MPA Technical Report

Goukamma BRUV

2013-2018

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Acronyms

BRUV	Baited Remote Underwater Video
SASC	South African Shark Conservancy
IUCN	International Union for Conservation of Nature
MPA	Marine Protected Area
Max N	Maximum number of individuals of each species recorded in one frame observed during 60 min of BRUV footage
FOV	Field of View
ANOVA	Multi-factor analysis of variance
GLM	Generalized Linear Models
MDS	Multidimensional Scaling
ANOSIM	Analysis of Similarity

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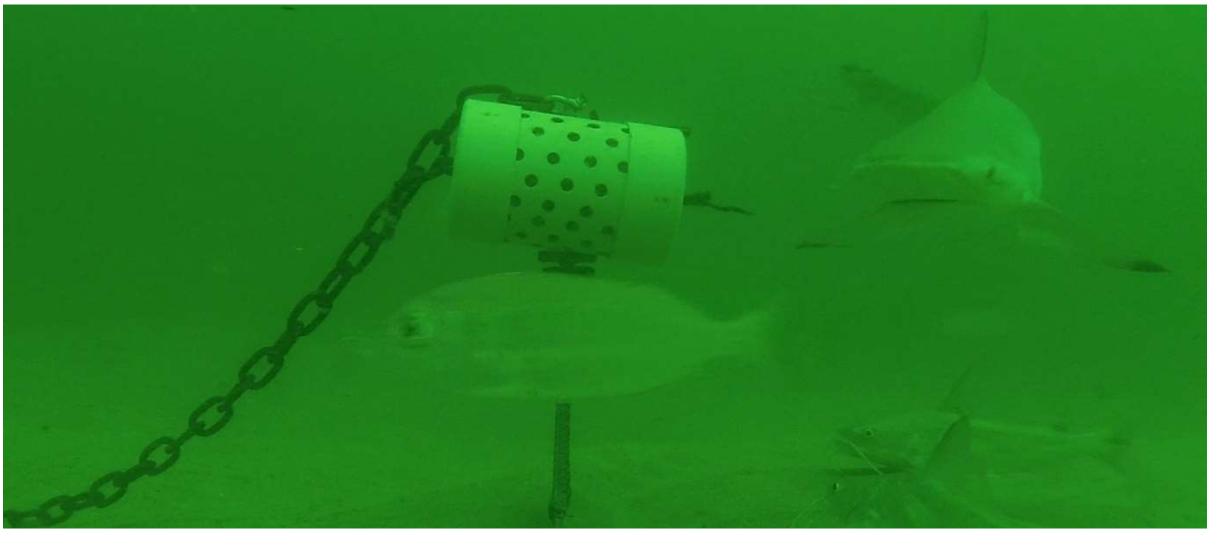

1. Abstract

The Goukamma Marine Protected Area (MPA) on South Africa's southern coast is vital for conserving marine biodiversity. Established initially as a marine reserve in 1960 and designated as an MPA in 1990, it spans 32 km² and includes diverse habitats such as sandy beaches, rocky shores, and subtidal reefs. Managed by CapeNature, the MPA aims to protect endangered species, maintain ecological integrity, and mitigate the effects of overfishing, habitat destruction, and pollution. Human activities, including commercial fishing and certain recreational practices, are restricted, while shoreline angling is allowed in designated areas. Ongoing scientific research, such as baited remote underwater video (BRUV) surveys, supports effective management and conservation efforts.

The data revealed significant year-to-year differences in species richness per site, notably with 2017 showing a significantly lower species count compared to 2013 and 2018, likely due to incomplete sampling across habitat types. Species richness was also found to be significantly lower in deeper waters, while intermediate and shallow depths exhibited similar richness. Additionally, species richness was lower inside the MPA compared to areas outside of it. Of the 91 species observed, 27 were categorized under IUCN threatened categories.

2. Background

Through a collaborative effort with Cape Nature, the South African Shark Conservancy (SASC) undertook the analysis of historical video footage and data collected by the Mono-BRUVS deployed in the Goukamma MPA in 2018. This data will be compared with earlier BRUV data previously analysed from 2013-2017. Funding for the video analyses and Technical Report was provided by WildTrust. This report will bear resemblance to the previous Technical Report for Stilbaai as the idea is to stick to a basic outline for these reports. No recommendations for changes were received for that previous report and so the same outline is followed for this one. These reports are intended to be relatively simple, however all the analysed data is available for further interrogation and will be stored with SAIAB.

2.1 Report limitations

There are some important limitations to this report. The lack of homogeneity in the sampling sites has the potential to create bias as does the uneven representation of sites across the years. The quality of data collection was negatively affected by both BRUV design as well as water visibility on survey days. Poor BRUV design, specifically the dimensions of the crossbars and the use of light steel meant that many of the BRUVs flipped over creating challenges for analysis and reducing the FOV. Most of the survey days were conducted in very poor visibility conditions and cameras were often mounted facing down and not level. Another problem that needs to be addressed for ongoing surveys, is that the survey boat was fishing in the vicinity of the BRUVs which could potentially harm results. This study utilises *MaxN* data in the absence of size-frequency data which limits the ability to fully describe the effectiveness of the MPA but it does provide important diversity data over an extended period.

There are some questions from the SASC side regarding species identification in the historical dataset provided to us, but these are hard to quantify without going all the footage for that data. For example, we suspect that the puffadder shy shark was previously misidentified and that they should have been recorded as dark shysharks.

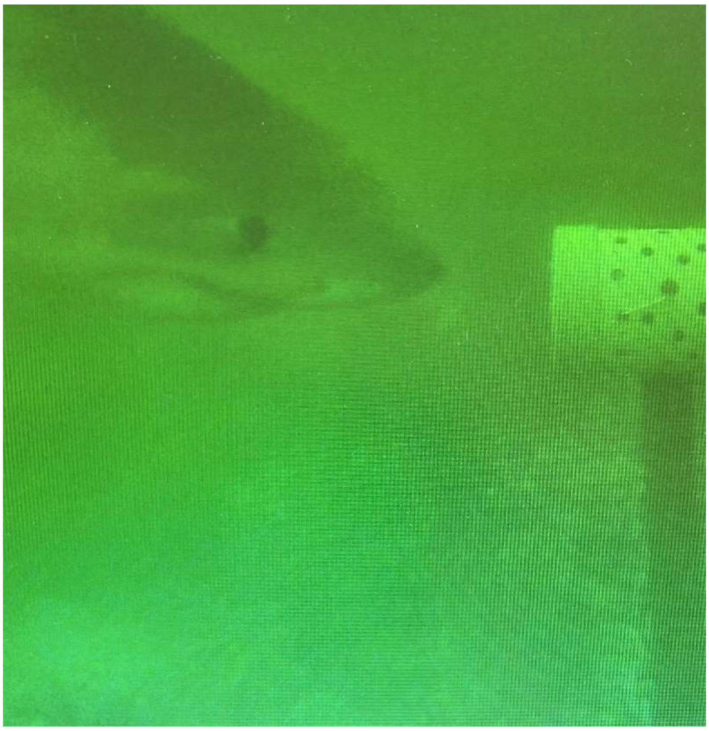

Figure 1: A White Shark visits the BRUV

2.2 Goukamma MPA

The Goukamma Marine Protected Area (MPA) plays a pivotal role in the conservation of marine life and biodiversity on the southern coast of South Africa. Its establishment as a marine reserve in 1960 and later as an MPA in 1990 underscores its critical importance. The Goukamma MPA, spanning 16.4 km along the shore of Sedgefield and wrapping around Buffels Bay, covers a total area of approximately 32 km^2. Its diverse habitats, including sandy beaches, rocky shores, and subtidal reefs, provide a sanctuary for many marine species, making it a key area for conservation efforts. The primary objectives of the Goukamma MPA are to promote and conserve marine biodiversity, protect endangered species, and maintain the ecological integrity of aquatic ecosystems. CapeNature, a public institution responsible for biodiversity conservation in the Western Cape, manages the area. CapeNature's responsibilities include enforcing the MPA's regulations, conducting research and monitoring, and engaging with stakeholders. To mitigate the impacts of overfishing, habitat destruction, and pollution, the MPA restricts human activities that include commercial fishing, unregulated recreational fishing activities, boating and boat fishing, removal of invertebrates, spearfishing, beach driving, and fishing at night. Angling from the shoreline is permitted in certain designated areas. Access points for shoreline fishing include the western part of the MPA, particularly in the Groenvlei area, as well as select points at Buffalo Bay on the eastern side. Ongoing scientific research and monitoring are essential to managing the Goukamma MPA. Various studies, including baited remote underwater video (BRUV) surveys, are inducted to assess the abundance of species within the MPA.

3. Methods

3.1 BRUV

Mono-BRUVs were deployed by CapeNature rangers over several years. The standard BRUV setup typically consists of a camera positioned approximately one meter from a bait canister and 14 cm above the seafloor, with sardines (Sardinops sagax) used as bait, following standard BRUV protocols in South Africa (Dando, 2020). Small action cameras, specifically GoPros, were selected for their cost-effectiveness, durability, and adaptability to variable ambient light conditions (Letessier et al., 2015; Bouchet et al., 2018; Langlois et al., 2018). The GoPro's standard video settings were utilized, and video analysis was conducted using VLC Media Player (version 2.2.6 Umbrella). Videos were analyzed for a standardized duration of one hour after the BRUVs had settled on the seafloor.

From 2013 to 2018, BRUVs were deployed in Goukamma, resulting in 357 successful deployments across reef and sand sites. A deployment was deemed successful if the BRUV rig landed with at least 50% of the field of view (FOV) unobstructed, visibility was at least 1 meter, a minimum of one hour of video footage was recorded, and at least one fish was observed. All fish species observed in the videos were recorded, with the maximum number of individuals of each species present in a single frame (MaxN) being noted to prevent double-counting and overestimation of species abundance (Willis et al., 2000). Relative abundance was calculated by summing the MaxN for each species and dividing it by the total number of sites surveyed.

Deployment details, abiotic variables, and species-specific MaxN counts were recorded for each BRUV deployment. Field data sheets were digitized using Microsoft® Excel, and all records were compiled into a single comma-separated values (CSV) file for statistical analysis. Figure 2 illustrates the various zones in and around the MPA with depth contours, while Figure 3 depicts the sampling design employed throughout the study period.

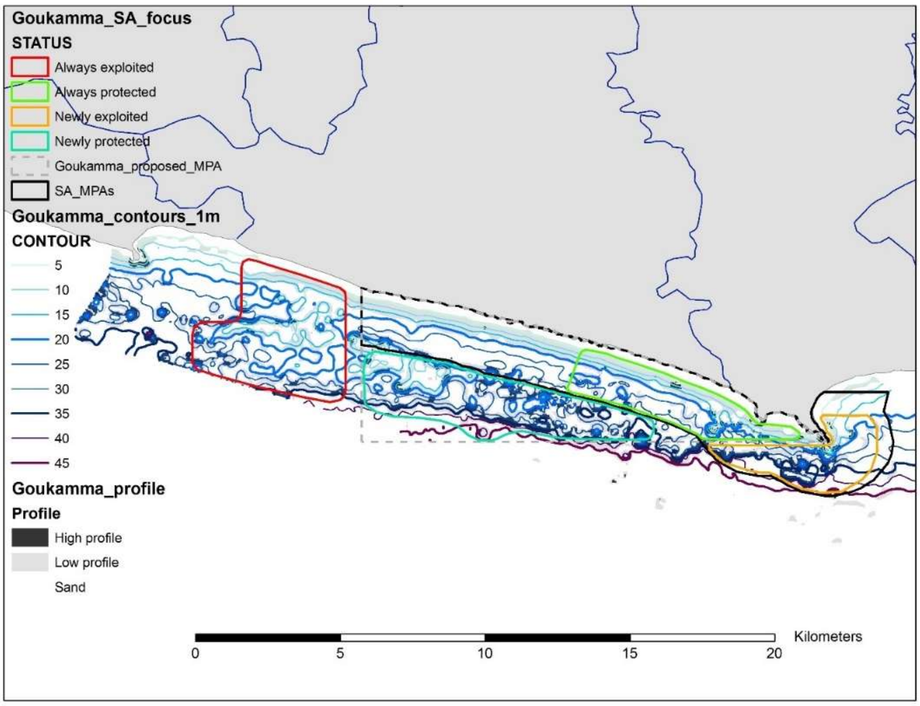

Figure 2: Boundary and bathymetry of the Goukamma MPA

Figure 3: Site map showing all survey sites in and around the Goukamma MPA

3.2 Statistical analysis

All statistical analyses were conducted using R (*version 3.6.1*) in the RStudio integrated design environment. Default parameters were used in all specified functions unless specifically stated. Functions that were used are described in the following format: the specified analysis and/or figure was produced using the R "function name" function (non-default parameter specification; "*package name*") (package citation) (R Core Team, 2023). ANOVA was used to compare effects of habitat type, sampling year, depth and protection status on diversity and abundance in Stillbaai.

An MDS (Multidimensional Scaling) plot is a way to visualize the similarity or dissimilarity between samples in a high-dimensional space. MDS (Multidimensional Scaling) plots for community matrices (by year, protection level and depth), and rarefication curves for species richness were also plotted for non-transformed data. To account for some sites being surveyed in repeated years, analysis was done using a site code (site+year) to avoid overlay of data points. ANOSIMs (Analysis of Similarity) were performed on the community matrices to provide a statistical measure of the separation between groups based on criteria such as depth. It supports the visual patterns observed in the MDS plot with quantitative evidence and helps validate the ecological interpretations derived from the MDS plot.

3.3 IUCN Red List Categories

The International Union for Conservation of Natures Red List of Threatened Species (IUCN) is one of the world's most comprehensive information sources on the global extinction risk status of animals, fungus, and plant species. It is not only used to identify those species in need of targeted recovery efforts, but also to focus on the conservation agenda by identifying the ones that need to be protected (IUCN, 2024). The IUCN Red List Categories and Criteria is a critical indicator of the health of the world's biodiversity. It divides species into nine categories: **Not Evaluated** or **Data Deficient**, **Least Concern**, **Near Threatened**, **Vulnerable**, **Endangered**, **Critically Endangered**, **Extinct in the Wild** and **Extinct.** Species listed as VU, EN and CR are considered as threatened species by IUCN (*Figure 4*).

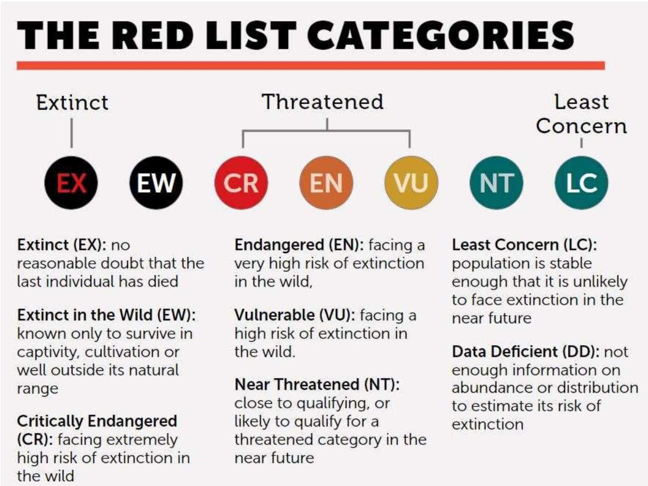

Figure 4. IUCN Red List Categories (IUCN, 2024).

4. Results and discussion

Over six years (2013-2018), there were 357 successful BRUV deployments (Table 1). SASC analysed the video footage for 2018 and corrected species names and IDs from earlier data where possible. The sampling period of six years resulted in 357 successful BRUV deployments, with 176 conducted outside the MPA and 181 within its boundaries. The fewest sites sampled outside the MPA occurred in 2017, with only four sites, while the other years show a similar number of sites sampled inside and outside the MPA. Additionally, a total of 199 sites were deployed in reef habitats, and 178 sites were deployed in sand habitats. A breakdown of the sample sites by protection level, year, and habitat are shown in Figures 5 and 6. These graphs indicate that there was reasonable representation between habitat and protection status (except for 2017).

Table 1: Total number of sites surveyed for each year.

Year	Sites Surveyed
2013	64
2014	122
2015	42
2016	56
2017	33
2018	40

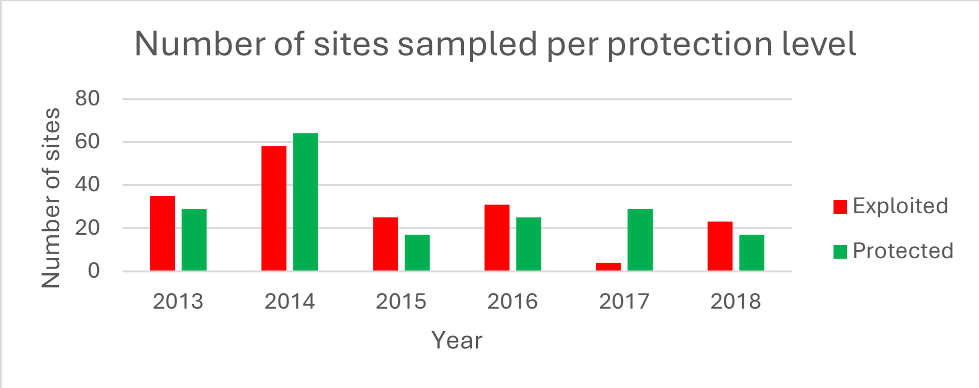

Figure 5: Number of sites sampled during the study period by protection level. Red bars indicate sites sampled outside the MPA (Exploited), while green bars indicate sites sampled inside the MPA (Protected)

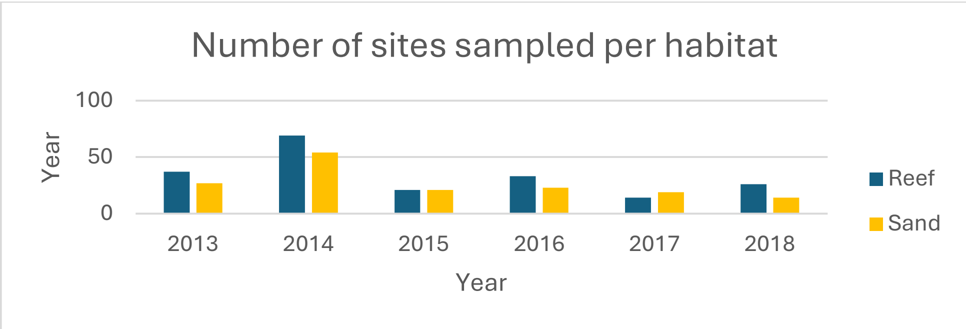

Figure 6: Number of sites sampled during the study period by habitat type

4.1 Species List

91 species from 44 families were identified over the 6-year study period (Table 2) with 27 species in the threatened IUCN categories (Figure 7).

Table 2: Complete list of species sighted during the study period, including the classification of IUCN Red List species.

Family name	Species name	Common Name	IUCN status
Ariidae	*Galeichthys ater*	Black seacatfish	LC
Ariidae	*Galeichthys feliceps*	White seacatfish	NE
Asteroidea	*Astropecten irregularis*	Pink Sandstar	NE
Callorhinchidae	*Callorhinchus capensis*	St. Joseph shark	LC
Carangidae	*Caranx sexfasciatus*	Bigeye kingfish	LC
Carangidae	*Lichia amia*	Leervis	LC
Carangidae	*Seriola lalandi*	Yellowtail	LC
Carangidae	*Trachurus capensis*	Cape horse mackerel	LC
Carangidae	*Trachurus trachurus*	Maasbanker	VU
Carcharhinidae	*Carcharhinus brachyurus*	Bronze whaler	VU
Carcharhinidae	*Carcharhinus obscurus*	Dusky Shark	EN
Cassidae	*Semicassis labiata zeylanica*	Helmet shell	NE
Chaetodontidae	*Chaetodon marleyi*	Doublesash butterflyfish	LC

Cheilodactylidae	*Cheilodactylus fasciatus*	Redfingers	LC
Cheilodactylidae	*Cheilodactylus pixi*	Barred fingerfin	NE
Cheilodactylidae	*Chirodactylus brachydactylus*	Twotone fingerfin	NE
Clinidae	*Clinus superciliosus*	Super klipfish	NE
Congiopodidae	*Congiopodus spinifer*	Spinynose horsefish	LC
Coracinidae	*Dichistius capensis*	Galjoen	NE
Dasyatidae	*Dasyatis brevicaudata*	Short-tail stingray	LC
Dasyatidae	*Dasyatis thetidis*	Thorntail Stingray	VU
Dasyatidae	*Pateobatis fai*	Pink stingray	NE
Dasyatidae	*Dasyatis chrysonota*	Blue stingray	NT
Gymnuridae	*Gymnura natalensis*	Diamond butterfly ray	LC
Haemulidae	*Pomadasys olivaceus*	Piggy	LC
Haemulidae	*Pomadasys striatus*	Striped grunter	LC
Hexanchidae	*Notorynchus cepedianus*	Sevengill cowshark	VU
Lamnidae	*Carcharodon carcharias*	White Shark	VU
Loliginidae	*Loligo vulgaris reynaudii*	Chokka squid	LC
Myliobatidae	*Aetomylaeus bovinus*	Bull ray	CR
Myliobatidae	*Myliobatis aquila*	Eagle ray	CR
Myxinidae	*Eptatretus hexatrema*	Sixgill hagfish	LC
Narkidae	*Narke capensis*	Onefin electric ray	LC
Nassariidae	*Bullia laevissima*	Fat plough shell	NE
Octopodidae	*Octopus vulgaris*	Common octopus	LC
Odontaspididae	*Carcharias taurus*	Ragged-tooth Shark	CR
Oplegnathidae	*Oplegnathus conwayi*	Cape Knifejaw	NE
Palinuridae	*Jasus lalandii*	West coast rock lobster	LC
Parascorpididae	*Parascorpis typus*	Jutjaw	NE
Pentanchidae	*Halaelurus natalensis*	Tiger catshark	VU
Pentanchidae	*Haploblepharus edwardsii*	Puffadder shyshark	EN
Pentanchidae	*Haploblepharus fuscus*	Brown shyshark	VU
Pentanchidae	*Haploblepharus pictus*	Dark shyshark	LC
Pomatomidae	*Pomatomus saltatrix*	Shad	VU
Rajidae	*Raja straeleni*	Biscuit skate	NT
Rajidae	*Rostroraja alba*	Spearnose skate	EN
Rhinobatidae	*Acroteriobatus annulatus*	Lesser guitarfish	VU
Sciaenidae	*Argyrosomus japonicus*	Dusky kob	EN
Sciaenidae	*Atractoscion aequidens*	Geelbek	NT
Sciaenidae	*Umbrina ronchus*	Slender baardman	DD
Scyliorhinidae	*Poroderma africanum*	Pyjama catshark	LC
Scyliorhinidae	*Poroderma pantherinum*	Leopard catshark	LC
Scyliorhinidae	*Scyliorhinus capensis*	Yellowspotted catshark	NT
Serranidae	*Acanthistius sebastoides*	Koester	LC
Serranidae	*Epinephelus marginatus*	Yellowbelly rock cod	VU
Serranidae	*Serranus cabrilla*	African seabass	LC
Sparidae	*Argyrozona argyrozona*	Carpenter	NT
Sparidae	*Boopsoidea inornata*	Fransmadam	LC
Sparidae	*Cheimerius nufar*	Santer	DD

Sparidae	*Chirodactylus grandis*	Bank steenbras	NE
Sparidae	*Chrysoblephus cristiceps*	Dageraad	CR
Sparidae	*Chrysoblephus gibbiceps*	Red stumpnose	EN
Sparidae	*Chrysoblephus laticeps*	Red roman	NT
Sparidae	*Cymatoceps nasutus*	Black musselcracker	VU
Sparidae	*Diplodus capensis*	Blacktail seabream	LC
Sparidae	*Diplodus hottentotus*	Zebra	LC
Sparidae	*Gymnocrotaphus curvidens*	Janbruin	LC
Sparidae	*Lithognathus lithognathus*	White steenbras	EN
Sparidae	*Lithognathus mormyrus*	Sand steenbras	LC
Sparidae	*Pachymetopon aeneum*	Blue hottentot	LC
Sparidae	*Pachymetopon grande*	Bronze bream	NT
Sparidae	*Pagellus natalensis*	Red tjor-tjor	LC
Sparidae	*Petrus rupestris*	Red steenbras	EN
Sparidae	*Polysteganus undulosus*	Seventy-four	CR
Sparidae	*Pterogymnus laniarius*	Panga	LC
Sparidae	*Rhabdosargus globiceps*	White stumpnose	VU
Sparidae	*Rhabdosargus holubi*	Cape stumpnose	LC
Sparidae	*Sarpa salpa*	Strepie	LC
Sparidae	*Spondyliosoma emarginatum*	Steenjie	LC
Sphyrnidae	*Sphyrna zygaena*	Smooth hammerhead	VU
Squalidae	*Squalus acutipinnis*	Bluntnose spiny dogfish	NT
Tetradontidae	*Amblyrhynchotes honckenii*	Evileye puffer	LC
Tetraodontidae	*Lagocephalus sceleratus*	Silver-cheeked toadfish	LC
Torpedinidae	*Torpedo fuscomaculata*	Blackspotted torpedo	DD
Triakidae	*Galeorhinus galeus*	Soupfin shark	CR
Triakidae	*Mustelus mustelus*	Common smoothhound shark	EN
Triakidae	*Mustelus palumbes*	White spotted smoothhound	LC
Triakidae	*Triakis megalopterus*	Spotted gully shark	LC
Triglidae	*Chelidonichthys kumu*	Bluefin gurnard	LC
Tripterygiidae	*Cremnochorites capensis*	Cape triplefin	LC

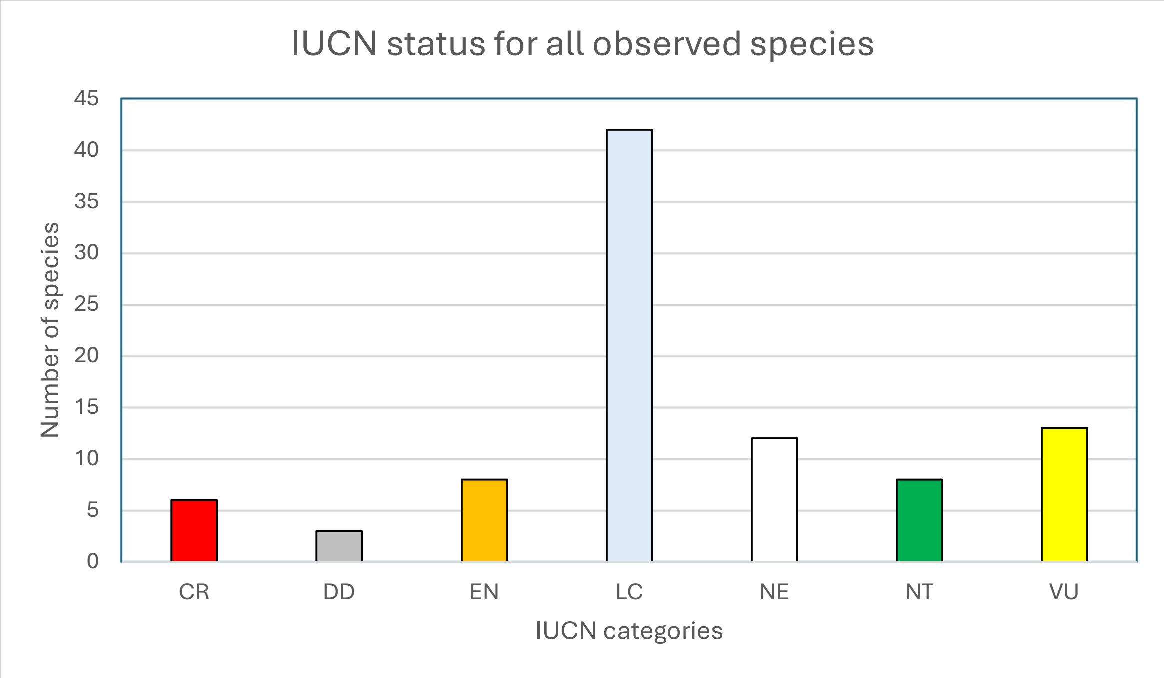

Figure 7: IUCN status for all observed species. Colour reflects the relevant status (CR - Critically Endangered; EN - Endangered; NT - Near Threatened; VU - Vulnerable; LC - Least Concern; NE - Not Evaluated; DD - Data Deficient)

4.2 Diversity

4.2.1 Species matrix

Table 3 represents all the species recorded over the study period.

Table 3: Matrix representing of the absence or presence of all species sighted during the study period. An 'X' indicates the presence of a species in a particular year, while a blank space indicates its absence.

Species name	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Acanthistius sebastoides	X	X	X	X	X	X
Acroteriobatus annulatus	X	X	X		X	X
Aetomylaeus bovinus						X
Amblyrhynchotes honckenii	X	X	X	X	X	X
Argyrosomus japonicus	X			X		
Argyrozona argyrozona						X
Astropecten irregularis						X
Atractoscion aequidens				X		
Boopsoidea inornata	X	X	X	X	X	X
Bullia laevissima						X
Callorhinchus capensis		X	X	X		
Caranx sexfasciatus						X
Carcharhinus brachyurus	X	X	X	X	X	
Carcharhinus obscurus	X	X			X	X
Carcharias taurus	X	X	X	X		X
Carcharodon carcharias	X	X	X	X		X
Chaetodon marleyi	X	X	X	X		

Cheilodactylus fasciatus	X	X	X	X	X	X
Cheilodactylus pixi	X	X	X	X		X
Cheimerius nufar	X	X	X	X	X	X
Chelidonichthys kumu			X		X	
Chirodactylus brachydactylus	X	X	X	X	X	X
Chirodactylus grandis	X			X		
Chrysoblephus cristiceps	X	X	X	X	X	X
Chrysoblephus gibbiceps	X	X	X	X	X	X
Chrysoblephus laticeps	X	X	X	X	X	X
Clinus superciliosus					X	
Congiopodus spinifer						X
Cremnochorites capensis		X				
Cymatoceps nasutus	X					X
Dasyatis brevicaudata	X	X	X	X	X	X
Dasyatis chrysonota		X	X			
Dasyatis thetidis						X
Dichistius capensis			X			
Diplodus capensis	X	X	X	X	X	X
Diplodus hottentotus	X	X	X	X	X	X
Epinephelus marginatus	X	X	X	X	X	X
Eptatretus hexatrema	X	X				
Galeichthys ater	X	X	X	X	X	X
Galeichthys feliceps	X	X	X	X	X	X
Galeorhinus galeus	X	X		X		X
Gymnocrotaphus curvidens	X	X	X	X		X
Gymnura natalensis				X		
Halaelurus natalensis	X	X	X	X	X	X
Haploblepharus edwardsii	X	X	X	X	X	
Haploblepharus fuscus	X	X	X	X	X	X
Haploblepharus pictus						X
Jasus lalandii						X
Lagocephalus sceleratus		X		X		
Lichia amia		X				
Lithognathus lithognathus						X
Lithognathus mormyrus	X	X	X	X	X	X
Loligo vulgaris reynaudii						X
Mustelus mustelus	X	X	X	X	X	X
Mustelus palumbes	X	X	X			X
Myliobatis aquila	X	X	X	X	X	X
Narke capensis			X			
Notorynchus cepedianus	X	X	X	X	X	
Octopus vulgaris						X
Oplegnathus conwayi	X	X	X	X	X	X
Pachymetopon aeneum	X	X	X	X	X	X
Pachymetopon grande			X	X		X
Pagellus natalensis	X	X	X	X	X	X
Parascorpis typus		X				

Pateobatis fai						X
Petrus rupestris	X	X	X	X	X	X
Polysteganus undulosus	X	X				
Pomadasys olivaceus	X	X	X	X	X	X
Pomadasys striatus		X				
Pomatomus saltatrix	X	X	X	X		
Poroderma africanum	X	X	X	X	X	X
Poroderma pantherinum	X	X	X	X	X	X
Pterogymnus laniarius	X	X	X	X	X	
Raja straeleni		X	X	X		X
Rhabdosargus globiceps						X
Rhabdosargus holubi	X					X
Rostroraja alba	X	X	X	X	X	X
Sarpa salpa	X	X		X	X	X
Scyliorhinus capensis	X					
Semicassis labiata						X
Seriola lalandi		X		X	X	
Serranus cabrilla	X	X	X	X		X
Sphyrna zygaena	X	X	X	X		
Spondyliosoma emarginatum	X	X	X	X	X	X
Squalus acutipinnis	X	X	X	X	X	X
Torpedo fuscomaculata		X				
Trachurus capensis						X
Trachurus trachurus	X		X	X	X	
Triakis megalopterus			X	X	X	X
Umbrina ronchus		X				

4.2.2 Relative Abundance

Figure 8 represents the relative abundance for all recorded species.

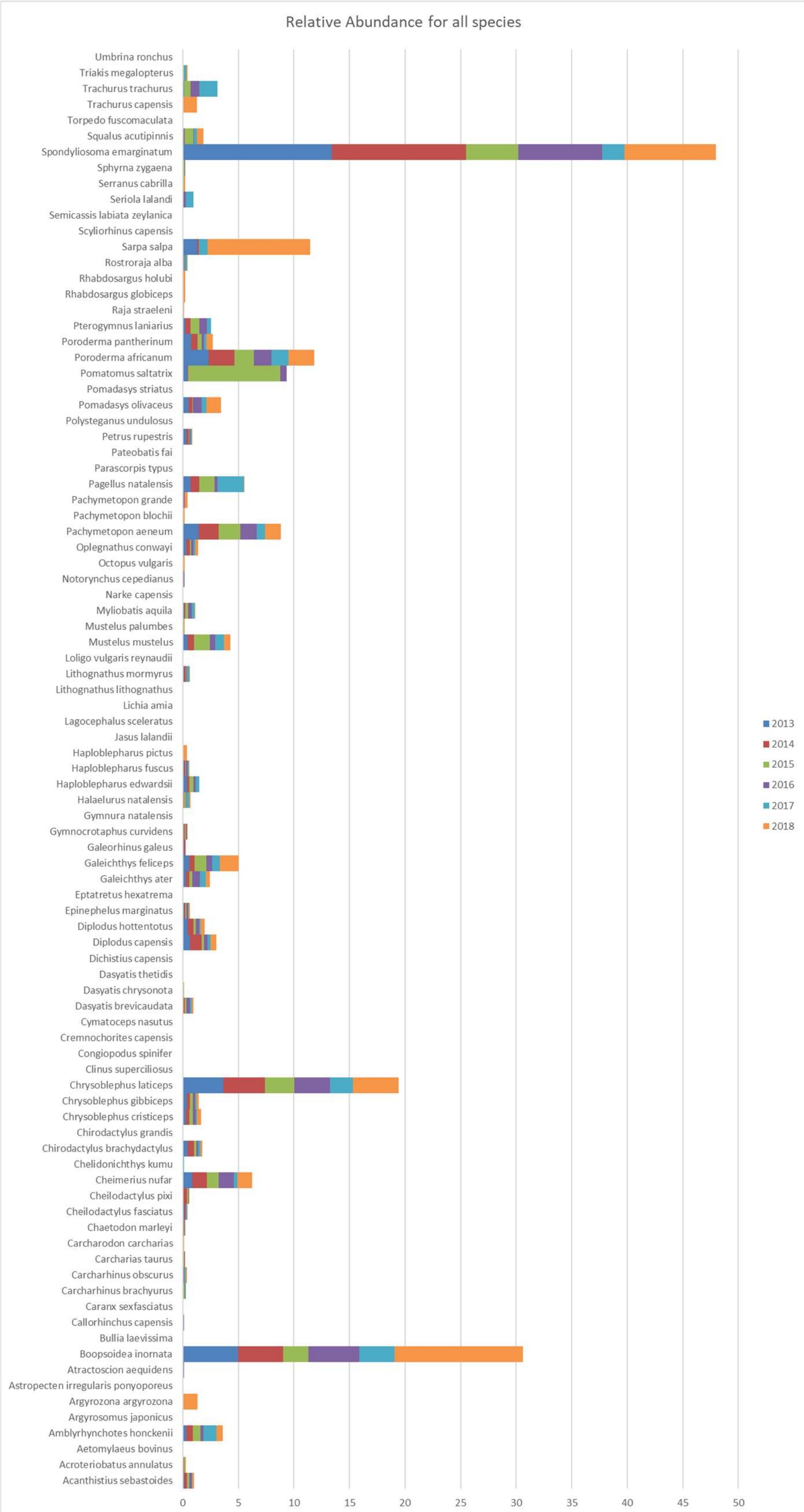

Figure 8: Relative Abundance for all species by year.

Figure 9 describes the number of species according to habitat, year and protection level. Once again you can see that 2017 is an anomaly with no sand habitat in the exploited zone surveyed.

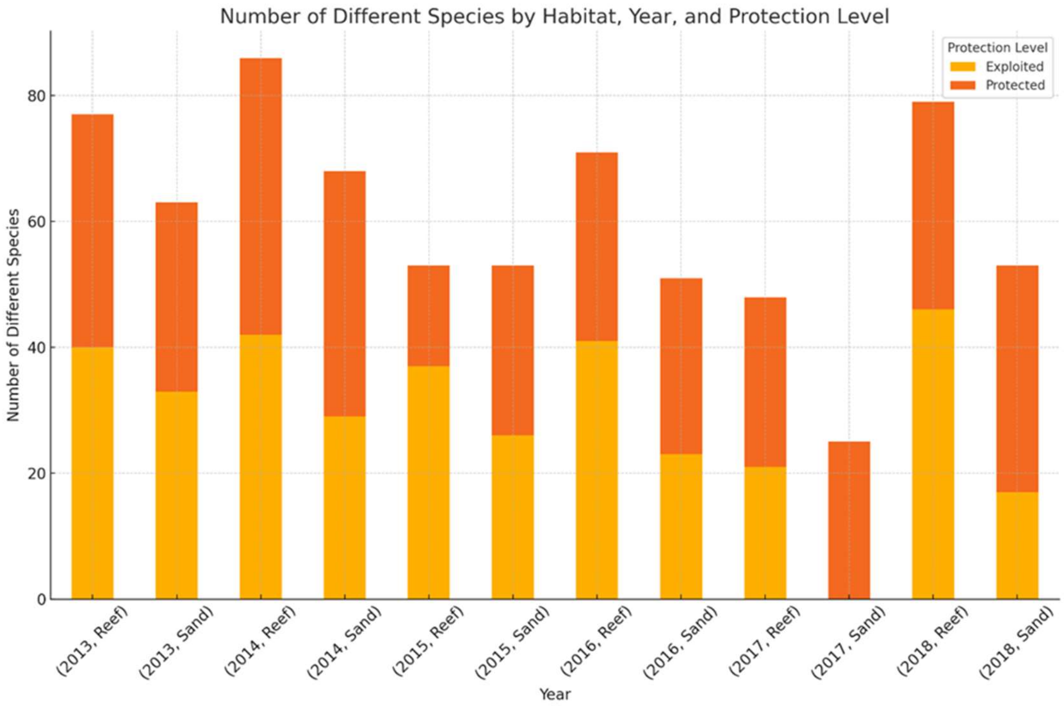

Figure 9: Number of species compared by habitat, year and Protection Level

4.2.3 Species richness

A rarefaction curve was plotted to estimate species richness, and this was shown to be approaching its asymptote (Figure 10). A rarefaction curve is a tool used in ecology to estimate species richness from a set of samples. It helps to understand the relationship between the number of individuals sampled and the number of species observed. When a rarefaction curve is approaching its asymptote, it indicates that most of the species in the community have been sampled, and additional sampling is likely to yield fewer new species. This is a useful metric to suggest that we are approaching a reasonably complete species list for the area (excluding rare species).

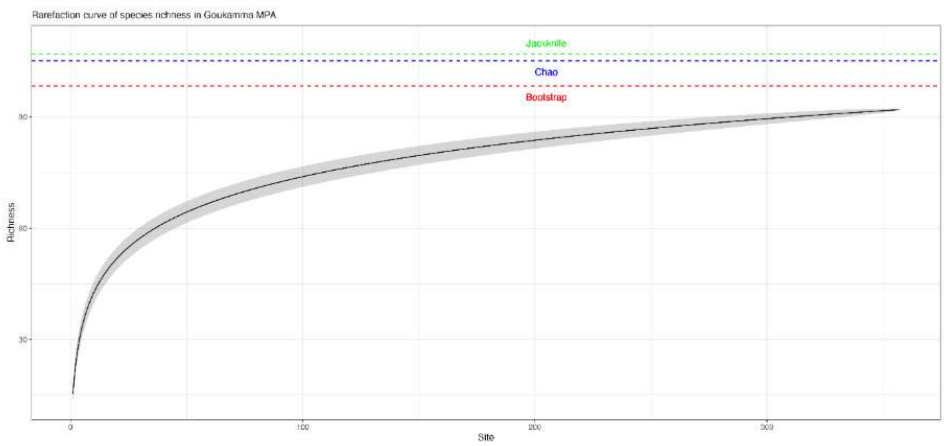

Figure 10: Rarefaction curve of species in the Goukamma MPA. Bootstrap, jackknife and Chao refer to extrapolated richness.

There was a significant difference in species richness (Figure 11) between surveyed years (ANOVA: F=2.916, p<0.05) with 2017 being significantly different from 2013 and 2018. This could be attributed to the smallest number of samples (Table 1) or other environmental conditions that unfortunately were not measured in 2017. In addition, only 4 of 33 sites surveyed in 2017 were in the Protected area, which suggests that this difference is reflected in the statistical analysis.

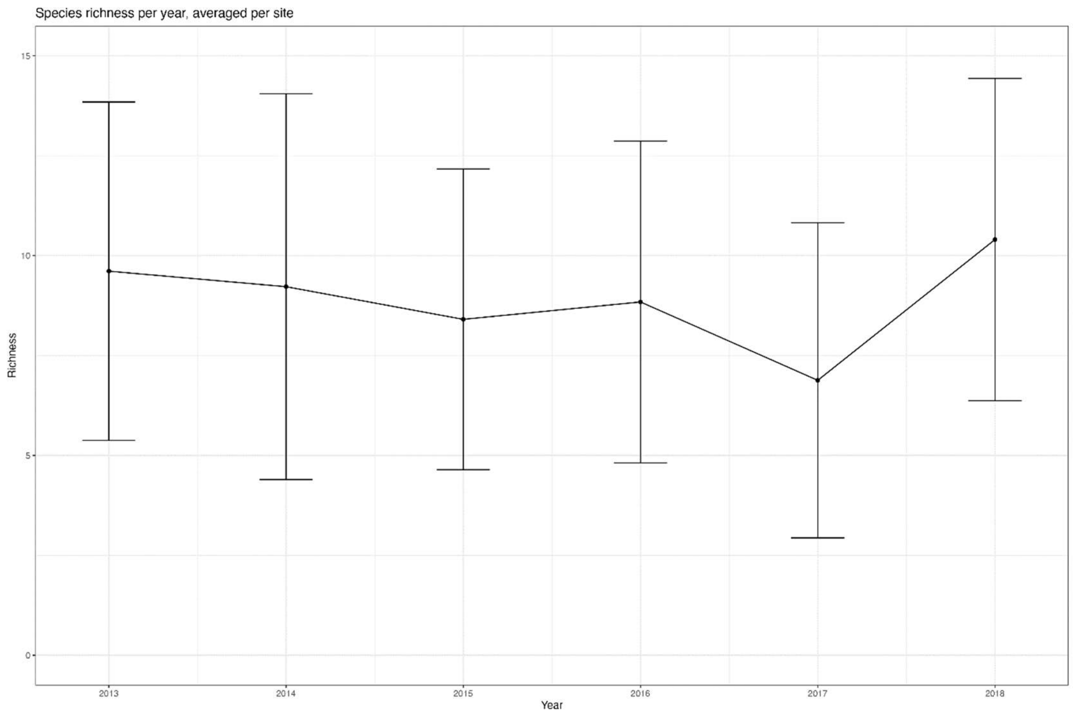

Figure 11: Species richness per year averaged per site. 2017 was statistically lower than all other years (F=2.916, p<0.05)

The MDS plot (Figure 12) showed differences in species richness between years with a significant stress value of 0.048 and an ANOSIM on the matrix showed the level of similarity (R = 0.06978, p = 0.001). With these MDS plots, you will see that the x-axis is in the minus region, rather than above and below 0. This is because the plot was extremely skewed by two sites: NEZ 11/5 and NEZ 12/4, both in 2015 (excluded from the plots). These deployments had *Narke capensis* in them, skewing the plot for some reason.

The stress value for the MDS plot is 0.048, meaning that the visualisation is a good fit despite the degree of overlap. To help understand an MDS plot there are some considerations:

Axes: The axes in an MDS plot represent dimensions that summarize the variation in the data. Unlike typical Cartesian coordinates, these axes don't have specific, interpretable meanings like "height" or "width." Instead, they are abstract dimensions that help visualize relationships between samples.

Points: Each point on the plot represents a sample from the fish community matrix. The distance between points reflects the similarity or dissimilarity of the fish communities in those samples. Points that are close together have similar fish communities, while points that are far apart have more dissimilar communities.

Stress Value: The stress value indicates how well the two-dimensional plot represents the multi-dimensional data. A lower stress value means a better representation. Generally, a stress value below 0.1 is considered a good fit, so 0.048 indicates that the plot is a reliable representation of the data.

Colours indicate depth in this case. Each sample point is coloured according to the depth at which it was taken. A gradient or discrete colours might be used to represent different depth ranges.

Look for patterns in the colours. For example, if points of similar colours (depths) are clustered together, it suggests that depth is an important factor in determining fish community composition. If points of different colours are mixed, depth might have less of an influence.

With the ANOSIM (Figure 13), it is important to note that the p-value doesn't indicate whether there's a significant difference or not, it's the R value. This ranges from 0 to 1, with 0 indicating "similar" and 1 "different". The p-value indicates whether this (dis)similarity is significant or not.

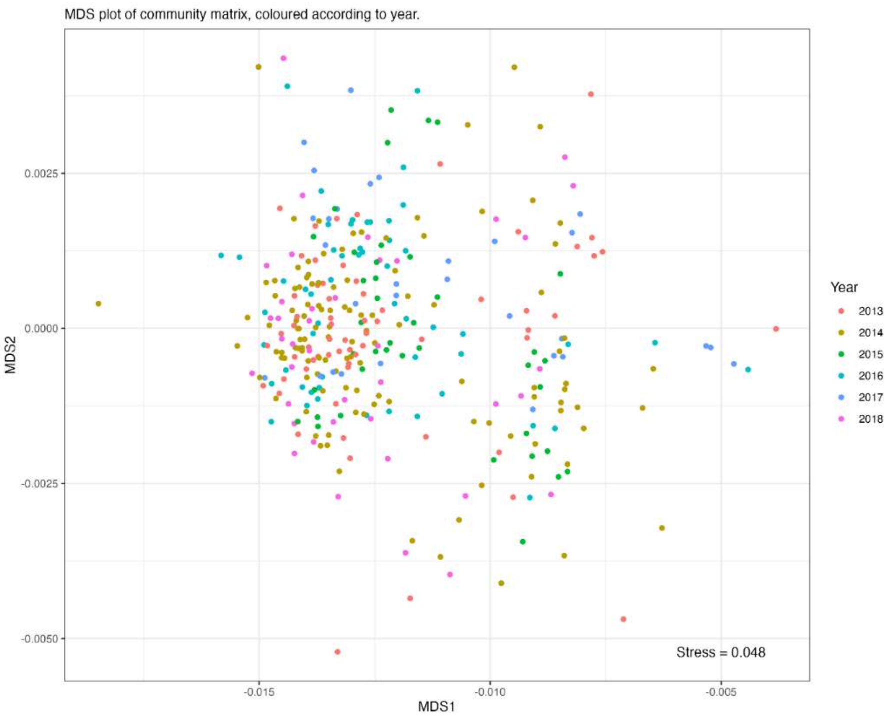

Figure 12: MDS plot of community matrix coloured by year.

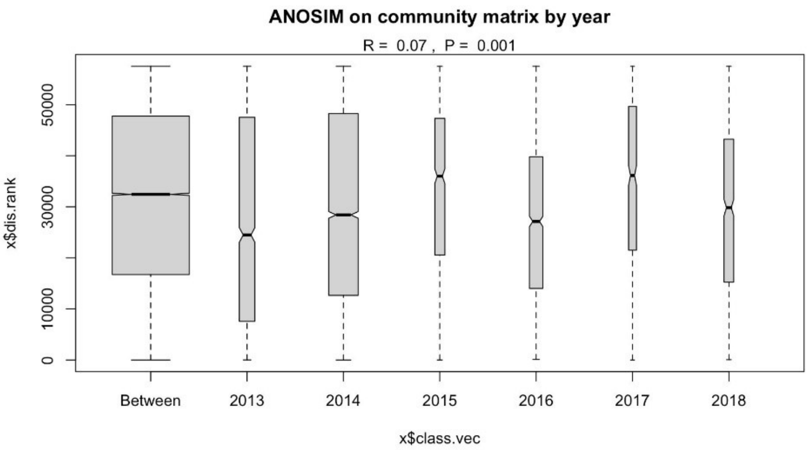

Figure 13: ANOSIM plot for community matrix according to the survey year.

4.2.4 Effect of depth on species richness

The effect of depth on species richness across all surveyed sites indicated that deep sites had significantly lower species richness than both shallow and intermediate sites (ANOVA: F=14.12, p<0.05; Figure 14).

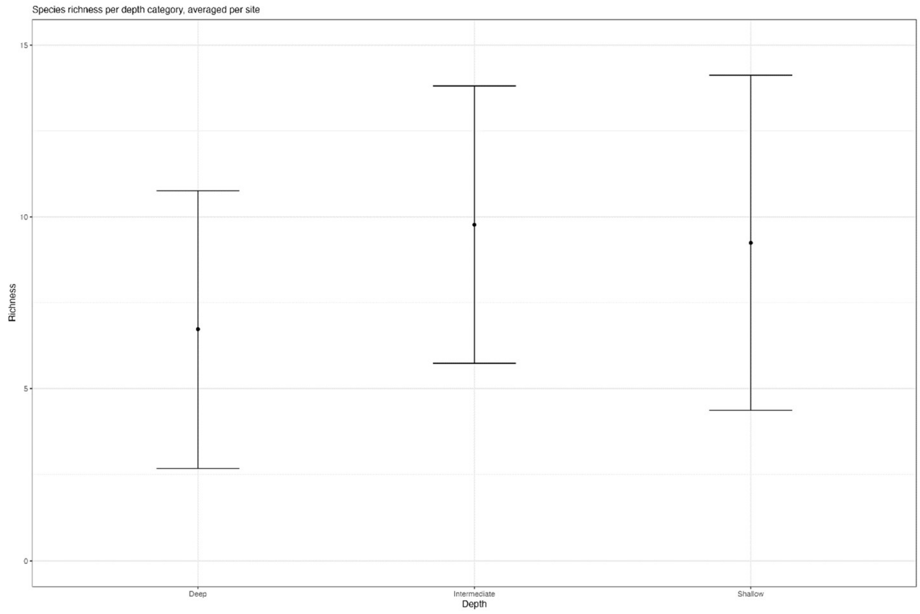

Figure 14: Species richness per depth category, averaged per site. Deep sites differed significantly from shallow and intermediate sites (ANOVA: F14.12, p<0.05)

This trend was also seen in the MDS plot below (Figure 15). ANOSIM was also used to confirm that the depth-related patterns in the fish community composition seen in the MDS plot were statistically significant (R = 0.2309, p = 0.001; Figure 16).

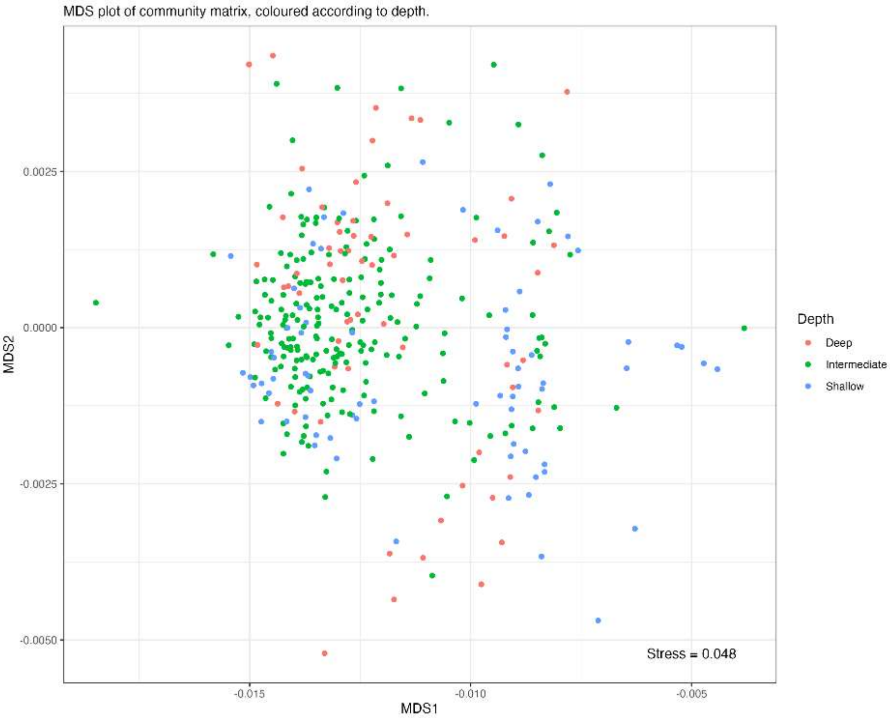

Figure 15: MDS plot of community matrix according to depth.

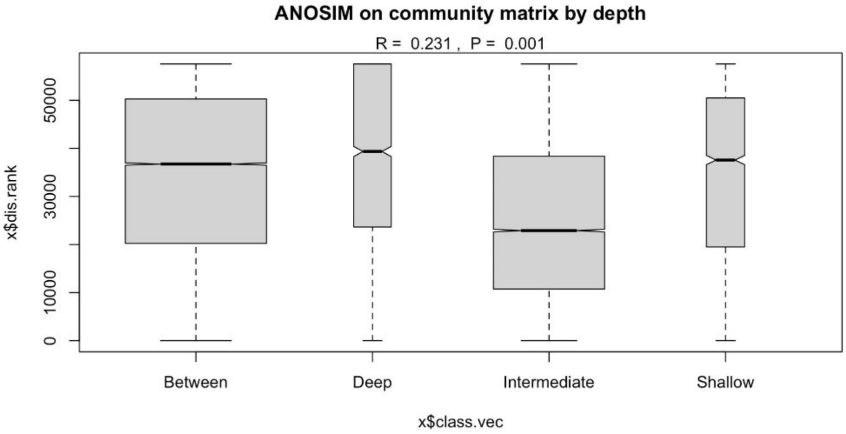

Figure 16: ANOSIM on community matrix for depth.

4.2.5 Effect of Protection status on species richness

A t-test showed that there was a significant difference in the mean number of species based on protection status (t =6.1118, df = 345.21, p-value = 2.661e-09, Figure 17), with a higher species richness outside the MPA. This could be used as possible motivation to extend the MPA but greater focus would need to be on the different habitats surveyed.

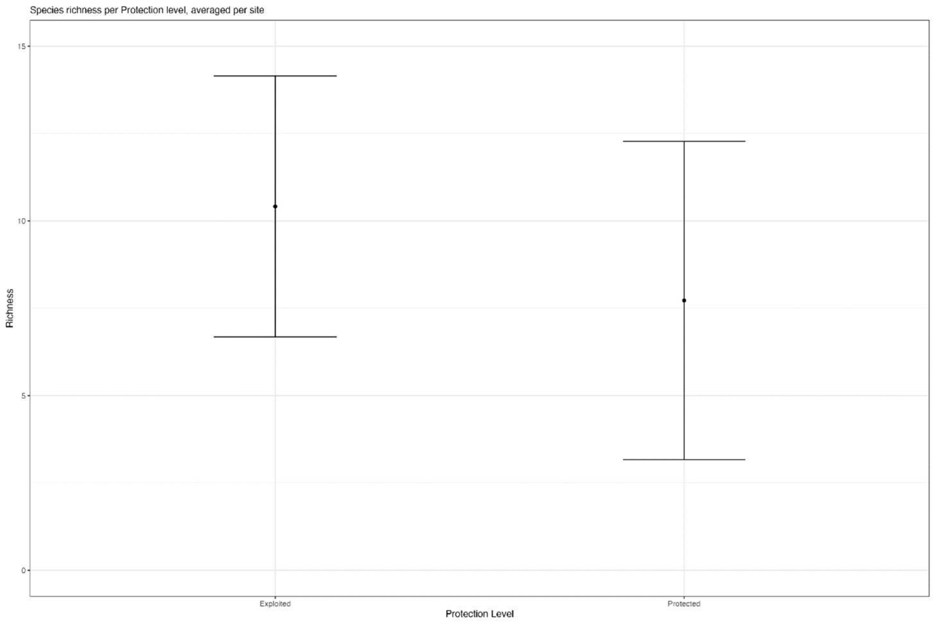

Figure 17: Species richness per protection level averaged per site for all years.

The MDS plot (Figure 18) also indicated differences in community structure between the Protected (MPA) area and surrounding Unprotected areas. This was supported by the ANOSIM results (Figure 19; R = 0.1376, p = 0.001)

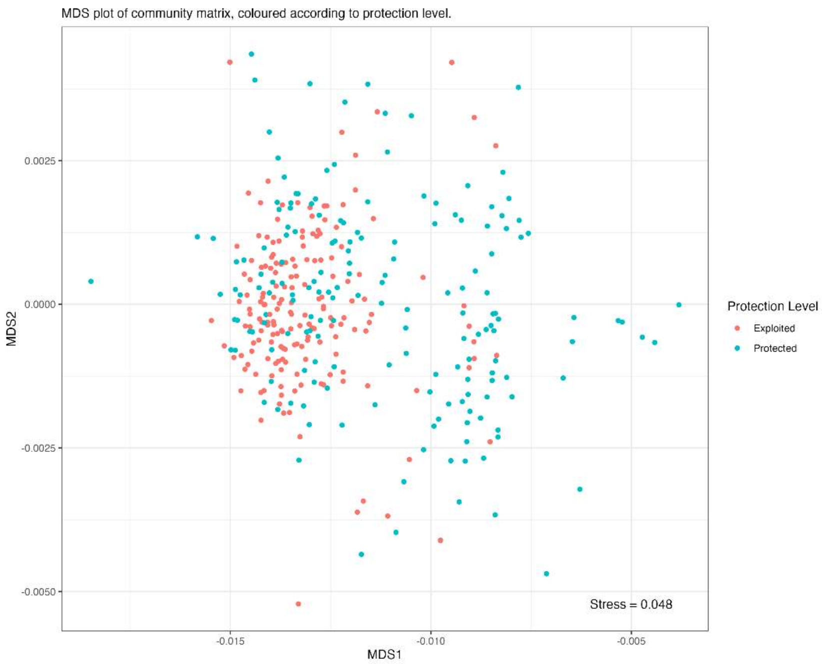

Figure 18: MDS plot for community matrix according to protection level

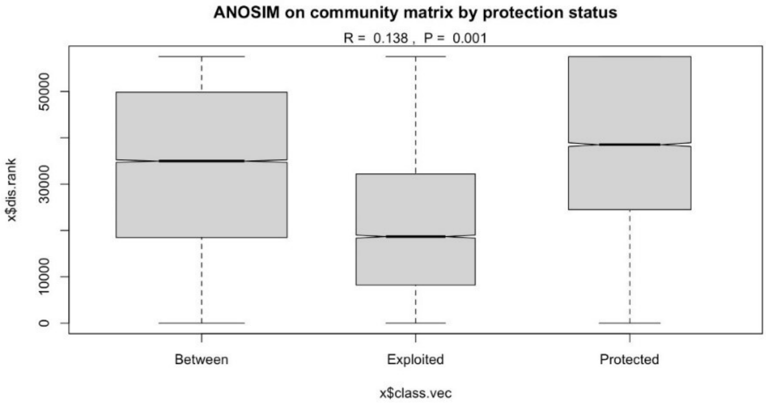

Figure 19: ANOSIM on community matrix by protection status.

4.3 Chondrichthyans

Figure 20: Short tailed stingray in Goukamma MPA

4.3.1 Chondrichthyan diversity

A complete list of all observed Chondrichthyans is provided in Table 4 below along with their current IUCN Status. This data is also represented as a Pie chart (Figure 21). A total of 16 Chondrichthyan species identified in this study have been classified as Threatened according to the IUCN List of Threatened Species. This includes four species listed as Critically Endangered (CR): bull ray, eagle ray, ragged-tooth shark, and soupfin shark. Four species are listed as Endangered (EN): dusky shark, puffadder shyshark, spear nose skate, and common smoothhound shark. Lastly, 13 species are listed as Vulnerable (VU): bronze whaler shark, thorntail stingray, sevengill cowshark, white shark, tiger catshark, brown shyshark, lesser guitarfish, smooth hammerhead shark. These threatened species make up 51,61% of all chondrichthyan sightings.

Table 4: Complete list of Chondrichthyans sighted during the study period according to IUCN Red List species classification.

Family name	Species name	Common Name	IUCN status
Callorhinchidae	*Callorhinchus capensis*	St. Joseph shark	LC
Carcharhinidae	*Carcharhinus obscurus*	Dusky Shark	EN
Carcharhinidae	*Carcharhinus brachyurus*	Bronze whaler	VU
Dasyatidae	*Dasyatis brevicaudata*	Short-tail stingray	LC
Dasyatidae	*Dasyatis thetidis*	Thorntail Stingray	VU
Dasyatidae	*Dasyatis chrysonota*	Blue stingray	NT
Dasyatidae	*Pateobatis fai*	Pink stingray	NE
Gymnuridae	*Gymnura natalensis*	Diamond butterfly ray	LC
Hexanchidae	*Notorynchus cepedianus*	Sevengill cowshark	VU
Lamnidae	*Carcharodon carcharias*	White Shark	VU
Myliobatidae	*Aetomylaeus bovinus*	Bull ray	CR
Myliobatidae	*Myliobatis aquila*	Eagle ray	CR
Narkidae	*Narke capensis*	Onefin electric ray	LC
Odontaspididae	*Carcharias taurus*	Ragged-tooth Shark	CR
Pentanchidae	*Halaelurus natalensis*	Tiger catshark	VU
Pentanchidae	*Haploblepharus edwardsii*	Puffadder shyshark	EN
Pentanchidae	*Haploblepharus fuscus*	Brown shyshark	VU
Pentanchidae	*Haploblepharus pictus*	Dark shyshark	LC
Rajidae	*Raja straeleni*	Biscuit skate	NT
Rajidae	*Rostroraja alba*	Spearnose skate	EN
Rhinobatidae	*Acroteriobatus annulatus*	Lesser guitarfish	VU
Scyliorhinidae	*Poroderma africanum*	Pyjama catshark	LC
Scyliorhinidae	*Poroderma pantherinum*	Leopard catshark	LC
Scyliorhinidae	*Scyliorhinus capensis*	Yellowspotted catshark	NT
Sphyrnidae	*Sphyrna zygaena*	Smooth hammerhead	VU
Squalidae	*Squalus acutipinnis*	Bluntnose spiny dogfish	NT
Torpedinidae	*Torpedo fuscomaculata*	Blackspotted torpedo	DD
Triakidae	*Galeorhinus galeus*	Soupfin shark	CR
Triakidae	*Mustelus mustelus*	Common smoothhound shark	EN
Triakidae	*Mustelus palumbes*	White spotted smoothhound	LC
Triakidae	*Triakis megalopterus*	Spotted gully shark	LC

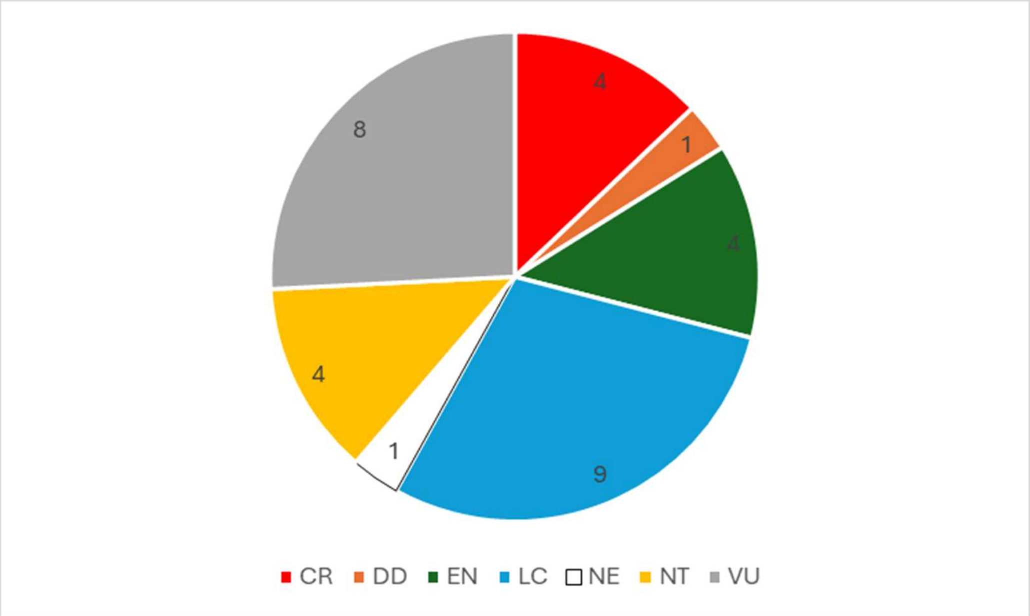

Figure 21: Breakdown of Chondrichthyans by IUCN status

4.3.2 Matrix of Chondrichthyan Occurrence

Table 5: Representation of the absence or presence of only Chondrichthyans sighted during the study period. An 'X' indicates the presence of a species in a particular year, while a blank space indicates its absence.

Species name	**2013**	**2014**	**2015**	**2016**	**2016**	**2017**
Acroteriobatus annulatus	X	X	X		X	X
Aetomylaeus bovinus						X
Callorhinchus capensis		X	X	X		
Carcharhinus brachyurus	X	X	X	X	X	
Carcharhinus obscurus	X	X			X	X
Carcharias taurus	X	X	X	X		X
Carcharodon carcharias	X	X	X	X		X
Dasyatis brevicaudata	X	X	X	X	X	X
Dasyatis chrysonota		X	X			
Dasyatis thetidis						X
Galeorhinus galeus	X	X		X		X
Gymnura natalensis				X		
Halaelurus natalensis	X	X	X	X	X	X
Haploblepharus edwardsii	X	X	X	X	X	
Haploblepharus fuscus	X	X	X	X	X	X
Haploblepharus pictus						X
Mustelus mustelus	X	X	X	X	X	X
Mustelus palumbes	X	X	X			X
Myliobatis aquila	X	X	X	X	X	X
Narke capensis			X			
Notorynchus cepedianus	X	X	X	X	X	
Pateobatis fai						X

Poroderma africanum	X	X	X	X	X	X
Poroderma pantherinum	X	X	X	X	X	X
Raja straeleni		X	X	X		X
Rostroraja alba	X	X	X	X	X	X
Scyliorhinus capensis	X					
Sphyrna zygaena	X	X	X	X		
Squalus acutipinnis	X	X	X	X	X	X
Torpedo fuscomaculata		X				
Triakis megalopterus			X	X	X	X

4.3.3 Relative Abundance of Chondrichthyans

Figure 22 illustrates the relative abundance of all chondrichthyans over the study time frame (2013-2018). Relative abundance was dominated by *P. africanum* followed by *M. mustelus* and *P. pantherium*. Appendix 2 provides a table of actual figures and can be used as a reference to this graph (Table 7).

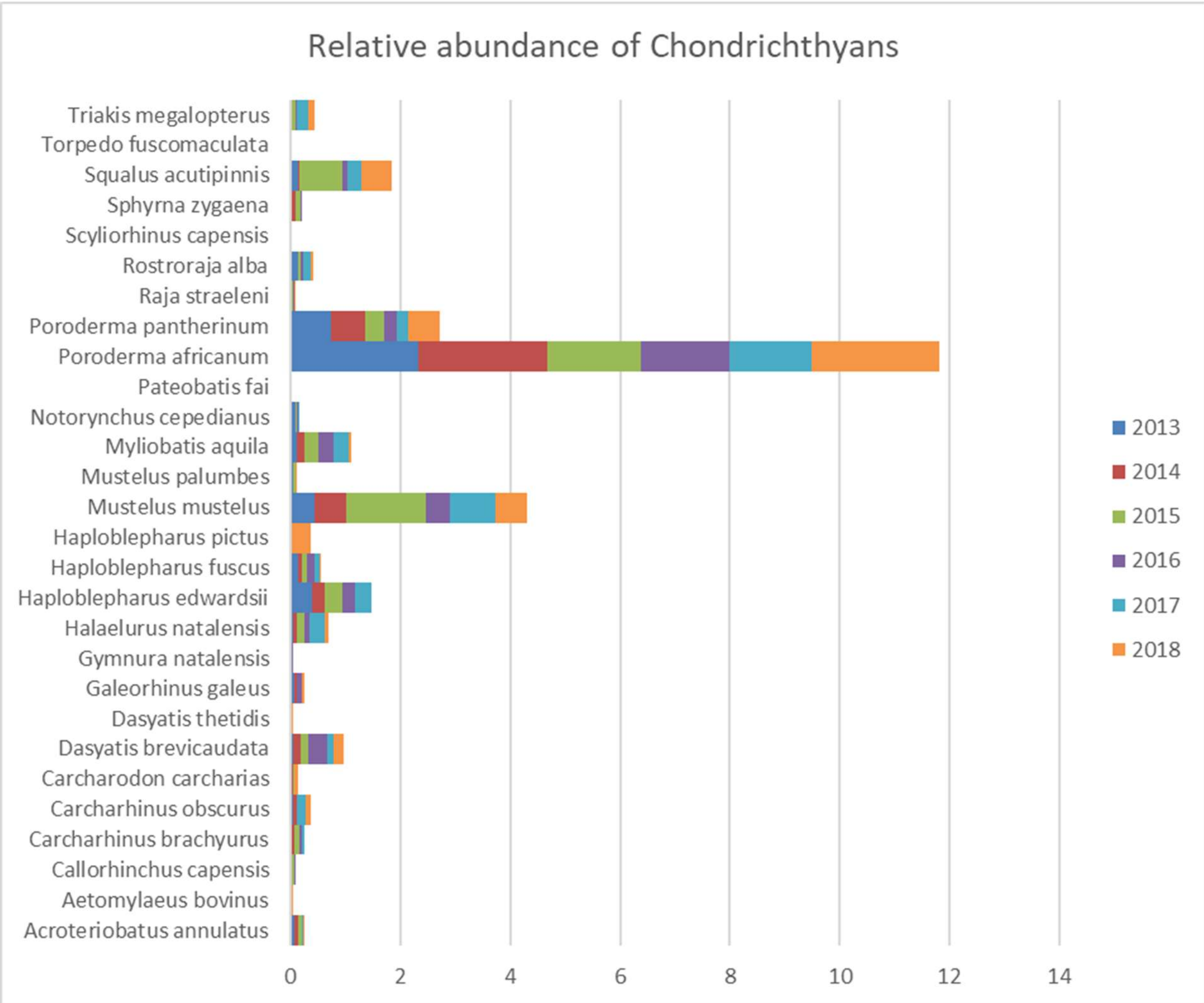

Figure 22: Relative Abundance of Chondrichthyans from 2013 to 2018.

5. Summary of results

1. Year: The data showed that there was a significant difference in the number of species per site between years. This was driven by 2017 being significantly lower to 2013 and 2018. This can in part be attributed to incomplete sampling across the habitat types.
2. Depth: Species richness was significantly lower in deeper water but intermediate depths and shallow depths were similar.
3. Protection Status: Species richness was lower in the MPA than outside the MPA.
4. IUCN threatened categories: 27 species from threatened categories were recorded out of a total of 91 observed species.

6. Conclusion and recommendations

In conclusion, the study revealed notable temporal and spatial variations in species richness, with 2017 showing significantly lower species counts compared to 2013 and 2018, likely due to incomplete sampling across habitat types. Depth also played a critical role, as species richness decreased significantly in deeper waters, while intermediate and shallow depths maintained similar levels of biodiversity. Interestingly, the study found lower species richness within Marine Protected Areas (MPAs) compared to areas outside these zones. Additionally, the presence of 27 species categorized as threatened by the IUCN, out of the 91 observed species, underscores the importance of ongoing conservation efforts. These findings highlight the complex interplay of environmental factors on biodiversity and emphasize the need for targeted management strategies to protect vulnerable species and habitats.

It is understood that Stereo-BRUV surveys have continued since 2018 and the recommendation is that a thorough Stereo survey be conducted across a wide range of site as soon as possible to validate the current state of the MPA. Use of Stereo-BRUV will provide much needed size frequency data which can be used to better understand the effectiveness of the MPA compared to its surroundings. I am not sure if mono-BRUV surveys are still continuing in the Goukamma MPA but if they are, the equipment needs to be brought up to standard and some SOPs produced for the rangers responsible for deployments.

Acknowledgments

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8. Annexes

Annexure 1 Relative abundance values for all observed species

Table 6: Relative Abundance values for all observed species

Species name	2013	2014	2015	2016	2017	2018
Acanthistius sebastoides	0,109375	0,245902	0,238095	0,196429	0,090909	0,15
Acroteriobatus annulatus	0,0625	0,065574	0,071429	0	0,030303	0,025
Aetomylaeus bovinus	0	0	0	0	0	0,05
Amblyrhynchotes honckenii	0,3125	0,590164	0,690476	0,285714	1,121212	0,6
Argyrosomus japonicus	0,015625	0	0	0,017857	0	0
Argyrozona argyrozona	0	0	0	0	0	1,325
Astropecten irregularis ponyoporeus	0	0	0	0	0	0,025
Atractoscion aequidens	0	0	0	0,142857	0	0
Boopsoidea inornata	4,96875	4,081967	2,238095	4,589286	3,181818	11,55
Bullia laevissima	0	0	0	0	0	0,075
Callorhinchus capensis	0	0,008197	0,047619	0,017857	0	0
Caranx sexfasciatus	0	0	0	0	0	0,025
Carcharhinus brachyurus	0,015625	0,04918	0,095238	0,053571	0,030303	0
Carcharhinus obscurus	0,046875	0,065574	0	0	0,151515	0,1
Carcharias taurus	0,03125	0,04918	0,02381	0,053571	0	0,05
Carcharodon carcharias	0,015625	0,016393	0,02381	0,017857	0	0,05
Chaetodon marleyi	0,046875	0,090164	0,047619	0,035714	0	0
Cheilodactylus fasciatus	0,09375	0,114754	0,02381	0,053571	0,090909	0,05
Cheilodactylus pixi	0,0625	0,319672	0,119048	0,053571	0	0,025
Cheimerius nufar	0,875	1,319672	1,02381	1,410714	0,272727	1,35
Chelidonichthys kumu	0	0	0,071429	0	0,030303	0
Chirodactylus brachydactylus	0,4375	0,598361	0,190476	0,160714	0,212121	0,15
Chirodactylus grandis	0,015625	0	0	0,053571	0	0
Chrysoblephus cristiceps	0,265625	0,311475	0,333333	0,285714	0,060606	0,4
Chrysoblephus gibbiceps	0,359375	0,311475	0,214286	0,232143	0,121212	0,2
Chrysoblephus laticeps	3,65625	3,762295	2,595238	3,232143	2,060606	4,1
Clinus superciliosus	0	0	0	0	0,030303	0
Congiopodus spinifer	0	0	0	0	0	0,025
Cremnochorites capensis	0	0,02459	0	0	0	0
Cymatoceps nasutus	0,015625	0	0	0	0	0,025
Dasyatis brevicaudata	0,046875	0,131148	0,142857	0,339286	0,121212	0,175
Dasyatis chrysonota	0	0,016393	0,095238	0	0	0
Dasyatis thetidis	0	0	0	0	0	0,05
Dichistius capensis	0	0	0,02381	0	0	0
Diplodus capensis	0,65625	1,032787	0,238095	0,285714	0,272727	0,55
Diplodus hottentotus	0,453125	0,483607	0,261905	0,285714	0,121212	0,35
Epinephelus marginatus	0,109375	0,090164	0,142857	0,125	0,060606	0,1
Eptatretus hexatrema	0,015625	0,02459	0	0	0	0
Galeichthys ater	0,28125	0,327869	0,238095	0,714286	0,484848	0,4

Galeichthys feliceps	0,59375	0,483607	1,071429	0,5	0,666667	1,725
Galeorhinus galeus	0,0625	0,04918	0	0,089286	0	0,05
Gymnocrotaphus curvidens	0,0625	0,114754	0,095238	0,089286	0	0,05
Gymnura natalensis	0	0	0	0,035714	0	0
Halaelurus natalensis	0,03125	0,081967	0,142857	0,089286	0,272727	0,075
Haploblepharus edwardsii	0,390625	0,221311	0,333333	0,232143	0,30303	0
Haploblepharus fuscus	0,140625	0,065574	0,095238	0,142857	0,090909	0,025
Haploblepharus pictus	0	0	0	0	0	0,375
Jasus lalandii	0	0	0	0	0	0,025
Lagocephalus sceleratus	0	0,016393	0	0,017857	0	0
Lichia amia	0	0,008197	0	0	0	0
Lithognathus lithognathus	0	0	0	0	0	0,025
Lithognathus mormyrus	0,140625	0,139344	0,047619	0,053571	0,212121	0,075
Loligo vulgaris reynaudii	0	0	0	0	0	0,025
Mustelus mustelus	0,4375	0,57377	1,452381	0,446429	0,818182	0,575
Mustelus palumbes	0,03125	0,016393	0,047619	0	0	0,025
Myliobatis aquila	0,109375	0,131148	0,261905	0,285714	0,272727	0,05
Narke capensis	0	0	0,071429	0	0	0
Notorynchus cepedianus	0,078125	0,016393	0,02381	0,017857	0,030303	0
Octopus vulgaris	0	0	0	0	0	0,15
Oplegnathus conwayi	0,328125	0,295082	0,142857	0,196429	0,181818	0,225
Pachymetopon aeneum	1,453125	1,754098	2	1,446429	0,727273	1,45
Pachymetopon grande	0	0	0,047619	0,107143	0	0,275
Pagellus natalensis	0,71875	0,795082	1,357143	0,267857	2,363636	0,025
Parascorpis typus	0	0,016393	0	0	0	0
Pateobatis fai	0	0	0	0	0	0,025
Petrus rupestris	0,328125	0,237705	0,047619	0,089286	0,090909	0,075
Polysteganus undulosus	0,015625	0,032787	0	0	0	0
Pomadasys olivaceus	0,53125	0,336066	0,02381	0,785714	0,454545	1,325
Pomadasys striatus	0	0,008197	0	0	0	0
Pomatomus saltatrix	0,4375	0,04918	8,261905	0,607143	0	0
Poroderma africanum	2,328125	2,336066	1,714286	1,607143	1,515152	2,325
Poroderma pantherinum	0,734375	0,614754	0,357143	0,214286	0,212121	0,575
Pterogymnus laniarius	0,21875	0,459016	0,809524	0,696429	0,363636	0
Raja straeleni	0	0,016393	0,02381	0,017857	0	0,025
Rhabdosargus globiceps	0	0	0	0	0	0,2
Rhabdosargus holubi	0,046875	0	0	0	0	0,175
Rostroraja alba	0,125	0,008197	0,047619	0,053571	0,121212	0,05
Sarpa salpa	1,296875	0,147541	0	0,017857	0,757576	9,225
Scyliorhinus capensis	0,015625	0	0	0	0	0
Semicassis labiata zeylanica	0	0	0	0	0	0,05
Seriola lalandi	0	0,016393	0	0,267857	0,69697	0
Serranus cabrilla	0,03125	0,040984	0,047619	0,017857	0	0,1
Sphyrna zygaena	0,015625	0,065574	0,095238	0,035714	0	0
Spondyliosoma emarginatum	13,40625	12,08197	4,690476	7,571429	2	8,25
Squalus acutipinnis	0,140625	0,02459	0,785714	0,071429	0,272727	0,55

Torpedo fuscomaculata	0	0,016393	0	0	0	0
Trachurus capensis	0	0	0	0	0	1,3
Trachurus trachurus	0,125	0	0,547619	0,803571	1,666667	0
Triakis megalopterus	0	0	0,095238	0,017857	0,212121	0,1
Umbrina ronchus	0	0,008197	0	0	0	0

Annexure 2 Relative abundance values for all chondrichthyans

Table 7: Relative Abundance values for all Chondrichthyans.

Species name	2013	2014	2015	2016	2017	2018
Acroteriobatus annulatus	0,0625	0,065574	0,071429	0	0,030303	0,025
Aetomylaeus bovinus	0	0	0	0	0	0,05
Callorhinchus capensis	0	0,008197	0,047619	0,017857	0	0
Carcharhinus brachyurus	0,015625	0,04918	0,095238	0,053571	0,030303	0
Carcharhinus obscurus	0,046875	0,065574	0	0	0,151515	0,1
Carcharodon carcharias	0,015625	0,016393	0,02381	0,017857	0	0,05
Dasyatis brevicaudata	0,046875	0,131148	0,142857	0,339286	0,121212	0,175
Dasyatis thetidis	0	0	0	0	0	0,05
Galeorhinus galeus	0,0625	0,04918	0	0,089286	0	0,05
Gymnura natalensis	0	0	0	0,035714	0	0
Halaelurus natalensis	0,03125	0,081967	0,142857	0,089286	0,272727	0,075
Haploblepharus edwardsii	0,390625	0,221311	0,333333	0,232143	0,30303	0
Haploblepharus fuscus	0,140625	0,065574	0,095238	0,142857	0,090909	0,025
Haploblepharus pictus	0	0	0	0	0	0,375
Mustelus mustelus	0,4375	0,57377	1,452381	0,446429	0,818182	0,575
Mustelus palumbes	0,03125	0,016393	0,047619	0	0	0,025
Myliobatis aquila	0,109375	0,131148	0,261905	0,285714	0,272727	0,05
Notorynchus cepedianus	0,078125	0,016393	0,02381	0,017857	0,030303	0
Pateobatis fai	0	0	0	0	0	0,025
Poroderma africanum	2,328125	2,336066	1,714286	1,607143	1,515152	2,325
Poroderma pantherinum	0,734375	0,614754	0,357143	0,214286	0,212121	0,575
Raja straeleni	0	0,016393	0,02381	0,017857	0	0,025
Rostroraja alba	0,125	0,008197	0,047619	0,053571	0,121212	0,05
Scyliorhinus capensis	0,015625	0	0	0	0	0
Sphyrna zygaena	0,015625	0,065574	0,095238	0,035714	0	0
Squalus acutipinnis	0,140625	0,02459	0,785714	0,071429	0,272727	0,55
Torpedo fuscomaculata	0	0,016393	0	0	0	0
Triakis megalopterus	0	0	0,095238	0,017857	0,212121	0,1