BIOLOGICAL & MARINE SCIENCES WITH PLYMOUTH UNIVERSITY

BIODIVERSITY, DISTRIBUTION AND ABUNDANCE OF FISH SPECIES WITHIN THE CAPE WHALE HOPE SPOT, SOUTH AFRICA.

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Copyright Statement

Abstract

This report investigates the biodiversity, abundance and distribution of marine species over a three year period from 2016 – 2019, in the waters off Hermanus, South Africa. This study used count data from Baited Remote Underwater Videos (BRUV) to evaluate community composition in a non-invasive way that allowed for the species to be assessed *in-situ*. The data obtained from these surveys was then subjected to extensive statistical analysis using the Shannon Diversity Index, t-tests and a two-way ANOVA. Kelp forests were found to have the highest biodiversity and abundance of species from varying trophic levels, followed closely by rocky/reef habitats. Sandy habitats were seen to have a continual decline in biodiversity over the time period which indicates a shift away from exposed habitats towards habitats that provide better shelter and higher resource availability. The aim of the study is to provide information that can be used to improve current or create new management methods to better preserve the environment from the ongoing effects of climate change as well as the anthropogenic pressures on the natural world, which has led to a dramatic loss of global biodiversity and has forced many species to the brink of extinction. Ideally management strategies would focus on a holistic approach to integrate the human use of natural resources with the protection of the whole ecosystem, aiming towards a more sustainable future.

[225 words]

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Thank you to all my friends that I've made whilst at the University of Plymouth and to those friends and family back home who have all helped and supported me throughout the past four years.

Finally, the biggest thank you to my mother, Maria, who's support, love, guidance and endless proof reads of my assignments and drafts have been appreciated every step of the way.

Author Declaration

I, BRENDON QUEIROZ, hereby declare that I am the sole author of this thesis. To the best of my knowledge this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted as part of the requirements of any other academic degree. The data presented in this thesis was obtained during an internship and by the South African Shark Conservancy in Hermanus, Cape Town. I played a major role in the preparation and execution of the field work and data collection. The data analysis and data interpretation are entirely my own work.

This is a true copy of the thesis, including final revisions.

1. Introduction

1.1 The importance of the area

It is becoming increasingly evident that a greater emphasis on conservation of the environment is required in order to mitigate the detrimental effects of anthropogenic activity and climate change. One method of achieving this is to investigate environments to understand the community compositions and use the results to effectively manage conservation strategies and ensure the survival of habitats and the species that depend on them (Anadón et al., 2011 and Filous et al., 2016).

This study took place within the Cape Whale Hope Spot (CWHS) in Hermanus, South Africa. The study sites include a range of marine species across three habitat types; kelp forests, sandy seabed and rocky/reef environments. The Hope Spot was designated on December 6, 2014, due to the high levels of biodiversity and abundance of endemic species. This report will define biodiversity as it was in the 1992 United Nations Convention on Biological Diversity (CBD), `The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species and of ecosystems'. (Cbd.int. 2019).

1.1.1 Hope Spots

Mission Blue is a non-profit organisation (NPO) which was created by Dr. Sylvia Earle, after winning the 2009 TED Prize (Ted.com, 2019). With the help of her team, Earle began focus on designating special areas within the ocean as Hope Spots. These Hope Spots can be ecologically important marine areas as well as Marine Protected Areas (MPA), which have strict laws and regulations enforced by governments. The Hope Spots are provided special protection under a global campaign comprised of an alliance of over 200 respected conservation groups and similar organisations such as the International Union for Conservation of Nature (IUCN). The aim of the protection is that the anthropogenic pressures on the hope spot will reduce, with the goal of developing into an MPA in the future.

In December 2017, the UN published a progress report which identified 85 Hope Spots across the world. Due to their work and development of public awareness, Mission Blue committed to the designation of 30 new Hope Spots, in support of the UN SDG14 (Oceanconference.un.org, 2017). The CWHS, encompasses approximately 200km of coastline, including Robben Island and Dassen Island (Hopespots.mission-blue.org, 2020). The location hosts some of the more well-known species such as the white shark (*Carcharodon carcharias)*, endemic sharks e.g. dark shyshark *(Haploblepharus pictus)*, marine mammals as well as smaller marine animals such as teleosts.

1.2 Threats to the environment

The current threats to the Cape Whale Coast Hope Spot are mainly anthropogenic activities occurring in the region. The competition and pressure on the environment is enormous and close to the carrying capacity of the area. This leads to further environmental degradation through habitat destruction, introduction of alien species and pollution of nearby water bodies (Hopespots.mission-blue.org, 2020).

1.2.1 Overfishing

South Africa's fishing industry is responsible for approximately 1% of the national gross domestic product (GDP) and an important livelihood for much of the population (Griffiths et al., 2010). Whilst the industry is invaluable to the country, many fishermen exploit the waters and the species within, which is highly detrimental to local ecosystems. Unfortunately this issue is not confined to this region but occurs throughout the world's oceans. Examples of the species in danger of overfishing are Musselcrackers (*Cymatoceps nasutus*) and Red Steenbras (*Petrus rupestris*) where it has been reported that the current population has been seriously depleted and now represents 5% or less of what the population was recorded at previously (Environment News South Africa, 2020).

1.2.2 Tourism

Tourism is a vital component of South Africa's GDP, generating over R100 billion ($6.5 billion) a year in revenue (Kara, 2018) and whilst the interaction with wildlife has become popular with tourists it has a variety of impacts on the wildlife involved (Orams, 2002). White shark diving in South Africa began in 1991 after a bill was passed to protect the sharks from fishing exploitation (Compagno, 1991) and has since grown exponentially. This comes with both positive and negative impacts. The sharks are often attracted to the boats via a process called 'provisioning' (Johnson and Kock, 2006) which involves chumming the surrounding waters to raise the chances of wildlife sightings. Overtime, provisioning changes the natural behaviour of the sharks as they begin to associate feeding with the presence of humans, which can have adverse effects on the ecosystem if the apex predator isn't feeding directly through the trophic levels (Brena et al., 2015 and Brunnschweiler and Barnett, 2013). The increased interaction with the boats also raises the potential for sharks to be captured by fishermen for their fins.

1.3 Data and method choice

In 2016, the South African Department of Environmental Affairs (DEA) initiated long-term monitoring and research programmes in MPAs, specifically estuaries and reef habitats. These programmes focus on utilising procedures such as underwater imagery, remote underwater video surveys (RUV) and SCUBA (Verheye et al., 2018)**.** The Baited Underwater Remote Video (BRUV) method was chosen for this study due to its low-disturbance and non-invasive nature which allows for successful *in situ* surveying of the spatial distribution and abundance of marine species (Brooks et al., 2011) by using bait to attract fish into the field of view of a camera attached to the rig, whilst allowing the user to obtain footage over a longer time period and at a higher quality (Mallet and Pelletier, 2014). A 2017 study on West Coast Rock Lobster (*Jasus lalandii),* (Roberson et al., 2017). It was shown in this study that the BRUV deployments outperformed the traditional net and trap methods when comparing the sampling effort, species abundance and the ability to detect change within the observed lobster population. In addition, sites in which BRUV were used compared to nonbaited sites recorded an increased abundance of predatory and scavenging species, whilst having no adverse effect on the abundance of herbivorous species (Harvey et al., 2007). Therefore, the BRUV sites provided a better understanding of the species richness and abundance in the area. Large elasmobranchs and piscivorous mammals have also been surveyed successfully using the technique (Sherman et al., 2018). The versatility of the method makes research throughout the oceans viable and has already been used in regions ranging from temperate and tropical environments to polar regions (Bernard and Götz, 2012; Devine et al., 2019; Pearson and Stevens, 2015 and Sherman et al., 2018).

1.4 Aims and objectives

This study has used count data obtained from BRUV surveys within the Cape Whale Hope Spot, shown in Figure. 1, and aims to determine the biodiversity, abundance and distribution of species over a 3 year period. Baseline data for reef ecosystems in South Africa is lacking due to the reduced availability of technology and resources compared to more developed nations such as the US. The data from this study will be investigated with the purpose of filling knowledge gaps of data within marine environments by highlighting any changes throughout the time period and suggesting possible causes, which could lead to the alteration or creation of marine management strategies in order to correctly conserve the environment. Based on the prior research (Steneck et al., 2002 and Toohey, Kendrick and Harvey, 2007) it is predicted that there will be a clear difference in community composition between the three main habitat types, this is due to the high productivity of the kelp forests and how species utilise the vast size of these kelp forest to disguise and evade predators.

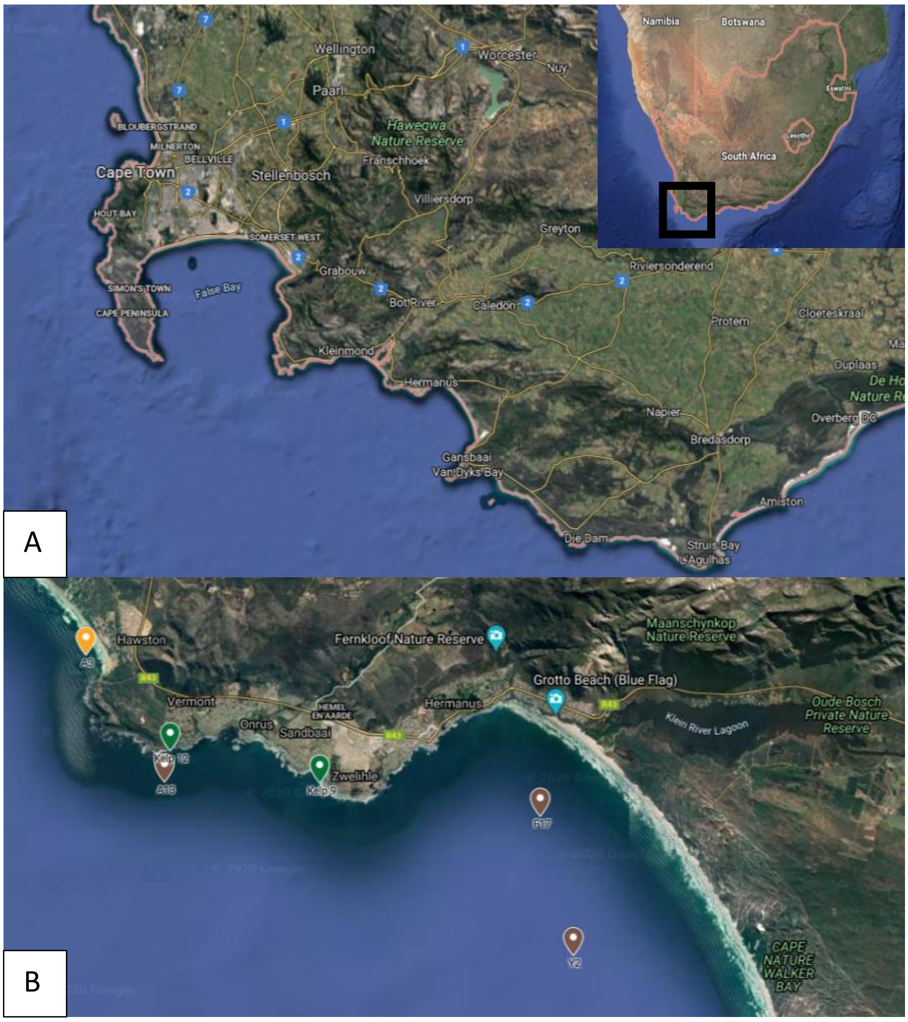

Figure 1. Two maps showing the location of the study site. Map (a) shows the Western Cape with an insert of where in South Africa it is located. Map (b) is a close up view of the bay in which the data was obtained from. The map insert shows the study area with pinned locations of 6 BRUV deployment sites. The differing colours of the pins correspond to the habitat type. Green represents Kelp, brown represents rocky/reef and yellow represents sandy habitats. Google maps.

2. Methodology

2.1 Method and materials

The techniques were carried out alongside trained professionals at the South African Shark Conservancy (SASC). To begin, the bait was crushed and then weighed out into 1kg portions and frozen until needed. The bait was standardised at 1kg throughout the experiment to remove skewed results due to bait quantity. The frozen portions were then defrosted and put into a bait canister; a plastic cylinder with holes (~2cm diameter) throughout to allow a sufficient scent plume and for species to access the bait whilst underwater (Figure. 2). The canister lid was secured with cable ties to prevent it from falling off and littering the ocean. The researchers, usually a team of four people made up of 1 skipper and 3 researchers used a Ski-Craft 680 vessel to transport themselves and the required gear to a predetermined location based on accessibility and weather conditions. The canisters were then secured onto a metal rig, with the end of each arms at a distance of 1 metre apart, using a locking pin to hold it in place. An EZ Viz S2 action camera was used to record the marine species (Ezvizlife.com, 2020) and attached to the opposite end of the rig, facing the canister (Figure. 3). The camera was then turned on and footage begins. The rig is deployed from the side of the boat and chained to a surface buoy, marked with relevant details so that the likelihood of other area users tampering with the rig was reduced. The time, location and depth were noted down onto a data sheet which would be entered into a Microsoft Excel spreadsheet once back in the laboratory. The rig was then left for 1 hour and 15 minutes to minimise the impact on the sightings of marine species due to boat presence. During this time, the team would deploy more rigs. A total of 3 rigs could be deployed at one time. Once the 1 hour and 15 minutes had lapsed the rig would be brought back aboard, where the camera was then stopped and bait canisters cleaned out ready for the next deployment. After completing the BRUV deployments, the camera was brought back to the lab and the videos were imported to a computer. The videos are viewed in full, at real time. Data recording for the sightings of marine organisms only started once 6 minutes had lapsed after the rig reached the seabed to allow for the disturbed seabed to settle and for the bait to emit an effectively dispersed scent plume. The videos were paused when an organism is seen and the species, number of individuals, time in the video and environmental data, such as visibility of the water which was estimated in metres using the rig for reference, the field of view measured as a percentage of the total camera frame was recorded into a excel spreadsheet. Data recording stopped when the rig began to be pulled back to the vessel. Following the 6 minute lapse at the start of the video, only 60 minutes worth of data was recorded. Any species that could not be identified due to obstructions or unclear footage have been excluded from the dataset. The species were identified using own knowledge, the knowledge of professionals and the help of published textbooks (Branch et al., 2016 and Compagno et al., 1989). Data spreadsheets of deployments carried out on the same day were then combined. The completed spreadsheets were then divided by season and year into folders, ready for statistical analysis.

Figure 2. Image of a bait canister being used during a BRUV deployment. Image was taken during another study in Mossel Bay, South Africa and is similar to the ones used in this study (Oceans Research, 2017).

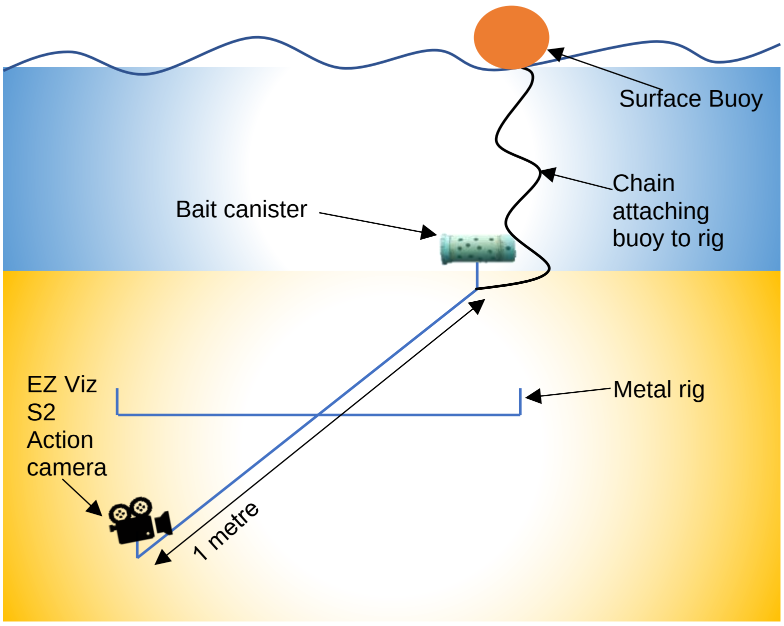

Figure 3. Diagram created using Microsoft Word to depict how the BRUV rig was set up during deployments.

2.1.1 Bait influence

The interaction between the canister and the surrounding community relies heavily on the type of bait used (Harvey et al., 2007 and Wraith, 2007). In this study the bait was made from crushed pilchard, 'sardines' *(Sardinops sagax).* However, due to the reduced availability of stock during June – September 2019, the South African Sustainable Seafood Initiative (SASSI) listed the pilchards under the orange category of their 'traffic light' system (the system which divides selected domestic and imported seafood species into categories based on their conservation status) (Western Cape Government, 2017). This resulted in the change of bait during those months, to consist of 1 whole chokka squid (*Loligo reynaudii)* with pacific saury, 'pike' (*Cololabis saira)* in order to accommodate SASSI's reports.

2.2 Statistical analysis and data interpretation

Statistical tests were carried out such as the Shannon Diversity Index (SDI). For each of the videos a SDI value of species diversity was calculated. The following equation shows how the SDI values were calculated (A), followed by equation (B), was used to calculate Shannon's equitability (E_H) which assumes a value between 0 and 1, with 1 being complete evenness.

(A): $H = -\sum_{i=1}^{S} p_i \ln p_i$ (B): $E_H = H / H_{max} = H / \ln S$

H	Shannon's Diversity Index
S	Total number of species in the community (Richness)
Pi	Proportion of S made up of the *i*th species
Eh	Equitability (evenness)

Hutcheson t-tests were used to compare diversity of the community samples using the calculated SDI values within the same year and throughout the dataset (Hutcheson, 1970). A significance level of $\alpha = 0.05$, was chosen for these t-tests. The formula is shown below (C).

$$\text{(C):} \quad t = \frac{H_a - H_b}{\sqrt{s^2_{H_a} + s^2_{H_b}}}$$

H	Shannon Diversity Index for each of the two samples (subscripted a and b)
S_{2H}	Variance of the Shannon Diversity Index

A two-way ANOVA was performed to examine the effects of habitat type and the season and year on SDI values for multiple study sites using IBM SPSS. The results were used to create tables and figures in Microsoft Excel and SPSS to visually display the community composition from 2016 to 2019. Data are mean ± standard deviation, unless otherwise stated. Residual analysis was carried out to test for the assumptions of the two-way ANOVA test. Boxplots were generated which identified some data points to be outliers (1.5 box-lengths from the edge of the box) as well as extreme outliers which are shown to be greater than 3 box lengths. The outliers were kept in the two-way ANOVA as removal or modification of the data would have caused the analysis to be inaccurate. All combinations of the two independent variables (Season and Year, Habitat types) and the dependent variable (SDI values) were statistically assessed to investigate if they were distributed normally or not. Skewness and Kurtosis values were computed for the combinations and their z scores of each habitat type were also calculated with a statistical significance level of 0.01 (±2.58). All combinations that were successfully assessed showed normal distribution. Some combinations were not assessed due to the fact that there was not enough data (N value) to run the statistical test. The data was also investigated using a Shapiro-Wilk test for each combination ($p > 0.05$) and the assumption of normality was fulfilled by this assessment for all values apart from Winter 2018, Rocky/Reef which showed a value of 0.023. The values for all of the sites can be found in Table. 1. Homogeneity of variances were assessed and proved using Levene's test. A test was also run to investigate whether interaction effects exist using the betweensubjects effects test. There was a statistically significant interaction between habitat type and the season and year for Shannon Diversity Index values. As a result, analysis of simple main effects for habitat types was conducted with Bonferroni adjustments.

Visualisations of sea surface temperature (SST) used in this study were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC (Acker and Leptoukh, 2007). Giovanni provided sea temperature and highlighted any anomalies which were useful in building a complete understanding of the region that could have affected the fish species and community composition.

3. Results

3.1 Statistical analysis results

The Levene's test result (p = 0.523), proved homogeneity of variances and indicated that the Levene's test was not statistically significant (because $p > 0.05$). There was a statistically significant interaction between habitat type and the season and year for Shannon Diversity Index values, $F(9, 161) = 2.207$, $p = 0.024$, partial $\eta^2 = 0.110$. The analysis of simple main effects for habitat types with Bonferroni adjustments, showed significance by being accepted at the level $p < 0.025$. For the three habitat types in Winter 2019, mean "SDI Values" score for Sandy was 0.45, standard deviation was not provided as there was only one SDI Value available for that combination of Season and Year and Habitat type, for Kelp it was 1.87 ± 0.30 and for Rocky/Reef habitat it was 1.65 ± 0.56, a statistically significant mean difference of 1.424 (95% CI, 0.374 to 2.474), $F(9, 161) = 2.207$, $p = .004$, partial $\eta^2 = 0.110$. There was also a statistically significant difference in mean 'SDI Values' for Kelp habitats compared to the other two types throughout the data series, $F(5, 161) = 2.646$, $p < 0.025$, partial $\eta^2 = 0.076$.

3.2 Habitat types and Shannon Diversity Index values

As expected the kelp habitats experienced a higher species diversity compared to the other habitats. When inspecting the SDI values for the Winter 2019 (Figure. 4), the data shows the diversity and evenness in site A13 are much higher than in site A3 . A13 not only has a greater number of species present, but the individuals in the community are distributed more equitably among these species. In A3 there are 11 fewer species and over 80% of the individuals belong to one species, strepie (*Sarpa salpa*). The west coast rock lobster (*Jasus lalandii*), on the other hand is the most common species in A13, makes up about 31% of the community. When comparing A13 and K12, the SDI for each site shows that K12 is more diverse with a more equal spread of individuals across the species where the two most common species make up 20% of the community (lobster and sixgill hagfish, *Eptatretus hexatrema*). The study sites mentioned above can be seen in Figure. 1.

Examination of the boxplot showing the highest SDI values throughout the years (Figure. 5), indicates that over the 3 year dataset the highest SDI values were rocky/reef in 2016 and 2017 and kelp sites in 2018 and 2019, the Kelp 9 site in 2018 was the highest overall with a SDI value of 2.18 and Shannon equitability of 0.95. Figure. 6 also shows a gradual positive correlation between SDI values and annual progression. The mean SDI value for 2017 was calculated to be 1.26 and in 2019 the value increased to 1.57, this 0.31 increase indicates there was a larger amount of species seen over the three habitat types in the course of two years. The increase is positive, as the method was carried out in the same way, removing the chances of outside influences effecting the results.

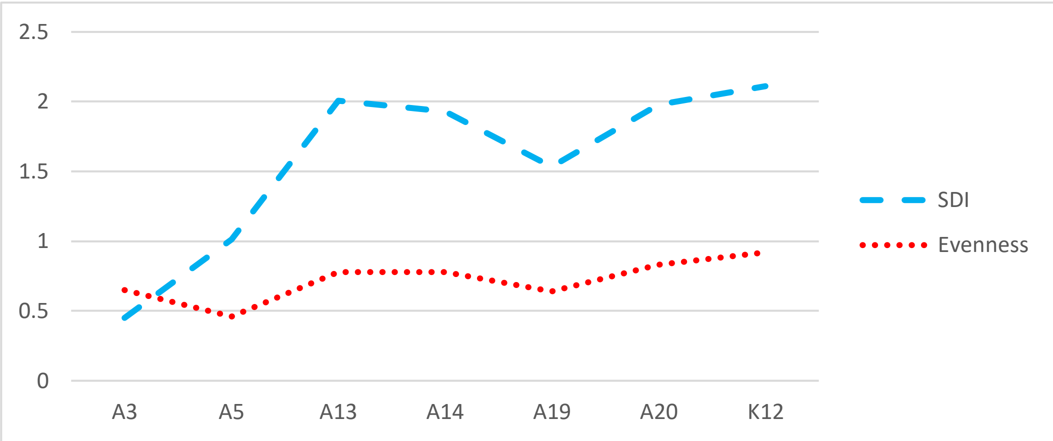

Figure 4. Line graph created using Microsoft Excel showing the Shannon Diversity Index and Evenness for each of the study sites in winter 2019

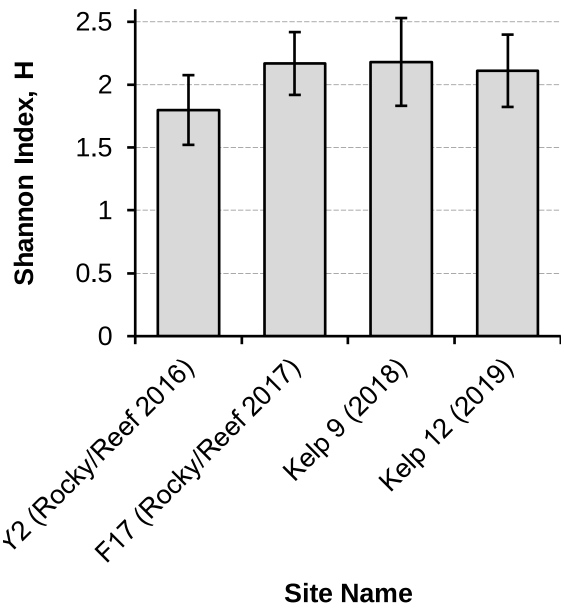

Figure 5. Boxplot with error bars of the highest SDI values per year throughout the course of the study.

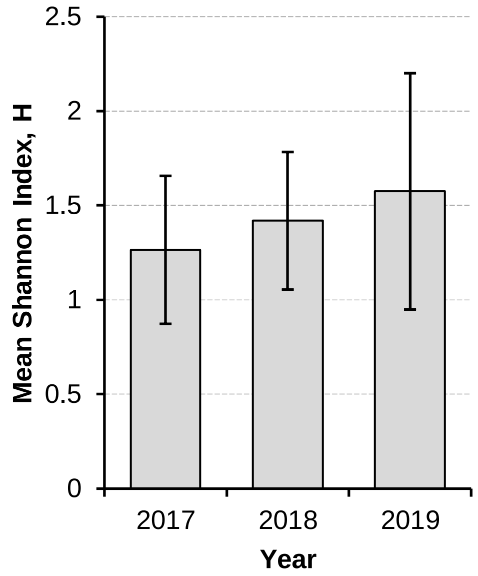

Figure 6. Boxplot with standard error bars for the mean SDI values per year. 2016 has been removed from the figure as only one site was examined in that year and so a mean is unable to be calculated.

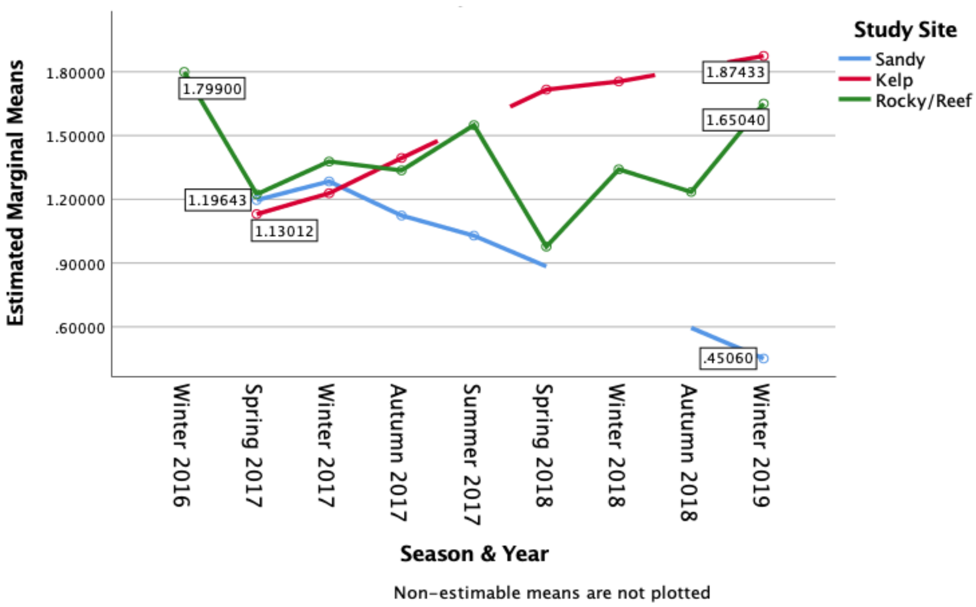

Figure 7. Graph created using SPSS Statistics to show the estimated means of the calculated SDI values per site. The means have been categorised by their habitat type to improve the ease of comparison between the habitats.

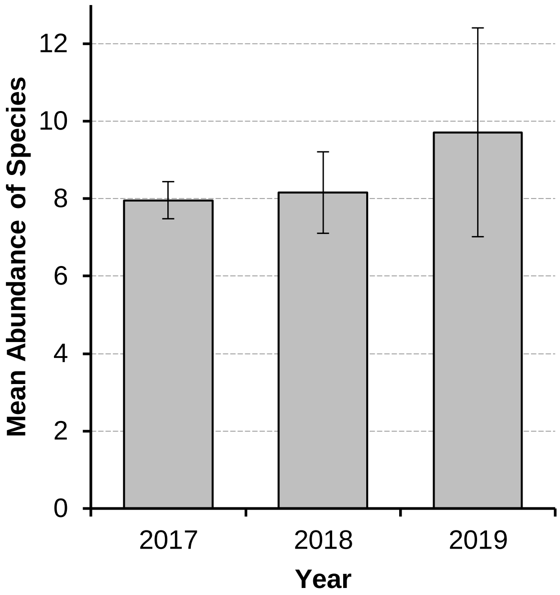

Figure 8. Boxplot with standard error bars showing the total mean species abundance per year. Means calculated from count data of each species. 2016 data was again omitted as means were not able to be calculated.

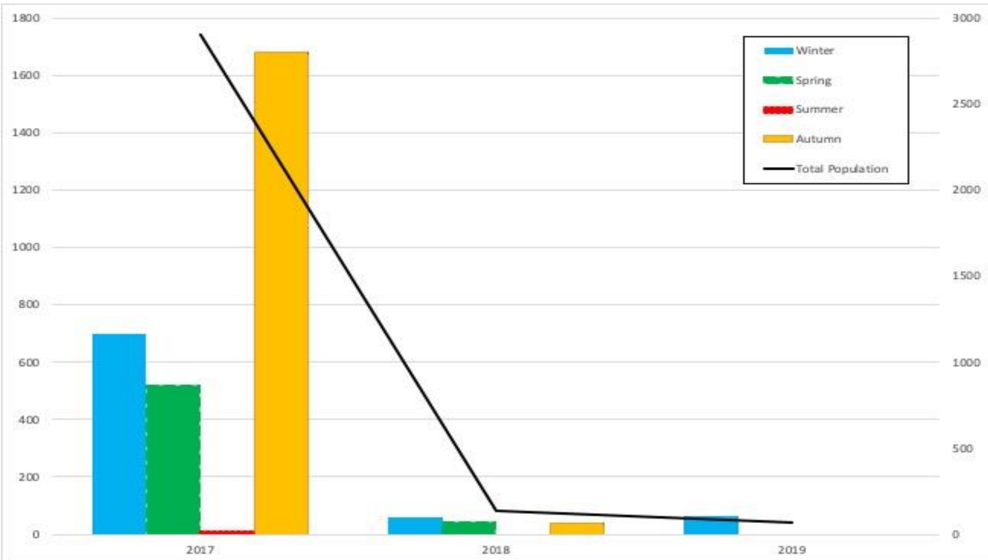

Figure 9. Bar chart showing the count data of lobsters per season per year. The graph also shows a data line, on the secondary axis, for the total amount of lobsters, calculated by adding all of the seasonal count data per year together.

4. Discussion

4.1 Kelp Forests

Upon evaluation of the estimated marginal means of SDI value per site graph (Figure. 7), it is clear to see that kelp habitats are the only environment that had an increasing species diversity with time, starting with an SDI value of 1.13 and improving to 1.87, following a positive correlation trend. Total mean abundance of species (Figure. 8) also followed an increasing trend throughout the years, peaking in 2019. The data for 2016 has been omitted as there is only one study site for that year and so the means were not able to be calculated. This graph shows a movement of species towards kelp forests, which could be as result of the protection that the forests provide. In sandy habitats which are exposed, leaving almost all species in the ecosystem at risk of being preyed upon or caught by fishermen (legally or illegally), usually resulting in death for the fish. The forests also act as primary producers for many trophic levels, due to the secretion of mucus that encourages the growth of bacteria. Kelp forests are known to be among the most phyletically diverse and productive systems in the oceans (Mann, 1973). However, they are under threat from the impacts of anthropogenic climate change which have led to altered food web dynamics such as a change in predator-prey population numbers, greater chance of disease and reduced ocean productivity (Hoegh-Guldberg and Bruno, 2010). Kelp forests are also critical, because they act as an equivalent to terrestrial forests, absorbing carbon dioxide from the atmosphere and converting it into food and sugars that the algae and sessile organisms feed from. Studies shows that with the effects of climate change e.g. rising temperatures and ocean acidification, could increase the chances of phase shifts in kelp forests. This is defined by the change from one stable community state to another, which can be due to environmental factors, predator change and anthropogenic activities.

4.2 Abalone poaching and its effect on kelp forest habitats

Illegal abalone poaching has become an epidemic and has been an issue since 1996 (Hauck, 1999). Abalone are a species of marine snail belonging to the class Gastropoda, which act as primary consumers in rocky habitats. South Africa is home to five endemic abalone species (Evans et al., 2004). The species are considered a delicacy in South-East Asian countries such as China and within 25 years the species has been poached to a level of commercial extinction, due to an increase in the illegal trade of the species (up to 95% of the poached abalone is smuggled to South-East Asia), which is often controlled by connected and powerful crime syndicates (Minnaar, van Schalkwyk and Kader, 2018). This has implications on the subtidal marine ecosystems as the over-exploitation has resulted in the collapse of abalone recruitment and sea urchin population, also believed to be because of the increased predation by rock lobster (Tarr, Williams and Mackenzie, 1996). This collapse could have a knock-on effect for the kelp forest ecosystems, as sea urchins naturally predate on the kelp, so with a decreased number of predators the kelp have been able to grow with reduced pressures and create an even more productive ecosystem (Mann and Breen, 1972; Breen and Mann, 1976 and Estes, 1998).

4.3 Keystone species

Lobsters are known as keystone species, which are defined as species that have a disproportionate effect on the persistence of all other species and with their removal, allows a prey population to explode and often decrease overall diversity (Bond, 1994). To evaluate this effect, the population of rock lobsters has been tracked and shown in Figure. 9. The graph shows an exponential boom in the abundance of rock lobsters in 2017, particularly during the autumn months, followed by a gradual decrease in each month respective to their starting values. The graph showing estimated marginal means of SDI values per site (Figure. 7) shows a similar trend of rocky/reef habitats SDI values to that of lobster populations, which may indicate that lobsters also have an effect on the SDI values in this habitat as well as the kelp forest, which shows a continual SDI value growth with slight dips but not large enough to show a direct correlation with the lobster population. Another effect of the large population of rock lobsters is the increased presence of teleosts, and consequently their natural predator, the broadnose sevengill shark (*Notorynchus cepedianus*) (Ebert, 1991 and Ebert, 1991). The shark is the only extant member of its genus and whilst it can be found in many different locations around the world, it is listed as vulnerable and near threatened in some areas of the Pacific according to the IUCN Red List (iucnredlist.org, 2020)**.** During Autumn 2017, the shark species was sighted 15 times and not again until the winter of 2018 where it was sighted twice. All of these sightings were equally spread between kelp forest and rocky/reef habitats which also correlates with the findings of the rock lobsters. This process of predator-prey interaction highlights the importance of correct holistic management of the ecosystem, as the change in population of one species can have drastic knock-on effects throughout the ecosystem. The species is also a target of the shark fin trade which involves hunting and catching a multitude of shark species for their meat, fins and livers in order to make Asian delicacies as well as being an ingredient in many cosmetic products found globally (Vannuccini, 1999 and Cedrola et al., 2009).

4.4 Oceanographic processes and sea surface temperature

The two figures below show the average sea surface temperature (SST), measured in Celsius (°C), in the study area from 2016-2019 by annual averages (Figure. 10) and the average temperatures of each winter throughout the study (Figure. 11). The figures were created using the NASA satellite Giovanni and both maps cover the same area. Temperature is a key component of the climate system as the sea surface acts as the interface for energy and gaseous exchanges. Figure. 10 indicates a reasonably stable and similar temperature for each year. However, in 2017 the map shows a lower temperature (10.86°C-16.29°C) than the usual (16.29°C-21.71°C), which was surprising as studies state that 2017 was one of the highest on record in the absence of an El Niño event and so the SST should be higher.

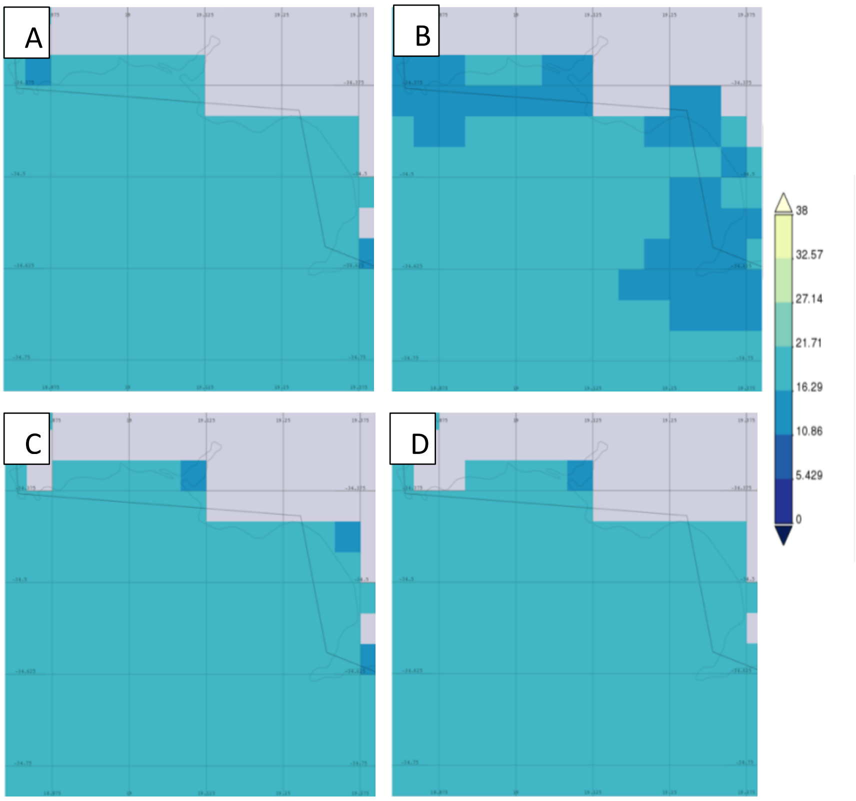

Figure 10. A map of the study area shaded according to the averaged annual sea surface temperatures (SST). Each map shows the same region but is separated by year. A: 2016. B: 2017. C: 2018. D: 2019. The figure was created using the Giovanni website. Time Averaged Map of Sea Surface Temperature at 11 microns (Day) monthly 4km [MODIS-Aqua MODISA_L3m_SST v2014] C. Region 18.7983E, 34.798S, 19.3998E, 34.268S.

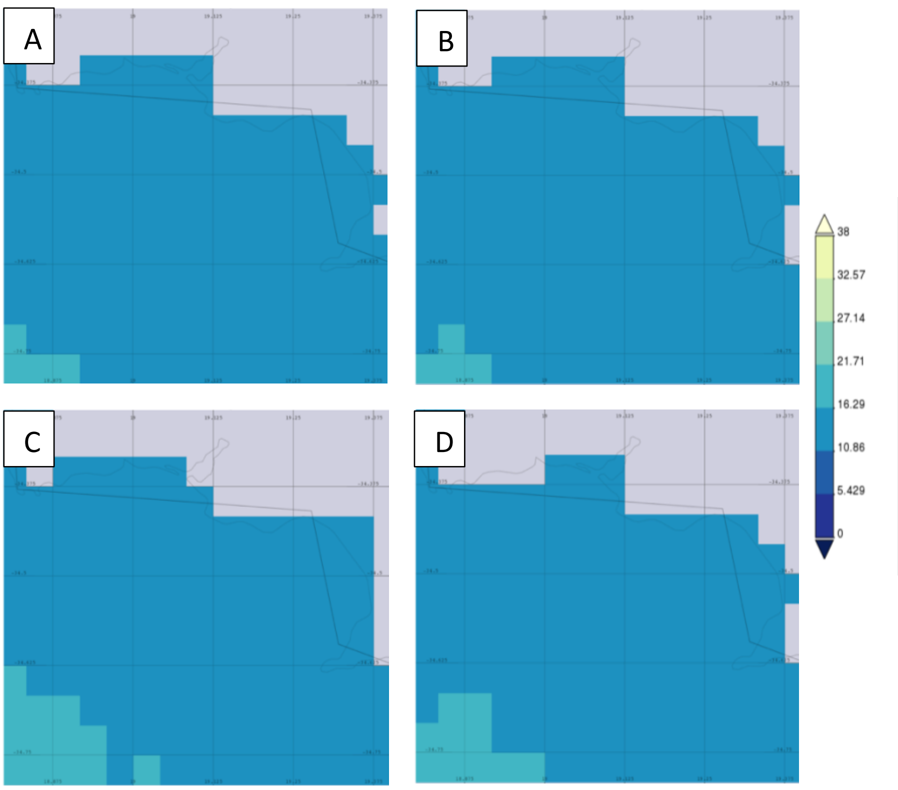

Figure 11. A map of the study area shaded according to the averaged sea surface temperatures (SST). Each map shows the same region but is separated by data for the winter of each year during the study. A: 2016. B: 2017. C: 2018. D: 2019. The figure was created using the Giovanni website. Time Averaged Map of Sea Surface Temperature at 11 microns (Day) monthly 4km [MODIS-Aqua MODISA_L3m_SST v2014] C. Region 18.7983E, 34.798S, 19.3998E, 34.268S.

4.5 Ocean currents and circulation

The following map (Figure. 12) taken from the 2017 Annual Global Climate Report by National Oceanic and Atmospheric Administration (NOAA) (NOAA National Centres for Environmental Information, 2018) shows the global temperature departure from 2017. It shows that whilst most of the world's land masses and oceans remain warm, there is a clear injection of cooler warmer that appears to start off the coast of Antarctica and reach South Africa and towards the northern border of Namibia.

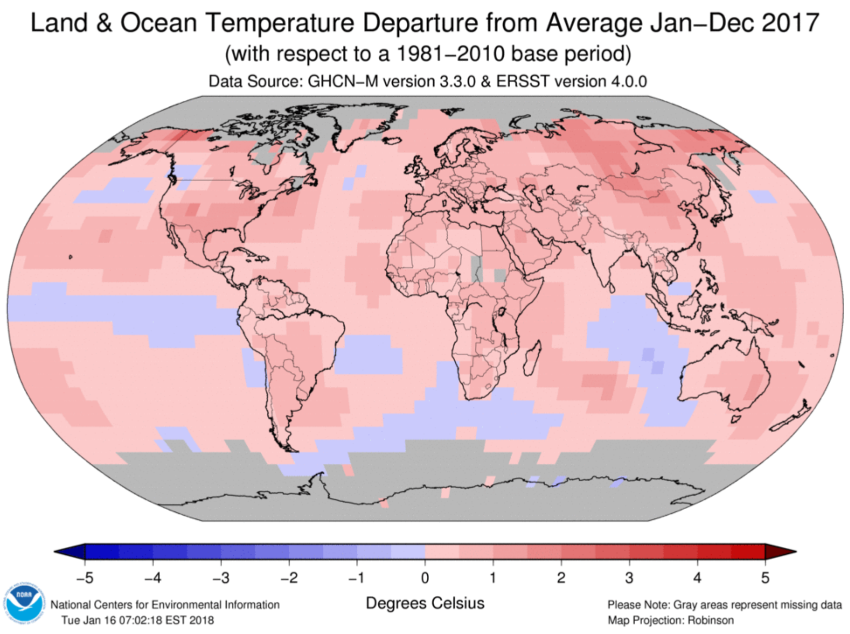

Figure 12. A global map taken from the Annual Global Climate Report by NOAA showing the average temperature of both land and oceans from 2017. The graph shows an injection of colder water (shown in light purple) from the southern ocean extending up to the coastal regions of South Africa.

Ocean water circulation is a result of the naturally occurring oceanographic processes. The Agulhas Bank is at the southern tip of the continental shelf, it extends to 250km south of Cape Agulhas and covers an area of 116 000km^2 (Hutchings et al., 2002). The Agulhas Current flows across the bank moving south from the Indian Ocean, towards the Atlantic Ocean where the two water masses collide, before retroflecting back towards the Indian Ocean (Figure. 13), shown by analysed bottom water samples exhibiting characteristics of both oceans (Lutjeharms et al., 1996). The retroflection could be the cause of the northward drag of the Southern Ocean, which brings cold, nutrient rich water with it and consequently lowers the sea surface temperatures within the study area. The retroflection also leads to the creation of strong eddy like water movements called Agulhas rings (Lutjeharms and Van Ballegooyen, 1988). The Agulhas rings are crucial in the global net movement of water masses and help to control the rate of thermohaline overturning (Lutjeharms, 2007).

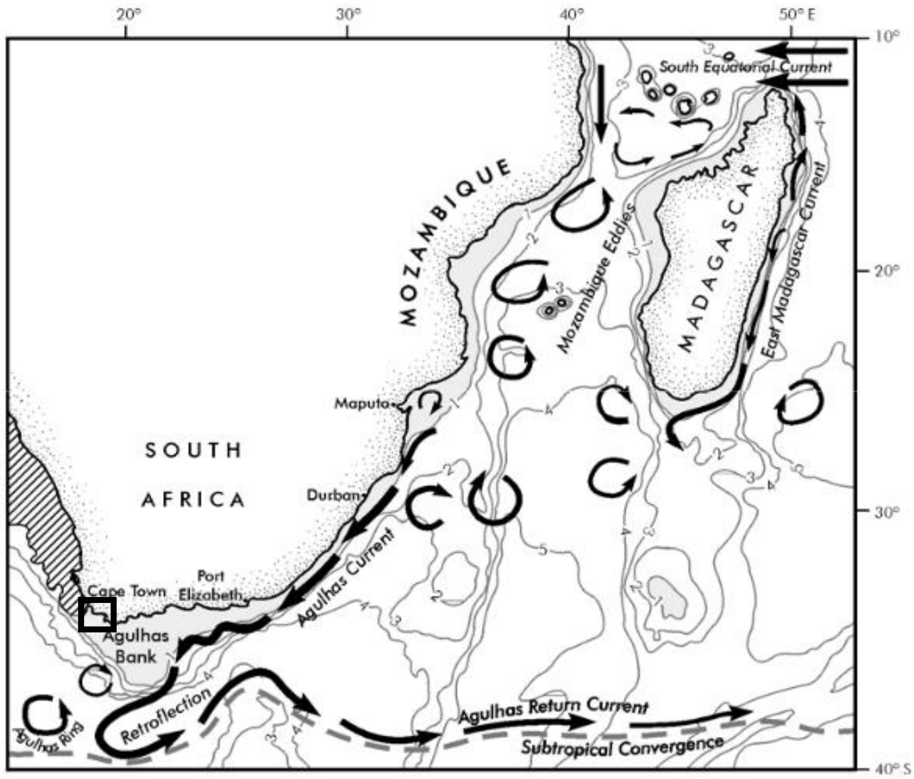

Figure 13. Bathymetry map of the oceanographic components in the South West Indian Ocean with a box around the location of the study. The map shows the direction of movement that the Agulhas current takes as it flows past the South African continental shelf. The figure also shows the Agulhas rings and the retroflection process as mentioned in the text. Shelf regions shallower than 1km are shaded and hatching shows upwelling (Lutjeharms, 2006).

5. Conclusion

This study was undertaken in hopes to better understand the marine environment within the Cape Whale Hope Spot. By investigating the trends in biodiversity, abundance and distribution of the marine species, the study has shown the importance of protecting kelp forests, as the results from data analysis suggest that increasingly more species are being found in the forests than in previous years. Species from all trophic levels have been sighted in the kelp forests, further proving the need for sufficient conservation methods covering all trophic levels. Whilst this is a positive result, the ecosystem is still not close to an acceptable standard. Therefore more effort should be invested into investigating and controlling the effects of anthropogenic activities within the forests and surrounding areas such as the DEA monitoring programmes. Although the late start of this programme is not ideal, the importance of using baseline datasets like this to monitor anthropogenic impacts and pressure on the environment is imperative.

All identification of species was carried out by volunteers with differing strengths and experience in the field and despite best efforts to be precise throughout the data collection, there are possibilities of incorrect identification of species, maximum number of sightings and data input errors. To reduce the risk of these factors, volunteers used the same identification guide and also had experts in the field to ask for help when unsure. The days and times at which BRUV deployments were carried out were not regimented, but rather whenever sea conditions were safe to do so. This may have resulted in some of the sites being visited more than others.

The BRUV method was crucial to obtaining data that truly reflected the community composition. The versatility of the method makes it a suitable choice for many future research projects due to its lower required skill level and a lower operating cost than other options. Continued research by the South African Shark Conservancy and other organisations alike are necessary to showcase the environment and highlight areas that need improvement. Further research could lead to comprehensive knowledge on how to better manage the marine ecosystems, to ensure that the marine species that interact with these locations have the best possible chance of continued survival. A holistic approach of management would be the ideal strategy because although kelp forests see the highest biodiversity there are also differing species utilising both the sandy and rocky/reef habitats shown in this study, and the vast number of other marine habitats that were not investigated in this report and those that are still undiscovered and to ignore these to focus solely on the known areas of highest productivity would be unethical and ill-advised.

[4717 words]

Appendices

A1:

Table 1. Results from tests completed during the two-way ANOVA. This includes Shapiro-Wilk test values as well as Skewness, Kurtosis and their respective standard error values. The table also displays the Z scores for both skewness and kurtosis. Cells filled with a forward slash '/' indicate instances where the test was unable to be completed as there were not enough SDI values to successfully evaluate any statistical differences but are still included in the table for full transparency and increased reliability.

Season&Year, Habitat Type	Shapiro-Wilk	Skewness	Std. Error	Kurtosis	Std. Error	Skewness Z Score	Kurtosis Z Score
Spring 2017, Sandy	0.707	-0.157	0.794	-1.41	1.587	-0.198	-0.089
Spring 2017, Kelp	0.062	-1.789	0.845	3.353	1.741	-2.117	1.926
Spring 2017, Rocky/Reef	0.051	-1.08	0.597	1.231	1.154	-1.809	1.067
Winter 2017, Sandy	0.803	0.223	0.794	-1.143	1.587	0.281	-0.72
Winter 2017, Kelp	/	/	/	/	/	/	/
Winter 2017, Rocky/Reef	0.444	0.046	0.524	-1.198	1.014	0.088	-1.181
Autumn 2017, Sandy	0.571	-0.307	0.472	-0.531	0.918	-0.65	-0.578
Autumn 2017, Kelp	0.342	0.56	0.536	-0.551	1.038	1.045	-0.531
Autumn 2017, Rocky/Reef	0.522	-0.406	0.393	-0.128	0.768	-1.033	-0.16
Summer 2017, Sandy	0.596	-0.295	0.58	0.565	1.121	-0.509	0.504
Summer 2017, Kelp	/	/	/	/	/	/	/
Summer 2017, Rocky/Reef	0.973	0.313	0.845	0.583	1.741	0.370	0.335
Spring 2018, Kelp	0.935	0.456	1.014	-0.561	2.619	0.450	-0.214
Spring 2018, Rocky/Reef	/	/	/	/	/	/	/
Winter 2018, Kelp	0.328	1.508	1.225	/	/	1.231	/
Winter 2018, Rocky/Reef	0.023	1.959	0.913	4.021	2	2.146	2.011
Autumn 2018, Rocky/Reef	0.587	-0.322	0.913	1.897	2	-0.353	0.949
Winter 2019, Sandy	/	/	/	/	/	/	/
Winter 2019, Kelp	0.415	-1.376	1.225	/	/	-1.123	/
Winter 2019, Rocky/Reef	0.131	-1.696	1.225	/	/	-1.384	/

A2: The following table shows how months of the year were grouped to calculate seasonal SDI values throughout the dataset.

Table 2. Table showing how the months of the year were grouped into seasons. The division is based upon the southern hemisphere seasons.

Summer	Autumn	Winter	Spring
December	*March*	*June*	*September*
January	*April*	*July*	*October*
February	*May*	*August*	*November*

A3: Biological Conservation author guide downloaded from the Elsevier website; https://www.elsevier.com/journals/biological-conservation/0006-3207/guide-for-authors.

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There are no strict requirements on reference formatting at submission. References can be in any style or format as long as the style is consistent. Where applicable, author(s) name(s), journal title/book title, chapter title/article title, year of publication, volume number/book chapter and the article number or pagination must be present. Use of DOI is highly encouraged. The reference style used by the journal will be applied to the accepted article by Elsevier at the proof stage. Note that missing data will be highlighted at proof stage for the author to correct.

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Please submit tables as editable text and not as images. Tables can be placed either next to the relevant text in the article, or on separate page(s) at the end. Number tables consecutively in accordance with their appearance in the text and place any table notes below the table body. Be sparing in the use of tables and ensure that the data presented in them do not duplicate results described elsewhere in the article. Please avoid using vertical rules and shading in table cells.

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Subdivision - numbered sections
Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

Introduction
State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

Material and methods
Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.

Results
Results should be clear and concise.

Discussion
This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions
The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

Appendices
If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

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