Biomass distribution of kingklip (*Genypterus capensis*) off the Namibian coast during summer.

BY:

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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 Mr P. Kainge and has not presented elsewhere for the award of the degree. All the sources have been duly and appropriately acknowledged.

Candidate Signature: ……………………………………………… Date: ………………………..

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CERTIFICATION

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

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Internal Examiner………………………………………………………………………

Head of Department……………………………………………………………………

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Abstract

Distribution and biomass of kingklip (Genypterus capensis) in bottom trawls during the annuals hake biomass surveys were investigated off the Namibian coast between Oranjemund and Kunene river area. Sampling followed a systematic transects design, along latitude gradients (29°S - 17°S). The sampling process took place at different bottom depths ranging between 100 – 700m; 2323 stations were sampled for a period of ten years in summer (January-February). Sampled catch were identified to species level, enumerated and weighted. Environmental data, mainly bottom temperature, salinity and dissolved oxygen were recorded automatically by a CTD instrument. One way analysis of variance (ANOVA) and regression analysis models were used to test for significant differences in biomass distribution of kingklip (Genypterus capensis) in relation to years, latitudes, depths and environmental data. Results obtained showed no significant differences in the species biomass over the years ($F = 0.45$, $p = 0.918$). Significant differences were found on the species biomass with changes in latitudes as well as changes in bottom depths ($F = 197.6$, $p = 0.01$) and ($F = 35.98$, $p = 0.01$), respectively. Environmental factors namely bottom water temperature, salinity and dissolved oxygen were found to have significant influences on the species biomass distribution. Therefore, this study could contribute to the understanding of the population dynamics of kingklip (Genypterus capensis) along the Namibian coastline and also it could contribute to knowledge based on sustainable management of kingklip fishery.

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CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1. General introduction

The Namibian marine environment is characterized by dynamic processes that cause dramatic changes in the distribution and biomass of demersal fish species such as kingklip. The kingklip (*Genypterus capensis*) is a bony fish that belongs to the ophidiidae family which contains 135 species (Van der Elst, 1988). The species belongs to the major class of Actinopterygii (Ray-finned fishes). The name kingklip was derived from the old Dutch kingklipvisch literally, the king of rock fish. The family is distributed through temperate and tropical waters around the world and ten species of this family are known to occur in southern Africa including Namibia (Van der elst, 1988). The *Genypterus capensis* is said to be endemic to southern Africa, and in Namibia it is found in deep waters of about 200-500 meters.

It is evident that kingklip normally grow up to 1.6 meters- long and have elongated bodies with a pointed tail whereby the dorsal and the caudal fins are joined together as a single fin (Smith, 1847). The head region of the kingklip is the broadest in the body, and it has a terminal mouth type. The body shape is more like that of an eel, but unlike most eels which have round cross section bodies; kingklip is moderately or laterally compressed. The colour is normally pink but, sometimes paler with irregular marked with brown blotches on the upper flanks. Fins are also darker brown. The body is normally covered with small scales that do not overlap one another and the scales are not firm and this soft bodied is rather slimy to the touch (Branch, 2005). Kingklip (*Genypterus capensis*) is a bottom dwelling fish and is among the 40 most abundant demersal fish species in the Namibian coast. Since it feeds on some other demersal species, high biomass of kingklip (Genypterus capensis) normally occurs in areas with high food (prey) abundance (Levition, 2001).

Kainge *et al* (2010) reported that kingklip (*Genypterus capensis*) in Namibia, is regarded as a commercial demersal species which normally occurs as bycatch of other demersal species such as hake and monk. This study is necessary towards understanding and monitoring the changes in the distribution and abundance of kingklip off the Namibian coast since a fish species population distribution is highly influenced by environmental and ecological factors that possibly affect the migration, spawning behaviour, recruitment success and availability. Results obtained from this study can therefore be used to determine areas within the Namibian coast with high biomass of kingklip fish, which can be incorporated in their management, conservation and utilization.

1.1.1 Problem statement

The population dynamics of kingklip (*Genypterus capensis*) hence its biomass and distribution, can be highly affected by the ecosystem biological productivity, ecosystem stability, catches by fisheries and environmental conditions such as upwelling intensity, water temperature, dissolved oxygen salinity and other ecological processes that affect its recruitment and optimum growth. As an important commercial species, the *Genypterus capensis* population or stock size has declined during the past few years in most seas of southern Africa, mainly due to increased fishing efforts (Lesch, 2002).

Within the Namibian Exclusive Economic Zone, certain areas are predominantly more productive than others, therefore such areas have higher biomass, for example the upwelling cell along Luderitz area. Environmental variables such as changes in sea temperatures, changes in salinity and variations in dissolved oxygen within a marine ecosystem, can cause fluctuations in the population size of most marine species including the *Genypterus capensis* (Lalli and Parson, 1997). Like many other demersal fish species, *Genypterus capensis* is not equally distributed along the Namibian coast (Lesch, 2002). Therefore, this study attempts to estimate and compare the biomass of kingklip (*Genypterus capensis*) in different areas within the Namibia EEZ and to compare the biomass distribution over ten years (2000-2010) and relate it to various environmental factors.

1.1.2 General objectives

This research study aims at understanding the distribution of kingklip (*Genypterus capensis*) and estimates their biomass off the Namibian coast between Orange River mouth (29^{o}S) and Kunene river mouth (17^{o}S).

1.1.3 Specific objectives

a) To determine and compare the biomass distribution of kingklip (*Genypterus capensis*) off the Namibian coast between the periods of 2000 - 2010.

b) To determine the influence of bottom depths on the distribution of kingklip *(Genypterus capensis*).

c) To determine the influence of latitude on the distribution of kingklip *(Genypterus capensis*).

d) To determine the influence of environmental conditions (such as temperature, dissolved oxygen and salinity) on the distribution of kingklip (*Genypterus capensis*).

1.1.4 Research questions

a) Are there significant differences in biomass distribution of Kingklip (*Genypterus capensis)* off the Namibian coast during the past ten years?

b) Are the significant differences in biomass of Kingklip (*Genypterus capensis)* with changes in bottom depths?

c) Are the significant differences in biomass of Kingklip (*Genypterus capensis)* with changes in latitudes?

d) Are there significant influences of environmental conditions (such as temperature, oxygen and salinity) on the distribution of kingklip (*Genypterus capensis)*?

1.1.5 Research hypothesis

a) There are significant differences in biomass distribution of kingklip (*Genypterus capensis*) over the past ten years off the Namibian coast.

b) There are significant differences in biomass of Kingklip (*Genypterus capensis)* with changes in bottom depths.

c) There are the significant differences in biomass of Kingklip (*Genypterus capensis)* with changes in latitude.

d) There are significant influences of environmental conditions (such as temperature, oxygen and salinity) on the distribution of kingklip (*Genypterus capensis*).

1.2 Literature Review

1.2.1 The general overview of Namibian Marine Environment

The Namibian coast, lies within the South Eastern Atlantic Ocean which is a very productive marine ecosystem region. The South Eastern Atlantic is characterized by a cold current (Benguela current) and upwelling's system due to cold currents that blow from the south pole, these currents in association with the upwelling cells, makes the South Western coast of Africa (South Africa, Namibia, and Angola) very rich in fish biomass due to high biological productivity, therefore this marine ecosystem is known as one of the world's most productive areas in terms of commercial fisheries (Kirkman, 2007). The Benguela system extends from the southwestern margin of Africa, from Cape Agulhas in the south, through Namibia into Angola at 10°S in the north. Circulation at the Agulhas Bank can influence the southern Benguela. Northern Boundary is provided by the Angola-Benguela Front at 14°S-17°S (Longhurst, 2007).

1.2.2 Biology of Kingklip (*Genypterus capensis*)

Smith (1847) reported that the bottom dwelling fish inhabits rocky areas of the continental shelf and upper slope from depths of 200-500m. The juvenile occur in shallower waters than adults. Studies have shown that the fish is carnivorous and its diet mainly consists of small bottom-living fishes such as hake, squids, and mantis shrimps. Feeding (predation) normally takes place on the bottom and at times at mid-water as well, depending on vertical migration of the prey (Branch and George, 1995).

As far as predation is concerned, the following are some of the organisms that prey on G*enypterus capensis*: hake (*Merliccius capensis* and *Merliccius paradoxus*) seal and sea lions (*Arctocephalus pusillus*) sharks and rays. By nature it is not an actively swimming fish, it may well be that kingklip lie in barrows or rock crevices. Studies have shown that the fish browse around and scavenges most of the digestible material lying on the bottom; they are also known as opportunistic feeder as are many fish species. Kingklip are apparently nocturnal feeders and subsist on considerably less food per unit body mass than most other fish, they are occasionally cannibalistic (McIntyre, 2010).

Van der elst (1981) stated in a preliminary research that among small kingklip there is higher percentage of male than female, and this possibly indicates dissimilar growth rates for sexes. Sexual maturity of the *Genypterus capensis* is reached at 4-5 years (50-60cm), and spawning takes place from August to October, around the no fishing season in Namibia.

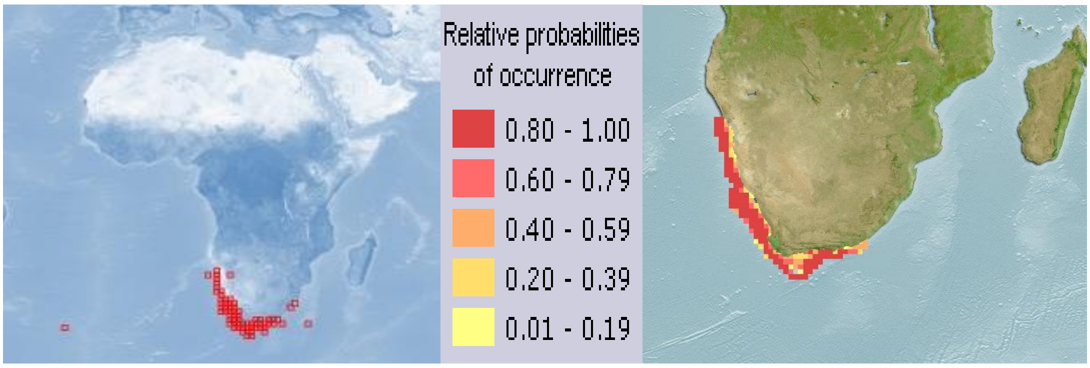

Figure 1. The geographic distribution of kingklip (*Genypterus capensis*) in the Atlantic Ocean. It is evident from the figure that the species is endemic to Southern African coast.

1. 2.3 Environmental influence on Kingklip abundance and distribution

Water parameters such as ocean temperature, ph, dissolved oxygen, salinity and other environmental and ecological factors such as upwelling intensity along the coast, predation and prey concepts intra and inter-specific competition, are factors that normally affect the distribution and biomass of most fish population including kingklip (*Genypterus capensis*) in the southern African marine environment (Reddy,2007).

Depletion of dissolved oxygen level, increased temperatures, very low or high ph levels, and higher salinity are known to disrupt or negatively affect the growth of most marine fish species (Lalli and Parson, 1997). For most marine fish, heat stress affects their reproductive and spawning behaviours. Furthermore, very low ph level (acidic) negatively affects the respiratory system of the fish by disrupting the function of the gills and low oxygen level implies low metabolism rates (Levition, 2001). It's believed that areas with high upwelling intensity normally have higher levels of dissolved oxygen due to higher primary productivity. High predation and catches by fisheries, definitely reduces the biomass. Catches by fisheries may also lead to the destruction of habitats of certain demersal species and direct or indirectly affect the distribution and biomass of kingklip in the marine environment.

1.2.2. Kingklip catches within the Namibian EEZ

Considerable numbers of Kingklip (*Genypterus capensis*) are trawled off the coast of Namibia, within the 200 nautical miles of the country's EEZ. In their book Branch and George (1995) stated that catches of this species are mainly by bottom trawls although long lines are also becoming common Previously the species was very important commercially, but was exploited by foreign fishing fleets mostly in the past when the Namibian fisheries management was not that effective as it is today, and the catches today only add up to a few thousand tonnes a year. Along the Namibian coast more kingklip (*Genypterus capensis*) catches occur in the south than at the northern part (Smith, 1847).

According to Branch and George (1995), Kingklip (*Genypterus capensis*) is probably the second most valuable groundfish species taken off southern African coast in terms of unit fish price, therefore successful attempts have been made to establish a directed fisheries for the species due to high demand, but still constitutes only a minor portion of the total groundfish catch because of the dominance of hakes. For many years kingklip were taken almost entirely as bycatch in the hake fishery. Bigger catches of kingklip could only be obtained if fishermen were willing to risk their trawl nets close to rocky outcrops; such areas are usually avoided by trawl men because of damage they can cause to nets. The fish is known to prefer rocky areas, as a result experienced longline fishermen were brought to Southern Africa in 1980, the method resounded success and kingklip catches rocked the catch rates in the longline fishery peaked in 1985 and then declined because some longliners switched their attention to hake. Kingklip longlining ceased in 1990 and trawled catches have now started to rise again (Branch 1995).

CHAPTER TWO

MATERIALS AND METHODS

2.1. Study area

The study area falls within the Namibian EEZ, between Orangemund (28° S) and Kunene river mouth (17° S). About 220 stations were sampled each year during 40 days (January-February hake biomass survey) so in total 2323 station were sampled over the period of ten years within the indicated latitudes (**Figure 2**). Sampling/ trawling was done in deep waters from about 100 metres to 1800 metres some kilometres away from the shore.

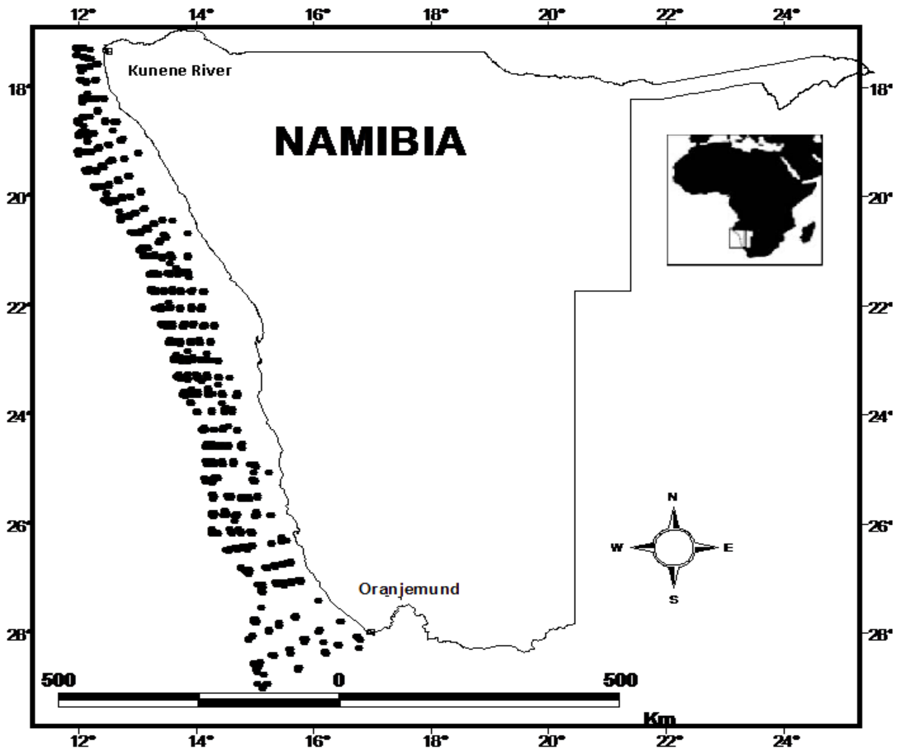

Figure 2. Sampling stations along the Namibian EEZ where the biomass survey took place over the ten years

2.2 Study design

The study design was based on transects, were stations are semi-randomly distributed along transects that run perpendicular to the coast. Stations within transects was 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 the shelves were wide, stations on the shelf were typically 10NM apart.

2.3. Sampling procedures

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 surveys.

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 kingklip (*Genypterus capensis).* Measurements were recorded on a data collection form.

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, dissolved oxygen 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 trawled station

2.3.3 Data analysis

Data used for this study were obtained from the Ministry of Fisheries and Marine Resources Swakopmund, Namibia. The statistical methods SPSS and GENSTAT were used to analyse the data pertaining to biomass distribution. One way analysis of variance (ANOVA) was performed on SPSS and GENSTAT to test for significant differences in biomass of kingklip (*Genypterus capensis*) with (a) years, (b) depth and (c) latitudes. Furthermore, to determine relation between biomass of kingklip (*Genypterus capensis*) and the environmental condition (i.e. temperature, salinity, and dissolved oxygen) a regression analysis, using linear model was performed using GENSTAT statistic software.

CHAPTER THREE

RESULTS

Considerable numbers of kingklip (*Genypterus capensis*) were caught over the years, ranging from 0.1 to 0.43 tones per square nautical miles during the period between 2000 and 2010. The biomass of kingklip sampled varied with depths (100 – 700m) and latitude (29°S - 17°S).

3.1. Biomass distribution of kingklip over the years

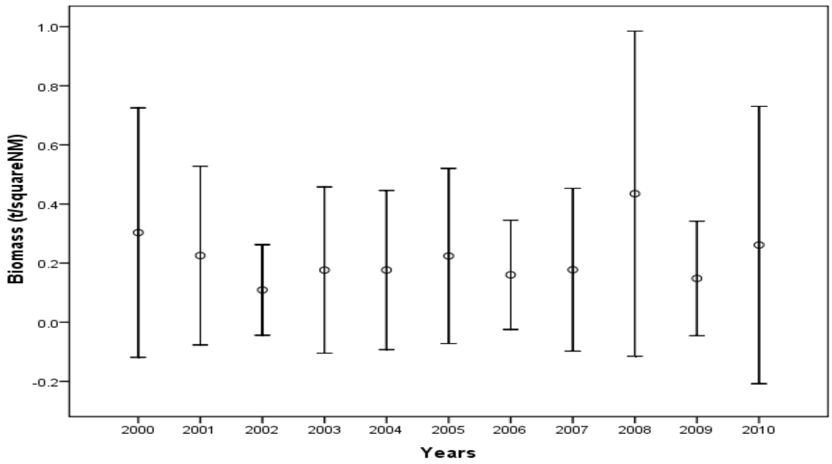

Figure 3: Variation in the mean biomass of kingklip (*Genypterus capensis*) over the years (2000 -2010). Error bars indicate 95% confidence interval of the mean.

The general trend observed in the figure above indicates that the biomass distribution of kingklip was highest in 2008 followed by 2000 and least in 2002 with an average of 0.8, 0.6 and 0.2 respectively. However, statistically there was no significant differences observed in biomass distribution over the years (ANOVA: d.f =76, F =0.45, p=0.918).

3.2. Biomass distribution of kingklip in relation to depths

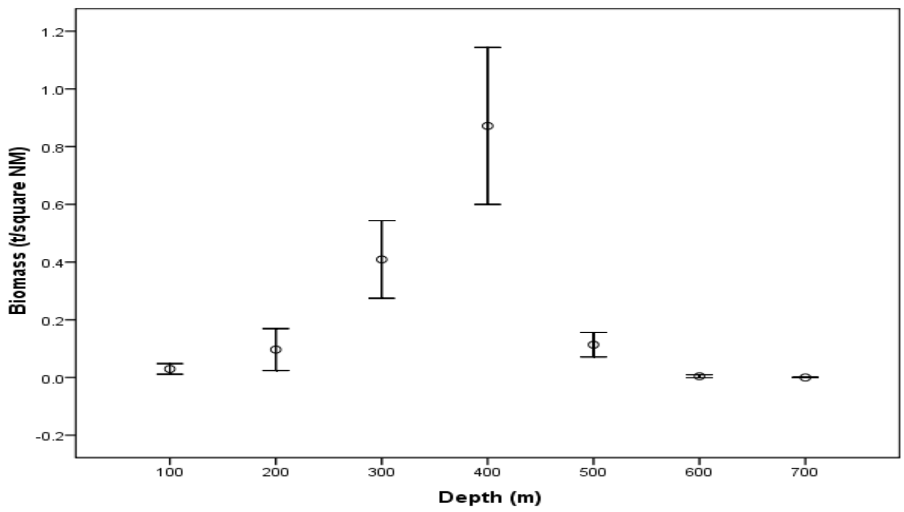

Figure 4: Biomass distribution of kingklip at different depths (100-700 m). Error bars indicate 95% confidence interval of the mean.

It is evident from figure 4 that the biomass distribution of kingklip was greatest at a depth of 400m with 0.9 t/NM² followed by 300m with 0.4 t/ NM². Statistical results indicate significant differences in biomass distribution with changes in depths (ANOVA: *d.f. =76*, *F=35.98*, *p = 0.01*). Significant differences were observed between 300m, 400m, and the rest of the depths) and between (500m and 600m, 700m).

3.3. Biomass distribution of kingklip (*Genypterus capensis*) with changes in latitudes

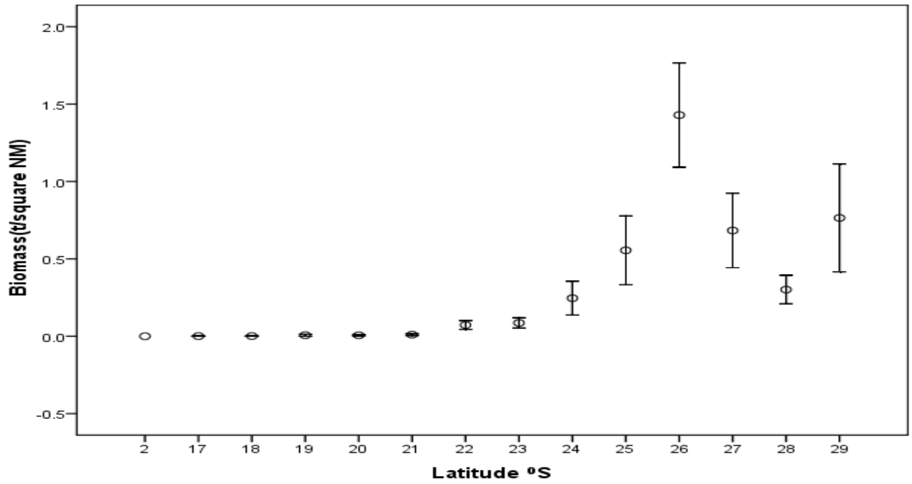

Figure 5: Comparison of means biomass in tones at different latitudes (17ºS - 29Sº). Error bars indicate 95% confidence interval of the mean.

Results from the figure above indicate increase in average means biomass of the fish with increasing latitude off the Namibian coast. The general trend that can be observed from figure 5 above, depicts a relative lower kingklip (*Genypterus capensis*) biomass at low latitude (i.e. 17°S) and a relative higher kingklip biomass at higher latitudes of 26°S and 27°S with mean biomass. Significance difference in means biomass as compared to different latitudes was observed (ANOVA: F=197.6, *d.f* =2321, $p<0.05$).

3.4. Environmental influences on the biomass distribution of kingklip

The results showed significant relationship (p values=0.01; $p<0.05$) between environmental factors (bottom water temperature, salinity and dissolved oxygen) and kingklip biomass.

The observed relationships on statistical analysis yielded the following model: $y=28.5-0.09x_1-0.793x_2+0.113x_3$ which showed a negative, non linear correlation of temperature (x_1), salinity (x_2) with kingkip biomass while dissolved oxygen (x_3) showed a positive correlation with the fish biomass as we can see from the model x_1 and x_2 have negative coefficients while x_3 has a positive coefficient. In addition, the results showed negative relationships between temperature and oxygen (figure 11), depth and oxygen (figure 10), and between depth and temperature (figures 9). Significant linear patterns (inverse relationships) were observed between temperature in relation to oxygen, and between depth and temperature while there was no significant linear relationship between depth and oxygen.

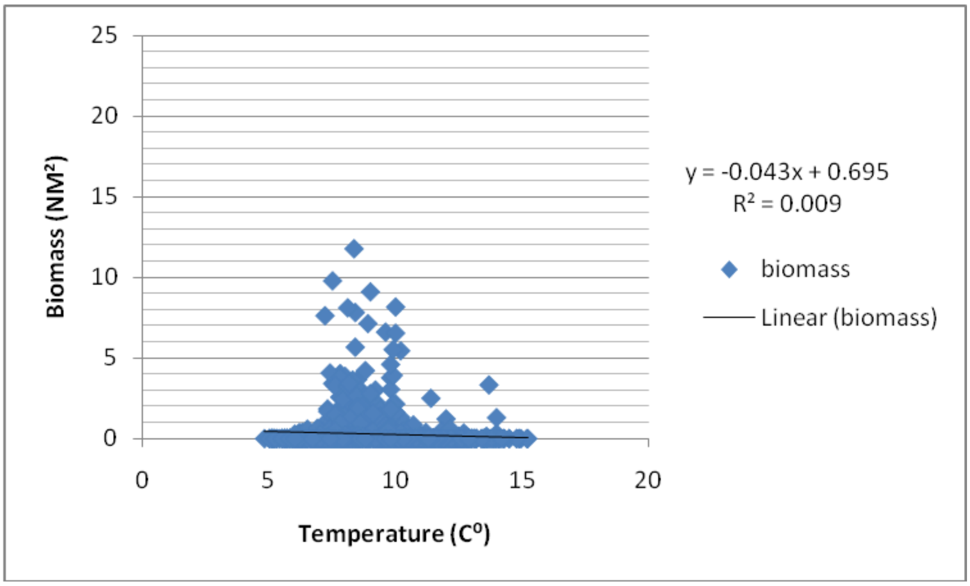

Figure 6: The relationship between Temperature and biomass distribution

The figure above shows how biomass of kingklip was changing or distributed with the change in temperature. There was no linear pattern observed. Kingklip biomass tends to be highest at temperatures of between 7 and 10^{o}C. There is linear relationship between temperature and biomass distribution (ANOVA: d.f *=2200, F=10 p =0.01*). The model y = -0.9019x+0.445 indicates a negative correlation between temperature and biomass.

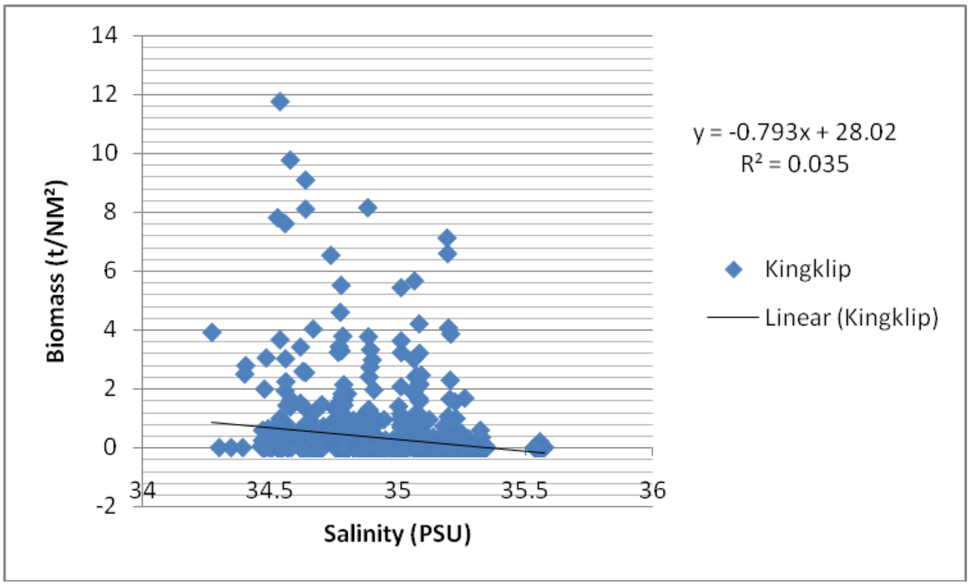

Figure 7: The Relationship between salinity and biomass distribution

The figure above shows how kingklip biomass was changing or distributed with the change in salinity. The model (y= -0.793x +28.02) shows a negative correlation between biomass and salinity. Significant linear pattern was observed with regard to biomass distribution and salinity (ANOVA: *d.f = 1256, F=46.34, p=0.01*).

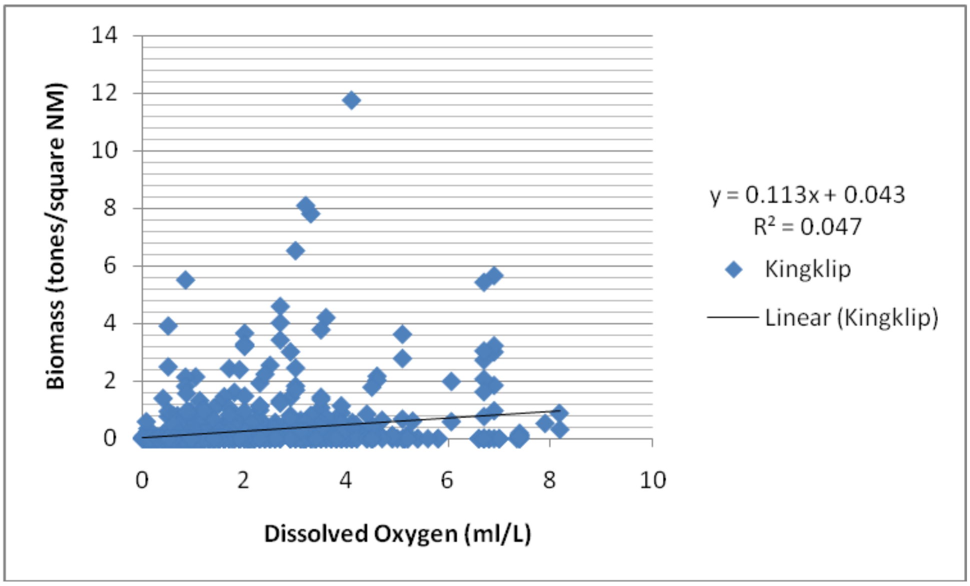

Figure 8: The Relationship between dissolved oxygen and biomass distribution

The observations in figure 8 above show that there is no linear pattern displayed by the data points (R^2= 0.047). However the model shows a positive correlation between the species *(Genypterus capensis*) biomass and oxygen, where y= 0.113(x) + 0.043. This relationship is however a poor correlation between biomass and dissolved oxygen. Significant linear pattern was observed with regard to biomass distribution and dissolved oxygen **(**ANOVA: *d.f*=1.9, *F*=45.37, *p*=0.01).

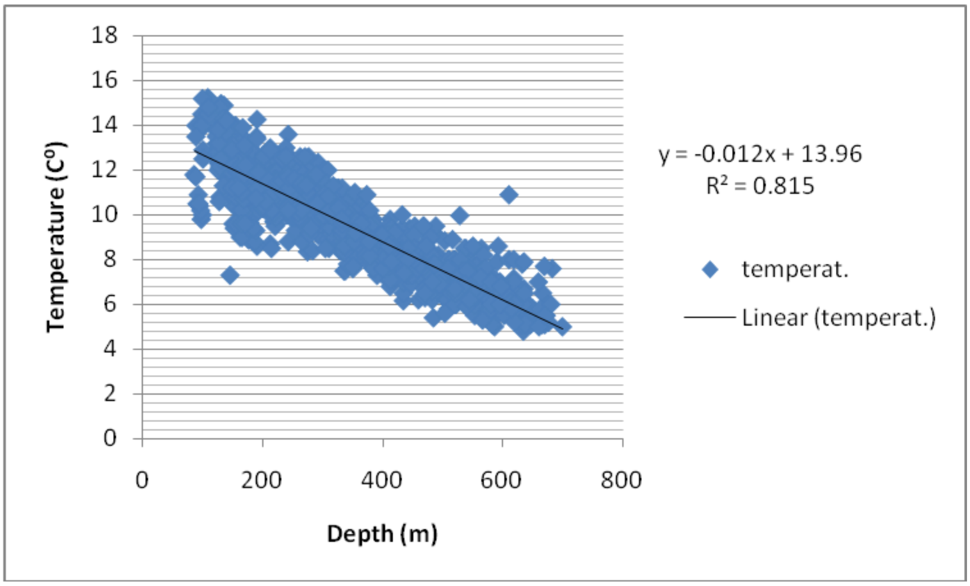

Figure 9: Relationship between depth (100-700 m) and temperature

The figure above shows how the temperature was changing with the change. The model y= -0.012x +14.44 shows a negative correlation between temperature and depth since x has a negative value. There is a significant relationship between temperature and depth in the ocean (ANOVA: *d.f*=2200, *F*=1404.67, *p*=0.01).

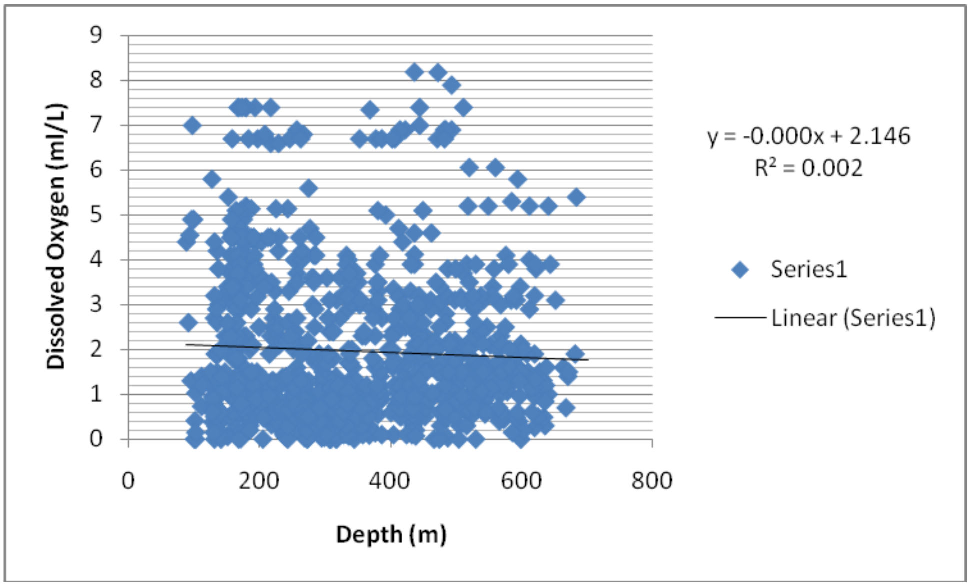

Figure 10: Relationship between depth (100-700 m) and dissolved oxygen

The figure above shows how the dissolved oxygen in ml/litres was changing with the change in depth ranging from 100-700 metres. A negative correlation between depth and dissolved oxygen is shown, as the model y= -0.000x+2.146 represents. A very weak correlation is shown since R^2=0.002. There is no significant relationship between temperature and dissolved oxygen in the ocean (ANOVA: *d.f* =907, *F*= 2.34 *p*= 0.127).

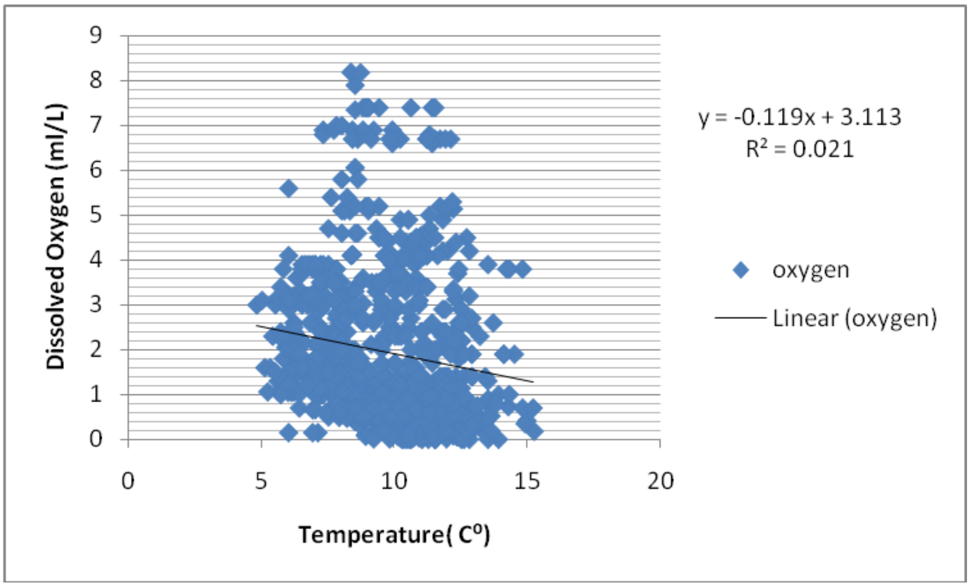

Figure 11: Relationship between temperature and dissolved oxygen

The figure above shows how the dissolved oxygen in ml/litres was changing with the change in temperature. A negative correlation between temperature and dissolved oxygen is shown. There is a significant relationship between temperature and dissolved oxygen in the ocean (ANOVA: *d.f*=907, F=19.99, *p*=0.01).

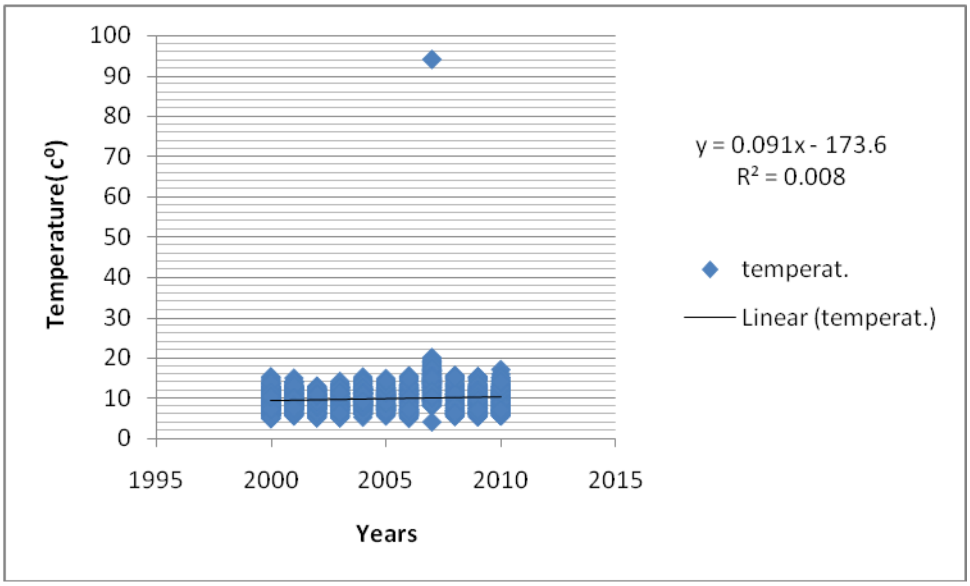

Figure 13: Variation in bottom temperature (100-700 m) over the years (2000 -2010)

The general trend shown by the figure above indicates fluctuation in bottom temperatures over the years (ANOVA: *d.f* =2200, F=10.38, *p*=0.01). There is a significant difference in temperature over the years. In 2007 the average ocean temperature at the sampled depths (100-700m) and stations, was the highest as compared to the other years.

CHAPTER FOUR

DISCUSSION, CONCLUSION, CONTRIBUTION TO KOWLEDGE AND STUDY LIMMITATION

4.1. Discussion

This study was aimed to determine and compare the biomass distribution of kingklip (*Genypterus capensis)* over years, latitudes, and depths and establish a relationship between the biomass distribution and environmental factors. Significant differences in the biomass in relation to latitudes, depths and environmental factors could be due to ecological differences (habitats) and variability in the environmental conditions within the Benguela system.

4.1.1. Kingklip biomass distribution over the years (2000-2010)

Over the past ten years (2000-2010), the biomass distribution of kingklip (*Genypterus capensis)* off the Namibian coast showed non-significant differences ($p=0.918$). It implies that during the past ten years the fish biomass along the Namibian coast did not change considerably, and it has always been caught as bycatch and no TAC was allocated for that period. Insignificant changes in the kingklip biomass over the past ten years shows a non good recovery of the stock, according to Branch and George (1995), the kingklip stocks (biomass) in Southern Africa had depleted significantly due to increased fishing effort. Although non-significant differences in biomass was observed, the biomass fluctuated during the years and catches were high in 2008 with 0.43 t/NM^2 and least in 2002 with 0.18 t/NM^2. These fluctuations might be a result of changes in upwelling intensities with years, since upwelling of new nutrients is the key to high biological productivity in the marine ecosystem (Mann and Lazier, 2008).

Factors that can cause variations in upwelling along the south western coast of Africa are changes in the strength of the wind component parallel to the shore, vertical structure of the water, variations in the bottom bathymetry, and in the upwelling process (Kirkman, 2007). Another possible factor that might have caused slight differences in biomass over years is the differences in trawling time. Branch (1995), stated that *Genypterus capensis* is a nocturnal feeder, it inhabits rock crevices and barrows and by nature it is not an actively swimming fish. During their feeding time (at night) there are more chances of catching higher numbers since the fish become more active to search for their prey. Results from figure 13 show significant differences in bottom temperature over the years (p=0.01), this can possibly be one of the factors explaining the slight biomass fluctuations over the years.

4.1.2. Influence of bottom depth on the biomass distribution of kinglip

The comparison of mean biomass in relation to depths show significant influence on kingklip biomass distribution (p=0.01). According to Van der elst (1981), kingklip occurrences is mostly at depths between 250-400 meters in the South Eastern Atlantic and this is the same case with the results obtained from this study (*see figure 4*). Higher biomass occurred at depths of 400 and 300 metres with 0.88 and 0.4 t/NM^2. At 200 and 500 metres the biomass was not that high but considerable numbers were caught from these depths. Noteworthy, observation made in figure 4 is that no kingklip caught Smith (1847), reported that in

Namibia the fish normally occurs between 200-500 metres, results show almost 0.0 t/NM² for depths of 600 and 700m. Ecological and environmental conditions in such depths are not suitable for kingklip (Branch and George, 1995).

4.1.3. Biomass distribution of kingklip with changes in latitudes

Results show a significant differences in biomass with changes in latitudes (p=0.01). Lower latitudes within the Namibian EEZ (17° – 21° S) show very little quantities in biomass of kingklip (*Genypterus capensis*). Trends begin to rise as from 22°S to 26° S were biomass was the highest. At 27°S and 29°S considerable numbers were also sampled (see figure 5). According to Smith (1947), more kingklip (*Genypterus capensis*) occur in the south than in the northern part of the Namibian EEZ, and the findings of this study depicted the same trend (*figure 5*). These differences can be explained by the fact that there is higher biological productivity in the south than north associated with the upwelling cell (Reddy, 2007).

Furthermore, environmental and ecological conditions possibly tend to be more favourable for the species in the south (23°S-29°S) than in the north (22°S-17°S). Factors that might play a role as well are those associated with the ocean bottom topography. Branch (2005) stated that kingklip species prefer rocky areas and according to Longhurst (2007), the southern coast of Namibia is rockier than the northern part. In addition, the southern region of the ocean floor has a wider continental shelf in comparison to the northern region which has a steeper continental shelf. In steeper continental shelf there is a random change in bottom depth, and as stated by Branch and George (1995) the depth range at which *Genypterus capensis* mostly inhabits is very narrow (200-500m). Sudden change in bottom depth implies that the habitat for the species is very narrow at low latitudes. Surprisingly, from figure 5, biomass of kingklip was low at 28^{o}S compared to 26^{o}S, 27^{o}S and 29^{o}S, this may possibly be due to slight differences in the characteristics of the habitats.

4.1.4. Environmental influences on the biomass distribution of kingklip

The results show significant influences of environmental factors (bottom water temperature, salinity and dissolved oxygen) on the species biomass distribution even though there are very weak correlations (meaning their influences can not highly be considered). Therefore, environmental factors do have influence on the species biomass distribution.

Bottom temperature shows a negative correlation with biomass (see figure 6). Temperature recorded ranged from 5-18^{o}C. Within this temperature range, biomass was observed to be higher at around 11^{o}C and then decreases with increasing temperature. Although, studies have indicated that 13^{o}C tend to be the optimum growth bottom water temperature of Namibian and South African kingklip stocks. Water temperatures above or below the optimum growth temperature is believed to affect the physiology of the fish (Lavition, 2001), therefore it results in very poor growth of the fish stock biomass in a certain area.

A very weak (poor correlation, R^2= 0.035) negative relationship was observed between salinity and biomass distribution. However, salinity has a significant influence on the biomass distribution (*p=0.01*). The salinity recorded at the bottom depths range from 34.5-35.6 PSU, and within this range biomass decreases with increasing salinity. Lower salinity (34.5 PSU) show higher biomass than higher salinity levels (35.6 PSU). The reason for the observed patterns might be that lower salinity is preferred by the kingklip. Higher salinity levels have negative effects on the physiology of most fish (Reddy, 2007). In addition, salinity affects the solubility of oxygen in water in such a way that solubility of oxygen decreases as salinity increases (non-linear relationship).

A positive relationship between dissolved oxygen and biomass distribution was observed (*See Figures 8*) and biomass of kingklip increased with increased level of dissolved oxygen. Oxygen was found to have a significant influence on the biomass distribution (*p=0.01*) even though with a poor correlation (R^2=0.047). According to King (2006), the oxygen level in the environment is important to organisms for cellular respiration. He further indicated that there is more oxygen per litre in air than in water. Since the rate of diffusion of oxygen in water is slower than the rate of diffusion in air, aquatic animals need to extract oxygen from the water. Thus, the reduction in the level of dissolved oxygen in water may be critical for marine fish like kingklip (*Genypterus capensis*) living in the ocean bottom. According to Mann and Lazier (2008), oxygen decreases with increased bottom depth due to higher primary productivity on the upper layers of the water column, but this was not the case with the results obtained in *figure 10*, as it shows no significant relationship between bottom depth and dissolved oxygen, and this is probably because of the wind mixing in the Benguela system. Wind mixing allows more oxygen to be dissolved and gives almost a uniform vertical distribution in the water column (Miller, 2008). Another factor affecting the solubility of oxygen in the ocean is temperature, according to McIntyre (2010), solubility of oxygen in water is affected non-linearly by temperature, and the rate of solubility decreases as the water temperature increases with all other factors constant.

4.2. Conclusion

Various trends in biomass of kingklip (*Genypterus capensis)* were observed in the study in relation to years, latitude, depths and environmental factors along the Namibian coast. The biomass distribution varied insignificantly over the years, significantly among different areas investigated, and significantly with changes in environmental factors. Over the past ten years kingklip biomass has not changed significantly even though there is no TAC allocated for kingklip catches in Namibia. Kingklip biomass distribution along the Namibian coast increases with increasing latitudes due to ecological and environmental factors. Environmental factors affect the species biomass distribution such that areas with optimum bottom water temperature, dissolved oxygen and salinity within their habitats, contain higher biomass. Results of this study support the results obtained by other authors on the same subject. This study has pointed some of the physical and ecological forces which shape the processes that influence the kingklip biomass distribution along the Namibian coast.

4.3. Contribution to knowledge

This study has contributed much to the investigators knowledge based on marine research, in such a ways that the investigator has gained knowledge in conducting fish biomass survey, understanding different Biological-physical interactions in the ocean, and gained knowledge on the Geographical distribution of the investigated fish species. The study also enabled the investigator to conduct an independent research therefore gaining knowledge of research design, data collection, analysis and interpretation. In addition, the ability to make use of other author′s work by means of literature review. This research can be used as a basis to determine biomass distribution of kingklip (*Genypterus capensis*) off the Namibian coast over time, among different areas.

4.4. Limitations to study

Some limitations to the study are due to the fact that sampling was only done during two months in summer. Sampling was done more during the day than at night, this can affect the quantities of the catches (bycatch) since literature review shows the fish to be more active at night. Biomass in tones, of the investigated species were not so much as they would, this is because the main target species of the survey was hake (*M. capensis and M. paradoxus).* As a result the hake species form larger portion of the catches during sampling. The other reason for minimal catch of kingklip during the surveys was the type of fishing gear used and that most trawling was done on soft bottom. According to Branch and George, (1995) longlines fishing methods catch more kingklip than trawl nets that were used during the survey. Namibia has yet to establish surveys strictly based on determine the biomass of kingklip.

References

Bianch,.G, Carpenter. K. E., Roux. J.P, Molloy, F.J, Boyer, D.H.J. (2005) *FAO species identification guide for fishery purposes*. Tool guide to the living marine resources of Namibia. Rome, 1999. 2650, p,11

Branch M, George (1995). *The living shores of Southern Africa*. 8th edition. Struik publishers.

Branch, G.M, Griffiths C.L, Branch M.C, Beckley L.E (2002). *Two oceans*. A guide to the *marine life of southern Africa*. 5th edition. David Philip publishers. Cape town.

Eleftherion A, Alasdair, Mclntyre (2005). *Methods for the study of marine benthos*. 3rd edition. Blackwell publishing.

Ferno A, Olsen S, (1994). *Marine fish behavior in capture and abundance estimations*. First edition. Blackwell wissenchafts.

Fish J.D, Fish S (1996). *Students guide to the seashore*. Second edition.Cambridge University press.

Hall S.J (1999). *The effect of fishing on marine ecosystems and communities*: *Fish biology and aquatic resources series 1*. First edition. Blackwell publishing.

Kainge, P., Kathena, J., Itembu, J. & Van der Plas, A. (2010). Cruise Report No 1/2010, FV Blue Sea 1, *Surveys of the hake stocks*, The National Marine Information and Research Centre. Windhoek.

King, M.G (2006). *Fisheries biology and management*. 2nd edition. Blackwell publishing. UK.

Kirkman S.P. (ed.) 2007. *Final Reportof the BCLME* (Benguela Current Large Marine Ecosystem) *Project on top Predator as Biological indicators of Ecosystem change in the* BCLME. Avian Demography Unit, Cape Town.

Lalli, C.M, Parson T.R (1997). *Biological Oceanography an introduction.* Second edition. Oxyford.

Lesch C. H. (2002) *state of the environment*. Directorate of resource management. Ministry of fisheries and marine resource. The National Marine Information and Research center, Swakopmund, Namibia.

Levition J.S (2001). *Marine Biology. Functions, biodiversity ecology*. Oxford University press.

Longhurst A. (2007) Ecological Geography of the sea. Second edition . USA.

Mann K H and Lazier JRN (2008). *Dynamics of marine ecosystem. Biological-physical interactions in the ocean*. 3rd edition . Blackwell publishing.

Mclntyre, A.D (2010). *Life in the worlds ocean*. *Diversity, distribution, and abundance*. Blackwell publishing. UK.

Miller C.B (2008). *Biological Oceanography*. Blackwell publishing.

Pallant J. (2010). *SPSS. A step by step guide to data analysis using SPSS program. Survival manual*. 4th edition. Allen and Uiwin book publishers.

Ray Hilborn, Carl J. Walters (1992). *Quantitative fisheries stock assessment: choices, dynamics, uncertainty*. Champ & Hall. England.

Reddy M.P.M (2007). *Ocean environment and fisheries*. Science publishers, Enfield, NH, USA.

Royce, W.F. (1996). *Introduction to the Practice of Fishery Science: Revised Edition*. Seattle, Washington. pp. 374-375.

Van der Elst. R. (1988*) a guide to the common sea fishes of southern Africa*. Second edition Cape town. Struik publishes.

APPENDIX

TEMPERATURE BIOMASS ANOVA

***** Regression Analysis ***** TEMPERATURE BIOMASS ANOVA OUTPUT

Response variation: Kingklip

Fitted terms: Constant, temperature

*** Summary of analysis ***

	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	8.	8.1937	10.38	0.001
Residual	2199	1736.	0.7893		
Total	2200	1744.	0.7927		

Percentage variance accounted for 0.4

Standard error of observations is estimated to be 0.888

* MESSAGE: The following units have large standardized residuals:

Unit	Response	Residual
9	4.030	4.21
27	11.770	12.93
32	7.820	8.49
38	7.620	8.24
39	9.780	10.67
43	9.100	9.94
50	8.110	8.81
61	3.420	3.51
241	3.330	3.55
250	3.770	3.96
253	8.160	8.90
320	3.860	4.02
329	6.600	7.14

332	7.130	7.72
338	4.070	4.24
469	3.670	3.82
652	4.210	4.43
693	5.670	6.07
876	5.440	5.85
878	3.630	3.77
925	3.920	4.13
1055	3.790	3.94
1077	4.600	4.89
1084	6.540	7.08
1093	3.430	3.54
1102	5.520	5.93
1310	5.960	6.45
1494	6.180	6.76
1501	7.690	8.43
1896	3.440	3.55
1927	4.450	4.69
1948	5.330	5.68
2113	8.760	9.54
2145	3.880	4.06
2149	3.450	3.57
2157	5.870	6.32
2178	7.580	8.26
2183	3.390	3.51

* MESSAGE: The residuals do not appear to be random;

for example, fitted values in the range 0.331 to 0.368

are consistently larger than observed values

and fitted values in the range 0.258 to 0.258

are consistently smaller than observed values

* MESSAGE: The following units have high leverage:

Unit	Response	Leverage
1588	0.000	0.0035

1595	0.000	0.0039
1630	0.000	0.0043
1642	0.000	0.0043
1643	0.000	0.0041
1648	0.000	0.0051
1649	0.000	0.0035
1651	0.000	0.0045
1655	0.000	0.0049
1656	0.000	0.0040
1660	0.000	0.3259
1661	0.000	0.0043
1663	0.000	0.0036

YEARS BIOMASS ANOVA OUTPUT (SPSS)

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Biomass	2322	.29	1.060	0	22

One-Sample Kolmogorov-Smirnov Test

		Biomass
N		2322
Normal Parameters[a]	Mean	.29
	Std. Deviation	1.060
Most Extreme Differences	Absolute	.393
	Positive	.352
	Negative	-.393
Kolmogorov-Smirnov Z		18.938

Asymp. Sig. (2-tailed)	.000
a. Test distribution is Normal.	

Oneway

Descriptives

Biomass

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
2000	223	.40	1.541	.103	.19	.60	0	12
2001	203	.33	1.086	.076	.18	.48	0	8
2002	212	.16	.438	.030	.10	.22	0	4
2003	196	.25	.738	.053	.15	.36	0	6
2004	212	.23	.719	.049	.14	.33	0	5
2005	211	.29	.876	.060	.17	.41	0	7
2006	201	.21	.594	.042	.13	.29	0	6
2007	213	.23	.792	.054	.12	.33	0	8
2008	212	.52	2.016	.138	.25	.80	0	22
2009	222	.23	.682	.046	.14	.32	0	5
2010	217	.30	1.054	.072	.16	.45	0	9
Total	2322	.29	1.060	.022	.24	.33	0	22

Post Hoc Tests

Post Hoc Tests

Multiple Comparisons

Dependent Variable:Biomass

	(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	2000	2001	.062	.103	1.000	-.27	.39
		2002	.238	.101	.403	-.09	.57
		2003	.144	.104	.951	-.19	.48
		2004	.162	.101	.886	-.17	.49
		2005	.103	.102	.995	-.22	.43
		2006	.187	.103	.769	-.14	.52
		2007	.170	.101	.849	-.16	.50
		2008	-.127	.101	.976	-.45	.20
		2009	.166	.100	.859	-.16	.49
		2010	.091	.101	.998	-.23	.42
	2001	2000	-.062	.103	1.000	-.39	.27
		2002	.176	.104	.840	-.16	.51
		2003	.082	.106	1.000	-.26	.42
		2004	.099	.104	.997	-.24	.43
		2005	.041	.104	1.000	-.29	.38
		2006	.125	.105	.984	-.21	.46
		2007	.107	.104	.995	-.23	.44
		2008	-.189	.104	.766	-.52	.15
		2009	.103	.103	.996	-.23	.43
		2010	.029	.103	1.000	-.30	.36
	2002	2000	-.238	.101	.403	-.57	.09
		2001	-.176	.104	.840	-.51	.16

		2003	-.094	.105	.998	-.43	.24
		2004	-.077	.103	1.000	-.41	.25
		2005	-.135	.103	.967	-.47	.20
		2006	-.051	.104	1.000	-.39	.28
		2007	-.068	.103	1.000	-.40	.26
		2008	-.365*	.103	.017	-.70	-.03
		2009	-.072	.102	1.000	-.40	.25
		2010	-.147	.102	.938	-.48	.18
	2003	2000	-.144	.104	.951	-.48	.19
		2001	-.082	.106	1.000	-.42	.26
		2002	.094	.105	.998	-.24	.43
		2004	.018	.105	1.000	-.32	.36
		2005	-.041	.105	1.000	-.38	.30
		2006	.043	.106	1.000	-.30	.39
		2007	.026	.105	1.000	-.31	.36
		2008	-.271	.105	.257	-.61	.07
		2009	.022	.104	1.000	-.31	.36
		2010	-.053	.104	1.000	-.39	.28
	2004	2000	-.162	.101	.886	-.49	.17
		2001	-.099	.104	.997	-.43	.24
		2002	.077	.103	1.000	-.25	.41
		2003	-.018	.105	1.000	-.36	.32
		2005	-.058	.103	1.000	-.39	.27
		2006	.026	.104	1.000	-.31	.36
		2007	.008	.103	1.000	-.32	.34
		2008	-.289	.103	.155	-.62	.04

	2009	.004	.102	1.000	-.32	.33
	2010	-.071	.102	1.000	-.40	.26
2005	2000	-.103	.102	.995	-.43	.22
	2001	-.041	.104	1.000	-.38	.29
	2002	.135	.103	.967	-.20	.47
	2003	.041	.105	1.000	-.30	.38
	2004	.058	.103	1.000	-.27	.39
	2006	.084	.104	.999	-.25	.42
	2007	.066	.103	1.000	-.26	.40
	2008	-.230	.103	.476	-.56	.10
	2009	.062	.102	1.000	-.27	.39
	2010	-.012	.102	1.000	-.34	.32
2006	2000	-.187	.103	.769	-.52	.14
	2001	-.125	.105	.984	-.46	.21
	2002	.051	.104	1.000	-.28	.39
	2003	-.043	.106	1.000	-.39	.30
	2004	-.026	.104	1.000	-.36	.31
	2005	-.084	.104	.999	-.42	.25
	2007	-.017	.104	1.000	-.35	.32
	2008	-.314	.104	.091	-.65	.02
	2009	-.021	.103	1.000	-.35	.31
	2010	-.096	.104	.998	-.43	.24
2007	2000	-.170	.101	.849	-.50	.16
	2001	-.107	.104	.995	-.44	.23
	2002	.068	.103	1.000	-.26	.40
	2003	-.026	.105	1.000	-.36	.31

		2004	-.008	.103	1.000	-.34	.32
		2005	-.066	.103	1.000	-.40	.26
		2006	.017	.104	1.000	-.32	.35
		2008	-.297	.103	.126	-.63	.03
		2009	-.004	.101	1.000	-.33	.32
		2010	-.079	.102	1.000	-.41	.25
	2008	2000	.127	.101	.976	-.20	.45
		2001	.189	.104	.766	-.15	.52
		2002	.365*	.103	.017	.03	.70
		2003	.271	.105	.257	-.07	.61
		2004	.289	.103	.155	-.04	.62
		2005	.230	.103	.476	-.10	.56
		2006	.314	.104	.091	-.02	.65
		2007	.297	.103	.126	-.03	.63
		2009	.293	.102	.129	-.03	.62
		2010	.218	.102	.553	-.11	.55
	2009	2000	-.166	.100	.859	-.49	.16
		2001	-.103	.103	.996	-.43	.23
		2002	.072	.102	1.000	-.25	.40
		2003	-.022	.104	1.000	-.36	.31
		2004	-.004	.102	1.000	-.33	.32
		2005	-.062	.102	1.000	-.39	.27
		2006	.021	.103	1.000	-.31	.35
		2007	.004	.101	1.000	-.32	.33
		2008	-.293	.102	.129	-.62	.03
		2010	-.075	.101	1.000	-.40	.25

	2010	2000	-.091	.101	.998	-.42	.23
		2001	-.029	.103	1.000	-.36	.30
		2002	.147	.102	.938	-.18	.48
		2003	.053	.104	1.000	-.28	.39
		2004	.071	.102	1.000	-.26	.40
		2005	.012	.102	1.000	-.32	.34
		2006	.096	.104	.998	-.24	.43
		2007	.079	.102	1.000	-.25	.41
		2008	-.218	.102	.553	-.55	.11
		2009	.075	.101	1.000	-.25	.40
Bonferroni	2000	2001	.062	.103	1.000	-.28	.40
		2002	.238	.101	1.000	-.10	.58
		2003	.144	.104	1.000	-.20	.49
		2004	.162	.101	1.000	-.18	.50
		2005	.103	.102	1.000	-.23	.44
		2006	.187	.103	1.000	-.15	.53
		2007	.170	.101	1.000	-.17	.51
		2008	-.127	.101	1.000	-.46	.21
		2009	.166	.100	1.000	-.17	.50
		2010	.091	.101	1.000	-.24	.43

Salinity biomass ANOVA

***** Regression Analysis *****

Response variate: Kingklip

Fitted terms: Constant, salinity

*** Summary of analysis ***

	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	42.	42.3734	46.34	<.001
Residual	1255	1148.	0.9145		
Total	1256	1190.	0.9475		

Temperature years ANOVA

*** Summary of analysis ***

	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	8.	8.1937	10.38	0.001
Residual	2199	1736.	0.7893		
Total	2200	1744.	0.7927		

Oxygen, biomass ANOVA

***** Regression Analysis *****

Response variate: Kingklip

Fitted terms: Constant, oxygen

*** Summary of analysis ***

	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	33.3	33.3459	45.37	<.001
Residual	906	665.8	0.7349		
Total	907	699.2	0.7709		

Oxygen depth relations

* Summary of analysis ***

	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	7.	6.693	2.34	0.127
Residual	906	2594.	2.863		
Total	907	2601.	2.868		

Oxygen ,temperature ANOVA OUTPUT

***** Regression Analysis *****

Response variate: oxygen

Fitted terms: Constant, temperat

*** Summary of analysis ***

	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	56.	56.151	19.99	<.001
Residual	906	2545.	2.809		
Total	907	2601.	2.868		

LATITUDE, BIOMASS ANOVA OUPUT

***** Regression Analysis *****

Response variate: Kingklip

Fitted terms: Constant, Latitude

*** Summary of analysis ***

	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	205.	204.779	197.62	<.001
Residual	2320	2404.	1.036		
Total	2321	2609.	1.124		

Temperature years

*** Summary of analysis ***

	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	8.	8.1937	10.38	0.001
Residual	2199	1736.	0.7893		
Total	2200	1744.	0.7927		