Analysis on species diversity of fish in relations to environmental conditions off the Namibian coast

BY:

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A report in the Department of Fisheries and Aquatic Sciences, faculty of Agriculture and Natural Resources

Submitted to the Department of Fisheries and Aquatic Science, Faculty of Agriculture and Natural Resources, University of Namibia, in partial fulfillment of the requirement for the award of the degree of Bachelor of Science in Fisheries and Aquatic Science of the University of Namibia.

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November, 2010

DECLARATION

I hereby declare that this work is the product of my own research efforts, undertaken under the supervision of Mr. F.P. Nashima and has not been presented elsewhere for the award of a degree or certificate. All sources have been duly and appropriately acknowledged.

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CERTIFICATION

This is to certify that the report has been examined and approved for the award of the degree of Bachelor of Science in Fisheries and Aquatic Sciences of the University of Namibia

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ACKNOWLEDGEMENT

Special thanks to the Department of Fisheries and Aquatic Sciences for granting me the opportunity of pursuing my degree at the University of Namibia. Mr. F.P. Nashima (supervisor) and Mr. P. Kainge (co-supervisor) have helped me every step of the way to make my project a success and this I would like to thank them for. Ms. Barbara Kachingunda has been the best statistics lecturer and her help has made the understanding of statistical analysis a lot simpler. The staff at NatMIRC, Mr. J. Titus, Mr. D. Kaanandunge, Mr. M. Shimhanda, Ms. S. Kashava and Mr. U.B. Tjiurutue were awesome to work with and I appreciate their help in collecting my data and for moral support. I would like to thank Mr. S. Mafwila and Mr. L. Kandjengo for helping me when my supervisor was away. Lastly I would like to thank my classmates for always encouraging me to give my best in all that I do.

ABSTRACT

Species diversity of fish was investigated along the Namibian coastline from Orange River (29°S) to Kunene River (17°S). This study was aimed at investigating diversity of fish species with regard to different bottom depths and latitudinal transects and furthermore relate species diversity to environmental conditions. This study was conducted during the annual hake biomass survey, that is based on transects running perpendicularly along the Namibian coastline at different latitudes (17°S - 29°S) and depths ranging from 93-681m. Results indicated no significant differences in means of fish species diversity at different bottom depths ($p = 0.849$) and latitudes ($p = 0.260$). Environmental conditions were found to have no significant influence on species diversity ($p>0.05$). This might be due to environmental fluctuations within the Benguela system. Thus, this study could help to better understand the dynamics of fish species diversity along the Namibian coastline and how this could contribute to sustainable fisheries management.

Key words: Bottom depth, environmental condition, Namibia, latitude, species diversity

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CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 General Introduction

The ocean is characterized by dynamic processes which can cause remarkable changes in distribution of fish species throughout the ocean (Gordoa *et al.*, 2006). There are clear trends of decreasing species diversity from south to north in the marine ecosystem of Namibia, contrary to global biodiversity trends (Sakko, 1998, Van Zyl, 2000).

The Benguela ecosystem, to which Namibia is part, extends from Cape Agulhas (35°S) up until Angola (15°S) and is naturally adapted to variable environmental conditions. Events such as, Benguela Niños, hypoxia (low oxygen concentrations) and changes in winds all have negative effects on the diversity and abundance of fish species (BCLME, 2002). It is believed that in the Southern Benguela, changes are mainly due to interannual variabilities of sea-surface temperature, whereas in the Northern Benguela, fish populations are believed to have responded to both changes in the local environment and processes in the tropical Atlantic. As a result, the marine environment may favour certain fish species then others, and this effect is believed to change with time (Shannon *et al.*, 1988). The present study aims to investigate the patterns in species diversity of fish for demersal species with regard to bottom depth and latitude and further relate diversity to environmental conditions within the ocean.

1.2 Problem Statement

The general global trends in species diversity both terrestrial and marine increase toward the equator, however , literature indicated that this general trend is not in accordance with what is being observed off the Namibian coast (Sakko, 1998, Van Zyl, 2000). Therefore with continuous changes in environmental conditions within the marine system, as influenced by other factors including climate change, there is a need to determine whether such irregular patterns still exist or new patterns will form and again try to determine factors which might have influenced such observation. Thus results from this study may help in determining areas with high species diversity and the current trends off the Namibian coast. This understanding may help contribute to better management of fisheries resources with regard to conservation.

1.3 Research Objectives

1. To determine and compare diversity of fish species at different latitudes between Orange River (29°S) and Kunene River (17°S).

2. To determine and compare diversity of fish species at different bottom depths from inshore to offshore.

3. To determine the influence of environmental conditions (such as temperature, oxygen and salinity) on fish species diversity.

1.5 Research Hypotheses

There are significant differences in diversity of fish at different latitudes between Orange River (29°S) and Kunene River (17°S)

There are significant differences in diversity of species at different bottom depths from inshore to offshore

There are significant influences of environmental conditions (such as temperature, oxygen and salinity) on fish species diversity

1.6 Literature Review

1.6.1 The Namibian marine and coastal environment

The Namibian coastal climate is temperate and humid throughout the year. However, the mean annual rainfall averages to less than 15 mm. The extreme arid climate of the Namib Desert is controlled by the interacting effects of the South Atlantic anticyclone, the divergent South East trade winds and the desert's location on the rainshadow side of southern Africa. Consequently, there is a pronounced climatic gradient resulting in a cool, foggy coastal climatic belt (Mastaller, 1998). This coastline extends from Kunene River up north till Orange River down south with a total length of 1 570km (Mauney, 2009).

1.6.2 The Benguela Current System

The Benguela Current system is one of the four major upwelling systems , the other three being the Humboldt, California and Canary currents (Berry, 2009). The Benguela system is part of the South Atlantic spiral and forms part of a much larger system (Berry, 2009). Though most of us believe the Benguela system starts at the Orange River down south and ends at the Kunene River up north, the actual fact is that the system actually starts in the south Atlantic where it interacts with the warm Agulhas Current and in the north at Moçâmedes it meets with the tropical Angolan Current (Berry, 2009). Due to this, the Benguela is quite popularly known as it is a cold-water current meeting up with two warm water currents. This mixture can have some negative effects on species diversity, like the 1994 'red tide'events which were brought about by the major invasion of the Angolan Current into the Benguela (Berry, 2009). This caused mass mortalities not only in marine organisms but also in birds that ate the organisms.

1.6.3 Environmental variabilities within the ocean:

Environmental impacts on the marine and coastal environments are both natural and man-made. The first category includes increased eutrophication leading to low oxygen conditions in shelf waters to major phytoplankton blooms, localized sulphur eruptions and the occurrence of Benguela Niño events. Environmental effects such are multifold, such as regime shifts, changes in trophic levels and species' composition changes.Marine biota are prone to suffer from environmental stress caused by the complex Benguela system that brings about great physical and hydrochemical fluctuations. Such deleterious changes occur on scales from hours to decades.

Levels of dissolved oxygen in the water may also change rapidly as patches of low-oxygen water move. Seasonal changes in atmospheric pressure also control the penetration of warm Angolan current waters into the northern Benguela region, with southerly movement of Angolan waters most likely in late summer and autumn. In addition, the exceptional southward incursions of warm Angolan waters as far as Walvis Bay (23°S), known as Benguela-Niños, occur on a decadal scale. The combination of these environmental changes creates a highly variable marine environment. It also makes the environment unpredictable, leading to mortalities of organisms that cannot cope with, or escape from, sudden changes. Similarly, fish stocks can dramatically decrease or shift to previously unrecorded areas and depth (Mastaller, 1998).

Our earth is shielded by the stratospheric ozone layer, but it is damaged by human produced and upward migrating compounds such as CFCs (chlorofluorocarbons). Ozone depletion causes the exposure to UV-B radiation, which is the shortest wavelength, and damage to coastal and marine biodiversity through reduction of productivity in phytoplankton, zooplankton and juvenile of some pelagic species in the surface waters, both in coastal and oceanic bodies (Kauvee, 2008).

According to marine ecologist Chris Frid, the fishing industry has been keen to identify pollution and global warming as the causes of unprecedented low fish levels in recent years. But it is clear that overfishing has also altered the way the ecosystem works. "Everybody would like to see the rebuilding of fish stocks and this can only be achieved if we understand all of the influences, human and natural, on fish dynamics." Frid adds: "Fish communities can be altered in a number of ways, for example they can decrease if particular sized individuals of a species are targeted, as this affects predator and prey dynamics. Fishing, however, is not the sole perpetrator of changes to marine life - pollution is another example. No one factor operates in isolation and components of the ecosystem respond differently to each individual factor."

Fish vary in their oxygen requirements somewhat according to their accustomed levels. Those that live near the surface of the ocean or in cool tumbling streams, where the waters are nearly saturated with oxygen, suffer much sooner than those species that live near the bottom of eutrophic waters. The low saturation level in warm seawater means a limited capacity of such waters to receive nutrient materials without damage to surface species of fish (Royce, 1996).

According to Bett (2010), increased ocean temperature is expected to reduce vertical water mixing and decrease oxygen solubility in seawater, and if this results in larger, more intense OMZs (oxygen minimum zones), the impact on biodiversity is likely to be negative."Another thing is that the ocean acts as a carbon sink, and with increased temperatures, the ocean is unable to take in as much excess CO_2 as it usually does. This leaves excess carbon dioxide in the ocean increases the hydrogen ion concentration, which increases the ph of the ocean.And as a result of this, ocean acidification is brought about. All this is initially due to global warming (Wikipedia, 2010).

Harmful Algal Blooms (HABs), also known as red tide, is another major environmental factor that could affect fish species diversity. These are caused by high biomass of dinoflagellate blooms which lead to oxygen depletion or hydrogen sulphide production. Sadly this is another contribution to fluctuations in fish stocks in the Benguela, as it has been known to be the cause of mass mortalities in the past (BCLME, 2010).

1.6.4 Climatic changes effects on fisheries

Climate change is another factor that contributes to the environmental uncertainties experienced in the ocean. As a result of increasing carbon dioxide concentration in the atmosphere leading to global warming, this has resulted in sea level rise and this has resulted in changes in distribution of species in the ocean (NEAQ, 2010).Following that, low latitude areas are believed to be at greater risk resulting in reduced diversity of ecosystems and extinction of many species as a result of climate change (Schneider *et al.*, 2007, Smith *et al.*, 2009).

According to a study on fish species in the North Sea by D'Arcy (2010), it was found that there is a link between climate change and latitudinal range which could very well lead to extinction of local and regional species. She also states that species richness decreases with latitude as it was found that fish species at lower latitudes were smaller than those at higher latitudes, and when the climate warmed, these small fish replaced the larger fish at higher latitudes, as the climatic warming causes a northward shift of fish.

According to Richardson (2008), "Marine ecosystems are under-resourced, overlooked and under threat and our collective knowledge of impacts on marine life are a mere drop in the ocean". Thus it is very important that continuous study to be carried out yearly in order to depict effects of environmental conditions on species diversity along the Namibian coastline. This early understanding may be of benefits to fishery managers with regards to fishery resource management but again may make us aware of the indirect effects posed on marine ecosystem as a result of land based activities.

Substantial changes in the patterns of global temperature and precipitation are predicted to occur over the next century (Jackson and Mandrak, 2002). Rising ocean temperatures and ocean acidification are radically altering aquatic ecosystems. Climate change is modifying fish distribution and the productivity of marine and freshwater species. This has impacts on the sustainability of fisheries and aquaculture, on the livelihoods of the communities that depend on fisheries, and on the ability of the oceans to capture and store carbon (biological pump). The effect of sea level rise means that coastal fishing communities are in the front line of climate change, while changing rainfall patterns and water use impact on inland (freshwater) fisheries and aquaculture (NEAQ, 2010). Reduction of flow simply reduces the living space for fish and limits populations during low-flow periods in summer or winter. Even changes in flood flows may force a change in population of a species that has adapted its life to the floods. Almost all changes in flow are accompanied by changes in water temperature. Lower summer flows will allow water to warm more rapidly. Lower winter flows in cold climates may allow the water body to freeze (Royce, 1996).

Global climate change will cause an alteration of circulation and consequent disruption of heat distribution to areas where climate depends on heat carried by ocean currents (Kauvee, 2008). Warm water used for cooling may cause fish to avoid the immediate area of entry as well as cause a change in species composition over a large area of warmed water. On the other hand, such changes may attract desirable fish that may be easy to catch and be regarded as beneficial (Royce, 1996). The effect of climate change on biodiversity depends mainly on how rapid it occurs; proportionate increase of climate change and related phenomena will not be detrimental to biodiversity, than a sudden change to another climatic regime (Kauvee, 2008). Oceans play a great role in global warming, as these serve as a sink for carbon dioxide. Most of the carbon dioxide that remains in the atmosphere is taken up by the oceans, but due to the climactic changes, there have been increased levels of carbon dioxide, which have led to ocean acidification. This is due to temperature rise, which disables the ocean from taking up the little carbon dioxide it used to (Smith *et al.*, 2009)This will in turn have negative impacts on the marine organisms in direct contact with this condition.

CHAPTER TWO

MATERIALS AND METHODS

2.1 Study Area

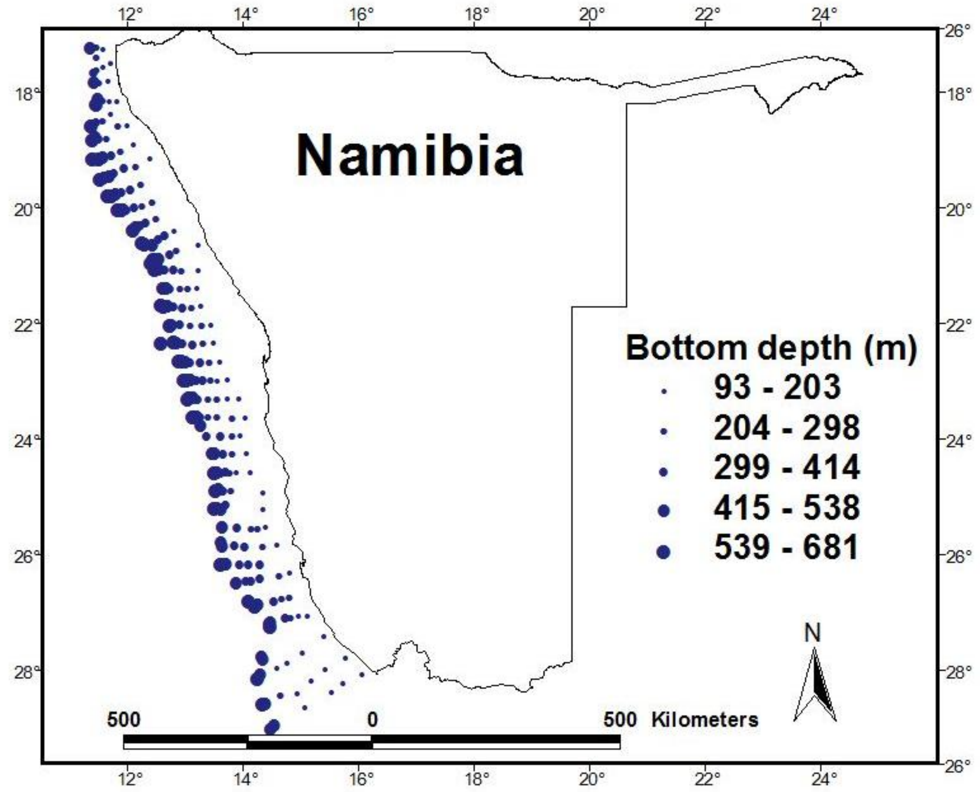

Figure 1: Spatial distribution of sampling stations with regard to changes in depth (m)

This study area falls within Namibia's 200NM EEZ (exclusive economic zone) and extends from the Orange River (29°S) to Kunene River (17°S). This survey was conducted during the period of 12th January until 21st February 2010 (Fig.1), during which data for this study was collected. In total 217 stations were covered, with depths ranging from 93m to 681m.

2.2 Study Design Layout

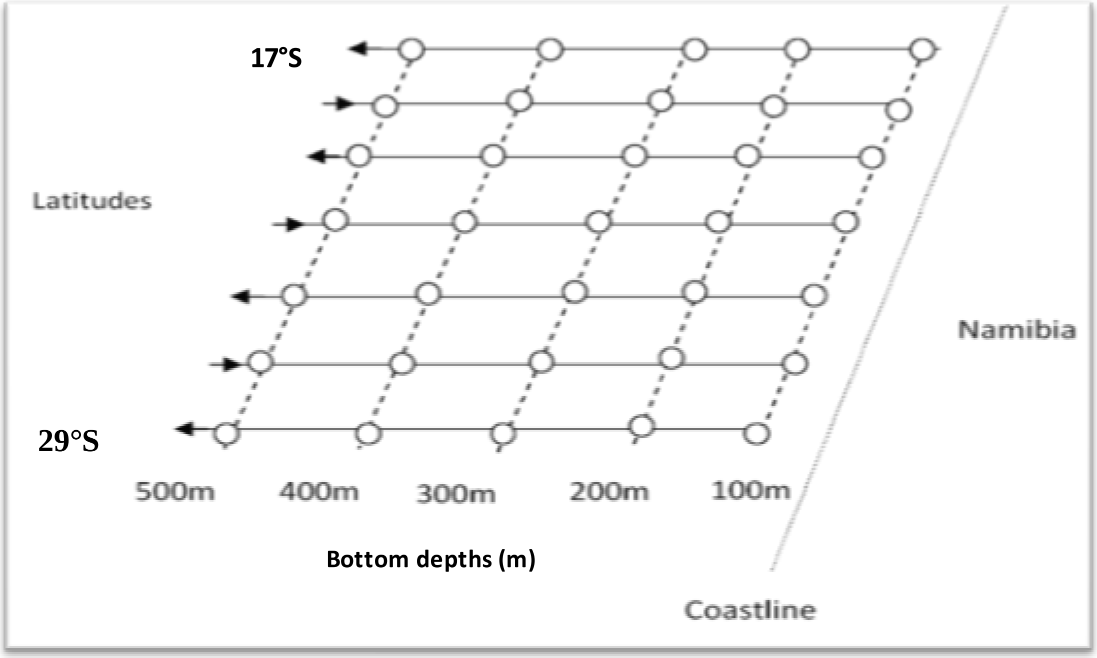

Figure 2: Layout of sampling stations during the survey

The survey design was based on transects, where stations were semi-randomly distributed along transects that run perpendicular to the coast (Fig.2). Stations within transects were selected in such a way that each 100m bottom depth had at least one station. Transects were usually 20-25NM (nautical miles) apart and covers a distance between 20-80NM. In the southern part where shelfs were wide, stations on the shelf were typically 10NM apart.

2.3 Collection of biological and environmental data

Sampling was conducted onboard the *MFV Blue Sea I* research vessel during the Ministry of Fisheries and Marine Resources annual hake biomass survey which follows pre-determined stations off the Namibian coast. A *Gisund Super two-panel* bottom trawl with head length 31m, footrope 47m and vertical net opening of 4.5 to 5.5 was used during the survey.

2.3.1 Biological data collection

At each trawled station, the entire catch was brought on deck to be sorted manually into species. . A weighing scale instrument was used to determine measurements of the total body mass (kg) of each group of fish species. Measurements of total body mass (kg) of fish species were used as surrogate for species abundance to calculate species diversity. This biological data were collected at a total of 217 stations.

Figure 3: Different fish species sorted in the baskets aboard the *MFV Blue Sea 1* vessel

2.3.2 Environmental data collection

The state of the environment was monitored with a *Seabird SBE 19plus* Conductivity-Temperature-Depth (CTD) instrument and a battery operated Hydrobios Slimline rosette. Spatial information, in particular trawling bottom depth, bottom temperature and salinity were monitored and recorded automatically by the CTD instrument. The CTD instrument collects measurements at 1-meter interval but for the purpose of this study they were all selected for bottom depths (m) of each station. Information recorded by the CTD instrument can directly be imported into the computer on board the vessel (NatMIRC,2010). A GPS (Global Positioning System) which is an electronic device on the vessel that uses positioning signals from satellites in order to locate precise latitude and longitude points, was used to record the coordinates at each trawling station.

2.3.3 Data Analysis

Data for species diversity in relation to environmental conditions was analysed using the *SPSS 16.0* and *Primer 5.0* statistical packages. For test of normality, the Kolmogorov-Smirnov (K-S) test was used to determine whether data for fish species diversity is normally distributed (see appendix:1).

The Shannon-Wiener index of diversity (H') was calculated for each trawled station using the proportional abundance (kg) of fish species caught by the net.

$H' = -\Sigma (pi) * (\ln pi)$

Where H' is the information content of the sample (value of Shannon-Wiener index of diversity): *ln* is the natural logarithm, while *pi* is the proportion of total sample belonging to the i^{th} species (Magurran, 1998).

The One-way Analysis of Variance (ANOVA) was used to test for significance differences in species diversity of fish at different bottom depths and latitudes respectively. Multiple regression analysis was used to measure how environmental factors (independent variables) including temperature, depth, salinity and dissolved oxygen affect fish species diversity (dependent variable) .

CHAPTER THREE

RESULTS

A number of different species of fish were investigated during this study, and comprises of varying body length and sizes. During the survey unidentified species were sampled and added to the bycatch batch or simply recorded as unidentified species for further laboratory identification.

3.1 Changes in species diversity at different bottom depths

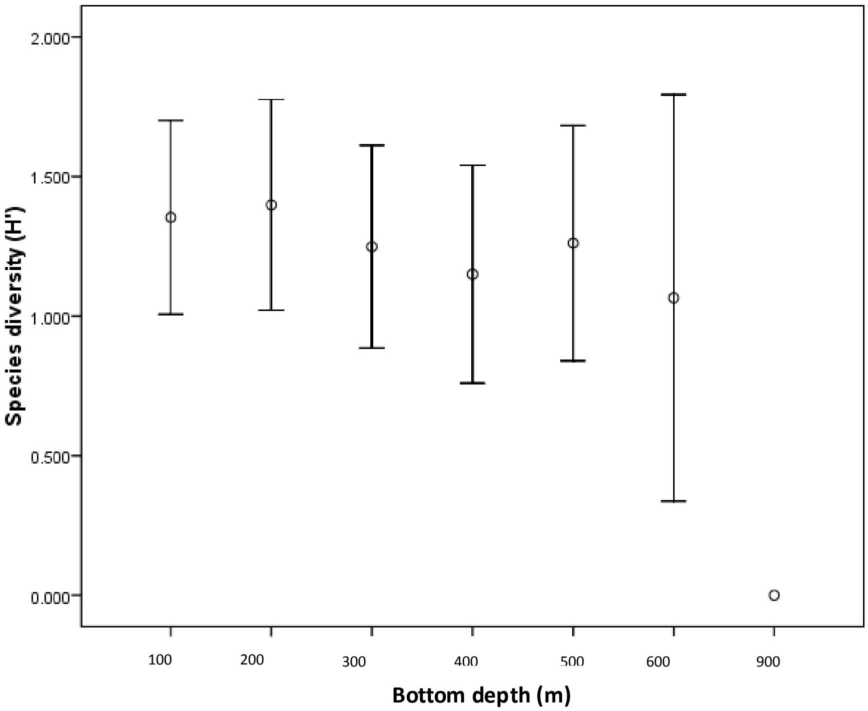

Figure 4: Comparison in mean species diversity at different bottom depths (m).

It is evident from figure 4 above that inshore areas (i.e 100-200 m) were found to be slightly more diverse than the offshore areas of 300 m and deeper. However no significant difference was observed in means comparison between species diversity and bottom depths for the whole depth range (F= 0.443, *df*= 6, p= 0.849) .

3.2 Changes in species diversity at different latitudes

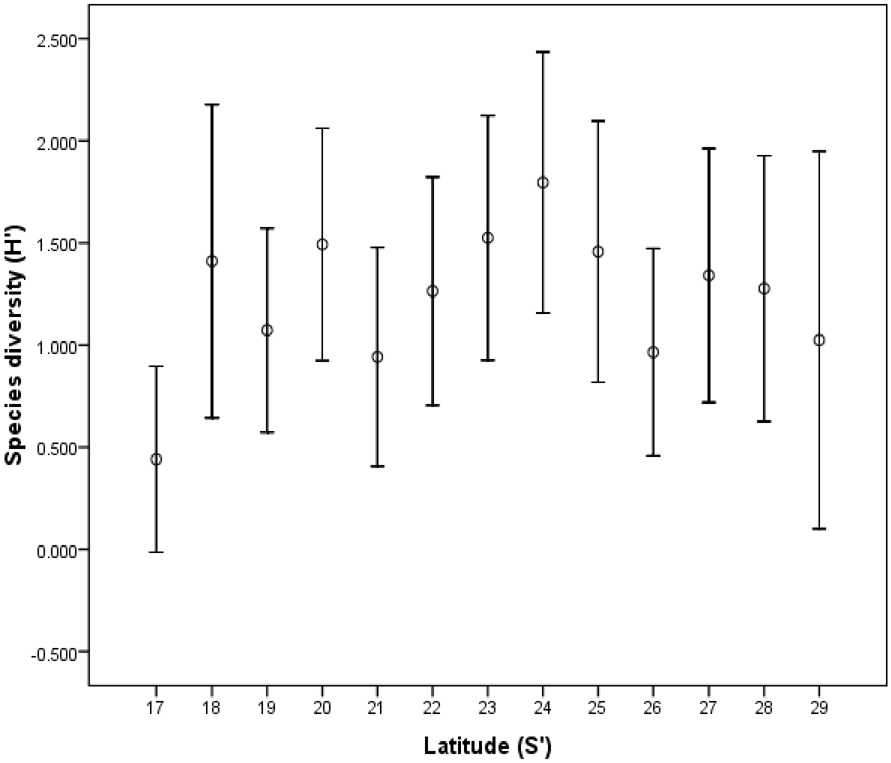

Figure 5: Comparison of means fish species diversity at different latitudes (S').

Results from the figure above indicate fluctuations in average means of species diversity of fish off the Namibian coast as observed at the different latitudes. The general trend that can be observed from figure 5 above depict a relative lower species diversity at low latitude (i.e 17°S) and a relative higher species diversity at 24°S with diversity values of *H'*= 0.44 and *H'*=1.80 respectively. However a non-significance difference in means of species diversity as compared to different latitudes was observed (ANOVA: F=1.236, *df*=12, p=0.260).

3.**3 The influence of environmental factors on fish species diversity**

The influence of environmental factors (temperature, salinity and dissolved oxygen) on species diversity was analysed using SPSS statistical package.

3.3.1 Temperature

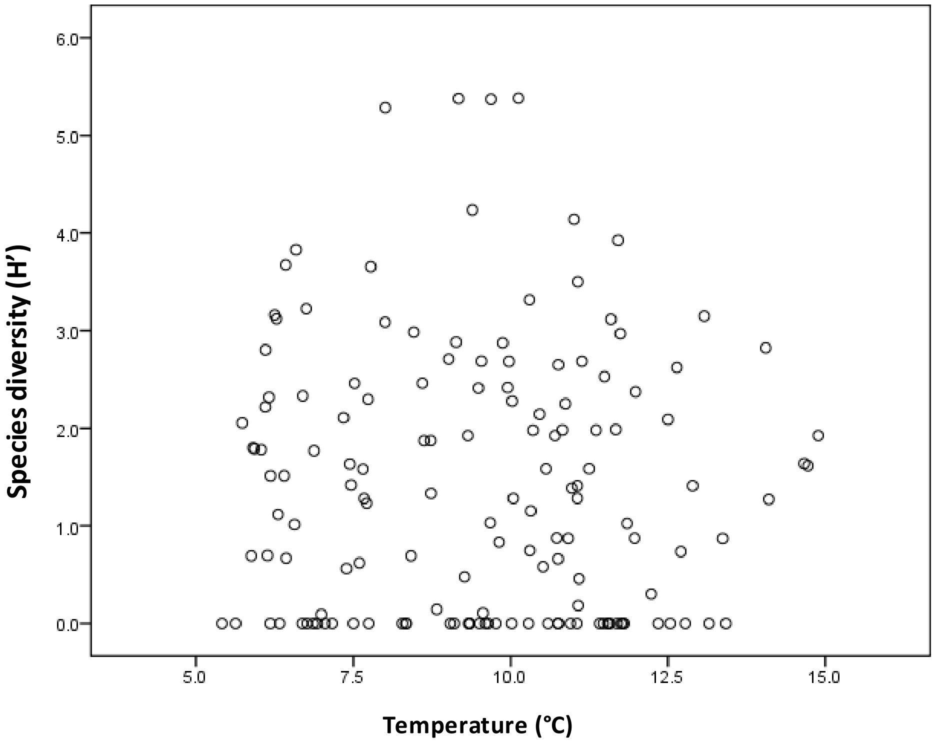

Figure 6: The relationship between temperature (°C) and species diversity (*H'*)

The diagram above (fig 6) shows no relationship between temperature and species diversity, as increase in temperature shows no significant influence on species diversity, where (p= 0.633).

3.3.2 Salinity

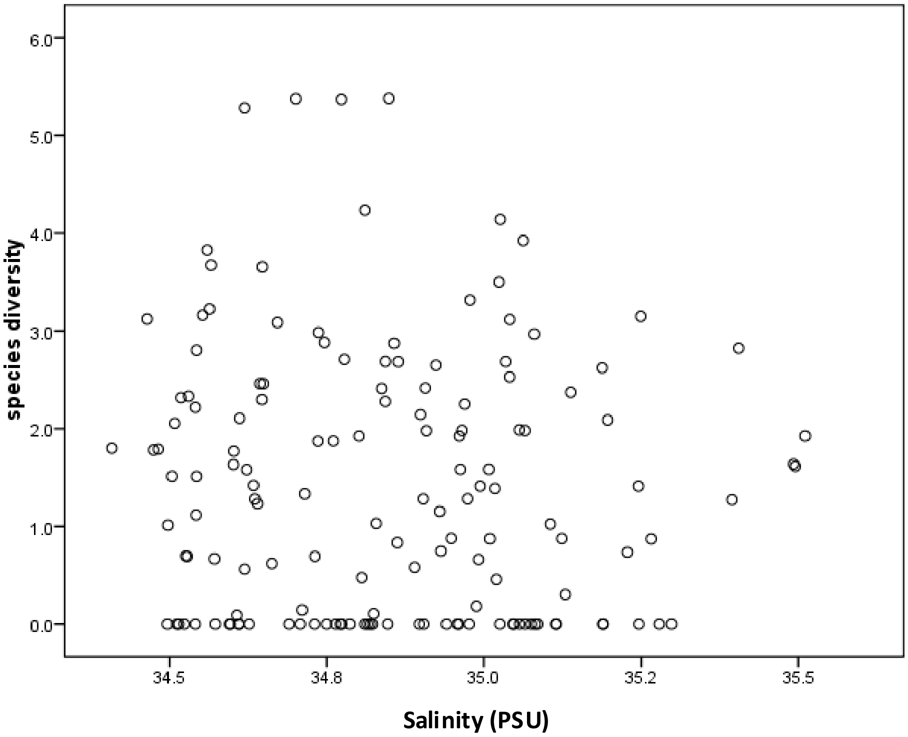

Figure 7: The relationship between species diversity (*H'*) and salinity (PSU).

The figure above shows no relationship between salinity and species diversity (p= 0.411), meaning salinity has no significant influence on species diversity.

3.3.3 Oxygen

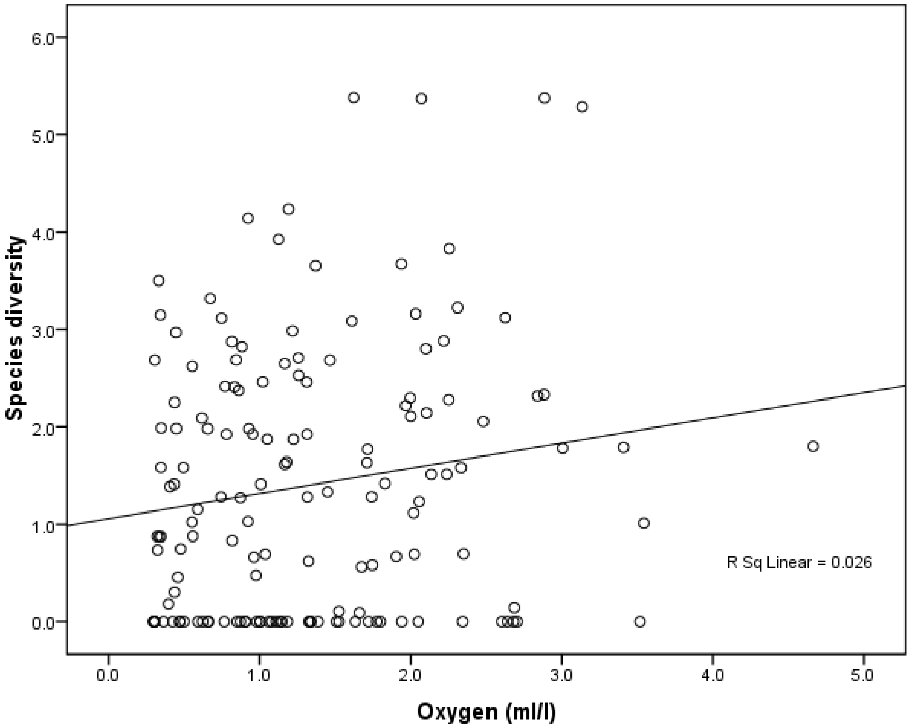

Figure 8: The relationship between oxygen(ml/l) and species diversity (*H'*)

The observations in figure 8 above show that there is no linear pattern displayed by the data points (R^2= 0.026). However the same model (fig. 8) shows a positive correlation between species diversity and oxygen, where y= 0.259(x) + 1.058. This relationship is however a poor correlation as the inverse relationship between oxygen and species diversity is not well displayed.

CHAPTER FOUR

DISCUSSION

The study looks at certain trends followed by fish species diversity distributed along the Namibian coastline, between Orange River (29°S) and Kunene River (17°S). The trends observed in this particular study were mainly due to variabilities in the environmental conditions experienced in the Benguela system. Noteworthy observation from this study is the aggregation of *Merluccius capensis* and *Merluccius paradoxus* in catches although believed to be found in different water coumns. *Merluccius capensis* is a shallow water species whereas *Merluccius paradoxus* is a deep-water species (Gordoa *et al*, 2006). This observation could be the result of environmental conditions fluctuations which could have caused a change in distribution of these species.

4.1 Changes in species diversity with bottom depths

The comparison of means of species diversity with regard to bottom depths from inshore to offshore showed no significance difference in means (p= 0.849). On the contrary, it was however found that diversity at 100m and 200m, where $H'=1.35$ and $H'=1.40$, was slightly higher than that found at 300m and above. Non significant trends observed could be associated with natural fluctuations in environmental conditions within the Benguela system. A bottom depth profile showed that depths were lower onshore and increased as you moved further offshore (fig1), starting at 93m and moving to 681 m respectively.

4.3 Changes in species diversity with latitudes

Comparison of species diversity to latitude, ranging from 29°S up until 17°S, showed no significant difference in means, where (p=0.260). According to Sakko (1998), the Namibian local trend in species diversity is incomparable to global biodiversity trends, as in general diversity increases as you move towards the equator, but in the case of Namibia however, diversity is found to increase as you move from north to south . Observations in this study supported that statement, as diversity was seen to decrease as we moved from 29°S at Orange River up to 17°S at Kunene River, where species diversity (*H'*) was found to be lowest at 17°S with a diversity value of *H'*=0.44 and highest at 24°S with diversity value of *H'*=1.80 respectively. This could be supported by the study made by Smith *et al.*(2009) which revealed that low latitude areas are believed to be at greater risk resulting in reduced diversity of ecosystems and extinction of many species as a result of climate change.

Low oxygen distributions over the Namibian shelf were experienced in the central part of the country, from 20°S to 27°S latitudes. This could very well be the reason for some of the irregular patterns in diversity at these areas, as it was observed that some areas had extremely high diversity, whereas others had very few diversity. Conditions within the Namibian water might be the cause of such uniform observed pattern. The general trends in means species diversity depict a slight decline along the Lüderitz area and this might be due to upwelling in the ocean, as Lüderitz is known to have one of the strongest upwelling cells in the world, which are known to be intense and perennial. As a result they could lead to anomalies in temperature, salinity and oxygen levels, which may not be favourable for several fish occurence. The upwelling cell provides nutrients to support high primary productivity, which contribute to oxygen depletion within the water column (Bruchert *et al*, 2006), and in turn might also contribute to the decline in species diversity.

4.4 Influence of environmental conditions on species diversity

Results found no relationship between temperature and salinity with regard to species diversity of fish. The reason for this could be due to the fact that the survey carried out was a hake survey and this limits possible relationships that could have been displayed between the aforementioned environmental conditions and species diversity of fish. A positive correlation , was however experienced between oxygen and species diversity. However we cannot entirely consider this, as it was a poor correlation between oxygen and species diversity, as oxygen did not have an inverse relationship with species diversity, as it is observed in normal positive correlations. The reason why species diversity was not influenced by temperature and salinity could be due to the different species having different adaptation mechanisms at various salinities and temperatures.

4.5 Conclusion and recommendation

This study observed several trends of fish species biodiversity along the Namibian coast line from Orange River down south, all the way to Kunene River up north. Diversity measures were taken along the bottom depths from onshore (93m) to offshore (681m) and also from latitudes ranging from 17°S to 29°S. Biodiversity varies among all areas investigated and with changes in environmental conditions. Oceanic temperatures were found to be higher onshore compared to those offshore, which shows a negative correlation with oxygen levels, as oxygen levels were higher offshore and lower onshore. Also the fact that diversity in Namibian waters increases from north to south unlike global trends, where diversity increases as you move towards the equator , shows how little importance global trends are within our Benguela system regarding latitudinal gradients. Environmental conditions had no significant influence on fish species diversity.

Sampling was carried out at different periods of the day, but minimal trawling was carried out at night to avoid vertical migration, as some species are known to lift off the bottom at night, possibly in search of prey (e.g. *Merluccius capensis*) (Kainge *et al*, 2010). Future studies might want to look at patterns of fish species diversity in relation to environmental conditions experienced in the pelagic division to see if similar trends will be experienced, as was in this benthic study. Also studies should be conducted at around the same time period so as to avoid the issue of unreliability in data extraction, as this might explain the issue of spatial distribution of fish species with regard to time and therefore also increase efficiency of commercial fishing.

Determining species diversity will also be more reliable if sampling was done at various seasons, in this case it was only done during summer and conditions in the marine environment are known to change with changing seasons and this is likely to change fish behaviour. Also different results might also have been obtained if it was done over an extended period of time, not just for a month. Another consideration would be for the Ministry of Fisheries and Marine Resources to strat conducting surveys which are strictly focused on determining species diversity at different water columns and during summer and winter, to really determine influence of environmental conditions on species diversity if fish. This would stop us relying on one species (e.g hake) as our most valuable and explore what other species can offer.

4.6 Limitations to the study

Since the sampling for the study was done both during the day and at night, vertical migration of certain species was taken into consideration, and therefore sampling at night was limited. This was done because when vertical migration takes place, certain species are known to drift away from their natural occurrence, so diversity at the given area would not reflect the true picture.

Another limitation is that we cannot determine which species appeared the most as results would then be biased. This is due to the fact that the survey was a hake survey, and therefore the hake species was the main catch during all sampling. Obviously richness would point more to the hake or other demersal species. Namibia has yet to establish surveys strictly based on looking at species diversity as a whole, and not just focus on specific species.

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APPENDICES

APPENDIX I: One Sample K-S test comparison of diversity and latitude

One-Sample Kolmogorov-Smirnov Test

		Diversity
N		217
Normal Parameters[a]	Mean	1.26572
	Std. Deviation	1.186972E0
Most Extreme Differences	Absolute	.161
	Positive	.161
	Negative	-.143
Kolmogorov-Smirnov Z		2.372
Asymp. Sig. (2-tailed)		.000

a. Test distribution is Normal.

APPENDIX II: One sample K-S test relating diversity to bottom depth

One-Sample Kolmogorov-Smirnov Test

		Diversity
N		217
Normal Parameters[a]	Mean	1.26572
	Std. Deviation	1.186972E0
Most Extreme Differences	Absolute	.161
	Positive	.161
	Negative	-.143
Kolmogorov-Smirnov Z		2.372
Asymp. Sig. (2-tailed)		.000

a. Test distribution is Normal.

APPENDIX III: Table of Environmental parameters and species diversity

Station	TEMP	SALIN	OX_CTD	Latitude	Longitude	Region	Depth	H'(loge)
1	10.1233	34.8489	1.6217	-28.3762	15.9357	5030	96	5.379896
2	9.6875	34.7735	2.071	-28.7883	15.8642	5030	157	5.369671
3	9.1723	34.701	2.8855	-28.9625	15.6428	5030	182	5.376148
4	8.0089	34.6194	3.1342	-29.5487	14.642	5030	420	5.284128
5	5.9092	34.4085	4.6645	-29.6893	14.5598	5030	498	1.799515
6	9.1348	34.7462	2.218	-29.1445	14.491	5030	360	2.882297
7	6.5671	34.4975	3.5436	-29.2138	14.466	5030	483	1.01248
8	10.514	34.8896	1.7453	-27.6293	15.2322	5030	132	0.581116
9	10.7593	34.9239	1.1653	-27.5698	15.0573	5030	172	2.649306
10	10.287	34.8971	0.7655	-27.6462	14.9357	5030	264	0

11	10.7352	34.9477	0.5566	-27.2823	14.7452	5030	290	0.87717
12	9.8762	34.8572	0.8158	-27.363	14.6312	5030	338	2.87424
13	7.5027	34.5951	2.7041	-27.3678	14.3187	5030	435	0
14	5.9307	34.4823	3.4091	-27.4458	14.304	5030	525	1.788925
15	6.0411	34.4748	3.0062	-27.3187	14.1582	5030	572	1.780783
16	6.1631	34.518	2.8403	-27.0403	13.9703	5030	505	2.316898
17	11.2482	35.0077	0.3453	-26.3593	14.6863	5030	168	1.584399
18	10.5943	34.9403	0.591	-26.3047	14.4067	5030	240	0
19	9.8194	34.8622	0.8178	-26.3617	14.1117	5030	351	0.833361
20	9.268	34.8054	0.9756	-26.3138	13.8908	5030	383	0.47599
21	10.9492	34.9765	0.4239	-26.0118	14.4665	5030	193	0
22	10.8705	34.9693	0.4357	-25.9823	14.3083	5030	215	2.251214
23	10.8224	34.965	0.4476	-	14.227	5030	254	1.982454

				26.0445				
24	9.6004	34.7866	1.1088	-25.9823	13.9483	5030	338	0
25	7.7165	34.6399	2.0564	-26.0277	13.6897	5030	471	1.23225
26	9.3505	34.8103	1.0785	-25.5732	13.7407	5030	354	0
27	8.3398	34.7081	1.5081	-25.6342	13.6593	5030	421	0
28	6.331	34.5232	2.6806	-25.625	13.5913	5030	541	0
29	11.0746	34.9881	0.3965	-25.6938	14.4222	5030	171	0.183236
30	11.559	35.0459	0.622	-25.365	14.4167	5030	151	0
31	10.7519	34.9598	0.66	-25.3622	13.8638	5030	265	0
32	9.6756	34.8286	0.9224	-25.297	13.7085	5030	331	1.029912
33	7.7381	34.6469	1.9957	-25.3463	13.624	5030	466	2.296923
34	6.2815	34.4644	2.6255	-25.3117	13.5705	5030	587	3.12148
35	11.5799	35.0474	0.3634	-25.0255	14.189	5020	170	0
36	11.5952	35.0409	0.7475	-24.9933	13.9347	5020	184	3.1162

37	11.0619	34.974	1.7412	-25.0328	13.835	5020	221	1.281919
38	9.7686	34.8471	1.3394	-24.9625	13.737	5020	310	0
39	9.0192	34.7783	1.255	-25.0292	13.6815	5020	373	2.708611
40	6.7541	34.5637	2.3095	-24.9702	13.5958	5020	510	3.224213
41	6.6972	34.5302	2.8824	-24.6957	13.5093	5020	497	2.331224
42	11.6905	35.0565	0.4988	-24.6918	14.124	5020	150	0
43	10.0243	34.8433	2.2516	-24.6545	13.842	5020	273	2.277939
44	8.8261	34.711	2.6851	-24.6927	13.7202	5020	370	0.144836
45	7.6561	34.6229	2.3333	-24.6385	13.5242	5020	435	1.580876
46	8.7366	34.715	1.4487	-24.3635	13.4153	5020	386	1.332191
47	7.3479	34.6114	1.9993	-24.1302	13.27	5020	476	2.106672
48	6.5914	34.5602	2.2552	-24.0483	13.2145	5020	514	3.828948

49	9.3469	34.7642	2.6025	-24.3543	13.6722	5020	328	0
50	9.6423	34.7719	3.5179	-24.31	13.8718	5020	275	0
51	11.7426	35.0799	0.4449	-24.3565	14.0055	5020	195	2.968581
52	11.6705	35.0563	0.347	-23.9943	14.0972	5020	166	1.988277
53	10.4606	34.8991	2.1043	-24.0348	13.876	5020	239	2.143635
54	10.7066	34.9606	0.78	-23.9705	13.3937	5020	292	1.924937
55	7.466	34.6337	1.8284	-23.9608	13.2087	5020	442	1.419161
56	10.3568	34.9085	0.9283	-24.0268	13.3123	5020	329	1.979852
57	9.3938	34.8105	1.1908	-23.6377	13.2335	5020	346	4.236447
58	8.0047	34.6715	1.6093	-23.686	13.164	5020	416	3.086464
59	6.4048	34.5038	2.2382	-23.6378	13.0718	5020	584	1.512989
60	6.1388	34.5257	2.3491	-23.6947	13.0758	5020	614	0.697063
61	11.0613	34.9941	1.007	-23.6933	13.4353	5020	265	1.411393

62	11.7568	35.075	1.0583	-23.6512	13.5855	5020	223	0
63	11.7081	35.0625	1.1248	-23.6417	13.9778	5020	169	3.925756
64	12.2336	35.1294	0.4359	-23.359	13.787	5020	163	0.302712
65	11.492	35.0407	1.257	-23.3287	13.4502	5020	248	2.529364
66	9.507	34.8148	1.3856	-23.3083	13.3283	5020	337	0
67	9.0426	34.774	1.3253	-23.3637	13.232	5020	378	0
68	7.4468	34.6016	1.7105	-23.301	13.0902	5020	479	1.632853
69	6.8653	34.5113	1.7992	-23.3555	13.0565	5020	535	0
70	5.7379	34.508	2.4806	-23.2935	12.9998	5020	634	2.054761
71	7.1664	34.6105	1.7748	-23.0357	13.0032	5020	524	0
72	6.187	34.5431	2.1353	-22.9602	12.933	5020	591	1.512288
73	5.4141	34.4967	2.641	-22.9632	12.8832	5020	691	0
74	9.5617	34.8246	1.5249	-23.0307	13.1222	5020	341	0.106715

75	9.3211	34.801	1.3135	-22.9757	13.3007	5020	359	1.924651
76	10.7588	34.9574	0.9796	-23.0285	13.448	5020	283	0
77	12.6399	35.1879	0.5532	-22.9737	13.6438	5020	151	2.621739
78	9.975	34.8637	1.4642	-22.6433	12.956	5020	313	2.684052
79	8.627	34.7358	1.2222	-22.2955	12.8105	5020	397	1.873126
80	7.3935	34.6195	1.6745	-22.3698	12.776	5020	503	0.562335
81	6.6892	34.5728	1.9402	-22.3105	12.7403	5020	566	0
82	12.5358	35.1893	0.4694	-22.0312	13.2923	5020	178	0
83	11.8499	35.1053	0.5518	-21.9943	13.1108	5020	233	1.023788
84	10.3025	34.9778	0.6719	-22.0358	12.9718	5020	306	3.316712
85	7.7802	34.6475	1.3696	-21.9728	12.6825	5020	473	3.654923
86	7.0509	34.6101	1.7209	-21.9702	12.6333	5020	567	0

87	6.1827	34.5412	2.0496	-21.9603	12.5935	5020	654	0
88	12.8926	35.2454	0.4329	-21.6962	13.2387	5020	155	1.41115
89	11.9723	35.1238	0.3204	-21.6328	13.0465	5020	250	0.87464
90	11.0879	35.0194	0.4577	-21.6457	12.9047	5020	298	0.457374
91	7.6737	34.6357	1.3156	-21.6972	12.6227	5020	520	1.280037
92	6.1074	34.5431	2.1003	-21.6417	12.5562	5020	621	2.803092
93	13.0749	35.2491	0.3424	-21.3585	13.2588	5020	130	3.148138
94	11.4123	35.0654	0.3019	-21.3168	12.9408	5020	274	0
95	10.3075	34.9315	0.4758	-21.3628	12.8157	5020	321	0.747264
96	9.5373	34.8434	0.8433	-21.3015	12.629	5020	379	2.686583
97	8.2806	34.7304	1.148	-21.3652	12.5497	5020	470	0
98	6.4357	34.5714	1.9041	-21.2945	12.4532	5020	602	0.668655

99	13.3692	35.2659	0.3341	-20.86	13.244	5010	103	0.87147
100	11.8034	35.1149	0.296	-20.9943	12.8712	5010	274	0
101	10.3225	34.9296	0.5899	-21.0252	12.7455	5020	339	1.153342
102	9.3309	34.8229	0.9041	-21.1902	12.5552	5020	429	0
103	6.8797	34.6022	1.7146	-21.128	12.445	5020	541	1.769669
104	6.2509	34.5528	2.0326	-21.1753	12.3997	5020	618	3.161125
105	13.1517	35.2788	0.4708	-20.6597	12.8105	5010	188	0
106	11.1357	35.0344	0.304	-20.6937	12.6377	5010	310	2.68543
107	10.5619	34.9624	0.4937	-20.7703	12.4928	5010	335	1.583414
108	8.4169	34.731	1.0359	-20.9177	12.4368	5010	437	0.692969
109	6.9932	34.6071	1.6602	-20.8508	12.2723	5010	559	9.17E-02
110	6.4294	34.5661	1.9378	-20.8887	12.272	5010	591	3.673178
111	11.7792	35.1142	0.3038	-20.4385	12.5023	5010	279	0

112	10.9144	35.0094	0.3459	-20.478	12.2998	5010	308	0.872952
113	10.0416	34.9035	0.7439	-20.5718	12.2325	5010	341	1.281302
114	8.6013	34.644	1.0199	-20.5357	12.0998	5010	463	2.461289
115	6.3057	34.5423	2.0184	-20.655	12.084	5010	589	1.117056
116	5.6324	34.5145	2.3431	-20.2335	11.7795	5010	663	0
117	12.7048	35.228	0.3228	-20.1385	12.4258	5010	220	0.735726
118	11.5454	35.085	0.3001	-20.1635	12.2228	5010	278	0
119	11.0683	35.0236	0.331	-20.2325	12.1147	5010	311	3.499969
120	9.4893	34.8375	0.8323	-20.2148	11.952	5010	406	2.41104
121	7.5985	34.6626	1.3233	-20.2697	11.9243	5010	493	0.620133
122	6.1042	34.5412	1.9666	-20.2332	11.837	5010	584	2.218557
123	12.5	35.1967	0.6171	-19.8283	12.2275	5010	233	2.089103
124	10.9713	35.0171	0.4057	-19.8617	12.0162	5010	323	1.387038

125	10.0172	34.9044	0.6562	-19.953	11.8883	5010	373	0
126	7.5199	34.6491	1.3115	-19.949	11.7253	5010	480	2.459968
127	14.104	35.3942	0.8714	-19.357	12.2747	5010	132	1.271985
128	14.0538	35.4049	0.8819	-19.1097	12.0927	5010	194	2.823516
129	11.3559	35.0654	0.6551	-19.1562	11.841	5010	297	1.981113
130	9.9535	34.9068	0.7704	-19.2803	11.7085	5010	338	2.415931
131	6.7667	34.5965	1.6319	-19.3572	11.4717	5010	523	0
132	7.7479	34.6902	1.1824	-17.3	11.2972	5010	433	0
133	14.8877	35.5106	0.9542	-17.3208	11.5228	5010	144	1.925681
134	11.987	35.1382	0.8598	-17.5222	11.41	5010	242	2.372374
135	9.1044	34.8191	1.0021	-17.7327	11.3612	5010	366	0
136	14.664	35.4923	1.1778	-17.9505	11.6142	5010	133	1.638375
137	11.4738	35.0811	0.849	-17.937	11.4412	5010	264	0
138	8.3391	34.7498	1.1342	-17.9718	11.3795	5010	406	0
139	10.7544	34.9916	0.962	-18.242	11.5277	5010	258	0.661563

140	13.4192	35.2981	1.3349	-18.3172	11.6465	5010	144	0
141	14.7217	35.4951	1.1655	-18.2797	11.7512	5010	117	1.614917
142	12.7764	35.2461	1.0022	-18.5497	11.669	5010	204	0
143	11.0083	35.0257	0.9227	-18.6168	11.5045	5010	251	4.14094
144	8.4615	34.7366	1.2163	-18.633	11.4137	5010	403	2.984884
145	5.8809	34.5282	2.0229	-19.0225	11.3355	5010	598	0.693141
146	8.7303	34.7605	1.0486	-18.9415	11.4407	5010	390	1.873999
147	6.9299	34.6268	1.5255	-18.9668	11.3838	5010	495	0
148	11.0558	35.025	0.8719	-19.022	11.588	5010	277	0
149	12.3469	35.1891	0.9046	-18.7897	11.8058	5010	209	0

APPENDIX IV: Regression analysis of environmental conditions and species diversity

a) Temperature

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.039[a]	.002	-.005	1.358538402968443E0

a. Predictors: (Constant), TEMP

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.627	.478		3.405	.001
	TEMP	-.023	.049	-.039	-.478	.633

a. Dependent Variable: H'(loge)

b) Oxygen

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.160[a]	.026	.019	1.342147228774163E0

a. Predictors: (Constant), OX_CTD

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.058	.208		5.085	.000
	OX_CTD	.259	.132	.160	1.961	.052

a. Dependent Variable: H'(loge)

c) Salinity

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.068[a]	.005	-.002	1.356463891273177E0

a. Predictors: (Constant), SALIN

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	14.305	15.651		.914	.362
	SALIN	-.370	.449	-.068	-.824	.411

a. Dependent Variable: H'(loge)