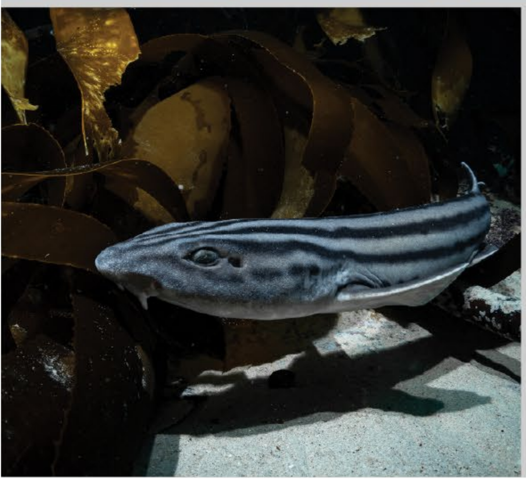
WILDTRUST™

Baited Remote Underwater Video Surveys Report (2013-2016)

STILBAAI MARINE PROTECTED AREA





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MPA Technical Report

Stilbaai BRUV

2013-2016

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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

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1. Abstract

The Stilbaai Marine Protected Area (MPA) was declared in 2008 and it's situated along the southern coast of the Western Cape west of Mossel Bay with a total size of 20 km^2 and the management authority is CapeNature. BRUVs were deployed in Stilbaai's MPA from 2013 to 2016. The survey produced 57 successful deployments across reef, rocky and sand sites. For this report, only habitat type and year of sampling were used as variables to infer variation in the diversity and abundance in the fish population. This was due to a lack of metadata as well as sampling bias. Fish abundance was recorded using the *MaxN* metric (count of the highest number of individuals of each species were presented in a single data frame). The deployment records were cleaned and converted into a single data frame for analysis in R studio.

In total, we identified 58 species from 21 families. The relative abundance, mean abundance, and species richness of all species were notably higher in 2016 and in reef habitats. The Sparidae family was the most frequently recorded, followed by Triakidae, Squalidae, and Tetraodontidae. Within the Sparidae family, the most commonly observed species were *Spondyliosoma emarginatum, Chrysoblephus laticeps, Diplodus hottentotus, Cheimerius nufar, Boopsoidea inornata,* and *Petrus rupestris*.

For Elasmobranchs, we identified 18 species from 7 families over the same period with Scyliorhinidae and Triakidae families most frequently recorded. The most common species within the Triakidae family was *Mustelus mustelus, while Poroderma pantherinum* and *Poroderma africanum* were the most prevalent in the Scyliorhinidae family. The species *Squalus acutipinnis*, a member of the Squalidae family, is also frequently represented. 2016 stood out for having the highest relative abundance and richness of Elasmobranch species. Interestingly, sand habitats exhibited the highest relative and mean abundance. Nine of the total Elasmobranch species identified in our study have been classified as Threatened (CR, EN and VU) according to the IUCN List of Threatened Species.

In total,18 species from 9 different families were classified as Threatened (CR, EN and VU) by the IUCN Red List Categories. Overall, abundance increased in 2015, particularly in rocky areas. When examining relative abundance, the pattern remains consistent. In terms of species richness, a notable increase was observed in 2015, with reef habitats showing greater species richness.

During the study period, 13 species from 4 families were considered to be commercial species. Of these, Sparidae was the most prevalent family, with the most common species being *Chrysoblephus laticeps, Cheimerius nufar,* and *Pachymetopon aeneum*. For commercial species, a consistent trend over time was observed, with improvements noted in both relative and mean abundance. In terms of habitat, reef environments demonstrated higher levels of both abundance and species richness. Four commercial species are listed as threatened (CR, EN and VU) on the IUCN Red List: *Pomatomus saltatrix, Epinephelus marginatus, Chrysoblephus cristiceps,* and *Chrysoblephus gibbiceps*.

Data gaps (as a result of infrequent sampling and lost metadata) posed significant challenges to our analysis and conclusions, underscoring the need for improved data collection and preservation. Future research should enrich reports with metadata for a comprehensive view of Stilbaai's biodiversity and to get a measure of the effectiveness of the MPA).

2. Background

SASC was approached by Cape Nature to analyse historical Mono-BRUV video data for the Stilbaai's MPA and surrounding area from 2013 to 2016. A standardised structure for these kinds of reports was discussed at the recent BRUV workshop and while this hasn't yet been formalised, this has been considered. Funding for the analyses and report was provided by WildTrust.

2.1 Report limitations

There are some important limitations to the current report dataset. The BRUV surveys lack most of the metadata such as location and depth, which restricts the report's potential uses, as it makes it challenging to determine whether we are inside or outside of a marine protected area. The lack of homogeneity in the sampling sites also makes it biased.

Furthermore, there has been substantial criticism of the value of *MaxN* (maximum number of individuals of each species recorded in one frame observed during 60 min of BRUV footage) as a measure of abundance in the literature (Cappo *et al*., 2003; Bacheler *et al*., 2013; Schobernd *et al*., 2014; Stobard *et al*., 2015); yet this study still describes the value of *MaxN* in the absence of size frequency data. *MaxN*'s ability to describe efficacy is limited. Without size frequency data, it is challenging to determine whether an MPA is operating or not. i.e. You can't draw conclusions that couldprove that larger fish are only found in MPAs.

It was also challenging to identify the habitat type. SASC generally uses three basic habitat categories, rock, reef, and kelp; however, the data that was given to use did not include kelp and provided no additional information on the distinction between reefs and rocks. We understand that the term reef refers to a stony ecosystem with more coral than rock.

Because of its overall bias, the reports analysis is unable to produce a precise estimate of Stillbaai's marine biodiversity.

2.2 Stillbaai MPA

The Stilbaai MPA was declared on 17 October 2008 in Government Notice No. 31517 with regulations in Government Notice No. 31516. The regulations provide specific objectives for the MPA, define restricted and controlled zones, and describe the requirements and procedures for various activities in the MPA. Management indicated that the legislation and regulations applicable to the MPA were well drafted and adequate for management purposes; however, it was suggested that the flexibility of the regulations be increased to allow for more adaptive practical spatial management (Toit & Attwood, 2008; Tunley, 2009; Chadwick *et al*., 2014). The IUCN Management Category has not been reported for Stillbaai's MPA (https://www.protectedplanet.net/555563466).

The Stilbaai MPA is situated along the southern coast of the Western Cape west of Mossel Bay (Chadwick *et al*., 2014; De Vos *et al*., 2014), it has a total size of 20 km^2 and the management authority is CapeNature (Tunley, 2009; Visagie & Saul, 2014; Marine Conservation Institute, 2018; UNEP-WCMC & IUCN, 2020). The ecology and habitats represented in the MPA consist of features that are typical to the warm-temperate south coast: abundant inter-tidal life, a productive estuary, diverse offshore fisheries, and an abundance of cetaceans. Its benthos is comprised of rocky reefs and sandy substrata. The coastal town of Stilbaai is set around the banks of the Goukou River Estuary and borders on a large part of the MPA (Chadwick *et al*., 2014; De Vos *et al*., 2014). A town centred on an estuary, an estuary starved of freshwater, displaced rural people, failed fisheries, transformation of traditional ways of life, and displacement by wealthy absentee landowners are some of the many problems represented in the MPA (Toit & Attwood, 2008). A unique feature of the Stillbaai's MPA is the culturally and historically significant stone-age fish traps known as *vywers*.

The Stillbaai MPA is the area between Noordkapperspunt (Bosbokduin) and Rietvlei *vywers* (length of protected coastline 13.8 km) and includes the Goukou River Estuary (to a point of 15.7 km upstream), sandy beaches, a shallow sandstone shelf and rocky shores (from the intertidal to 30-40 m depth). The high water mark on the coast and in the estuary is the landward boundary while the seaward boundary is defined by straight lines extending eastward from Noordkapperspunt to a point 4.2km offshore from Rietvlei *vywers* and from this offshore point back to the coast at Rietvlei *vywers* (Tunley, 2009).The Goukou Estuary is one of the few permanently open estuaries (Dando, 2020), being highly productive and forming an important nursery area for coastal fish. This is the first estuary to be included in a MPA in the Western Cape. Reef fish species (mostly of the sea-bream family), Southern Right whales, two species of eel (mottled and longfin eel), pansy shell, and ragged-tooth sharks are some of the iconic species represented in the MPA (Tunley, 2009), many whom are threatened by excessive fishing pressure (Toit & Attwood, 2008).

There are four small nature reserves in the vicinity (*Figure 1*): three Restricted Zones and one Controlled Zone within Stillbaai's Marine Protected Area. The no take zones, where all types of fishing are prohibited, are:

- the Geelkrans restricted zone, adjacent to the Geelkrans Nature Reserve at the eastern end of the MPA;
- Skulpiesbaai Restricted Zone at Noordkapperspunt, incorporating the *vywers*;
- and part of the Goukou Estuary, from approximately 4 km upstream of the mouth to 15km from the mouth.

The remainder of the MPA is a Controlled Zone, located between the estuary mouth and ocean (Toit & Attwood, 2008; Tunley, 2009).

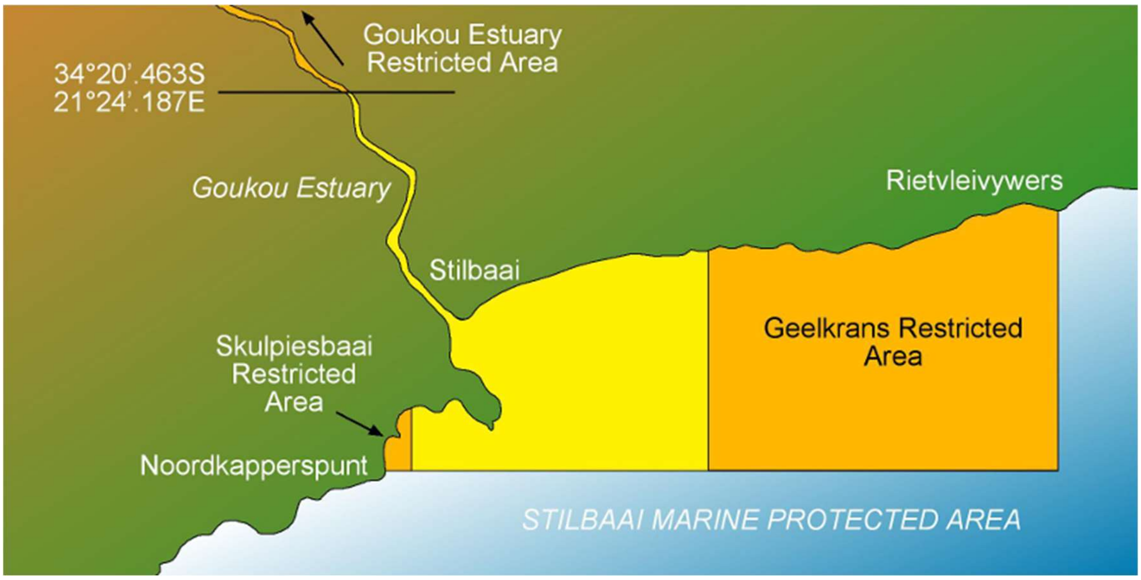

Figure 1. *Map of Stilbaai showing the terrestrial reserves relative to the Controlled and Restricted Zones of the MPA, including the Goukou Estuary (Toit & Attwood, 2008).*

3. Methods

3.1 Mono-BRUVs

Mono-BRUVs were deployed over years by Cape Nature rangers. The basic BRUV design typically involves a camera equipped with a bait canister fixed within its field of view (FOV), around one metre away from the bait cannister and 14 cm above the seafloor. The selected bait for optimal attraction is sardines (*Sardinops sagax*), as is the standard for BRUV surveys in South Africa (Dando, 2020).

Small action GoPro cameras were used in the BRUV rigs due to their relatively low cost, the robustness of their design, and their ability to adjust to highly variable ambient light (Letessier *et al*., 2015; Bouchet *et al*., 2018; Langlois *et al*., 2018). The GoPro's standard video settings were used. Video analysis was conducted on VLC Media Player (*version 2.2.6 Ubrella*). Videos were analysed for a standardised period of one hour following the BRUVs settling on the sea floor.

BRUVs were deployed in Stillbaai from 2013 to 2016. The survey produced 57 successful deployment records across reef, sand and rocky sites. Deployments were considered successful when the BRUV rig landed suitably enough for the footage to be analysed (50% or more of the FOV was not obstructed and visibility was 1 m or greater), a minimum of one hour of video footage was recorded, and a minimum of one fish was recorded. Information was not always included in the BRUV rigs' deployment times and the depth and coordinates for each deployment site.

All fish species identified in the videos were recorded and the count at the instance when the highest number of individuals of each species was present in a single frame was recorded as the species' *MaxN*. This method mitigates the possibility of recounting the same individuals and inflating species' *MaxN* counts (Willis *et al*., 2000). Relative abundance was calculated by summing the *MaxN* of each species and dividing it by the total number of sites surveyed.

The deployment details, abiotic variables, and *MaxN* counts per species were contained in a single record for each BRUV deployment. Field data sheets were digitised in Microsoft® Excel. All records were converted into a single data frame of comma-separated values (CSV) file format for statistical analysis.

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).

Habitat type and sampling year were tested to determine whether they affected diversity and abundance in Stillbaai. Other important variables such as depth and site coordinates were neither consistently nor reliably measured throughout the four-year data collection period and were therefore excluded from final analyses.

3.2.1 Diversity and abundance

Species richness and abundance were determined along with the Shannon-Wiener and Simpson's diversity indices to assess diversity. Abundance was calculated by summing the *MaxN* counts for each species. *MaxN* reduces high volumes of fish to a small number that fits into the FOV. The Shannon-Wiener and Simpson's indices were calculated using the diversity function (index = "Shannon" and index = "Simpson", respectively; *vegan v2.4-2*) (Okansen *et al*., 2018). This was done to provide additional insights into diversity, complementing the measures of abundance and species richness, but these indices were not tested for significant differences. Graphics were used to visually represent variations in each of the dependent variables as a result of each of the independent variables. The plots were created using the ggplot2 function (*graphics v3.6.2*) (Friedmann & Schellenberg, 2018). Relative abundance was calculated by summing the *Max N* of each species and dividing it by the total number of sites surveyed. The dependent variables were species richness and abundance, while the independent variables were habitat type, sampling site and year.

Following visual analysis, variables were examined to see if they met the *anova* assumptions of homogeneity or normality. Each dependent variable's subset of independent variables was tested for homogeneity of variance using Levene's test. The levene_test function (*rstatix v0.3.1*) (Kassambara, 2019) was used to perform these tests. In cases where all of the dependent variables' variances were homogenous, the independent variables' levels were tested for normality using Shapiro-Wilk tests. The shapiro.test function (*stats v3.6.2*) was used to perform these tests.

No cases were found in which the independent variable's variances meet the *anova* assumptions for homogeneity or normality. Because multi-factor analysis of variance (ANOVA) could not be performed, the non-parametric Kruskal-Wallis and Wilcoxon sign ed-rank tests were used to test the significance of each of the independent variables, using the kruskal_test and wilcox_test functions (*stats v3.6.2*), respectively (Hollander & Douglas, 1973). Kruskal-Wallis tests were used to determine whether habitat type, sampling site and sampling year significantly affected their species richness, relative abundance, and Shannon-Wiener and Simpson's similarity index scores. However, Kruskal-Walli's output was not computed successfully due to insufficient data, too many ties in the data, one or more groups only containing a single observation, or missing or undefined values in the data frame. As a result, they were not included in this report. Generalized Linear Models (GLM) were run for species and family abundance, and richness using the function *GLM* (*stats v3.6.2) (*Bates *et al*., 2015*)*.

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 source 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 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 2*).

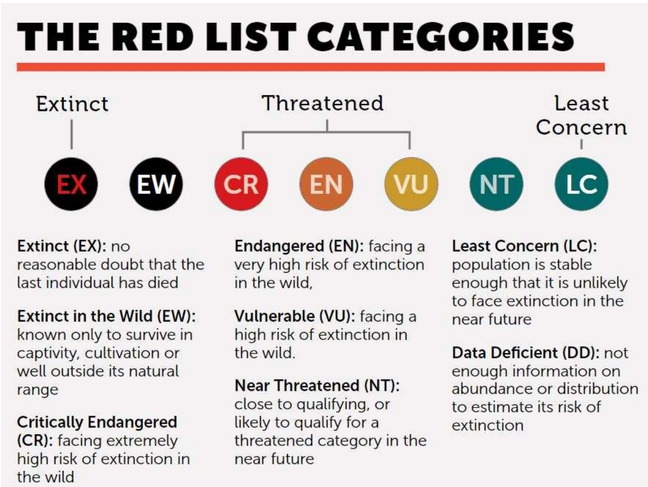

Figure 2. IUCN Red List Categories (IUCN, 2024).

4. Results and discussion

Over a period of four years (2013-2016), there were 57 successful BRUV deployments. Due to a higher number of BRUV installations in those years or to failed deployments in the other years, the data set is skewed toward the years 2015 and 2016 (*Table 1*). Reduced or non-existent visibility, bad weather, and BRUVs getting stuck in benthos were all examples of unsuccessful BRUVs. 2015 was the year with the highest count of species, and count of threatened species.

Table 1. Annual variation of the number of sampled sites, the total count of species, and number of threatened species based on the IUCN Red List Categories (CR: Critically Endangered; EN: Endangered; and VU: Vulnerable). No: number.

Year	No. of sites sampled	Total no. of species	No. of threatened species (IUCN)
2013	8	29	8
2014	12	35	8
2015	17	42	13
2016	20	31	9

4.1 Trends in Diversity

4.1.1 Assumption tests and significance models

GLMs were used to determine whether there are substantial differences in species richness and abundance across habitats, sites, and years (*Annexes 6, 7, 8 and 9*).

Reef sites had significantly higher species (*GLM*: t value = 2.00e+15, P < 2e-16***) and family (*GLM*: t value = 1.66e+15, P < 2e-16***) richness than sand and rocky habitats (*Annexes 6 and 7*). Abundance followed the same tendency (*GLM*: t value = 9.457, P < 2e-16***) (*Annexes 10)*

Species and family richness differed overtime. All four year (2013, 2014, 2015 and 2016) showed significant differences for both species (*GLM*: t value = 1.19e+15, P < 2e-16***; t value = -2.03e+00, P < 0.0428*; t value = -2.09e+00, P < 0.0373* and t value = -2.01e+00, P < 0.0452*, respectively) and family (*GLM*: t value = 1.02e+15, P < 2e-16***; t value = 2.06e+00, P < 0.0400*; t value = -2.12e+00, P < 0.0347* and t value = -2.04e+00, P < 0.0423*, respectively) richness (*Annexes 6 and 7*). However, 2013 showed higher significant differences than the following years. On the other hand, abundance was only statistically significant in 2013 and 2016 (*GLM*: t value = 3.943, P < 8.93e-05*** and t value = 2.975, P < 0.00304**, respectively) (*Annexes 10)*.

Our *GLM* models showed that only the sites AB8 and L4 were statistically significant for species (*GLM*: t value = 3.28e+14, P < 2e-16*** and t value = 4.73e+00, P < 2.88e-06***, respectively) and families (*GLM*: t value = 2.78e+14, P < 2e-16*** and t value = 4.73e+00, P < 2.88e-06***, respectively) richness. Due to a lack of information on the sites, we cannot determine whether the variance in richness is due to random chance or is more likely related to the different conditions or characteristics of the sites. This could be influenced by a variety of factors such as differences in habitat, availability of resources, or environmental conditions across the sites. As to abundance, significant differences were showed for sites F6 and G7 (*GLM*: t value = 2.396, P < 0.0169* and t value = 7.045, P < 5.18e-12***, respectively) (*Annexes 8, 9 and 10*).

4.1.2 Richness and abundance

The two greatest average abundances of fish per BRUV deployment were observed in the 2016 and 2015 surveys (mean *Max N*= 4.53, mean *Max N*= 3.41, respectively) (*Table 2, Figure 3*). However, the total recorded species richness was higher in 2014 and 2015 (35 and 42 respectively). 2013 saw the lowest levels of average abundance (mean *Max N* = 2.34) and overall species richness (29).

Table 2. Key parameters of all ichthyofauna combined, stratified by year and habitat during the four-year timeframe. Mean Max N: Average maximum number of individuals observed per sample: Toal Abundance: The overall count of individuals across all samples; Relative Abundance: Average abundance per sample; Total Species Richness: Total number of distinct species recorded; Mean H": Mean of the Shannon-Wiener diversity index; Mean D: Simpsons diversity index.

Year	Mean Max N	Total Abundance	Relative Abundance	Species Richness	Mean H"	Mean D	Mean Species Richness
2013	2.336957	215	3.77193	29	0.36982	0.21219	1.586207
2014	2.134831	380	6.666667	35	0.4337248	0.245789	3.068966
2015	3.415094	724	12.701754	42	0.5857205	0.328841	3.655172
2016	4.532934	757	13.280702	31	0.647989	0.340959	2.87931
Habitat	**Mean Max N**	**Total Abundance**	**Relative Abundance**	**Species Richness**	**Mean H"**	**Mean D**	**Mean Species Richness**
Reef	3.425703	853	14.964912	45	0.6115992	0.338283	4.293103
Rocky	2.557047	762	13.368421	44	0.4962204	0.262745	5.137931
Sand	4.519608	461	8.087719	28	0.5956124	0.351035	1.758621

The habitats found in reef and rocky areas exhibited the highest overall species richness and abundance. Nonetheless, the sand substrate had the highest average abundance, most likely because of the majority of BRUVs being deployed in sand in 2016 (*Figure 3*).

Over the course of four years, 57 sites were sampled. *Table 2* and *Figure 3* show that most locations are associated with rocky and reef environments. The largest amount of sampling was completed in the years 2015 and 2016, while 2013 had the least.

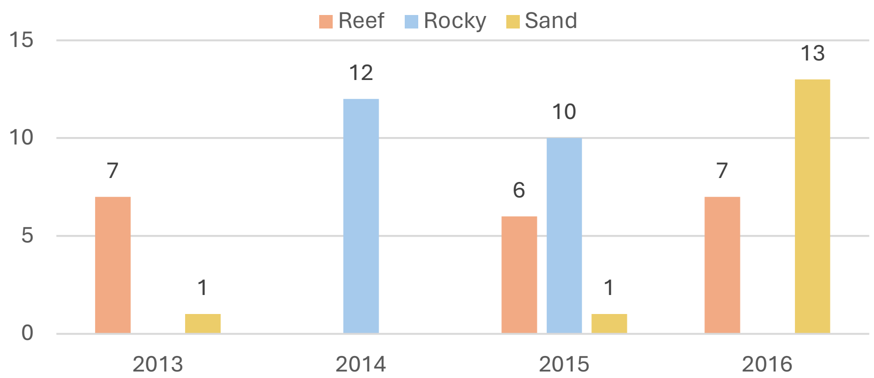

Figure 3. Number of habitat types sampled by year. X-axis represent the timeline. Y-axis represents the count of habitats.

Only in 2015 were the three types of habitats studied. In 2013 and 2016, no rocky environment was sampled; however, in 2014, all the sampled locations were rocky habitats. Higher species richness and total abundance appear to correlate with higher prevalence of reef (*Table 2*, *Figure 4*). Sand environment had the lowest richness and abundance, most likely due to sample bias: in total 22 reef, 20 rocky, and 15 sand sites were sampled over the 4-year period (*Figure 3*).

The analysis of total abundance for both species and families across different habitats revealed that rocky habitats harbour the greatest abundances, closely followed by reef habitats (*Figure 4*). Additionally, when examining the total abundance of species over the years, 2016 recorded the highest numbers, with 2014 coming in second. In contrast, when considering the annual abundance of families, the highest value was observed in 2015 (*Figure 4*).

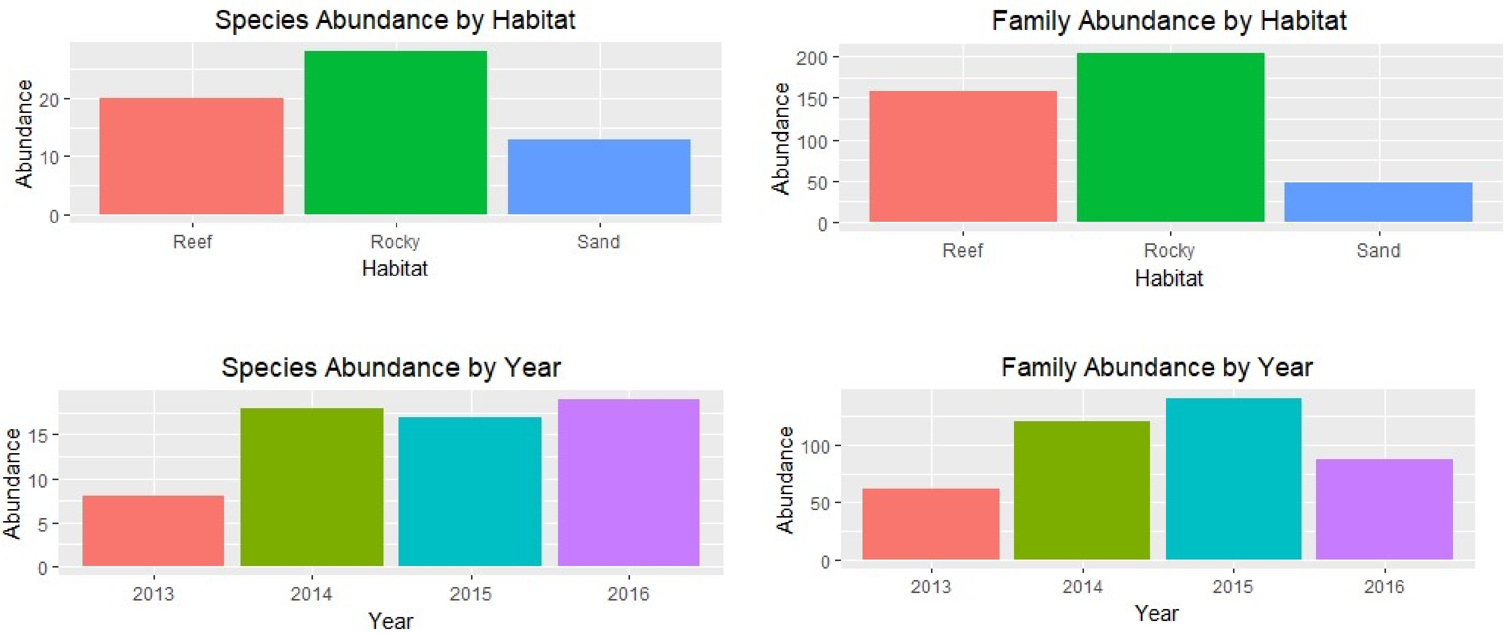

Figure 4. Species (left side of the figure) and family (right side of the figure) abundances for each habitat type (upper part of the figure) and year (bottom part of the figure).

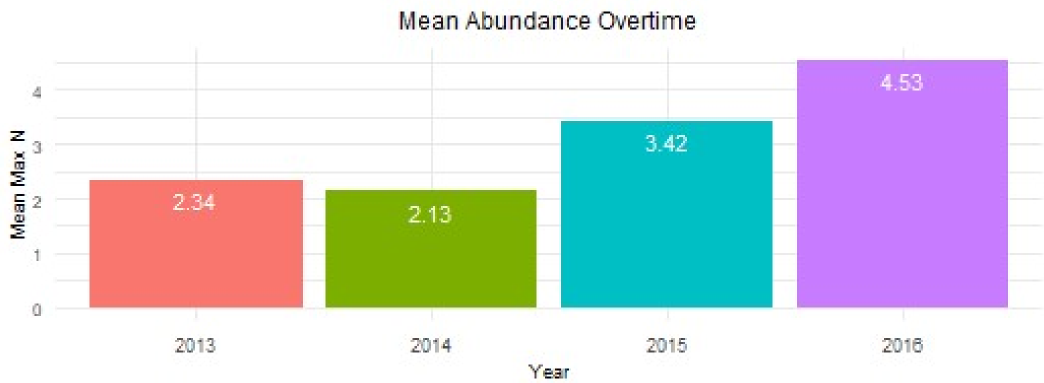

Figure 5. Mean of the species abundance (Max N) over the four-year period of this study.

Figure 5 illustrates the mean of the species abundance from 2013 to 2016. This trend suggests that the species' abundance has increased over time, particularly noting a substantial growth from 2014 to 2016. It is evident that 2016 had the highest abundance, likely due to a greater number of BRUVs deployed that year compared to previous years.

58 species from 21 families were identified over a 4-year period (*Table 3*). The most frequently recorded family was by far Sparidae, with a total of 409 observations; followed by Scyliorhinidae, with 78 observations (*Annexes 2*). Triakidae, Squalidae and Tetraodontidae were the next most common families. The Ariidae family had a low species count but a greater relative abundance than other families with comparable species count (*Annexes 1 and 3*). Carangidae, Dasyatidae, Dinopercidae, Lamnidae, Pomatomidae were the only five families where a single organism was reported (*Annexes 2*).

At the species level, the most common observations within the Sparidae family were: *Spondyliosoma emarginatum, Chrysoblephus laticeps, Diplodus hottentotus, Cheimerius nufar ,Boopsoidea inornata,* and *Petrus rupestris (Annexes 3)*. The most prevalent species in the Scyliorhinidae was *Poroderma pantherinum*. The species *Mustelus mustelus* which is a member of the Triakidae family is also worth mentioning.

Table 3. *Complete list of species identified in this project. For the sake of simplicity, all the species classified as "Data Deficient" (DD), "Not Evaluated" (NE) or "Not Applicable" (NA) have been combined into one category for this report: "No Data" (ND). Species: scientific name of each species identified; Common name: common name of each species; Family: Biological Family to which the species belongs; IUCN: Species classification according to the IUCN Red List.*

Species	Common name	Family	IUCN [a,b]
Aetomylaeus bovinus	Bull ray	Myliobatidae	CR
Amblyrhynchotes honckenii	Evileyed puffer	Tetraodontidae	LC
Argyrozona argyrozona	Carpenter	Sparidae	NT
Boopsoidea inornata	Fransmadam	Sparidae	LC
Carcharodon carcharias	White Shark	Lamnidae	VU
Chaetodon marleyi	Doubleslash butterfly	Chaetodontidae	LC
Cheilodactylus fasciatus	Redfingers	Cheilodactylidae	LC
Cheilodactylus pixi	Barred fingerfin	Cheilodactylidae	ND
Cheimerius nufar	Santer	Sparidae	ND
Chirodactylus brachydactylus	Twotone fingerfin	Cheilodactylidae	ND
Chrysoblephus anglicus	Englishman	Sparidae	NT
Chrysoblephus cristiceps	Dageraad	Sparidae	CR
Chrysoblephus gibbiceps	Red stumpnose	Sparidae	EN
Chrysoblephus laticeps	Red roman	Sparidae	NT
Clinus venustris	Speckled Klipfish	Clinidae	LC
Cymatoceps nasutus	Black musselcracker	Sparidae	VU
Dasyatis chrysonota	Blue stingray	Dasyatidae	NT
Dichistius multifasciatus	Banded galjoen	Sparidae	ND
Dinoperca petersi	Cavebass	Dinopercidae	ND
Diplodus capensis	Blacktail seabream	Sparidae	LC
Diplodus hottentotus	Zebra	Sparidae	LC
Epinephelus andersoni	Catface grouper	Serranidae	NT
Epinephelus marginatus	Yellowbelly rock cod	Serranidae	VU
Galeichthys ater	Black seacatfish	Ariidae	LC
Galeichthys feliceps	White seacatfish	Ariidae	ND

Galeorhinus galeus	Soupfin shark	Triakidae	CR
Gymnocrotaphus curvidens	Janbruin	Sparidae	LC
Halaelurus natalensis	Tiger catshark	Scyliorhinidae	VU
Haploblepharus edwardsii	Puffadder shyshark	Scyliorhinidae	EN
Haploblepharus fuscus	Brown shyshark	Scyliorhinidae	VU
Haploblepharus pictus	Dark shyshark	Scyliorhinidae	LC
Hexanchus griseus	Bluntnose Sixgill shark	Hexanchidae	NT
Lichia amia	Garrick	Carangidae	LC
Lithognathus lithognathus	White steenbras	Sparidae	EN
Mustelus mustelus	Smooth-hound shark	Triakidae	EN
Mustelus palumbes	White spotted smoothhound	Triakidae	LC
Myliobatis aquila	Eagle ray	Myliobatidae	CR
Notorynchus cepedianus	Sevengill cowshark	Hexanchidae	VU
Octopus vulgaris	Common octopus	Octopodidae	LC
Oplegnathus conwayi	Cape Knifejaw	Oplegnathidae	ND
Pachymetopon aeneum	Blue hottentot	Sparidae	LC
Pachymetopon blochii	Hottentot	Sparidae	LC
Pachymetopon grande	Bronze bream	Sparidae	NT
Petrus rupestris	Red steenbras	Sparidae	EN
Pomatomus saltatrix	Shad	Pomatomidae	VU
Poroderma africanum	Pyjama catshark	Scyliorhinidae	LC
Poroderma pantherinum	Leopard catshark	Scyliorhinidae	LC
Pterogymnus laniarius	Panga	Sparidae	LC
Raja straeleni	Biscuit skate	Rajidae	NT
Rhabdosargus globiceps	White stumpnose	Sparidae	VU
Rhabdosargus holubi	Cape stumpnose	Sparidae	ND
Rostroraja alba	Spearnose skate	Rajidae	EN
Sarpa salpa	Strepie	Sparidae	LC
Spondyliosoma emarginatum	Steenjie	Sparidae	LC
Squalus acutipinnis	Bluntnose Spiny Dogfish	Squalidae	NT
Triakis megalopterus	Spotted gully shark	Triakidae	LC
Umbrina canariensis	Baardman	Oplegnathidae	LC
Umbrina robinsoni	Slender baardman	Umbrina	ND

[a] Abbreviations: VU, Vulnerable; EN, Endangered; CR, Critically Endangered.

[b] Conservation status taken from IUCN Red List (IUCN, 2024).

Table 4. Matrix representing the occurrence (presence) or non-occurrence (absence) of all the species and families' overtime. Each row corresponds to the different species or family group identified in the study, and each column represent the specific year during the period of 2013 to 2016. The "X" inside the matrix indicates the presence of the species in that particular year, while a black space indicates the absence.

Species	**2013**	**2014**	**2015**	**2016**
Aetomylaeus bovinus			X	X
Amblyrhynchotes honckenii	X	X	X	X
Argyrozona argyrozona	X	X	X	X
Boopsoidea inornata	X	X	X	X
Carcharodon carcharias			X	
Chaetodon marleyi	X		X	X
Cheilodactylus fasciatus		X	X	
Cheilodactylus pixi		X	X	
Cheimerius nufar	X	X	X	X
Chirodactylus brachydactylus			X	
Chrysoblephus anglicus			X	
Chrysoblephus cristiceps			X	
Chrysoblephus gibbiceps	X	X	X	X
Chrysoblephus laticeps	X	X	X	X
Clinus venustris	X		X	
Cymatoceps nasutus	X		X	
Dasyatis chrysonota			X	
Dichistius multifasciatus		X	X	
Dinoperca petersi			X	
Diplodus capensis	X	X	X	X
Diplodus hottentotus	X	X	X	X
Epinephelus andersoni				X
Epinephelus marginatus	X		X	
Galeichthys ater			X	
Galeichthys feliceps		X		X
Galeorhinus galeus	X		X	X
Gymnocrotaphus curvidens			X	X
Halaelurus natalensis				X
Haploblepharus edwardsii		X		
Haploblepharus fuscus			X	
Haploblepharus pictus		X	X	X
Hexanchus griseus		X		
Lichia amia			X	
Lithognathus lithognathus		X	X	
Mustelus mustelus	X	X	X	X
Mustelus palumbes			X	X
Myliobatis aquila	X	X	X	X
Notorynchus cepedianus		X		
Octopus vulgaris	X			X
Oplegnathus conwayi	X	X	X	
Pachymetopon aeneum	X	X	X	X
Pachymetopon blochii	X	X	X	

Pachymetopon grande			X	
Petrus rupestris	X	X	X	X
Pomatomus saltatrix				X
Poroderma africanum	X	X	X	X
Poroderma pantherinum	X	X	X	X
Pterogymnus laniarius	X	X		X
Raja straeleni	X	X		
Rhabdosargus globiceps	X	X	X	X
Rhabdosargus holubi		X		X
Rostroraja alba				X
Sarpa salpa	X	X	X	X
Spondyliosoma emarginatum	X	X	X	X
Squalus acutipinnis		X		X
Triakis megalopterus	X	X		
Umbrina canariensis		X		
Umbrina robinsoni	X	X		

Family	**2013**	**2014**	**2015**	**2016**
Tetraodontidae	X	X	X	X
Ariidae		X	X	X
Dasyatidae			X	
Carangidae			X	
Chaetodontidae	X		X	X
Cheilodactylidae		X	X	
Clinidae	X		X	
Dinopercidae			X	
Hexanchidae		X		
Lamnidae			X	
Myliobatidae	X	X	X	X
Octopodidae	X			X
Oplegnathidae	X	X	X	
Pomatomidae				X
Rajidae	X	X		X
Scyliorhinidae	X	X	X	X
Serranidae	X		X	X
Sparidae	X	X	X	X
Squalidae		X		X
Triakidae	X	X	X	X
Umbrina	X	X		

Due to the lack of metadata, no inferences regarding the effect of depth or the protection status of the sites. For this reason, the graphics provided for the sites are only serve visual purposes and have not been statistically analysed for significant differences.

However, the visual representation shows that the highest species diversity was recorded at site S7 (sampled in 2014, located in a rocky habitat), followed by sites Y6 and Z6 (both sampled in 2016, and located in reef habitats). Family diversity was greater at sites O5 (sampled in 2013, reef habitat) and Y6. Following closely behind are Y8 and Z10 (sampled in 2014, rocky habitats), AD3 (sampled in 2015, rocky habitat), V7 and Z6 (sampled in 2015, reef habitats) (*Figure 6*).

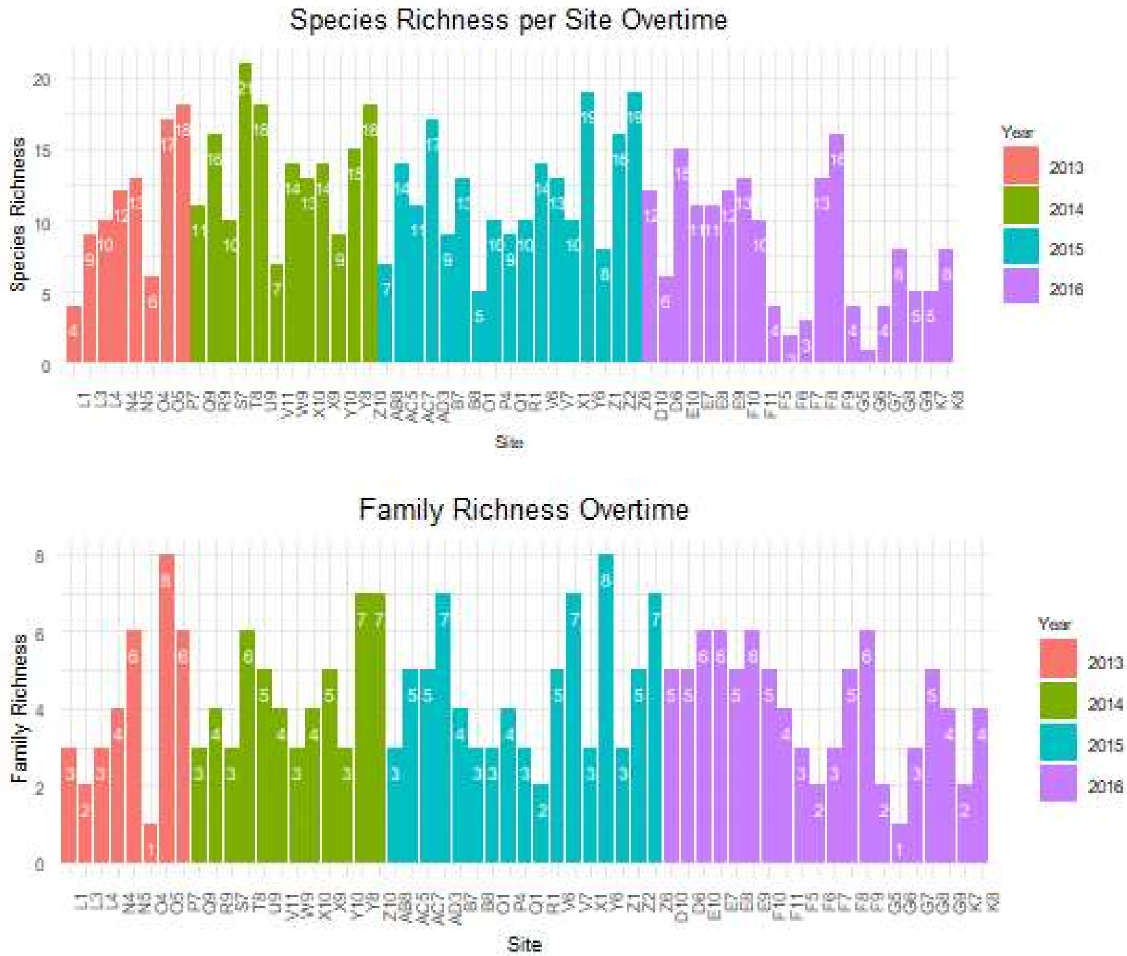

Figure 6. Richness of species (upper part of the figure) and families (bottom part of the figure) per site over time. X-axis represent the sites are organized in chronological order; Y-axis represents the richness, ranging from 0-20.

4.2 Relative abundance over project duration

The relative abundance of all species was greater in 2016 (*Table 2*). 2015 saw a comparable abundance, which was double that of 2014. 2013 had the lowest relative abundance, probably because fewer sites were sampled.

36.46% and 34.87% of the species' total relative abundance were found in 2016 and 2015, respectively. Similarly, reefs and rocky habitats accounted for 41.09% and 36.71% of the species' overall relative abundance, respectively (*Figure 7*). Sand habitats, on the other hand, held only 22.21% of the total relative abundance.

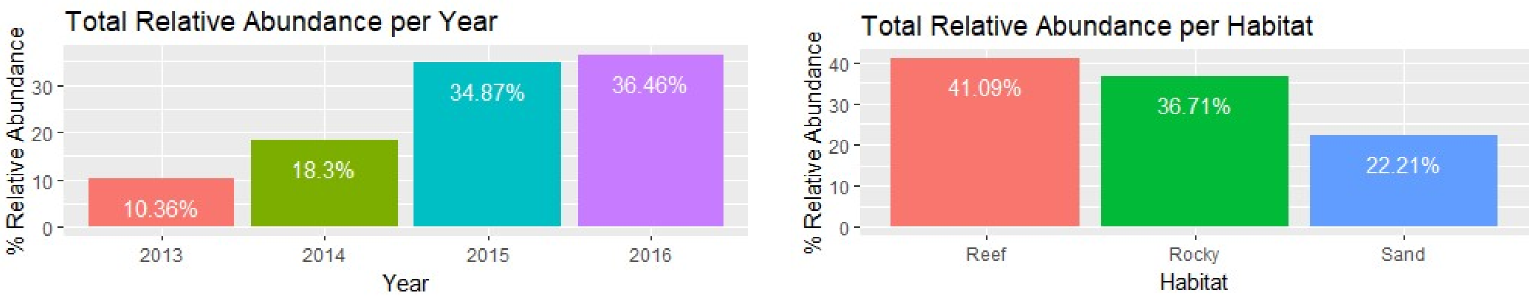

Figure 7. Percentage of the total relative abundance of species per year (left side of the figure) and per habitat type (right side of the figure).

We can see that the relative abundance has increased each year with the lowest in 2013 at 10.36% and the highest in 2016 at 36.46%. Furthermore, when comparing different habitats, reef exhibits the highest relative abundance.

4.3 Elasmobranch diversity and abundance over time

18 species from 7 families of the class elasmobranch were identified over a 4-year period. The most frequently recorded family was by Scyliorhinidae, with a total of 78 observations; followed by Triakidae, with 42 observations (*Annexure 3*). Hexanchidae and Rajidae were the least represented families, with 2 and 5 observations respectively. Lamnidae was the only family where a single individual was recorded.

At the species level, the most common observations within the Triakidae family were the species *Mustelus mustelus*. The most prevalent species in the Scyliorhinidae were *Poroderma pantherinum* and *Poroderma africanum*. The species *Squalus acutipinnis*, which is a member of the Squalidae family is also worth mentioning (*Annexure 3*).

Table 5. Key parameters of all the Elasmobranchs identified, stratified by year and habitat during the four-year timeframe. Mean Max N: Average maximum number of individuals observed per sample: Toal Abundance: The overall count of individuals across all samples; Relative Abundance: Average abundance per sample; Total Species Richness: Total number of distinct species recorded; Mean H": Mean of the Shannon-Wiener diversity index; Mean D: Simpsons diversity index.

Year	Mean Max N	Total Abundance	Relative Abundance	Species Richness	Mean H"	Mean D	Mean Species Richness
2013	1.388888889	25	0.4385965	7	0.1884889	0.1334629	1
2014	2.040816327	100	1.754386	11	0.3583509	0.2085539	2.722222
2015	1.736842105	66	1.1578947	10	0.4512763	0.2963929	2.111111
2016	3.53125	226	3.9649123	11	0.7384402	0.3967677	3.555556

Habitat	Mean Max N	Total Abundance	Relative Abundance	Species Richness	Mean H"	Mean D	Mean Species Richness
Reef	2.262295082	138	2.421053	13	0.5099683	0.2945418	3.388889
Rocky	1.890625	121	2.122807	12	0.38772	0.2261326	3.555556
Sand	3.590909091	158	2.77193	10	0.6762961	0.3839967	2.444444

The year 2016 was notable for having the highest relative abundance and richness of elasmobranch species. Interestingly, during this period, sand habitats exhibited the highest relative and mean abundance. However, the richness of species was more pronounced in reef habitats (*Table 5*). A plausible explanation for this observation could be the prevalence of the species Spiny Dogfish, which is one of the most frequently recorded species in BRUVs in Stilbaai and is known to thrive in sand habitats. In this context, *Figures 9* and *10* visually represent the abundance of each elasmobranch species per year and habitat.

Table 6. Complete list Elasmobranchs identified in this project. For the sake of simplicity, all the species classified as "Data Deficient" (DD), "Not Evaluated" (NE) or "Not Applicable" (NA) have been combined into one category for this report: "No Data" (ND). Species: scientific name of each species identified; Common name: common name of each species; Family: Biological Family to which the species belongs; IUCN: Species classification according to the IUCN Red List.

Species	Common name	Family	IUCN [a,b]
Aetomylaeus bovinus	Bull ray	Myliobatidae	CR
Carcharodon carcharias	White Shark	Lamnidae	VU
Galeorhinus galeus	Soupfin shark	Triakidae	CR
Haploblepharus edwardsii	Puffadder shyshark	Scyliorhinidae	EN
Haploblepharus fuscus	Brown shyshark	Scyliorhinidae	VU
Haploblepharus pictus	Dark shyshark	Scyliorhinidae	LC
Hexanchus griseus	Bluntnose Sixgill shark	Hexanchidae	NT
Mustelus mustelus	Smooth-hound shark	Triakidae	EN
Mustelus palumbes	White spotted smoothhound	Triakidae	LC
Myliobatis aquila	Eagle ray	Myliobatidae	CR
Notorynchus cepedianus	Sevengill cowshark	Hexanchidae	VU
Poroderma africanum	Pyjama catshark	Scyliorhinidae	LC
Poroderma pantherinum	Leopard catshark	Scyliorhinidae	LC
Raja straeleni	Biscuit skate	Rajidae	NT
Rostroraja alba	Spearnose skate	Rajidae	EN

Squalus acutipinnis	Bluntnose Spiny Dogfish	Squalidae	NT
Triakis megalopterus	Spotted gully shark	Triakidae	LC

[a] Abbreviations: VU, Vulnerable; EN, Endangered; CR, Critically Endangered.

[b] Conservation status taken from IUCN Red List (IUCN, 2024).

More than half of elasmobranch total relative abundance was recorded in 2016 (54.2%), while the least was 2013 (6%). As opposed to the overall species trends, elasmobranchs were most abundant in sand habitats (37.89%) (*Figure 8*).

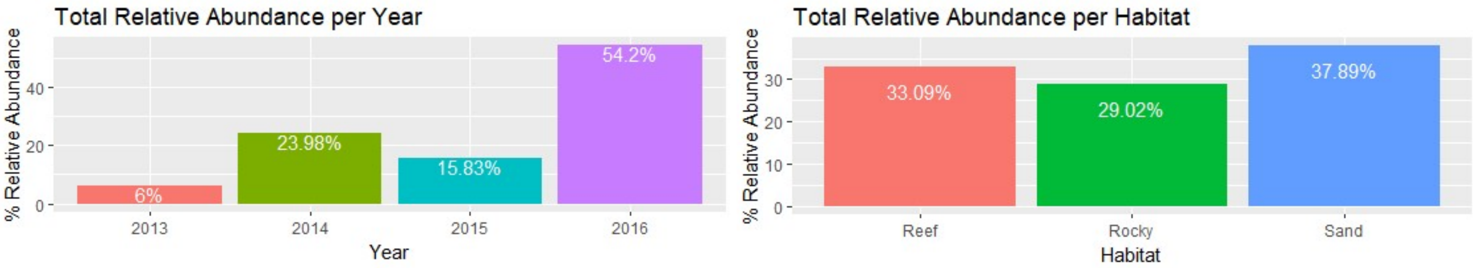

Figure 8. Percentage of the total relative abundance of elasmobranchs per year (left side of the figure) and per habitat type (right side of the figure).

9 of the total elasmobranch species identified in our study have been classified as Threatened according to the IUCN List of Threatened species. This includes three species listed as Critically Endangered (CR): the bull ray, eagle ray, and soupfin shark. Two species are listed as Endangered (EN): the puffadder shyshark and the smooth-hound shark. Additionally, four species are classified as Vulnerable (VU): the brown shyshark, sevengill cowshark, tiger catshark, and white shark. This highlights the urgent need for conservation efforts targeted at these species (*Table 6*).

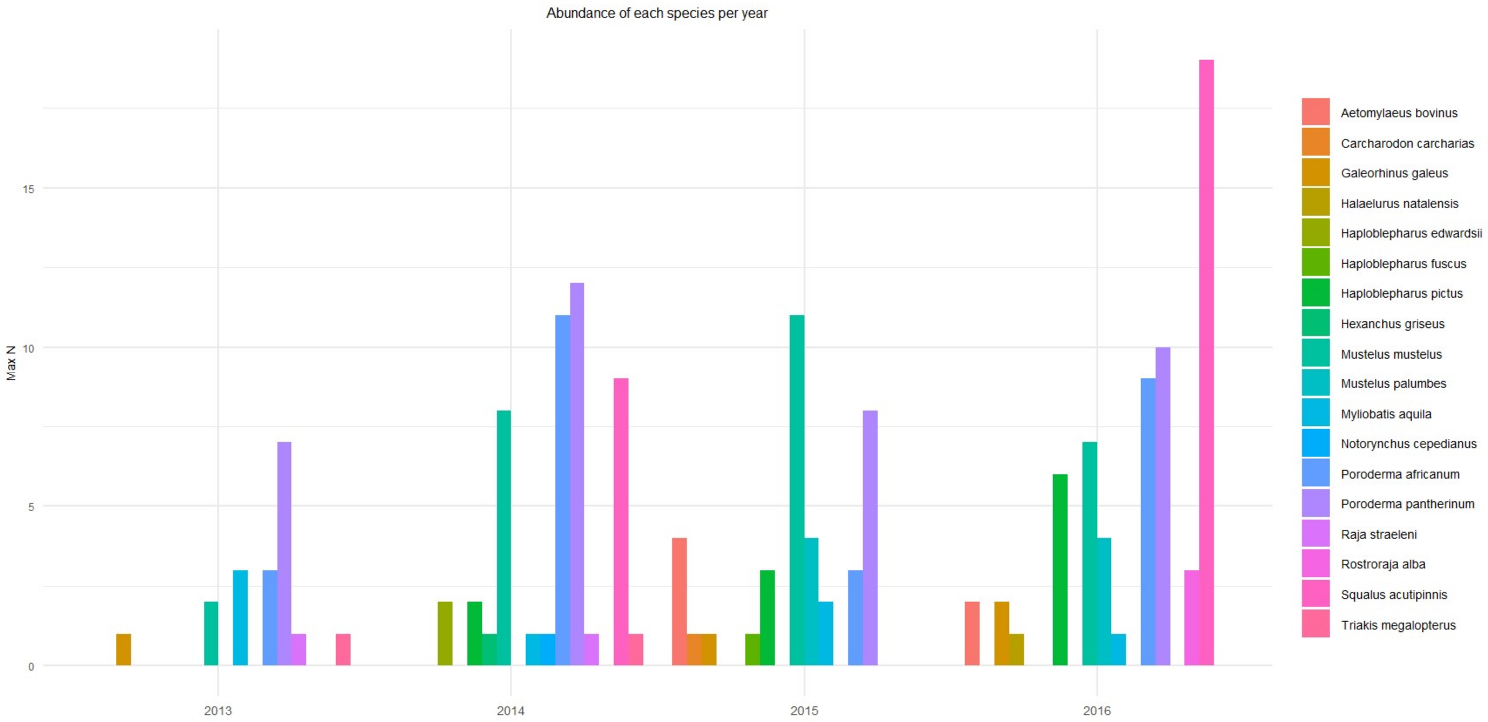

Figure 9. Abundance of elasmobranch species per year from 2013 to 2016. Each color corresponds to a different species. The x-axis represent the time line, and the y-axis shows the quantity of each species.

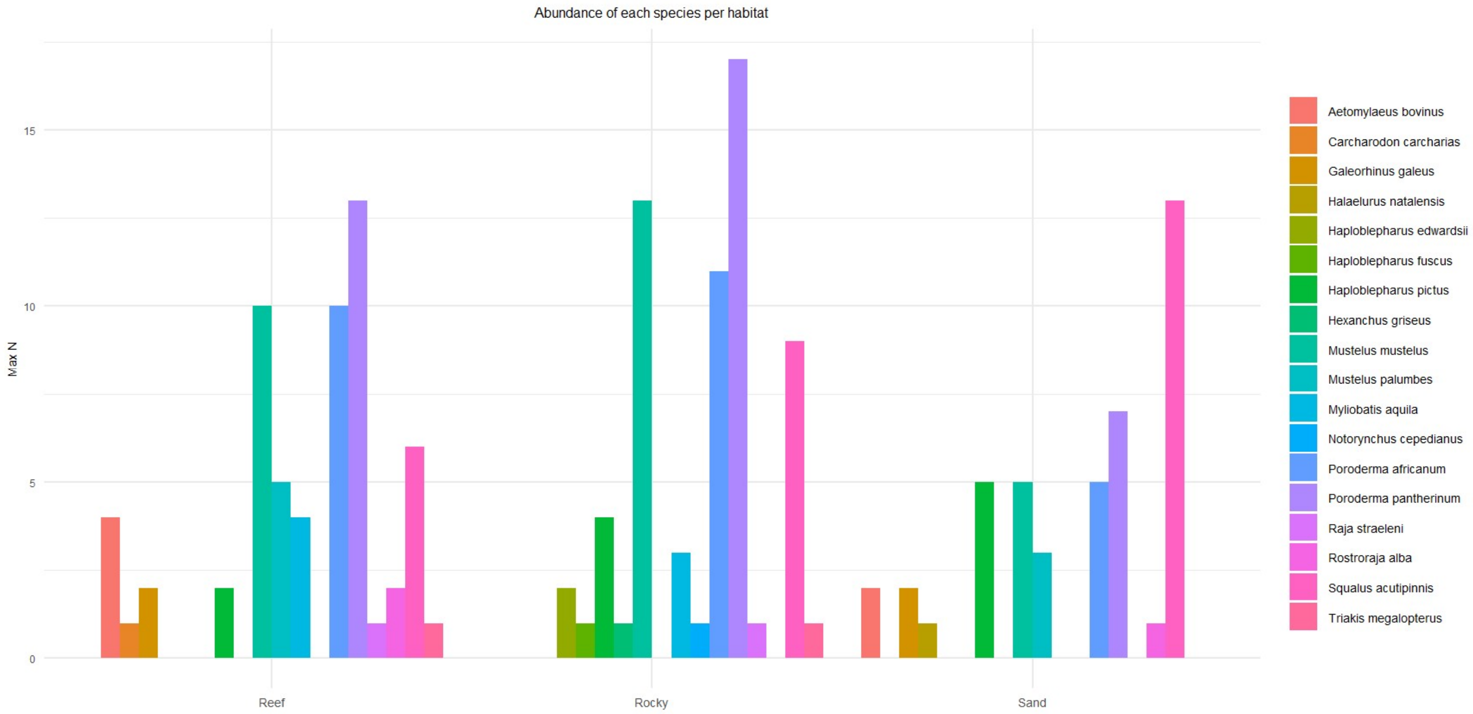

Figure 10. Abundance of elasmobranch species in each habitat. Each color corresponds to a different species. The x-axis shows the three types of habitats, and the y-axis shows the quantity of each species.

4.4 IUCN threatened species diversity and abundance over time

All the species listed on the IUCN Red List as Vulnerable, Endangered and Critically Endangered categories of the were classified as Threatened (IUCN, 2024). This includes 18 (from 9 different families) of the 58 observed species over the 4-year period (*Table 8*).

When we look at the abundance of species listed as threatened by the IUCN, the most abundant species observed was *Petrus rupestris*, followed by *Mustelus mustelus*, and *Lithognathus lithognathus*. Although less frequent, species such as *Rhabdosargus globiceps*, *Chrysoblephus gibbiceps,* and *Aetomylaeus bovinus* were still noticeably present in our observations. In terms of family abundance, Sparidae was by far the most prevalent, followed by Triakidae and Myliobatidae (*Annexes 3*). Interestingly, a significant proportion of the IUCN threatened species are Elasmobranchs.

If we only look at IUCN endangered species, we can see that overall abundance increased in 2015, particularly in rocky areas. When we look at relative abundance, the pattern remains consistent. In terms of species richness, there was a notable increase observed in 2015, but this time reef habitat showed a greater richness of species (*Table 7*). The diversity indexes, H” and D, also showed the similar tendency.

None of the threatened species IUCN classifications have changed over time (*Figure 11*), hence the difference in diversity and abundance is due to the biased sampling.

Table 7. Key parameters of the Threatened Species, stratified by year and habitat during the four-year timeframe. Mean Max N: Average maximum number of individuals observed per sample: Toal Abundance: The overall count of individuals across all samples; Relative Abundance: Average abundance per sample; Total Species Richness: Total number of distinct species recorded; Mean H": Mean of the Shannon-Wiener diversity index; Mean D: Simpsons diversity index.

Year	Mean Max N	Total Abundance	Relative Abundance	Species Richness	Mean H"	Mean D	Mean Species Richness
2013	3	30	0.5263158	8	0.1187838	0.07	1
2014	5	75	1.3157895	8	0.4950931	0.3009951	2.444444
2015	7	112	1.9649123	13	0.5177263	0.319139	3.388889
2016	3	30	0.5263158	9	0.2388055	0.1546032	1.277778
Habitat	**Mean Max N**	**Total Abundance**	**Relative Abundance**	**Species Richness**	**Mean H"**	**Mean D**	**Mean Species Richness**
Reef	5	87	1.5263158	13	0.3936199	0.254633	2.888889
Rocky	6	135	2.3684211	11	0.5063833	0.2866699	4.333333
Sand	3	25	0.4385965	9	0.1326166	0.09111111	0.88888889

Table 8. Complete list of the Threatened Species identified in this project. For the sake of simplicity, all the species classified as "Data Deficient" (DD), "Not Evaluated" (NE) or "Not Applicable" (NA) have been combined into one category for this report: "No Data" (ND). Species: scientific name of each species identified; Common name: common name of each species; Family: Biological Family to which the species belongs; IUCN: Species classification according to the IUCN Red List.

Species	Common name	Family	IUCN [a,b]
Aetomylaeus bovinus	Bull ray	Myliobatidae	CR
Carcharodon carcharias	White Shark	Lamnidae	VU
Chrysoblephus cristiceps	Dageraad	Sparidae	CR
Chrysoblephus gibbiceps	Red stumpnose	Sparidae	EN
Cymatoceps nasutus	Black musselcracker	Sparidae	VU
Epinephelus marginatus	Yellowbelly rock cod	Serranidae	VU
Galeorhinus galeus	Soupfin shark	Triakidae	CR
Halaelurus natalensis	Tiger catshark	Scyliorhinidae	VU
Haploblepharus edwardsii	Puffadder shyshark	Scyliorhinidae	EN
Haploblepharus fuscus	Brown shyshark	Scyliorhinidae	VU
Lithognathus lithognathus	White steenbras	Sparidae	EN
Mustelus mustelus	Smooth-hound shark	Triakidae	EN
Myliobatis aquila	Eagle ray	Myliobatidae	CR
Notorynchus cepedianus	Sevengill cowshark	Hexanchidae	VU
Petrus rupestris	Red steenbras	Sparidae	EN
Pomatomus saltatrix	Shad	Pomatomidae	VU
Rhabdosargus globiceps	White stumpnose	Sparidae	VU
Rostroraja alba	Spearnose skate	Rajidae	EN

[a] Abbreviations: VU, Vulnerable; EN, Endangered; CR, Critically Endangered.

[b] Conservation status taken from IUCN Red List (IUCN, 2024).

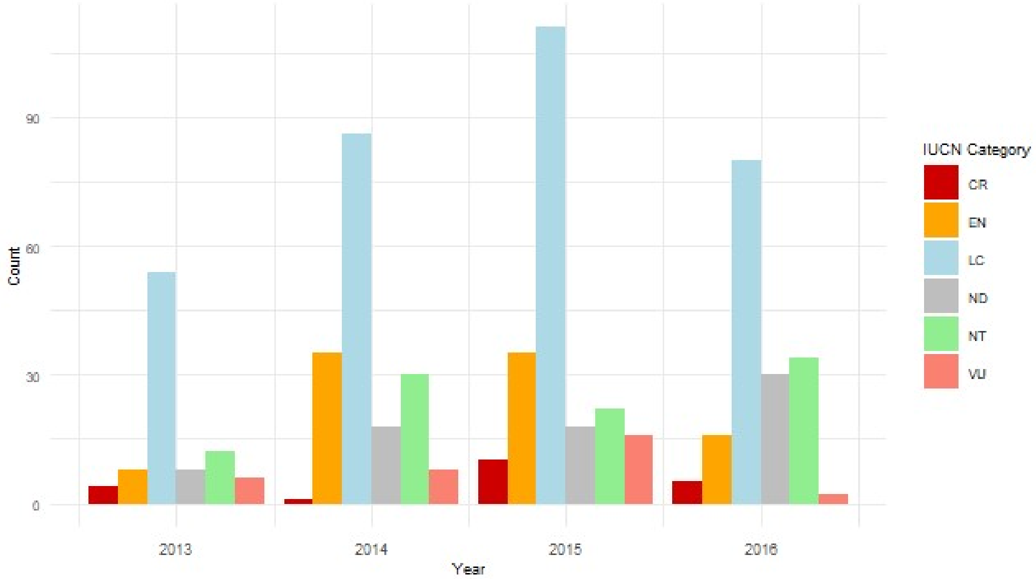

Figure 11. Count of species classified into each IUCN Red List Category overtime. Abbreviations: CR Critically Endangered; EN, Endangered; LC, Least Concern; ND, No Data; NT, Near Threatened; VU, Vulnerable.

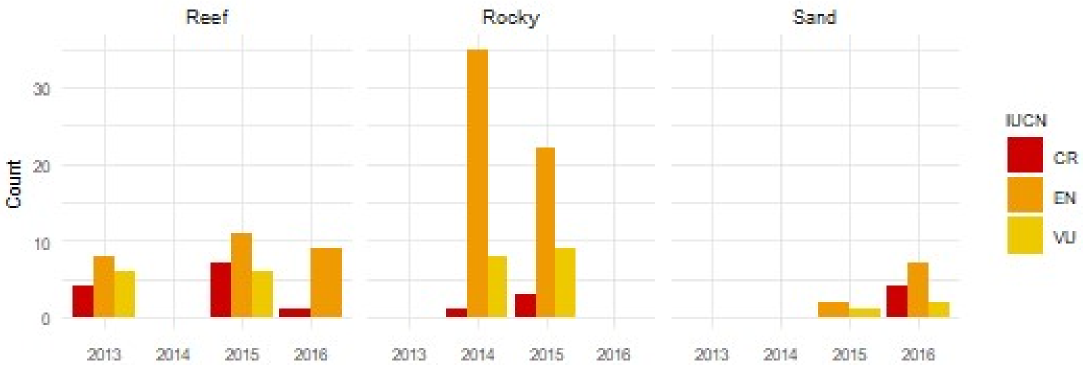

Figure 12. *Count of species belonging to he Threatened Species Category (CR, EN, and VU) according to the IUCN Red List overtime, stratified by habitat type. Abbreviations: CR, Critically Endangered; EN, Endangered; VU, Vulnerable.*

Each of the 6 IUCN categories was represented across all years and habitats (*Table 9*). *Figure 11* illustrates the count for each category on a yearly basis. The species classified as "Least Concern" were the most prevalent across all years, but notably higher in 2015 with 111 species classified as LC. The "Near Threatened" (NT) category was the second most common, accounting for 98 species, closely trailed by the "Endangered" (EN) category with 94 species over the four-year period. The categories "Vulnerable" (VU) and "Critically Endangered" (CR) were the least represented (*Table 9*).

However, the CR, VU, and "Endangered" (EN) categories were also considerable higher in 2015, especially in reef and rocky habitats. This could likely be attributed to a bias in sampling. However, without the specific coordinates, a site-based discussion would not be meaningful.

Figure 12 shows the count of species in the threatened category in each habitat per year. The most abundant category was EN, with the highest counts in 2014 and 2015, respectively. Threatened species were missing from reef habitats in 2014, in rocky habitats in 2013 and 2016, and in sand habitats in 2013 and 2014. This lack of representation could be attributed to the limited sample carried out in those early years.

Table 9. Summary of the species under the IUCN Red List Categories per year and habitat. Total column is the count for the 4-year study, without distinguishing between habitat and year.

	Year				**Habitat**			
	2013	**2014**	**2015**	**2016**	**Reef**	**Rocky**	**Sand**	Total
CR	4	1	10	5	12	4	4	20
EN	8	35	35	16	28	57	9	94
LC	54	86	111	80	130	153	48	331
ND	8	18	18	30	31	27	16	74
NT	12	30	22	34	36	40	22	98
VU	6	8	16	2	12	17	3	32

4.5 Commercial species of interest

During the four-year study, 13 species from 4 families were commercial species. Sparidae was the most prevalent family, with the most common species being *Chrysoblephus laticeps Cheimerius nufar*, and *Pachymetopon aeneum*. Pomatomidae was the least represented family, with only one observation of the species *Pomatomus saltatrix (Annexes 3)*.

Table 10. Key parameters of the commercial species, stratified by year and habitat during the four-year timeframe. Mean Max N: Average maximum number of individuals observed per sample: Toal Abundance: The overall count of individuals across all samples; Relative Abundance: Average abundance per sample; Total Species Richness: Total number of distinct species recorded; Mean H": Mean of the Shannon-Wiener diversity index; Mean D: Simpsons diversity index.

Year	**Mean Max N**	**Total Abundance**	**Relative Abundance**	**Species Richness**	**Mean H"**	**Mean D**	**Mean Species Richness**
2013	5	47	0.8245614	10	0.2790333	0.1666655	0.2790333
2014	6	109	1.9122807	9	0.42028	0.2454533	0.42028
2015	8	151	2.6491228	9	0.7000003	0.3912959	0.7000003
2016	10	268	4.7017544	10	0.8736602	0.4734907	0.8736602

Habitat	**Mean Max N**	**Total Abundance**	**Relative Abundance**	**Species Richness**	**Mean H"**	**Mean D**	**Mean Species Richness**
Reef	9	297	5.210526	12	0.780698	0.418978	0.780698
Rocky	8	153	2.684211	10	0.4269111	0.2283121	0.4269111
Sand	10	125	2.192982	10	0.6648925	0.4100128	0.6648925

In the case of commercial species, there appears to be a consistent trend over time, with improvements observed in both relative and mean abundance. However, when it comes to species richness, there hasn't been much change over time. In terms of habitat, reef environments have demonstrated higher levels of both abundance and species richness (*Table 10*).

Only four commercial species are listed as threatened on the IUCN Red List: two VU species from the families Pomatomidae (*Pomatomus saltatrix*) and Serranidae (*Epinephelus marginatus*), and two CR and EN species from the Sparidae family (*Chrysoblephus cristiceps* and *Chrysoblephus gibbiceps* respectively) (*Table 11*).

Table 11. Complete list of the Commercial Species identified in Stilbaai's BRUVs analysis. For the sake of simplicity, all the species classified as "Data Deficient" (DD), "Not Evaluated" (NE) or "Not Applicable" (NA) have been combined into one category for this report: "No Data" (ND). Species: scientific name of each species identified; Common name: common name of each species; Family: Biological Family to which the species belongs; IUCN: Species classification according to the IUCN Red List.

Species	**Common name**	**Family**	**IUCN [a,b]**
Argyrozona argyrozona	Carpenter	Sparidae	NT
Cheimerius nufar	Santer	Sparidae	ND
Chrysoblephus cristiceps	Dageraad	Sparidae	CR
Chrysoblephus gibbiceps	Red stumpnose	Sparidae	EN
Chrysoblephus laticeps	Red roman	Sparidae	NT
Diplodus hottentotus	Zebra	Sparidae	LC
Epinephelus marginatus	Yellowbelly rock cod	Serranidae	VU
Octopus vulgaris	Common octopus	Octopodidae	LC
Pachymetopon aeneum	Blue hottentot	Sparidae	LC
Pachymetopon blochii	Hottentot	Sparidae	LC
Pomatomus saltatrix	Shad	Pomatomidae	VU
Pterogymnus laniarius	Panga	Sparidae	LC
Rhabdosargus holubi	Cape stumpnose	Sparidae	ND

[a] Abbreviations: VU, Vulnerable; EN, Endangered; CR, Critically Endangered.

[b] Conservation status taken from IUCN Red List (IUCN, 2024).

Species relative abundance increased in 2016, accounting for more than half of total relative abundance (46.61%). The reef ecosystem exhibits a higher level of relative abundance (51.65%). Commercial species richness follows the same trend (*Figure 13*).

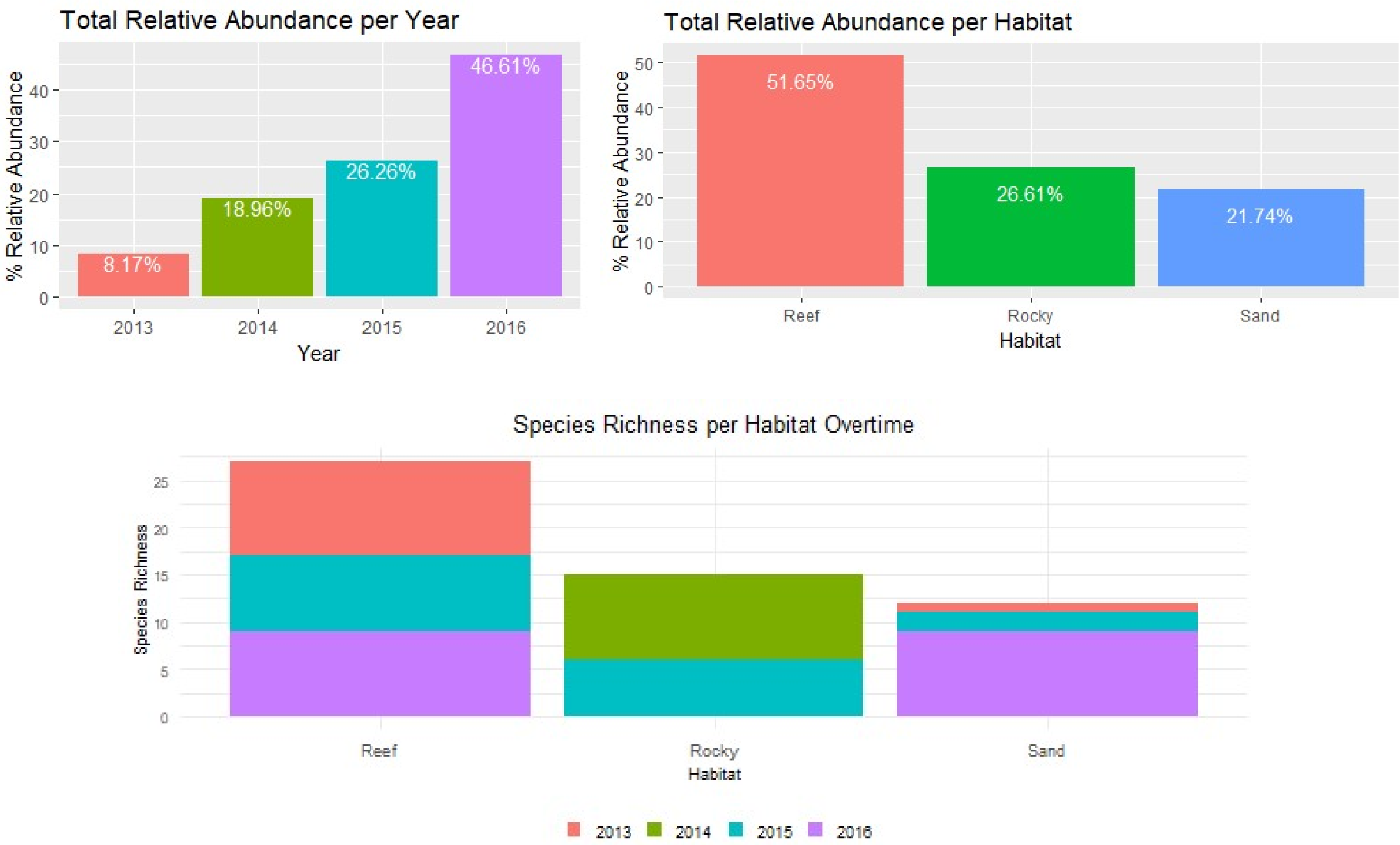

Figure 13. Top left of the figure represents the percentage of commercial species relative abundace for each year from 2013 to 2016, and for each type of habitat (top right of the figure). The bottom part of the figure represents the total species richness per habitat overtime.

4.6 Interesting species sightings

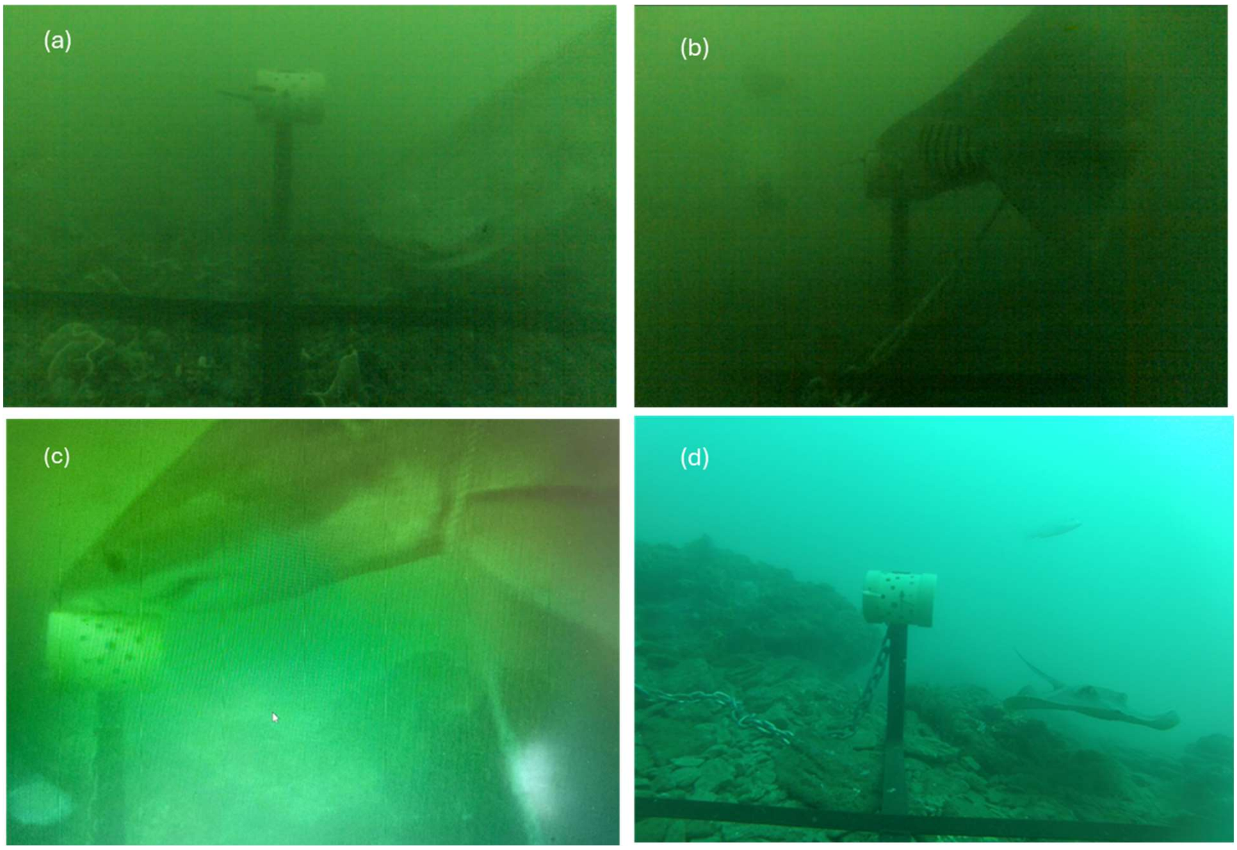

Figure 14. Interesting species recorded in Stilbaai's BRUVs (2013-2016). (a) Sevengill cow shark (Notorynchus cepedianus), (b) Bluntnose sixgill shark (Hexanchus griseus), (c) White Shark (Carcharodon carcharias), (d) Blue stingray (Dasyatis chrysonota).

5. General Discussion

The data shows a clear upward trend in the species total relative abundance over the years. Notably, reef and rocky habitats exhibit a higher relative abundance compared to other habitats. This observation could suggest a potential preference or suitability of reef and rocky habitats for the species under study. However, it's important to consider that this trend may also be influenced by other ecological factors such as depth, temperature, and salinity. Additionally, It's worth noting that the majority of our study sites were located in rocky and reef habitats, which could be introducing a bias in our results, as these habitats might be overrepresented in our data. To draw more definitive conclusions and to better understand the dynamics of species diversity across different habitats and over time, further research is necessary (Turpie., *et al* 2009; Solano-Fernandez., *et al* 2012).

5.1 Elasmobranchs

In general, the relative abundance of elasmobranchs has shown a noticeable increase over the years. It is particularly evident that both the relative and mean abundance were higher in sandy habitats, while species richness was greater in reef habitats. This could be attributed to the prevalence of certain elasmobranch species, such as the Spiny Dogfish, which are more commonly found in sandy environments.

In this section, it is worth mentioning that most of the elasmobranch species are classified as threatened according to the categories of the International Union for Conservation of Nature (IUCN) Red List. This underscores the importance of ongoing conservation efforts for these species.

5.2 IUCN threatened species

Focusing solely on IUCN endangered species, an increase in overall abundance was observed in 2015, especially in rocky habitats. This trend was consistent when examining relative abundance. In terms of species richness, 2015 also saw a significant increase, with reef habitats exhibiting greater species richness. It's important to note that the IUCN classifications of threatened species remained unchanged over time, suggesting that more effective conservation efforts are needed. Significant improvements in their status will only be observed with better protection measures for these species. This underscores the importance of continuous research, monitoring, and policy-making in biodiversity conservation.

5.3 Commercial species

When talking about commercial species, the study observed a consistent upward trend in both relative and mean abundance over time, while species richness remained relatively stable. Reef habitats were found to have higher levels of both abundance and species richness. However, it's important to note that four commercial species, namely the Shad, Yellow belly rock cod, Dageraad and Red stumpnose are listed as threatened on the IUCN Red List. In light of our findings, it becomes increasingly clear that overfishing these four species not only threatens their survival, but it could also disrupt the delicate balance of Stilbaai's biodiversity.

6. Conclusion

In conclusion, this research demonstrates the importance having accurate and precise data for robust outcomes. We encountered numerous gaps in our data, which posed significant challenges to our analysis, testing, and the derivation of reliable conclusions. The loss of valuable information has been a significant challenge, highlighting the need for improved practices in data collection and preservation. Further research should consider incorporating metadata to enrich future reports and provide a more comprehensive view of Stilbaai's biodiversity. It is clear that something needs to change. This could involve expanding the study to include a more diverse range of habitats and implementing controls for potential confounding factors. By doing so, we can enhance our understanding of the complex dynamics of species diversity and inform more effective conservation strategies.

7. Summary

The data shows an upward trend in the species' total relative abundance over the years, with reef and rocky habitats exhibiting a higher relative abundance.

The relative abundance of elasmobranchs has increased over the years, with higher abundance in sandy habitats and greater species richness in reef habitats. Most elasmobranch species are classified as threatened, highlighting the importance of conservation efforts.

There was an increase in the overall abundance of IUCN endangered species in 2015, especially in rocky habitats. However, the IUCN classifications of threatened species remained unchanged over time, suggesting the need for more effective conservation efforts.

The study observed a consistent upward trend in both relative and mean abundance of commercial species over time, with reef habitats having higher levels of both abundance and species richness. Overfishing of certain commercial species listed as threatened on the IUCN Red List could potentially lead to a collapse in these fisheries.

The study encountered numerous gaps in the data, posing challenges to analysis and the derivation of reliable conclusions. This highlights the need for improved data collection and preservation practices, and the potential benefits of incorporating metadata in future researchs.

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9. Annexes

Annexure 1. Matrix representing the occurrence (presence) or non-occurrence (absence) of all species per habitat over time. Each row corresponds to the different species and the family group to which they belong. Columns represent the specific year within the period of 2013 to 2016, and the three types of habitats for each year. The "X" inside the matrix indicates the presence of the species in that particular year, while a black space indicates the absence.

		2013			**2014**			**2015**			**2016**		
Species	**Family name**	**Reef**	**Rocky**	**Sand**	**Reef**	**Rocky**	**Sand**	**Reef**	**Rocky**	**Sand**	**Reef**	**Rocky**	**Sand**
Aetomylaeus bovinus	Myliobatidae							X					X
Amblyrhynchotes honckenii	Tetraodontidae	X		X		X		X	X				X
Argyrozona argyrozona	Sparidae	X		X		X		X		X	X		
Boopsoidea inornata	Sparidae	X				X		X	X		X		
Carcharodon carcharias	Lamnidae							X					
Chaetodon marleyi	Chaetodontidae	X						X	X		X		
Cheilodactylus fasciatus	Cheilodactylidae					X			X				
Cheilodactylus pixi	Cheilodactylidae					X			X				
Cheimerius nufar	Sparidae	X				X		X			X		X
Chirodactylus brachydactylus	Cheilodactylidae							X	X				
Chrysoblephus anglicus	Sparidae							X					
Chrysoblephus cristiceps	Sparidae							X	X				
Chrysoblephus gibbiceps	Sparidae	X				X		X	X		X		X
Chrysoblephus laticeps	Sparidae	X				X		X	X	X	X		X
Clinus venustris	Clinidae	X							X				
Cymatoceps nasutus	Sparidae	X						X	X				
Dasyatis chrysonota	Dasyatidae							X					
Dichistius multifasciatus	Sparidae					X			X				
Dinoperca petersi	Dinopercidae								X				
Diplodus capensis	Sparidae	X				X		X	X		X		X
Diplodus hottentotus	Sparidae	X				X		X	X		X		X
Epinephelus andersoni	Serranidae										X		
Epinephelus marginatus	Serranidae	X						X					
Galeichthys ater	Ariidae							X					
Galeichthys feliceps	Ariidae					X					X		X
Galeorhinus galeus	Triakidae	X						X					X
Gymnocrotaphus curvidens	Sparidae							X			X		X
Halaelurus natalensis	Scyliorhinidae												X
Haploblepharus edwardsii	Scyliorhinidae					X							
Haploblepharus fuscus	Scyliorhinidae								X				
Haploblepharus pictus	Scyliorhinidae					X		X	X		X		X
Hexanchus griseus	Hexanchidae					X							
Lichia amia	Carangidae								X				
Lithognathus lithognathus	Sparidae					X		X	X				

Mustelus mustelus	Triakidae	X		X	X	X	X	X	X
Mustelus palumbes	Triakidae				X			X	X
Myliobatis aquila	Myliobatidae	X		X		X		X	
Notorynchus cepedianus	Hexanchidae			X					
Octopus vulgaris	Octopodidae	X						X	X
Oplegnathus conwayi	Oplegnathidae	X		X	X	X			
Pachymetopon aeneum	Sparidae	X		X	X	X		X	X
Pachymetopon blochii	Sparidae	X		X		X			
Pachymetopon grande	Sparidae					X			
Petrus rupestris	Sparidae	X		X	X	X	X	X	
Pomatomus saltatrix	Pomatomidae								X
Poroderma africanum	Scyliorhinidae	X	X	X	X			X	X
Poroderma pantherinum	Scyliorhinidae	X	X	X	X	X	X	X	X
Pterogymnus laniarius	Sparidae	X		X				X	X
Raja straeleni	Rajidae	X		X					
Rhabdosargus globiceps	Sparidae	X		X		X	X		
Rhabdosargus holubi	Sparidae			X				X	X
Rostroraja alba	Rajidae							X	X
Sarpa salpa	Sparidae	X		X	X	X	X		X
Spondyliosoma emarginatum	Sparidae	X		X	X	X		X	X
Squalus acutipinnis	Squalidae			X				X	X
Triakis megalopterus	Triakidae	X		X					
Umbrina canariensis	Oplegnathidae			X					
Umbrina robinsoni	Umbrina	X		X					

Annexure 2. *Count of species from each family observed per year from 2013 to 2016 and per habitat, reef, rocky and sand. Grand Total is the total count of species in the whole study.*

	2013			**2014**		**2015**				**2016**			
	Reef	**Sand**	**Total**	**Rocky**	**Total**	**Reef**	**Rocky**	**Sand**	**Total**	**Reef**	**Sand**	**Total**	**Grand Total**
Ariidae				3	3	1			1	3	6	9	13
Carangidae							1		1				1
Chaetodontidae	1		1			1	1		2	1		1	4
Cheilodactylidae				2	2	2	7		9				11
Clinidae	1		1				1		1				2
Dasyatidae						1			1				1
Dinopercidae							1		1				1
Hexanchidae				2	2								2
Lamnidae						1			1				1
Myliobatidae	3		3	1	1	4	2		6	1	2	3	13
Octopodidae	1		1							1	2	3	4
Oplegnathidae	2		2	2	2	2	1		3				7
Pomatomidae											1	1	1
Rajidae	1		1	1	1					2	1	3	5
Scyliorhinidae	8	2	10	27	27	6	8	1	15	11	15	26	78
Serranidae	1		1			2			2	1		1	4
Sparidae	61	1	62	120	120	50	84	6	140	47	40	87	409
Squalidae				9	9					6	13	19	28
Tetraodontidae	4	1	5	1	1	4	9		13		1	1	20
Triakidae	4		4	9	9	10	5	1	16	4	9	13	42
Umbrina	1		1	1	1								2
Grand Total	**88**	**4**	**92**	**178**	**178**	**84**	**120**	**8**	**212**	**77**	**90**	**167**	**649**

Annexure 3. Count of species observed per year from 2013 to 2016 and per habitat, reef, rocky and sand. Grand Total is the total count of species in the whole study.

	2013			2014		2015				2016			Grand Total
	Reef	**Sand**	**Total**	**Rocky**	**Total**	**Reef**	**Rocky**	**Sand**	**Total**	**Reef**	**Sand**	**Total**	
Aetomylaeus bovinus						4			4		2	2	6
Amblyrhynchotes honckenii	4	1	5	1	1	4	9		13		1	1	20
Argyrozona argyrozona	3	1	4	8	8	1		1	2	2		2	16
Boopsoidea inornata	8		8	6	6	6	9		15	1		1	30
Carcharodon carcharias						1			1				1
Chaetodon marleyi	1		1			1	1		2	1		1	4
Cheilodactylus fasciatus				1	1		1		1				2
Cheilodactylus pixi				1	1		1		1				2
Cheimerius nufar	5		5	6	6	5			5	7	8	15	31
Chirodactylus brachydactylus						2	5		7				7
Chrysoblephus anglicus						1			1				1
Chrysoblephus cristiceps						2	1		3				3
Chrysoblephus gibbiceps	1		1	5	5	3	3		6	3	2	5	17
Chrysoblephus laticeps	7		7	11	11	6	9	2	17	7	5	12	47
Clinus venustris	1		1				1		1				2
Cymatoceps nasutus	1		1			3	5		8				9
Dasyatis chrysonota						1			1				1
Dichistius multifasciatus				3	3		1		1				4
Dinoperca petersi							1		1				1
Diplodus capensis	3		3	2	2	3	8		11	1	2	3	19
Diplodus hottentotus	6		6	10	10	5	6		11	4	4	8	35
Epinephelus andersoni										1		1	1
Epinephelus marginatus	1		1			2			2				3
Galeichthys ater						1			1				1
Galeichthys feliceps				3	3					3	6	9	12
Galeorhinus galeus	1		1			1			1		2	2	4
Gymnocrotaphus curvidens						2			2	2	2	4	6
Halaelurus natalensis											1	1	1
Haploblepharus edwardsii				2	2								2
Haploblepharus fuscus							1		1				1
Haploblepharus pictus				2	2	1	2		3	1	5	6	11
Hexanchus griseus				1	1								1
Lichia amia							1		1				1
Lithognathus lithognathus				7	7	1	6		7				14
Mustelus mustelus	2		2	8	8	5	5	1	11	3	4	7	28
Mustelus palumbes						4			4	1	3	4	8
Myliobatis aquila	3		3	1	1		2		2	1		1	7
Notorynchus cepedianus				1	1								1
Octopus vulgaris	1		1							1	2	3	4
Oplegnathus conwayi	2		2	1	1	2	1		3				6

Pachymetopon aeneum	2		2	1	1	4	6		10	5	4	9	22
Pachymetopon blochii	1		1	8	8		1		1				10
Pachymetopon grande							1		1				1
Petrus rupestris	5		5	13	13	2	8	1	11	1		1	30
Pomatomus saltatrix											1	1	1
Poroderma africanum	2	1	3	11	11	3			3	5	4	9	26
Poroderma pantherinum	6	1	7	12	12	2	5	1	8	5	5	10	37
Pterogymnus laniarius	2		2	1	1					3	4	7	10
Raja straeleni	1		1	1	1								2
Rhabdosargus globiceps	4		4	7	7		3	1	4				15
Rhabdosargus holubi				3	3					4	2	6	9
Rostroraja alba										2	1	3	3
Sarpa salpa	6		6	11	11	1	7	1	9		1	1	27
Spondyliosoma emarginatum	7		7	18	18	5	10		15	7	6	13	53
Squalus acutipinnis				9	9					6	13	19	28
Triakis megalopterus	1		1	1	1								2
Umbrina canariensis				1	1								1
Umbrina robinsoni	1		1	1	1								2
Grand Total	**88**	**4**	**92**	**178**	**178**	**84**	**120**	**8**	**212**	**77**	**90**	**167**	**649**

Annexure *4. Annual distribution of relative abundance for each species.*

Species	2013	2014	2015	2016	Total relative abundance
Aetomylaeus bovinus			0.24561404	0.03508772	0.28070175
Amblyrhynchotes honckenii	0.22807018	0.01754386	0.68421053	0.03508772	0.96491228
Argyrozona argyrozona	0.12280702	0.19298246	0.0877193	0.35087719	0.75438596
Boopsoidea inornata	0.49122807	0.24561404	0.89473684	0.03508772	1.66666667
Carcharodon carcharias			0.01754386		0.01754386
Chaetodon marleyi	0.03508772		0.05263158	0.05263158	0.14035088
Cheilodactylus fasciatus		0.01754386	0.01754386		0.03508772
Cheilodactylus pixi		0.01754386	0.01754386		0.03508772
Cheimerius nufar	0.10526316	0.12280702	0.24561404	0.77192982	1.24561404
Chirodactylus brachydactylus			0.1754386		0.1754386
Chrysoblephus anglicus			0.01754386		0.01754386
Chrysoblephus cristiceps			0.0877193		0.0877193
Chrysoblephus gibbiceps	0.01754386	0.10526316	0.14035088	0.10526316	0.36842105
Chrysoblephus laticeps	0.33333333	1.05263158	1.05263158	0.71929825	3.15789474
Clinus venustris	0.03508772		0.03508772		0.07017544
Cymatoceps nasutus	0.03508772		0.15789474		0.19298246
Dasyatis chrysonota			0.01754386		0.01754386
Dichistius multifasciatus		0.05263158	0.01754386		0.07017544
Dinoperca petersi			0.01754386		0.01754386
Diplodus capensis	0.0877193	0.03508772	0.54385965	0.05263158	0.71929825
Diplodus hottentotus	0.12280702	0.19298246	0.28070175	0.14035088	0.73684211
Epinephelus andersoni				0.01754386	0.01754386
Epinephelus marginatus	0.01754386		0.03508772		0.05263158
Galeichthys ater			0.01754386		0.01754386
Galeichthys feliceps		0.0877193		2.24561404	2.33333333
Galeorhinus galeus	0.03508772		0.01754386	0.05263158	0.10526316
Gymnocrotaphus curvidens			0.03508772	0.07017544	0.10526316
Halaelurus natalensis				0.03508772	0.03508772
Haploblepharus edwardsii		0.03508772			0.03508772
Haploblepharus fuscus			0.01754386		0.01754386
Haploblepharus pictus		0.03508772	0.05263158	0.1754386	0.26315789
Hexanchus griseus		0.01754386			0.01754386
Lichia amia			0.01754386		0.01754386
Lithognathus lithognathus		0.1754386	0.35087719		0.52631579
Mustelus mustelus	0.03508772	0.33333333	0.31578947	0.19298246	0.87719298
Mustelus palumbes			0.0877193	0.12280702	0.21052632
Myliobatis aquila	0.05263158	0.01754386	0.05263158	0.01754386	0.14035088
Notorynchus cepedianus		0.01754386			0.01754386
Octopus vulgaris	0.01754386			0.07017544	0.0877193
Oplegnathus conwayi	0.03508772	0.01754386	0.07017544		0.12280702
Pachymetopon aeneum	0.03508772	0.01754386	0.70175439	0.31578947	1.07017544
Pachymetopon blochii	0.01754386	0.15789474	0.01754386		0.19298246
Pachymetopon grande			0.01754386		0.01754386
Petrus rupestris	0.26315789	0.43859649	0.42105263	0.01754386	1.14035088

Pomatomus saltatrix				0.01754386	0.01754386
Poroderma africanum	0.0877193	0.28070175	0.15789474	0.35087719	0.87719298
Poroderma pantherinum	0.19298246	0.31578947	0.19298246	0.28070175	0.98245614
Pterogymnus laniarius	0.03508772	0.01754386		0.98245614	1.03508772
Raja straeleni	0.01754386	0.01754386			0.03508772
Rhabdosargus globiceps	0.07017544	0.19298246	0.10526316		0.36842105
Rhabdosargus holubi		0.05263158		1.22807018	1.28070175
Rostroraja alba				0.05263158	0.05263158
Sarpa salpa	1	0.92982456	1.31578947	0.10526316	3.35087719
Spondyliosoma emarginatum	0.21052632	0.73684211	3.89473684	1.98245614	6.8245614
Squalus acutipinnis		0.66666667		2.64912281	3.31578947
Triakis megalopterus	0.01754386	0.01754386			0.03508772
Umbrina canariensis		0.01754386			0.01754386
Umbrina robinsoni	0.01754386	0.01754386			0.03508772

Annexure 5. *Annual distribution of relative abundance for each family*

Family	2013	2014	2015	2016	Total relative abundance
Ariidae		0.087719	0.017544	2.24561404	2.35087719
Carangidae			0.017544		0.01754386
Chaetodontidae	0.035088		0.052632	0.05263158	0.14035088
Cheilodactylidae		0.035088	0.210526		0.24561404
Clinidae	0.035088		0.035088		0.07017544
Dasyatidae			0.017544		0.01754386
Dinopercidae			0.017544	0.03508772	0.01754386
Hexanchidae		0.035088			0.03508772
Lamnidae			0.017544		0.01754386
Myliobatidae	0.052632	0.017544	0.298246	0.05263158	0.42105263
Octopodidae	0.017544			0.07017544	0.0877193
Oplegnathidae	0.035088	0.035088	0.070175		0.14035088
Pomatomidae				0.01754386	0.01754386
Rajidae	0.017544	0.017544		0.05263158	0.0877193
Scyliorhinidae	0.280702	0.666667	0.421053	0.84210526	2.21052632
Serranidae	0.017544		0.035088	0.01754386	0.07017544
Sparidae	2.947368	4.719298	10.38596	6.87719298	24.92982456
Squalidae		0.666667		2.64912281	3.31578947
Tetraodontidae	0.22807	0.017544			0.96491228
Triakidae	0.087719	0.350877	0.421053	0.36842105	1.22807018
Umbrina	0.017544	0.017544			0.03508772

Annexes 6. Summary of the Generalized Linear Model (GLM) analysis examining the relationship between species richness (the number of the different species present) per year and habitat. Estimate: estimated coefficient for the predictor variable in the model; Std. Error: standard error of the estimated coefficient; t value: test statistic for the hypothesis test on the predictor variable (it is calculates as the estimated coefficient divided by its standard error); Pr(>|t|): p-value associated with the t-statistic.

Species richness	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**	
Reef	5.80E+01	2.91E-14	2.00E+15	<2e-16 ***	
Rocky	-4.51E-14	3.94E-14	-1.15E+00	0.253	
Sand	-4.51E-14	5.39E-14	-8.36E-01	0.403	
Significance key:	"***" = 0.001	"**" = 0.01	"*" = 0.05	"." = 0.1	" " = 1

Species richness	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**	
2013	5.80E+01	4.88E-14	1.19E+15	<2e-16 ***	
2014	-1.22E-13	6.01E-14	-2.03E+00	0.0428 *	
2015	-1.22E-13	5.84E-14	-2.09E+00	0.0373 *	
2016	-1.22E-13	6.08E-14	-2.01E+00	0.0452 *	
Significance key:	"***" = 0.001	"**" = 0.01	"*" = 0.05	"." = 0.1	" " = 1

Annexure 7. Summary of the Generalized Linear Model (GLM) analysis examining the relationship between family richness (the number of the different species present) per year and habitat. Estimate: estimated coefficient for the predictor variable in the model; Std. Error: standard error of the estimated coefficient; t value: test statistic for the hypothesis test on the predictor variable (it is calculates as the estimated coefficient divided by its standard error); Pr(>|t|): p-value associated with the t-statistic.

Family richness	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**	
Reef	2.10E+01	1.26E-14	1.66E+15	<2e-16 ***	
Rocky	1.93E-14	1.71E-14	1.13E+00	0.261	
Sand	1.93E-14	2.34E-14	8.22E-01	0.411	
Significance key:	"***" = 0.001	"**" = 0.01	"*" = 0.05	"." = 0.1	" " = 1

Family richness	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**	
2013	2.10E+01	2.06E-14	1.02E+15	<2e-16***	
2014	5.21E-14	2.53E-14	2.06E+00	0.0400*	
2015	5.21E-14	2.46E-14	2.12E+00	0.0347*	
2016	5.21E-14	2.56E-14	2.04E+00	0.0423*	
Significance key:	"***" = 0.001	"**" = 0.01	"*" = 0.05	"." = 0.1	" " = 1

Annexure *8. Summary of the Generalized Linear Model (GLM) analysis examining the relationship between species richness (the number of the different species present) per site sampled. Estimate: estimated coefficient for the predictor variable in the model; Std. Error: standard error of the estimated coefficient; t value: test statistic for the hypothesis test on the predictor variable (it is calculates as the estimated coefficient divided by its standard error); Pr(>|t|): p-value associated with the t-statistic.*

Species richness	Estimate	Std. Error	t value	Pr(>|t|)
AB8	5.80E+01	1.77E-13	3.28E+14	< 2e-16 ***
AC5	6.45E-27	2.17E-13	0.00E+00	1.00E+00
AC7	-3.38E-27	2.29E-13	0.00E+00	1.00E+00
AD3	-6.65E-28	2.15E-13	0.00E+00	1.00E+00
B7	-5.69E-27	2.43E-13	0.00E+00	1.00E+00
B8	9.48E-27	2.25E-13	0.00E+00	1.00E+00
D10	-4.47E-27	2.29E-13	0.00E+00	1.00E+00
D6	-1.04E-27	2.70E-13	0.00E+00	1.00E+00
E10	4.45E-27	2.17E-13	0.00E+00	1.00E+00
E7	4.27E-27	2.33E-13	0.00E+00	1.00E+00
E8	-3.71E-28	2.33E-13	0.00E+00	1.00E+00
E9	-6.16E-28	2.25E-13	0.00E+00	1.00E+00
F10	3.63E-27	2.25E-13	0.00E+00	1.00E+00
F11	2.74E-27	2.38E-13	0.00E+00	1.00E+00
F5	7.97E-28	3.07E-13	0.00E+00	1.00E+00
F6	-1.44E-27	3.96E-13	0.00E+00	1.00E+00
F7	2.29E-27	3.39E-13	0.00E+00	1.00E+00
F8	3.40E-28	2.25E-13	0.00E+00	1.00E+00
F9	-2.57E-27	2.15E-13	0.00E+00	1.00E+00
G5	1.37E-27	3.07E-13	0.00E+00	1.00E+00
G6	-6.24E-27	5.31E-13	0.00E+00	1.00E+00
G7	2.99E-27	3.07E-13	0.00E+00	1.00E+00
G8	-1.68E-27	2.50E-13	0.00E+00	1.00E+00
G9	6.43E-27	2.86E-13	0.00E+00	1.00E+00
K7	5.80E-29	2.86E-13	0.00E+00	1.00E+00
K8	-5.27E-28	2.43E-13	0.00E+00	1.00E+00
L1	1.13E-27	3.07E-13	0.00E+00	1.00E+00
L3	1.52E-27	2.38E-13	0.00E+00	1.00E+00
L4	1.12E-12	2.38E-13	4.73E+00	2.88e-06 ***
N4	1.98E-27	2.29E-13	0.00E+00	1.00E+00
N5	6.09E-27	2.25E-13	0.00E+00	1.00E+00
O1	-3.86E-29	2.86E-13	0.00E+00	1.00E+00
O4	2.49E-27	2.70E-13	0.00E+00	1.00E+00
O5	3.32E-27	2.15E-13	0.00E+00	1.00E+00
P4	1.84E-27	2.38E-13	0.00E+00	1.00E+00
P7	8.32E-28	2.10E-13	0.00E+00	1.00E+00
Q1	3.08E-28	2.38E-13	0.00E+00	1.00E+00
Q9	2.03E-27	2.29E-13	0.00E+00	1.00E+00
R1	2.69E-28	2.38E-13	0.00E+00	1.00E+00
R9	1.99E-27	2.17E-13	0.00E+00	1.00E+00

S7	1.97E-27	2.33E-13	0.00E+00	1.00E+00
T8	1.51E-27	2.07E-13	0.00E+00	1.00E+00
U9	9.05E-28	2.11E-13	0.00E+00	1.00E+00
V11	1.18E-27	2.50E-13	0.00E+00	1.00E+00
V6	1.86E-27	2.19E-13	0.00E+00	1.00E+00
V7	2.05E-27	2.25E-13	0.00E+00	1.00E+00
W9	1.93E-27	2.17E-13	0.00E+00	1.00E+00
X1	1.57E-27	2.38E-13	0.00E+00	1.00E+00
X10	1.33E-27	2.22E-13	0.00E+00	1.00E+00
X9	9.85E-28	2.19E-13	0.00E+00	1.00E+00
Y10	9.51E-28	2.38E-13	0.00E+00	1.00E+00
Y6	1.32E-27	2.10E-13	0.00E+00	1.00E+00
Y8	1.00E-27	2.19E-13	0.00E+00	1.00E+00
Z1	1.49E-27	2.50E-13	0.00E+00	1.00E+00
Z10	6.93E-28	2.10E-13	0.00E+00	1.00E+00
Z2	1.23E-27	2.15E-13	0.00E+00	1.00E+00
Z6	2.55E-28	2.11E-13	0.00E+00	1.00E+00

Significance key: “***” = 0.001 “**” = 0.01 “*” = 0.05 “.” = 0.1 “ ” = 1

Annexure 9. *Summary of the Generalized Linear Model (GLM) analysis examining the relationship between family richness (the number of the different species present) per site sampled. Estimate: estimated coefficient for the predictor variable in the model; Std. Error: standard error of the estimated coefficient; t value: test statistic for the hypothesis test on the predictor variable (it is calculates as the estimated coefficient divided by its standard error); Pr(>|t|): p-value associated with the t-statistic.*

Family richness	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
AB8	2.10E+01	7.57E-14	2.78E+14	< 2e-16 ***
AC5	-3.61E-27	9.27E-14	0.00E+00	1.00E+00
AC7	8.18E-28	9.77E-14	0.00E+00	1.00E+00
AD3	-2.03E-28	9.18E-14	0.00E+00	1.00E+00
B7	-8.73E-28	1.04E-13	0.00E+00	1.00E+00
B8	-1.21E-27	9.62E-14	0.00E+00	1.00E+00
D10	3.36E-27	9.77E-14	0.00E+00	1.00E+00
D6	-6.34E-28	1.16E-13	0.00E+00	1.00E+00
E10	-1.12E-27	9.27E-14	0.00E+00	1.00E+00
E7	-7.50E-28	9.95E-14	0.00E+00	1.00E+00
E8	-2.22E-27	9.95E-14	0.00E+00	1.00E+00
E9	-1.74E-27	9.62E-14	0.00E+00	1.00E+00
F10	-6.34E-28	9.62E-14	0.00E+00	1.00E+00
F11	-2.38E-27	1.02E-13	0.00E+00	1.00E+00
F5	-1.05E-27	1.31E-13	0.00E+00	1.00E+00
F6	-3.99E-27	1.69E-13	0.00E+00	1.00E+00
F7	1.19E-27	1.45E-13	0.00E+00	1.00E+00
F8	-2.13E-27	9.62E-14	0.00E+00	1.00E+00
F9	-4.36E-28	9.18E-14	0.00E+00	1.00E+00
G5	-5.03E-27	1.31E-13	0.00E+00	1.00E+00
G6	-1.82E-27	2.27E-13	0.00E+00	1.00E+00

G7	-2.43E-27	1.31E-13	0.00E+00	1.00E+00
G8	-2.59E-27	1.07E-13	0.00E+00	1.00E+00
G9	-3.20E-27	1.22E-13	0.00E+00	1.00E+00
K7	-2.71E-27	1.22E-13	0.00E+00	1.00E+00
K8	-3.11E-27	1.04E-13	0.00E+00	1.00E+00
L1	-1.59E-27	1.31E-13	0.00E+00	1.00E+00
L3	-1.07E-27	1.02E-13	0.00E+00	1.00E+00
L4	-4.80E-13	1.02E-13	-4.73E+00	2.88e-06 ***
N4	-9.82E-28	9.77E-14	0.00E+00	1.00E+00
N5	-4.72E-28	9.62E-14	0.00E+00	1.00E+00
O1	6.71E-29	1.22E-13	0.00E+00	1.00E+00
O4	-1.10E-27	1.16E-13	0.00E+00	1.00E+00
O5	9.44E-28	9.18E-14	0.00E+00	1.00E+00
P4	-9.14E-28	1.02E-13	0.00E+00	1.00E+00
P7	-1.09E-27	8.95E-14	0.00E+00	1.00E+00
Q1	-1.29E-27	1.02E-13	0.00E+00	1.00E+00
Q9	-1.29E-27	9.77E-14	0.00E+00	1.00E+00
R1	-8.12E-28	1.02E-13	0.00E+00	1.00E+00
R9	-7.31E-28	9.27E-14	0.00E+00	1.00E+00
S7	-1.19E-27	9.95E-14	0.00E+00	1.00E+00
T8	-7.35E-28	8.84E-14	0.00E+00	1.00E+00
U9	-6.37E-28	9.02E-14	0.00E+00	1.00E+00
V11	-1.20E-27	1.07E-13	0.00E+00	1.00E+00
V6	-1.09E-27	9.37E-14	0.00E+00	1.00E+00
V7	-1.04E-27	9.62E-14	0.00E+00	1.00E+00
W9	-1.11E-27	9.27E-14	0.00E+00	1.00E+00
X1	-7.11E-28	1.02E-13	0.00E+00	1.00E+00
X10	-1.06E-27	9.49E-14	0.00E+00	1.00E+00
X9	-8.43E-28	9.37E-14	0.00E+00	1.00E+00
Y10	-8.62E-28	1.02E-13	0.00E+00	1.00E+00
Y6	-9.92E-28	8.95E-14	0.00E+00	1.00E+00
Y8	-7.84E-28	9.37E-14	0.00E+00	1.00E+00
Z1	-8.55E-28	1.07E-13	0.00E+00	1.00E+00
Z10	-6.13E-28	8.95E-14	0.00E+00	1.00E+00
Z2	-8.09E-28	9.18E-14	0.00E+00	1.00E+00
Z6	-6.17E-28	9.02E-14	0.00E+00	1.00E+00

Significance key: “***” = 0.001 “**” = 0.01 “*” = 0.05 “.” = 0.1 “ ” = 1

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Annexure 10. *Summary of the Generalized Linear Model (GLM) analysis examining the relationship between species abundance (Max N) by habitat, year and site sampled. Estimate: estimated coefficient for the predictor variable in the model; Std. Error: standard error of the estimated coefficient; t value: test statistic for the hypothesis test on the predictor variable (it is calculates as the estimated coefficient divided by its standard error); Pr(>|t|): p-value associated with the t-statistic.*

Max N	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**	
Reef	3.4257	0.3622	9.457	<2e-16 ***	
Rocky	-0.8687	0.4908	-1.77	0.0772 .	
Sand	1.0939	0.672	1.628	0.104	
Significance key:	"***" = 0.001	"**" = 0.01	"*" = 0.05	"." = 0.1	" " = 1

Max N	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**	
2013	2.337	0.5927	3.943	8.93e-05 ***	
2014	-0.2021	0.7299	-0.277	0.78194	
2015	1.0781	0.7097	1.519	0.12923	
2016	2.196	0.7381	2.975	0.00304 **	
Significance key:	"***" = 0.001	"**" = 0.01	"*" = 0.05	"." = 0.1	" " = 1

Max N	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
AB8	2.625	1.936162	1.356	0.1757
AC5	3.8125	2.371305	1.608	0.1084
AC7	-0.041667	2.499574	-0.017	0.9867
AD3	-0.625	2.347941	-0.266	0.7902
B7	0.152778	2.661	0.057	0.9542
B8	0.144231	2.460819	0.059	0.9533
D10	-0.041667	2.499574	-0.017	0.9867
D6	-0.125	2.957536	-0.042	0.9663
E10	1.6875	2.371305	0.712	0.477
E7	1.375	2.544615	0.54	0.5892
E8	3.284091	2.544615	1.291	0.1973
E9	1.144231	2.460819	0.465	0.6421
F10	0.605769	2.460819	0.246	0.8056
F11	1.575	2.597634	0.606	0.5445
F5	4.125	3.353531	1.23	0.2192
F6	10.375	4.32939	2.396	0.0169 *
F7	2.041667	3.707468	0.551	0.5821
F8	2.528846	2.460819	1.028	0.3045
F9	0.669118	2.347941	0.285	0.7758
G5	2.125	3.353531	0.634	0.5265
G6	8.375	5.808486	1.442	0.1499
G7	23.625	3.353531	7.045	5.18e-12 ***
G8	0.625	2.738147	0.228	0.8195
G9	1.175	3.121968	0.376	0.7068
K7	-0.825	3.121968	-0.264	0.7917
K8	-0.291667	2.661	-0.11	0.9128
L1	-1.375	3.353531	-0.41	0.6819
L3	-1.225	2.597634	-0.472	0.6374
L4	0.375	2.597634	0.144	0.8853

N4	-0.541667	2.499574	-0.217	0.8285
N5	-0.009615	2.460819	-0.004	0.9969
O1	-1.025	3.121968	-0.328	0.7428
O4	0.041667	2.957536	0.014	0.9888
O5	-0.036765	2.347941	-0.016	0.9875
P4	-0.425	2.597634	-0.164	0.8701
P7	-0.275	2.290898	-0.12	0.9045
Q1	-0.225	2.597634	-0.087	0.931
Q9	0.125	2.499574	0.05	0.9601
R1	-0.725	2.597634	-0.279	0.7803
R9	-0.6875	2.371305	-0.29	0.772
S7	-0.988636	2.544615	-0.389	0.6978
T8	-1.170455	2.26095	-0.518	0.6049
U9	-0.309211	2.308058	-0.134	0.8935
V11	-0.875	2.738147	-0.32	0.7494
V6	3.108333	2.397508	1.296	0.1953
V7	-0.701923	2.460819	-0.285	0.7756
W9	0.1875	2.371305	0.079	0.937
X1	-0.325	2.597634	-0.125	0.9005
X10	-0.625	2.427108	-0.258	0.7969
X9	-0.091667	2.397508	-0.038	0.9695
Y10	-0.025	2.597634	-0.01	0.9923
Y6	1.625	2.290898	0.709	0.4784
Y8	-1.225	2.397508	-0.511	0.6096
Z1	-0.375	2.738147	-0.137	0.8911
Z10	-0.125	2.290898	-0.055	0.9565
Z2	-0.683824	2.347941	-0.291	0.771
Z6	4.269737	2.308058	1.85	0.0648 .

Significance key: “***” = 0.001 “**” = 0.01 “*” = 0.05 “.” = 0.1 “ ” = 1