621	0.8
267	iSiphingo	30°57'4.53959"	29°59'45.229"	VH	VH	VH	VH	L	L	M	L	109.4	2.9	0	0.8
268	Durban Bay	31°3'.45.0288"	29°51'58.085"	VH	H	M	VH	VH	0	0	L	36.3	63.4	15 880	95.9
269	uMngeni	31°2'.33.4031"	29°48'30.585"	VH	VH	VH	VH	VH	L	M	VH	671.3	208.5	121 999	8.9
270	uMhlanga	31°6'.5.30279"	29°42'10.832"	H	H	VH	M	M	U	M	H	13.3	22.3	4 983	0.9
271	uMdloti	31°7'.44.9328"	29°39'2.1348"	H	H	VH	H	M	U	M	H	100.2	85.0	7 529	2.9
272	uThongathi	31°11'5.58600"	29°34'24.275"	H	M	VH	H	L	U	M	H	70.8	79.2	12 422	0.8
273	uMhlali	31°16'41.4119"	29°27'36.575"	H	M	VH	H	M	0	M	N	56.3	53.7	800	1.9
274	Bob's Stream	31°17'41.0496"	29°26'16.717"	L	L	H	M	L	0	0	N	0.5	0.5	0	0.0
275	uSetheni	31°18'10.4544"	29°25'45.667"	L	L	H	H	L	0	0	N	1.4	1.4	0	0.2
276	uMvoti	31°20'5.47439"	29°23'30.775"	H	H	H	VH	L	U	H	H	374.7	225.6	12 156	2.9
277	uMdlotane	31°22'25.7844"	29°21'8.6507"	L	L	H	L	M	U	0	N	6.0	5.8	0	0.8
278	iNonoti	31°24'25.4880"	29°19'7.8852"	M	L	H	H	M	U long time	0	N	36.2	34.7	330	1.4
279	iZinkwazi	31°26'36.5207"	29°16'53.724"	L	L	M	M	H	U	0	N	14.5	14.0	0	4.2
280	uThukela	31°30'3.62160"	29°13'27.310"	H	M	H	H	VH	U	M	VH	3 753.6	2 756.4	0	29.8
281	aMatigulu/iNyoni	31°38'40.3872"	29°5'1.30559"	L	L	L	L	H	U	0	N	192.3	178.0	0	24.0
282	iSiyaya	31°45'47.2968"	28°58'0.7716"	VH	VH	VH	VH	M	0	0	N	6.5	6.5	0	0.2
283	uMlalazi	31°49'22.8971"	28°56'40.995"	L	M	L	M	H	L	M	H	164.3	124.6	0	23.4
284	uMhlathuze	32°2'59.9675"	28°50'55.949"	H	L	VH	VH	VH	0	0	H	645.0	645.0	0	140.1
285	Richards Bay	32°5'51.9611"	28°48'51.138"	H	H	H	VH	VH	0	0	N	0.0	0.0	0	263.0
286	iNhlabane	32°15'25.6247"	28°39'41.061"	VH	M	H	VH	H	P	0	N	29.0	29.0	0	53.2

#	NAME	East DD MM SS	South DD MM SS	Cumulative	Flow	Pollution	Habitat loss	Fishing Effort	Artificial Breaching	Invasive Aliens: Plants	Invasive Aliens: Fish	Natural MAR (MCM)	Present MAR (MCM)	WW volume	Fish Catches (t)
287	iMfolozi/uMsubuze	32°25'30.1836"	28°23'21.390"	H	L	VH	VH	VH	L	H	N	885.0	885.0	0	14.9
288	St Lucia	32°25'29.0243"	28°22'57.226"	H	L	M	M	VH	L	M	N	417.9	362.3	0	296.0
289	uMgobezeleni	32°40'50.1419"	27°32'22.390"	L	L	L	L	H	U	0	N	0.0	0.0	0	4.6
290	Kosi	32°52'50.8404"	26°53'42.626"	L	L	L	L	VH	Y	L	N	0.0	0.0	0	349.8

APPENDIX D: ESTUARY CONDITION AND BIODIVERSITY (CONSERVATION) PRIORITIES

NAME	Present Ecological State	Recommended Ecological Condition	Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie et al. 2002, Turpie en Clark 2009)	Biodiversity priority core set (national and/or CAPE)	Biodiversity Priority Rating (5 =High priority)	Ramsar status	IBA	EBSA	DAFF Important Fish Nurseries (5 =Very High priority, 3= Priority)
Orange	D	D	High Importance	SA/CAPE	Priority	YES	YES	YES	High
Buffels	D	D	Low to Average Importance						Low
Swartlintjies	B	B	Low to Average Importance						Low
Spoeg	A/B	A/B	Low to Average Importance	SA	Priority			Adjacent	Medium-Low
Groen	B	B	Low to Average Importance	SA	Priority			Adjacent	Low
Sout (Noord)	E	E	Low to Average Importance					Adjacent	Low
Olifants	C	C	High Importance	SA/CAPE/WC	Priority		YES		High
Jakkals	D	D	Low to Average Importance						Low
Wadrift	E	E	Low to Average Importance					Adjacent	Low
Verlorenvlei	D	D	Important	SA/WC	Priority	YES	YES	Adjacent	Medium
Groot Berg	C	C	High Importance	SA/CAPE/WC	Priority		YES	Adjacent	High
Langebaan	B	B	High Importance	SA/WC	Priority		YES	YES	High
Diep/Rietvlei	D	D	Important	SA/CAPE	Priority		YES		High
Sout (Wes)	F	F	Low to Average Importance						Low
Disa	E	E	Low to Average Importance						Low
Wildevoëllei	D/E	D	High Importance						Low
Schuster	B	B	Low to Average Importance						Low
Krom	A/B	A	Low to Average Importance	SA/CAPE	Priority				Low
Silwermyr	E	E	Low to Average Importance					Adjacent	Low
Zand	D	D	Important	SA/CAPE	Priority			Adjacent	High
Zeekoei	E	E	Low to Average Importance					Adjacent	Low
Eerste	E	E	Low to Average Importance	SA/CAPE	Priority			Adjacent	Medium-Low
Lourens	D	D	Low to Average Importance	SA/CAPE	Priority			Adjacent	Low
Sir Lowry's Pass	E	E	Low to Average Importance					Adjacent	Low
Steenbras	B	B	Low to Average Importance					Adjacent	Low
Rooiels	A	A	Low to Average Importance	WC	Priority			Adjacent	Low
Buffels (Oos)	B	B	Low to Average Importance					Adjacent	Low
Palmiet	C	C	Important	SA/CAPE/WC	Priority			Adjacent	Low
Bot/Kleinmond	C	C	High Importance	SA/CAPE/WC	Priority	YES	YES	Adjacent	High
Onrus	D	D	Low to Average Importance					Adjacent	Low
Klein	C	C	High Importance	SA/CAPE/WC	Priority			Adjacent	High
Uilkraals	D	D	Important	SA/WC	Priority			Adjacent	Medium
Ratel	B	B	Low to Average Importance	SA	Priority			Adjacent	Low
Heuningnes	C/D	B	High Importance	SA/CAPE/WC	Priority	YES	YES	Adjacent	High
Klipdriffontein	A	A	Low to Average Importance	SA/CAPE	Priority				Low
Brede	B/C	B	High Importance	SA/WC	Priority				High
Duiwenhoks	C	C	High Importance						High-Medium
Goukou	C	C	High Importance	SA/CAPE/WC	Priority				High-Medium
Gouritz	C/D	C	Important	SA/CAPE	Priority				High
Blinde	B/C	C	Low to Average Importance						Low
Tweekuilen	D/E	E	Low to Average Importance						Low
Gericke	D/E	E	Low to Average Importance						Low
Hartenbos	D	D	Important						Medium
Klein Brak	C	C	Low to Average Importance						High-Medium

Groot Brak	D	D	Important						Medium
Maalgate	B	B	Low to Average Importance						Low
Gwaing	B/C	B	Low to Average Importance						Low
Kaaimans	B	B	Low to Average Importance	SA	Priority				Low
Touw/Wilderness	B/C	C	High Importance	SA/CAPE	Priority	YES	YES		High
Swartvlei	B/C	B	High Importance	SA/CAPE	Priority				High
Goukamma	A/B	B	Important	SA/CAPE/WC	Priority				Medium
Knysna	B/C	B	High Importance	SA/CAPE	Priority				High
Noetsie	B	B	Low to Average Importance	CAPE/WC	Priority				Low
Piesang	D	D	Important	SA	Priority			Adjacent	Medium
Keurbooms	A/B	A/B	High Importance	SA/CAPE/WC	Priority			Adjacent	High
Matjies	A/B	A/B	Low to Average Importance					Adjacent	Low
Sout (Oos)	A	A	Low to Average Importance	SA/CAPE	Priority			Adjacent	Low
Groot (Wes)	B	B	Important	SA/CAPE	Priority			Adjacent	Low
Bloukrans	A	A	Low to Average Importance	SA/CAPE	Priority			Adjacent	Low
Lottering	A	A	Low to Average Importance	SA/CAPE	Priority			Adjacent	Low
Elandsbos	A	A	Low to Average Importance	SA/CAPE	Priority			Adjacent	Low
Storms	A	A	Low to Average Importance	SA/CAPE	Priority			Adjacent	Low
Elands	A	A	Low to Average Importance	SA/CAPE	Priority			Adjacent	Low
Groot (Oos)	A/B	A/B	Low to Average Importance	SA/CAPE	Priority			Adjacent	Low
Tsitsikamma	B	B	Low to Average Importance	SA	Priority				Low
Klipdrif (Oos)	B/C	B	Low to Average Importance						Low
Slang	C/D	C	Low to Average Importance						Low
Kromme	D	D	High Importance	SA/CAPE	Priority				High
Seekoei	D/E	D	Important	SA/CAPE	Priority				Medium
Kabeljous	C	C	Important						Medium
Gamtoos	B/C	B	High Importance	SA/CAPE	Priority		YES		High
Van Stadens	B	B	Low to Average Importance	SA/CAPE	Priority		YES		Low
Maitland	B/C	B	Low to Average Importance	SA/CAPE	Priority		YES		Low
Baakens	E	E	Low to Average Importance					Adjacent	Low
Papkuils	F	F	Low to Average Importance					Adjacent	Low
Swartkops	D	D	High Importance	SA/CAPE	Priority		YES	YES	High
Coega (Ngqurha)	E	E	Low to Average Importance					Adjacent	Low
Sundays	C	C	Important	SA/CAPE	Priority			YES	High
Boknes	C	C	Low to Average Importance					Adjacent	Low
Bushmans	B/C	B	Important	SA/CAPE	Priority			YES	High
Kariega	C	C	High Importance	SA/CAPE	Priority			YES	High
Grant's	C	C	Low to Average Importance					Adjacent	Low
Kasouga	B	B	Important					YES	Medium
Kowie	C	C	High Importance					YES	High
Rufane	C	C	Low to Average Importance					Adjacent	Low
Riet	B	B	Important					Adjacent	Low
West Kleinemonde	B	B	Important					Adjacent	Medium
East Kleinemonde	B	B	Important					Adjacent	Medium
Great Fish	C	C	High Importance	SA/CAPE	Priority			YES	High
Old Woman's	C	C	Low to Average Importance					Adjacent	Low
Mpekweni	B	B	High Importance					Adjacent	Medium
Mtati (Mthathi)	B	B	High Importance	CAPE	Priority			Adjacent	Medium
Mgwalana	B	B	High Importance	SA	Priority			Adjacent	Medium
Bira (Bhirha)	B	B	Important	SA	Priority			Adjacent	Medium
Gqutywa	B	B	Important	SA/CAPE	Priority			Adjacent	Medium
Ngculura (Ngculurha)	B	B	Low to Average Importance					Adjacent	Low
Mtana	B	B	Low to Average Importance					Adjacent	Low
Keiskamma	B/C	B	High Importance	SA/CAPE	Priority			YES	High
Nqinisa	A/B	A	Low to Average Importance	SA	Priority			Adjacent	Low
Kiwane (Khiwane)	A/B	A	Low to Average Importance					Adjacent	Medium
Tyolomnqa	B	B	Important					Adjacent	Medium
Shelbertsroom	B/C	B	Low to Average Importance					Adjacent	Low
Lilyvale	B	B	Low to Average Importance					Adjacent	Low
Ross' Creek	A/B	A/B	Low to Average Importance					Adjacent	Low
Ncera (Ncerha)	B	B	Low to Average Importance	SA	Priority			Adjacent	Low
Mlele	B	B	Low to Average Importance					Adjacent	Low
Mcantsi	B	B	Low to Average Importance					Adjacent	Low
Gxulu	B/C	B	Low to Average Importance					Adjacent	Medium
Goda	B	B	Low to Average Importance	CAPE	Priority			Adjacent	Low

Hlozi	B	B	Low to Average Importance					Adjacent	Low
Hickman's	B	B	Low to Average Importance					Adjacent	Low
Buffalo	D	D	Low to Average Importance					Adjacent	Medium
Blind	D	D	Low to Average Importance					Adjacent	Low
Hlaze (iHlanze)	C/D	C	Low to Average Importance					Adjacent	Low
Nahoon	C	C	Important					Adjacent	Medium
Qinira (Quinirha)	B/C	B	Important					Adjacent	Low
Gqunube	B	B	Important	SA	Priority			Adjacent	Medium
Kwelerha (Kwelerha)	B	B	Important	SA	Priority			Adjacent	Medium
Bulura (Bulurha)	B	B	Low to Average Importance					Adjacent	Low
Cunge	A/B	A/B	Low to Average Importance					Adjacent	Low
Cintsa	B	B	Low to Average Importance					Adjacent	Low
Cefane	B	B	Important					Adjacent	Medium
Kwenxura (Kwenxurha)	A/B	A/B	Low to Average Importance	SA/CAPE	Priority			Adjacent	Medium
Nyara (Nyarha)	A/B	A/B	Low to Average Importance					Adjacent	Low
Imtwendwe (Mtwendwe)	A/B	A/B	Low to Average Importance					Adjacent	Low
Haga-haga	A/B	A/B	Low to Average Importance					Adjacent	Low
Mtendwe	A/B	A/B	Low to Average Importance					Adjacent	Low
Quko	A	A	Low to Average Importance	SA/CAPE	Priority			Adjacent	Medium
Morgan	B	B	Low to Average Importance					Adjacent	Medium
Cwili	B	B	Low to Average Importance					Adjacent	Low
Great Kei	C	C	High Importance	SA/CAPE	Priority			YES	High
Gxara (Gxarha)	A/B	A/B	Low to Average Importance						Low
Ngogwane	B	B	Low to Average Importance						Low
Qolora (Qolorha)	B	B	Important						Low
Ncizele	A/B	A/B	Low to Average Importance	SA	Priority				Low
Timba	B	B	Low to Average Importance						Low
Kobonqaba (Khobonqaba)	B	B	Low to Average Importance						Medium
Nxaxo/Ngqusi	B	B	Important	SA/CAPE	Priority				Medium
Cebe	A/B	A/B	Low to Average Importance				YES		Low
Gqunqe	A/B	A/B	Low to Average Importance						Low
Zalu	A/B	A/B	Low to Average Importance						Low
Ngqwara (Ngqwarha)	A/B	A/B	Low to Average Importance	SA	Priority				Low
Sihlontlweni	A/B	A/B	Low to Average Importance						Low
Nebelele	A/B	A	Low to Average Importance						Low
Qora (Qhorha)	A/B	A/B	Important	SA/CAPE	Priority				Medium
Jujura (Jujurha)	A/B	A/B	Low to Average Importance						Low
Ngadla	A/B	A/B	Low to Average Importance	SA	Priority				Low
Shixini	A/B	A/B	Low to Average Importance	CAPE	Priority				Low
Beechamwood	A/B	A/B	Low to Average Importance						Low
Kwazlelitsha (Kwazwedala)	A/B	A/B	Low to Average Importance						Low
Kwa-Goqo	A/B	A/B	Low to Average Importance						Low
Ku-Nocekedwa	A/B	A/B	Low to Average Importance						Low
Nqabara/Nqabarana	A/B	A/B	Important	SA	Priority				Medium
Ngomane (East)	B	B	Low to Average Importance						Low
Ngoma/Kobule	A/B	A/B	Low to Average Importance						Low
Mendu	A/B	A/B	Low to Average Importance	SA	Priority				Low
Mendwana	A	A	Low to Average Importance	SA	Priority				Low
Mbashe	B	B	High Importance	SA/CAPE	Priority				High
Ku-Mpenzu	A/B	A/B	Low to Average Importance	SA/CAPE	Priority				Low
Ku-Bhula (Mbhanyana)	A/B	A	Low to Average Importance	SA/CAPE	Priority				Low
Kwa-Suku	A/B	A/B	Low to Average Importance	SA	Priority				Low
Ntlonyane	B	B	Low to Average Importance	SA/CAPE	Priority				Low
Nkanya	B	B	Low to Average Importance	SA/CAPE	Priority				Low
Sundwana	A	A	Low to Average Importance	SA	Priority				Low
Xora	A/B	A/B	Important	SA	Priority				Medium
Bulungula	A/B	A/B	Low to Average Importance						Low
Ku-Amanzimuzama	A	A	Low to Average Importance						Low
Nqakanqa	A/B	A/B	Low to Average Importance	SA	Priority				Low
Mdikana	A	A	Low to Average Importance						Low
Mncwasa	B	B	Low to Average Importance						Low
Mpako	A/B	A/B	Low to Average Importance						Low

Nenga	C	C	Low to Average Importance						Low
Mapuzi	A/B	A/B	Low to Average Importance						Low
Mtata	C	C	Important	SA	Priority				Medium
Thsani	B	B	Low to Average Importance						Low
Mdumbi	B	B	Important	CAPE	Priority				Medium
Lwandilana	A/B	A/B	Low to Average Importance	SA	Priority				Low
Lwandile	A/B	A/B	Low to Average Importance						Low
Mtakatye	A/B	A/B	Important	SA	Priority			Adjacent	Medium
Hluleka	A/B	A/B	Low to Average Importance	SA	Priority			Adjacent	Low
Mnenu	A/B	A/B	Low to Average Importance					Adjacent	Medium
Mtonga	A/B	A/B	Low to Average Importance					Adjacent	Low
Mpande	A/B	A/B	Low to Average Importance					Adjacent	Low
Sinangwana	B	B	Low to Average Importance					Adjacent	Low
Mngazana	B	B	High Importance	SA	Priority			Adjacent	High
Mngazi	B	B	Low to Average Importance					Adjacent	Medium
Gxwaleni	A	A	Low to Average Importance					Adjacent	Low
Bulolo	B	B	Low to Average Importance					Adjacent	Low
Mtumbane	B	B	Low to Average Importance					Adjacent	Low
Mzimvubu	B	B	Important	SA	Priority			Adjacent	High
Ntlupeni	A/B	A/B	Low to Average Importance					Adjacent	Low
Nkodusweni	A/B	A/B	Low to Average Importance	SA	Priority			Adjacent	Low
Mntafufu	B	B	Important	SA	Priority			Adjacent	Medium
Ingo	A	A	Low to Average Importance					Adjacent	Low
Mzintlava	A/B	A	Low to Average Importance	SA	Priority			Adjacent	Medium
Mzimpunzi	A/B	A/B	Low to Average Importance	SA	Priority			Adjacent	Low
Kwanyambalala	B	B	Low to Average Importance	SA	Priority			Adjacent	Low
Mbotyi	B	B	Important	SA	Priority			Adjacent	Low
Mkozi	A	A	Low to Average Importance	SA	Priority			Adjacent	Low
Sikatsha	A	A	Low to Average Importance	SA	Priority			Adjacent	Low
Lupatana	A/B	A/B	Low to Average Importance	SA	Priority			Adjacent	Low
Mkweni	A	A	Low to Average Importance	SA	Priority			Adjacent	Low
Msikaba	A/B	A	Low to Average Importance	SA	Priority			Adjacent	Low
Mgwegwe	A	A	Low to Average Importance	SA	Priority			Adjacent	Low
Mgwetyana	A	A	Low to Average Importance	SA	Priority			Adjacent	Low
Mtentu	A/B	A/B	Important	SA	Priority			Adjacent	Medium
Sikombe	A/B	A/B	Low to Average Importance	SA	Priority			Adjacent	Low
Kwanyana	A/B	A	Low to Average Importance	SA	Priority			Adjacent	Low
Mtolane	A	A	Low to Average Importance	SA	Priority			Adjacent	Low
Mnyameni	A/B	A/B	Low to Average Importance	SA	Priority			Adjacent	Low
Mpahlanganyana	A/B	A/B	Low to Average Importance	SA	Priority			Adjacent	Low
Mpahlane	A/B	A/B	Low to Average Importance	SA	Priority			Adjacent	Low
Mzamba	B	B	Important	SA	Priority			Adjacent	Medium
Mtentwana	C	C	Low to Average Importance	SA	Priority			Adjacent	Low
uMthavuna	B	B	Important	SA	Priority		YES	Adjacent	High
iSolwane	B	B	Low to Average Importance					Adjacent	Low
iSandlu	C	C	Low to Average Importance					Adjacent	Low
uMbhoyibhoyi	B	B	Low to Average Importance					Adjacent	Low
uMuntongazi	B/C	B	Low to Average Importance					Adjacent	Low
iKhandalendlovu	B	B	Low to Average Importance					Adjacent	Low
iMpenjani	B/C	C	Low to Average Importance	SA	Priority			Adjacent	Low
uMhlangomkhulu (South) (Umhlangankulu)	C	C	Low to Average Importance					Adjacent	Low
iKhaba	C	C	Low to Average Importance					Adjacent	Low
iMbizana	B	B	Low to Average Importance					Adjacent	Low
iMvutshini	B/C	B	Low to Average Importance					Adjacent	Low
iBilanhlonhlo	C	C	Low to Average Importance					Adjacent	Low
uVuzana	C	C	Low to Average Importance					Adjacent	Low
iKongeni	D/E	D	Low to Average Importance					Adjacent	Low
uVunguza	B	B	Low to Average Importance					Adjacent	Low
oHlangeni	C	C	Low to Average Importance					Adjacent	Low
iZotsha	B/C	B	Low to Average Importance	SA/KZN	Priority			Adjacent	Low
iBhobhoyi	B/C	B	Low to Average Importance					Adjacent	Low
uMbango	E	E	Low to Average Importance					Adjacent	Low
uMzimkhulu	B	B	Important	SA/KZN	Priority			Adjacent	High

uMthente	C	C	Low to Average Importance					Adjacent	Low
uMhlangomkhulu (North) (Mhlangamkulu)	C	C	Low to Average Importance					Adjacent	Low
iDombe	D	D	Low to Average Importance	SA/KZN	Priority			Adjacent	Low
iKhoshwana	C/D	C	Low to Average Importance	SA/KZN	Priority			Adjacent	Low
iNjambili	C	C	Low to Average Importance	SA/KZN	Priority			Adjacent	Low
uMzumbe	C/D	C	Low to Average Importance					Adjacent	Low
uMhlabashana	B/C	B	Low to Average Importance	SA	Priority			Adjacent	Medium
uMhlungwa	C	C	Low to Average Importance					Adjacent	Low
uMfazazala	C	C	Low to Average Importance	SA/KZN	Priority			Adjacent	Low
uMakhosi	B/C	B/C	Low to Average Importance	SA/KZN	Priority			Adjacent	Low
uMnamfu	C	C	Low to Average Importance					Adjacent	Low
uMthwalume	C	C	Low to Average Importance					Adjacent	Low
uMvuzi	C	C	Low to Average Importance					Adjacent	Low
iFafa	C/D	C	Important					Adjacent	Low
uMdesingane	D	D	Low to Average Importance					Adjacent	Low
iSezela	C	C	Low to Average Importance					Adjacent	Low
uMkhumbane	C	C	Low to Average Importance					Adjacent	Low
iNkomba	C	C	Low to Average Importance					Adjacent	Low
uMuziwezinto	C/D	C	Low to Average Importance					Adjacent	Low
uMzimayi	C/D	C	Low to Average Importance					Adjacent	Low
Rocky Bay	C/D	C/D	Low to Average Importance					Adjacent	Low
uMphambanyoni	C	C	Low to Average Importance					Adjacent	Low
aMahlongwa	C	C	Low to Average Importance	KZN	Priority			Adjacent	Low
uMahlongwane	C	C	Low to Average Importance	KZN	Priority			Adjacent	Low
uMkhomazi	C	C	Important	SA/KZN	Priority			Adjacent	High
iNgane	C	C	Low to Average Importance					Adjacent	Low
uMgababa	C	C	Low to Average Importance	SA/KZN	Priority			Adjacent	Medium
uMsimbazi	B/C	B	Low to Average Importance	SA/KZN	Priority			Adjacent	Medium
iLovu	C/D	C	Low to Average Importance	SA/KZN	Priority				Medium
aManzanamtoti	E	E	Low to Average Importance						Low
aManzimtoti	D/E	D	Low to Average Importance						Low
iZimbokodo	E	E	Low to Average Importance						Low
iSiphingo	F	F	Low to Average Importance						Low
Durban Bay	E	E	High Importance	SA/KZN	Priority				High
uMngeni	E	E	Important	SA	Priority				Medium
uMhlanga	D	D	Important	SA/KZN	Priority				Low
uMdloti	D	D	Important						Low
uThongathi	D	D	Important						Low
uMhlali	D	D	Important	SA/KZN	Priority				Low
Bob's Stream	B/C	B	Low to Average Importance					Adjacent	Low
uSetheni	B/C	B	Low to Average Importance					Adjacent	Low
uMvoti	D	D	Low to Average Importance	SA/KZN	Priority			Adjacent	Low
uMdlotane	B	B	Important	SA/KZN	Priority			Adjacent	Low
iNonoti	C	C	Low to Average Importance					Adjacent	Low
iZinkwazi	B/C	B	Important	SA/KZN	Priority			Adjacent	High
uThukela	D	D	Important	KZN	Priority			YES	Medium
aMatigulu/iNyoni	B	B	Important	SA	Priority			Adjacent	High
iSiyaya	E	E	Low to Average Importance	SA	Priority			Adjacent	Low
uMlalazi	B	B	High Importance	SA	Priority		YES	Adjacent	High
uMhlathuze	D	D	High Importance	SA	Priority		YES	Adjacent	High
Richards Bay	D	D	Important	SA	Priority			Adjacent	High
iNhlabane	E	E	Important	KZN	Priority			Adjacent	Medium
iMfolozi/uMsunduze	D	D	High Importance	SA	Priority	YES	YES		High
St Lucia	D	D	High Importance	SA	Priority	YES	YES		High
uMgobezeleni	B	B	Low to Average Importance	SA	Priority				Low
Kosi	A/B	A	High Importance	SA	Priority	YES	YES		High

APPENDIX E: RESTORATION MEASURES NEEDED TO IMPROVE ESTUARY CONDITION AND PRODUCTIVITY

Estuary	PES	REC	Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie et al. 2002, Turpie en Clark 2009)	DAFF Important Fish Nurseries (5 =Very High priority, 3= priority)	Restore/protect base flows	Restore floods	Manage/reduce stormwater & drainage from flood plain	Improve river water quality	Monitor & reduce/reuse WW	Restore connectivity/ hydrodynamic functioning	Improve mouth management	Rehabilitate riparian areas/ wetlands	Remove alien vegetation	Reduce grazing (sheep, cattle, goats)	Implement cattle exclusion zone	Control mangrove harvesting	Control recreational activities impacting on birds	Remove/reduce fishing pressure/ bait collection	Investigate eradication of alien fish	Restore/protect against impact from mining
Orange	D	D	High Importance	High	●	●	Agric	Agric		●	●	●	●	●				●		●
Buffels	D	D	Low to Average Importance	Low	●		Agric	Agric		●	●	●	●							●
Swartlinterjies	B	B	Low to Average Importance	Low																●
Spoeg	A/B	A/B	Low to Average Importance	Medium-Low	●															●
Groen	B	B	Low to Average Importance	Low	●								●							
Sout (Noord)	E	E	Low to Average Importance	Low	●					●		●								●
Olifants	C	C	High Importance	High	●	●	Agric	Agric	●			●	●	●				●*	●	
Jakkals	D	D	Low to Average Importance	Low	●		Agric	Agric			●	●								
Wadrift	E	E	Low to Average Importance	Low	●		Agric	Agric		●		●		●						
Verlorenvlei	D	D	Important	Medium	●			Agric		●	●	●		●				●*	●	
Groot Berg	C	C	High Importance	High	●	●		Agric	●			●	●				●	●*	●	
Langebaan	B	B	High Importance	High													●	●*		●
Diep/Rietvlei	D	D	Important	High	●		Urban	Urban	●	●	●	●	●				●	●	●	
Sout (Wes)	F	F	Low to Average Importance	Low	●		Urban	Urban												
Disa	E	E	Low to Average Importance	Low	●		Urban						●				●		●	
Wildevoolvlei	D/E	D	High Importance	Low	●				●	●		●	●							

Estuary	PES	REC	Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie et al. 2002, Turpie en Clark 2009)	DAFF Important Fish Nurseries (5 =Very High priority, 3= priority)	Restore/protect base flows	Restore floods	Manage/reduce stormwater & drainage from flood plain	Improve river water quality	Monitor & reduce/reuse WW	Restore connectivity/ hydrodynamic functioning	Improve mouth management	Rehabilitate riparian areas/ wetlands	Remove alien vegetation	Reduce grazing (sheep, cattle, goats)	Implement cattle exclusion zone	Control mangrove harvesting	Control recreational activities impacting on birds	Remove/reduce fishing pressure/ bait collection	Investigate eradication of alien fish	Restore/protect against impact from mining
Schuster	B	B	Low to Average Importance	Low	●		Urban													
Krom	A/B	A	Low to Average Importance	Low																
Silwermyr	E	E	Low to Average Importance	Low	●		Urban	Urban		●	●						●		●	
Zand	D	D	Important	High	●		Urban	Urban		●	●	●	●				●	●	●	
Zeekoei	E	E	Low to Average Importance	Low	●		Urban	Urban	●	●	●		●				●		●	
Eerste	E	E	Low to Average Importance	Medium-Low	●			Urban	●	●	●	●	●						●	
Lourens	D	D	Low to Average Importance	Low	●		Urban	Urban			●	●	●				●		●	
Sir Lowry's Pass	E	E	Low to Average Importance	Low	●		Urban	Urban					●							
Steenbras	B	B	Low to Average Importance	Low	●								●							
Rooiels	A	A	Low to Average Importance	Low									●				●			
Buffels (Oos)	B	B	Low to Average Importance	Low	●								●							
Palmiet	C	C	Important	Low	●	●		Agric		●		●	●						●	
Bot/Kleinmond	C	C	High Importance	High	●			Agric	●		●		●				●	●*	●	
Onrus	D	D	Low to Average Importance	Low	●	●	Urban	Urban			●		●						●	
Klein	C	C	High Importance	High	●		Urban	Agric	●		●		●				●	●*	●	
Uilkraals	D	D	Important	Medium	●			Agric	●	●	●	●	●				●	●		
Ratel	B	B	Low to Average Importance	Low				Agric												
Heuningnes	C/D	B	High Importance	High	●		Agric	Agric		●	●	●	●	●			●	●	●	
Klipdrifsfontein	A	A	Low to Average Importance	Low																
Brede	B/C	B	High Importance	High	●			Agric				●	●				●	●	●	
Duiwenhoks	C	C	High Importance	High-Medium	●		Agric	Agric				●	●				●	●	●	

Estuary	PES	REC	Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie et al. 2002, Turpie en Clark 2009)	DAFF Important Fish Nurseries (5 =Very High priority, 3= priority)	Restore/protect base flows	Restore floods	Manage/reduce stormwater & drainage from flood plain	Improve river water quality	Monitor & reduce/reuse WW	Restore connectivity/ hydrodynamic functioning	Improve mouth management	Rehabilitate riparian areas/ wetlands	Remove alien vegetation	Reduce grazing (sheep, cattle, goats)	Implement cattle exclusion zone	Control mangrove harvesting	Control recreational activities impacting on birds	Remove/reduce fishing pressure/ bait collection	Investigate eradication of alien fish	Restore/protect against impact from mining
Goukou	C	C	High Importance	High-Medium	●		Agric	Agric	●			●	●				●	●	●	
Gouritz	C/D	C	Important	High	●	●						●	●				●	●	●	
Blinde	B/C	C	Low to Average Importance	Low	●			Urban					●							
Tweekuilen	D/E	E	Low to Average Importance	Low	●		Agric			●										
Gericke	D/E	E	Low to Average Importance	Low	●		Agric			●										
Hartenbos	D	D	Important	Medium	●	●			●	●	●	●	●				●		●	
Klein Brak	C	C	Low to Average Importance	High-Medium	●		Urban	Agric	●	●		●	●				●	●	●	
Groot Brak	D	D	Important	Medium	●	●	Urban	Agric		●	●	●	●				●	●	●	
Maalgate	B	B	Low to Average Importance	Low	●								●							
Gwaing	B/C	B	Low to Average Importance	Low			Urban		●				●						●	
Kaaimans	B	B	Low to Average Importance	Low	●								●				●			
Touw/Wilderness	B/C	C	High Importance	High	●					●	●		●				●	●	●	
Swartvlei	B/C	B	High Importance	High	●			Agric		●	●		●				●			
Goukamma	A/B	B	Important	Medium	●			Agric		●			●				●	●	●	
Knysna	B/C	B	High Importance	High	●		Urban		●								●	●	●	
Noetsie	B	B	Low to Average Importance	Low									●							
Piesang	D	D	Important	Medium	●		Urban	Urban		●	●	●	●				●			
Keurbooms	A/B	A/B	High Importance	High									●				●		●	
Matjies	A/B	A/B	Low to Average Importance	Low																
Sout (Oos)	A	A	Low to Average Importance	Low																

Estuary	PES	REC	Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie et al. 2002, Turpie en Clark 2009)	DAFF Important Fish Nurseries (5 =Very High priority, 3= priority)	Restore/protect base flows	Restore floods	Manage/reduce stormwater & drainage from flood plain	Improve river water quality	Monitor & reduce/reuse WW	Restore connectivity/ hydrodynamic functioning	Improve mouth management	Rehabilitate riparian areas/ wetlands	Remove alien vegetation	Reduce grazing (sheep, cattle, goats)	Implement cattle exclusion zone	Control mangrove harvesting	Control recreational activities impacting on birds	Remove/reduce fishing pressure/ bait collection	Investigate eradication of alien fish	Restore/protect against impact from mining
Groot (Wes)	B	B	Important	Low	●								●					●		
Bloukrans	A	A	Low to Average Importance	Low																
Lottering	A	A	Low to Average Importance	Low																
Elandsbos	A	A	Low to Average Importance	Low																
Storms	A	A	Low to Average Importance	Low																
Elands	A	A	Low to Average Importance	Low																
Groot (Oos)	A/B	A/B	Low to Average Importance	Low				Agric												
Tsitsikamma	B	B	Low to Average Importance	Low	●			Agric												
Klipdrif (Oos)	B/C	B	Low to Average Importance	Low				Agric												
Slang	C/D	C	Low to Average Importance	Low				Agric												
Kromme	D	D	High Importance	High	●	●		Agric				●					●	●	●	
Seekoei	D/E	D	Important	Medium	●			Agric		●	●	●	●							
Kabeljous	C	C	Important	Medium	●			Agric					●						●	
Gamtoos	B/C	B	High Importance	High	●		Agric	Agric				●	●				●	●	●	
Van Stadens	B	B	Low to Average Importance	Low	●								●							
Maitland	B/C	B	Low to Average Importance	Low	●								●							
Baakens	E	E	Low to Average Importance	Low	●		Urban	Urban												
Papkuils	F	F	Low to Average Importance	Low	●		Urban	Urban	●											
Swartkops	D	D	High Importance	High	●	●		Urban				●	●				●	●*	●	
Coega (Ngqurha)	E	E	Low to Average Importance	Low	●							●							●	
Sundays	C	C	Important	High	●			Agric				●	●				●	●	●	

Estuary	PES	REC	Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie et al. 2002, Turpie en Clark 2009)	DAFF Important Fish Nurseries (5 =Very High priority, 3= priority)	Restore/protect base flows	Restore floods	Manage/reduce stormwater & drainage from flood plain	Improve river water quality	Monitor & reduce/reuse WW	Restore connectivity/ hydrodynamic functioning	Improve mouth management	Rehabilitate riparian areas/ wetlands	Remove alien vegetation	Reduce grazing (sheep, cattle, goats)	Implement cattle exclusion zone	Control mangrove harvesting	Control recreational activities impacting on birds	Remove/reduce fishing pressure/ bait collection	Investigate eradication of alien fish	Restore/protect against impact from mining
Boknes	C	C	Low to Average Importance	Low	●															
Bushmans	B/C	B	Important	High	●				●								●	●	●	
Kariega	C	C	High Importance	High	●				●								●	●		
Grant's	C	C	Low to Average Importance	Low	●															
Kasouga	B	B	Important	Medium																
Kowie	C	C	High Importance	High	●				●			●	●				●	●	●	
Rufane	C	C	Low to Average Importance	Low	●															
Riet	B	B	Important	Low																
West Kleinemonde	B	B	Important	Medium																
East Kleinemonde	B	B	Important	Medium				Agric												
Great Fish	C	C	High Importance	High	●			Agric					●				●	●	●	
Old Woman's	C	C	Low to Average Importance	Low	●		Agric	Agric												
Mpekweni	B	B	High Importance	Medium	●			Agric									●	●		
Mtati (Mthathi)	B	B	High Importance	Medium	●															
Mgwalana	B	B	High Importance	Medium	●															
Bira (Bhirha)	B	B	Important	Medium	●															
Gqutywa	B	B	Important	Medium	●															
Ngculura (Ngculurha)	B	B	Low to Average Importance	Low	●															
Mtana	B	B	Low to Average Importance	Low																
Keiskamma	B/C	B	High Importance	High	●			Urban				●			●		●	●	●	

Estuary	PES	REC	Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie et al. 2002, Turpie en Clark 2009)	DAFF Important Fish Nurseries (5 =Very High priority, 3= priority)	Restore/protect base flows	Restore floods	Manage/reduce stormwater & drainage from flood plain	Improve river water quality	Monitor & reduce/reuse WW	Restore connectivity/ hydrodynamic functioning	Improve mouth management	Rehabilitate riparian areas/ wetlands	Remove alien vegetation	Reduce grazing (sheep, cattle, goats)	Implement cattle exclusion zone	Control mangrove harvesting	Control recreational activities impacting on birds	Remove/reduce fishing pressure/ bait collection	Investigate eradication of alien fish	Restore/protect against impact from mining
Nqinisa	A/B	A	Low to Average Importance	Low																
Kiwane (Khiwane)	A/B	A	Low to Average Importance	Medium																
Tyolomnqa	B	B	Important	Medium														●		
Shelbertsstroom	B/C	B	Low to Average Importance	Low				Agric					●							
Lilyvale	B	B	Low to Average Importance	Low																
Ross' Creek	A/B	A/B	Low to Average Importance	Low																
Ncera (Ncerha)	B	B	Low to Average Importance	Low	●															
Mlele	B	B	Low to Average Importance	Low				Agric												
Mcantsi	B	B	Low to Average Importance	Low																
Gxulu	B/C	B	Low to Average Importance	Medium																
Goda	B	B	Low to Average Importance	Low	●		Agric	Agric												
Hlozi	B	B	Low to Average Importance	Low				Agric												
Hickman's	B	B	Low to Average Importance	Low				Urban												
Buffalo	D	D	Low to Average Importance	Medium	●		Urban	Urban										●	●	
Blind	D	D	Low to Average Importance	Low	●		Urban	Urban												
Hlaze (iHlanze)	C/D	C	Low to Average Importance	Low	●		Urban	Urban		●										
Nahoon	C	C	Important	Medium	●	●	Urban	Urban					●				●	●	●	
Qinira (Quinirha)	B/C	B	Important	Low			Urban	Urban			●							●		
Gqunube	B	B	Important	Medium								●						●	●	
Kwelera (Kwelerha)	B	B	Important	Medium														●		
Bulura (Bulurha)	B	B	Low to Average Importance	Low														●		●

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Cunge	A/B	A/B	Low to Average Importance	Low									●							
Cintsa	B	B	Low to Average Importance	Low														●		
Cefane	B	B	Important	Medium														●		
Kwenxura (Kwenxurha)	A/B	A/B	Low to Average Importance	Medium								●	●					●		
Nyara (Nyarha)	A/B	A/B	Low to Average Importance	Low																
Imtwendwe (Mtwendwe)	A/B	A/B	Low to Average Importance	Low																
Haga-haga	A/B	A/B	Low to Average Importance	Low																
Mtendwe	A/B	A/B	Low to Average Importance	Low																
Quko	A	A	Low to Average Importance	Medium																
Morgan	B	B	Low to Average Importance	Medium						●								●	●	
Cwili	B	B	Low to Average Importance	Low															●	
Great Kei	C	C	High Importance	High	●	●			●			●						●	●	
Gxara (Gxarha)	A/B	A/B	Low to Average Importance	Low				Agric				●								
Ngogwane	B	B	Low to Average Importance	Low	●			Agric												
Qolora (Qolorha)	B	B	Important	Low																
Ncizele	A/B	A/B	Low to Average Importance	Low																
Timba	B	B	Low to Average Importance	Low	●															
Kobonqaba (Khobonqaba)	B	B	Low to Average Importance	Medium	●							●								
Nxaxo/Ngqusi	B	B	Important	Medium								●	●		●			●		
Cebe	A/B	A/B	Low to Average Importance	Low																

Estuary	PES	REC	Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie et al. 2002, Turpie en Clark 2009)	DAFF Important Fish Nurseries (5 =Very High priority, 3= priority)	Restore/protect base flows	Restore floods	Manage/reduce stormwater & drainage from flood plain	Improve river water quality	Monitor & reduce/reuse WW	Restore connectivity/ hydrodynamic functioning	Improve mouth management	Rehabilitate riparian areas/ wetlands	Remove alien vegetation	Reduce grazing (sheep, cattle, goats)	Implement cattle exclusion zone	Control mangrove harvesting	Control recreational activities impacting on birds	Remove/reduce fishing pressure/ bait collection	Investigate eradication of alien fish	Restore/protect against impact from mining
Gqunqe	A/B	A/B	Low to Average Importance	Low																
Zalu	A/B	A/B	Low to Average Importance	Low																
Ngqwara (Ngqwarha)	A/B	A/B	Low to Average Importance	Low	●							●								
Sihlontlweni	A/B	A/B	Low to Average Importance	Low																
Nebelele	A/B	A	Low to Average Importance	Low																
Qora (Qhorha)	A/B	A/B	Important	Medium								●						●		●
Jujura (Jujurha)	A/B	A/B	Low to Average Importance	Low	●															
Ngadla	A/B	A/B	Low to Average Importance	Low																
Shixini	A/B	A/B	Low to Average Importance	Low														●		
Beechamwood	A/B	A/B	Low to Average Importance	Low																
Kwazlelitsha (Kwazwedala)	A/B	A/B	Low to Average Importance	Low																
Kwa-Goqo	A/B	A/B	Low to Average Importance	Low																
Ku-Nocekedwa	A/B	A/B	Low to Average Importance	Low																
Nqabara/Nqabarana	A/B	A/B	Important	Medium								●	●		●			●		
Ngomane (East)	B	B	Low to Average Importance	Low																
Ngoma/Kobule	A/B	A/B	Low to Average Importance	Low																
Mendu	A/B	A/B	Low to Average Importance	Low														●		
Mendwana	A	A	Low to Average Importance	Low														●		
Mbashe	B	B	High Importance	High	●							●			●			●*	●	
Ku-Mpenzu	A/B	A/B	Low to Average Importance	Low													●	●		

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Ku-Bhula (Mbhanyana)	A/B	A	Low to Average Importance	Low	●							●	●		●			●		
Kwa-Suku	A/B	A/B	Low to Average Importance	Low														●		
Ntlonyane	B	B	Low to Average Importance	Low								●			●			●		●
Nkanya	B	B	Low to Average Importance	Low																
Sundwana	A	A	Low to Average Importance	Low																
Xora	A/B	A/B	Important	Medium									●			●		●		
Bulungula	A/B	A/B	Low to Average Importance	Low									●							
Ku-Amanzimuzama	A	A	Low to Average Importance	Low																
Nqakanqa	A/B	A/B	Low to Average Importance	Low												●				
Mdikana	A	A	Low to Average Importance	Low																
Mncwasa	B	B	Low to Average Importance	Low				Agric												
Mpako	A/B	A/B	Low to Average Importance	Low				Agric										●		●
Nenga	C	C	Low to Average Importance	Low				Agric		●		●				●		●		
Mapuzi	A/B	A/B	Low to Average Importance	Low				Agric												
Mtata	C	C	Important	Medium	●	●		Urban				●	●		●	●		●	●	●
Thsani	B	B	Low to Average Importance	Low				Agric												
Mdumbi	B	B	Important	Medium								●	●		●	●		●		●
Lwandilana	A/B	A/B	Low to Average Importance	Low																

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Lwandile	A/B	A/B	Low to Average Importance	Low																
Mtakatye	A/B	A/B	Important	Medium								●	●		●	●		●		
Hluleka	A/B	A/B	Low to Average Importance	Low								●	●					●		
Mnenu	A/B	A/B	Low to Average Importance	Medium														●		
Mtonga	A/B	A/B	Low to Average Importance	Low																
Mpande	A/B	A/B	Low to Average Importance	Low																
Sinangwana	B	B	Low to Average Importance	Low																
Mngazana	B	B	High Importance	High	●							●			●	●		●*		
Mngazi	B	B	Low to Average Importance	Medium												●		●		
Gxwaleni	A	A	Low to Average Importance	Low																
Bulolo	B	B	Low to Average Importance	Low														●		
Mtumbane	B	B	Low to Average Importance	Low	●							●								
Mzimvubu	B	B	Important	High	●			Agric					●					●	●	
Ntlupeni	A/B	A/B	Low to Average Importance	Low																
Nkodusweni	A/B	A/B	Low to Average Importance	Low								●								
Mntafufu	B	B	Important	Medium								●	●			●	●	●		
Ingo	A	A	Low to Average Importance	Low																
Mzintlava	A/B	A	Low to Average Importance	Medium								●				●		●		

Estuary	PES	REC	Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie et al. 2002, Turpie en Clark 2009)	DAFF Important Fish Nurseries (5 =Very High priority, 3= priority)	Restore/protect base flows	Restore floods	Manage/reduce stormwater & drainage from flood plain	Improve river water quality	Monitor & reduce/reuse WW	Restore connectivity/ hydrodynamic functioning	Improve mouth management	Rehabilitate riparian areas/ wetlands	Remove alien vegetation	Reduce grazing (sheep, cattle, goats)	Implement cattle exclusion zone	Control mangrove harvesting	Control recreational activities impacting on birds	Remove/reduce fishing pressure/ bait collection	Investigate eradication of alien fish	Restore/protect against impact from mining
Mzimpunzi	A/B	A/B	Low to Average Importance	Low								●								
Kwanyambalala	B	B	Low to Average Importance	Low								●						●		
Mbotyi	B	B	Important	Low								●						●		
Mkozi	A	A	Low to Average Importance	Low												●				
Sikatsha	A	A	Low to Average Importance	Low																
Lupatana	A/B	A/B	Low to Average Importance	Low																
Mkweni	A	A	Low to Average Importance	Low																
Msikaba	A/B	A	Low to Average Importance	Low									●					●		
Mgwegwe	A	A	Low to Average Importance	Low																
Mgwetyana	A	A	Low to Average Importance	Low																
Mtentu	A/B	A/B	Important	Medium	●							●	●			●		●	●	
Sikombe	A/B	A/B	Low to Average Importance	Low								●								
Kwanyana	A/B	A	Low to Average Importance	Low																
Mtolane	A	A	Low to Average Importance	Low																
Mnyameni	A/B	A/B	Low to Average Importance	Low								●						●		
Mpahlanyana	A/B	A/B	Low to Average Importance	Low														●		
Mpahlane	A/B	A/B	Low to Average Importance	Low														●		
Mzamba	B	B	Important	Medium									●					●		

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Mtentswana	C	C	Low to Average Importance	Low	●		Urban			●		●				●				
uMthavuna	B	B	Important	High									●					●		
iSolwane	B	B	Low to Average Importance	Low				Agric					●							●
iSandlu	C	C	Low to Average Importance	Low				Agric					●							
uMbhoiyibhoiyi	B	B	Low to Average Importance	Low			Urban						●							
uMuntongazi	B/C	B	Low to Average Importance	Low			Urban		●											
iKhandalendlovu	B	B	Low to Average Importance	Low			Urban	Agric					●							●
iMpenjani	B/C	C	Low to Average Importance	Low					●			●	●					●		●
uMhlangomkhulu (South) (Umhlangankulu)	C	C	Low to Average Importance	Low			Urban	Agric												
iKhaba	C	C	Low to Average Importance	Low			Urban	Agric				●	●							●
iMbizana	B	B	Low to Average Importance	Low			Urban	Agric					●					●	●	
iMvutshini	B/C	B	Low to Average Importance	Low			Urban	Agric					●							
iBilanhlonhlo	C	C	Low to Average Importance	Low			Urban	Agric			●	●	●							
uVuzana	C	C	Low to Average Importance	Low			Urban	Agric					●							
iKongeni	D/E	D	Low to Average Importance	Low	●		Urban	Agric	●	●	●	●						●	●	
uVunguza	B	B	Low to Average Importance	Low			Urban		●				●							
oHlangeni	C	C	Low to Average Importance	Low			Urban		●		●	●						●		●
iZotsha	B/C	B	Low to Average Importance	Low				Agric			●	●	●					●		
iBhobhoiyi	B/C	B	Low to Average Importance	Low				Agric	●			●								
uMbango	E	E	Low to Average Importance	Low	●		Urban	Agric	●	●		●								●

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uMzimkhulu	B	B	Important	High							●		●					●*		
uMthente	C	C	Low to Average Importance	Low	●		Urban	Agric				●								
uMhlangomkhulu (North) (Mhlangamkulu)	C	C	Low to Average Importance	Low	●		Urban	Agric					●							
iDombe	D	D	Low to Average Importance	Low	●		Urban	Agric		●		●	●							
iKhoshwana	C/D	C	Low to Average Importance	Low			Urban	Agric	●			●								
iNjambili	C	C	Low to Average Importance	Low	●			Agric		●		●	●						●	●
uMzumbe	C/D	C	Low to Average Importance	Low				Agric				●	●							
uMhlabashana	B/C	B	Low to Average Importance	Medium			Urban	Agric	●			●	●							
uMhlungwa	C	C	Low to Average Importance	Low			Urban	Agric				●	●							
uMfazezala	C	C	Low to Average Importance	Low	●			Agric				●						●		
uMakhosi	B/C	B/C	Low to Average Importance	Low				Agric				●								
uMnamfu	C	C	Low to Average Importance	Low				Agric										●		●
uMthwalume	C	C	Low to Average Importance	Low			Urban	Agric					●					●		
uMvuzi	C	C	Low to Average Importance	Low				Agric										●		●
iFafa	C/D	C	Important	Low	●						●	●	●					●		
uMdesingane	D	D	Low to Average Importance	Low			Urban	Agric		●		●						●		
iSezela	C	C	Low to Average Importance	Low			Urban	Agric	●			●						●		
uMkhumbane	C	C	Low to Average Importance	Low			Urban	Agric				●						●		
iNkomba	C	C	Low to Average Importance	Low			Urban	Agric				●								
uMuziwezinto	C/D	C	Low to Average Importance	Low	●			Agric			●	●						●		

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uMzimayi	C/D	C	Low to Average Importance	Low	●			Agric		●								●		
Rocky Bay	C/D	C/D	Low to Average Importance	Low	●								●					●		●
uMphambanyoni	C	C	Low to Average Importance	Low			Urban		●			●						●		●
aMahlongwa	C	C	Low to Average Importance	Low								●	●					●		
uMahlongwane	C	C	Low to Average Importance	Low			Urban	Agric	●			●	●					●		●
uMkhomazi	C	C	Important	High	●			Agric	●			●	●				●	●*	●	●
iNgane	C	C	Low to Average Importance	Low								●	●							
uMgababa	C	C	Low to Average Importance	Medium	●			Urban				●	●					●*		
uMsimbazi	B/C	B	Low to Average Importance	Medium				Urban				●	●					●*		●
iLovu	C/D	C	Low to Average Importance	Medium	●		Urban				●	●	●					●*		
aManzanamtoti	E	E	Low to Average Importance	Low	●		Urban	Urban	●	●	●	●	●							●
aManzimtoti	D/E	D	Low to Average Importance	Low	●		Urban				●	●	●							●
iZimbokodo	E	E	Low to Average Importance	Low	●		Urban		●	●		●	●							
iSiphingo	F	F	Low to Average Importance	Low	●		Urban	Urban		●	●	●	●							
Durban Bay	E	E	High Importance	High	●		Urban	Urban	●			●						●*		●
uMngeni	E	E	Important	Medium	●	●	Urban	Urban	●		●	●	●					●*	●	
uMhlanga	D	D	Important	Low	●			Urban	●	●	●	●	●					●	●	●
uMdloti	D	D	Important	Low	●		Urban	Urban	●	●	●	●	●					●	●	●
uThongathi	D	D	Important	Low	●		Urban	Urban	●		●	●	●						●	●
uMhlali	D	D	Important	Low	●		Urban	Urban	●			●	●					●		
Bob's Stream	B/C	B	Low to Average Importance	Low			Urban	Urban												

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uSetheni	B/C	B	Low to Average Importance	Low			Urban	Urban				●								●
uMvoti	D	D	Low to Average Importance	Low	●		Urban	Urban	●		●	●	●						●	
uMdlotane	B	B	Important	Low			Urban	Urban			●	●						●		●
iNonoti	C	C	Low to Average Importance	Low			Urban	Urban	●			●						●		●
iZinkwazi	B/C	B	Important	High			Urban	Agric			●	●						●*		●
uThukela	D	D	Important	Medium	●			Agric			●	●	●					●*	●	
aMatigulu/iNyoni	B	B	Important	High							●							●*		
iSiyaya	E	E	Low to Average Importance	Low	●			Agric		●		●	●					●*		
uMlalazi	B	B	High Importance	High	●		Agric	Agric			●	●	●				●	●*	●	●
uMhlathuze	D	D	High Importance	High			Agric	Agric		●		●						●*	●	
Richards Bay	D	D	Important	High	●					●		●						●*		●
iNhlabane	E	E	Important	Medium	●			Urban		●		●						●*		●
iMfolozi/uMsunduze	D	D	High Importance	High				Agric				●	●			●		●*		
St Lucia	D	D	High Importance	High						●			●			●		●*		
uMgobezeleni	B	B	Low to Average Importance	Low							●					●		●*		
Kosi	A/B	A	/	High	●								●			●		●*		

APPENDIX F: ESTUARINE RED LISTED SPECIES

TAXONOMIC GROUPING	COMMON NAME	STATUS	SCOPE	ENDEMISM
Fish	Esturine Pipefish	CR	Global	Y
Fish	Knysna Seahorse	EN	Global	Y
Fish	Bot River Klipvis	EN	Global	Y
Fish	African mottled eel	NT	Global	N
Fish	Madagascar mottled eel	LC	Global	N
Fish	Longfin eel	LC	Global	N
Fish	Shortfin eel	NT	Global	N
Fish	Dusky kob, Daga salmon, Kabeljou	EN	National	N
Fish	White Steenbras	EN	Global	Y
Fish	Cape Stompnose	LC	Global	N
Fish	White Stumpnose	EN	Global	Y
Fish	Elf/Shad	VU	Global	N
Fish	Leervis	VU	National	N
Fish	Spotted Gurunter	VU	National	N
Fish	Harders	LC	National	Near endemic
Fish	Moonies	LC	Global	N
Fish	Longsnout Pipefish	LC	Global	Y
Fish	Opossum Pipefish	LC	Global	N
Fish	Freshwater Pipefish	DD	Global	N
Fish	Freshwater Mullet	VU	Global - Update	Y
Plants	Seagrass	EN	National	N
Plants	Indian Mangrove	LC	National	N
Plants	Black Mangrove	LC	National	N
Plants	Red Mangrove	NT	National	N
Plants	Tonga Mangrove	EN	National	N
Plants	White Mangrove	LC	National	N
Plants	Mangrove Mahogany	NA	National	N
Invertebrates	Pink Ghost Shrimp, Pink Sandprawn	LC	National	N
Invertebrates	Giant mud crab	VU	National	N
Invertebrates	Pencil Bait	DD	National	?
Invertebrates	Cape Mud Shrimp (English)	LC	Global	N
Invertebrates	River swimming crab	EN	National?	N
Birds	Great White Pelican	VU	National	N
Birds	White-breasted Cormorant	LC	National	N
Birds	Greater Flamingo	NT	National	N
Birds	Lesser Flamingo	NT	National	N

Birds	African Black Oystercatcher	LC	National	N
Birds	Common Ringed Plover	LC	National	N
Birds	White-fronted Plover	LC	National	N
Birds	Chestnut-banded Plover	NT	National	N
Birds	Greater Sand Plover	LC	National	N
Birds	Grey Plover	LC	National	N
Birds	Ruddy Turnstone	LC	National	N
Birds	Terek Sandpiper	LC	National	N
Birds	Common Sandpiper	LC	National	N
Birds	Common Greenshank	LC	National	N
Birds	Red Knot	LC	National	N
Birds	Curlew Sandpiper	LC	National	N
Birds	Little Stint	LC	National	N
Birds	Sanderling	LC	National	N
Birds	Bar-tailed Godwit	LC	National	N
Birds	Eurasian Curlew	NT	National	N
Birds	Common Whimbrel	LC	National	N
Birds	Pied Avocet	LC	National	N
Birds	Black-winged Stilt	LC	National	N
Birds	Water thick-knee	LC	National	N
Birds	Kelp Gull	LC	National	N
Birds	Hartlaub's Gull	LC	National	N
Birds	Caspian Tern	VU	National	N
Birds	Swift Tern	LC	National	N
Birds	Sandwich Tern	LC	National	N
Birds	Common Tern	LC	National	N
Birds	Damara Tern	CR	National	N
Birds	Little Tern	LC	National	N
Birds	Mangrove Kingfisher	EN	National	N
Birds	Pink backed Pelican	VU	National	N
Birds	Squacco Heron	LC	National	N

APPENDIX I: LIST OF MEETINGS HELD FOR DEVELOPMENT OF THIS REPORT

The following key meetings were held for the development of this technical report. Meeting reports are available on request.

Venue	Nature of meeting	Participants
SANBI Kirstenbosch	Estuarine Functional zone delineation	Van Niekerk, L., Adams, J., Fernandez, M., Lamberth, S.J., MacKay, F., Ramjukhad, C-L., Riddin, T., Van Deventer, H., Skownw, A., Dayaram, A.
SANBI Kirstenbosch	Estuary Ecosystem classification & Health review	Van Niekerk, L., Adams, J.B., James, N., Lamberth, S.J., MacKay, F., Turpie, J.K., Rajkaran, A., Weerts, S., Whitfield, A..K.
CSIR Durban	Estuary Fishing Pressure	Lamberth, S., Van Niekerk, L., Weerts, S., Parak, O., Bashoo, S., MacKay, F.
SANBI, Kirstenbosch	SANCOR review of marine, coastal and estuarine results	SANCOR community
DEA, Cape Town	Discussion and review of estuary results	DEFF Working Group 8 members