ANALYSIS OF THE CONDITION FACTOR OF THE HAKES, *Merluccius capensis* AND *Merluccius paradoxus* IN THE NAMIBIAN WATERS BETWEEN 1994 AND 2001, 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 it has not been presented elsewhere for the award of a degree or certificate. All 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 a degree of Bachelor of Science in Fisheries and Aquatic Sciences of the University of Namibia.

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External examiner………………………………………..signature…..……………………………...

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DEDICATION

This work is dedicated to my family and friends who have provided me with a lot of love and support during my studies.

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ABSTRACT

A study on condition factor of the two hake species (*Merluccius capensis* and *Merluccius paradoxus*) found off the Namibian coast was conducted during the period 1994-2001. The data used was obtained from the annual hake biomass surveys carried out in January and February. The data collected includes year, species, weight, length, sex and gonad maturity. The average condition factor for each year was then used to determine if there have been significant changes in condition factor. Fulton's condition factor was used to determine the well-being of the fish. Both species were analysed to determine if there have been significant changes in condition factor over the years. The Chi-square test using multiple linear models was used to analyse the data. Results showed significant changes in the condition factor of both *M. capensis* and *M. paradoxus* ($p < 0.05$). Maturity also had a significant influence on the condition factor of both species ($p < 0.05$). On the other hand sex only had a significant effect on the condition factor of *M. capensis* ($p < 0.005$) but not on *M. paradoxus* ($p > 0.05$). This study can be used to understand changes in condition factors over the years and to establish proper management measures to enhance the sustainability of the hake stocks.

Key words: Condition factor, *Merluccius capensis*, *Merluccius paradoxus***,** Namibia, Sustainability

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1. General introduction

Fish welfare is one of the commonly observed concerns of humans to situations were fish appear to be suffering. This can be determined by measuring the condition factor of the fish. Condition factor can be defined as an index of the physiological well-being of a fish and can also be considered as an integrator of conditions encountered during some previous period. It is believed that the condition factor of fish is affected by various factors such as food availability, physical factors and the physiology (Kreiner *et al.*, 2001). Seasonality is among other factors, believed to significantly influence the condition factor of fish due to changes in environmental conditions which can influence the wellbeing of fish (Nash *et al.,* 2006).

The basic assumption underlying the use of the condition factor is that fish in better condition, in terms of nutritional and health status are more full-bodied and are therefore heavier at a given length (Nash *et al*., 2006). Fish condition has been traditionally estimated by the equation proposed by Fulton. According to Nash *et al*., (2006), Fulton's condition factor is widely used in fisheries and general fish biology studies to determine the well-being of fish. This condition factor is calculated by looking at the relationship between the whole weight (g) and the total length of the fish (cm). This weight-length relationship is then used to describe the condition factor of the fish. Condition factor assumes that heavier fish of a given length are in better condition.

In Namibian waters, the most important commercial fish species, in terms of export revenues is hake (*M. capensis* and *M. paradoxus*). These two species have different geographical distribution within the water column. With *M. capensis* being found at depths of 50-350 m and *M. paradoxus* being found at depths of 300-1000 m (Payne, 1989). Thus their condition factors might vary as subjected to different environmental conditions. There has been a decline in hake stocks being caught off the coast since about 1999 (Kainge *et al*., 2009). Thus it is very vital to study and understand all parameters related to the biology, including the condition factor of the two species, to determine whether there have been changes over the past years. This understanding may help fishery scientists and managers to better understand the causes of the decline in hake stocks.

1.1.1 Justification of the study

The Namibian fishing industry is highly dominated by hake species which contribute significantly to revenue earnings through export. Although Namibia is regarded to have the best management practices when it comes to the utilization of its fishery resources it is now observed that there is a decline in the hake stock, observed over the years (Kainge *et al*., 2009).

In the past, a decline in fish stock was associated with overexploitation from foreign fishing fleets. To date, it is uncertain whether the decline in fish stocks has been due to overexploitation or changes in environmental conditions. Thus, it is very important to study the condition factor of hake to enable fisheries managers to understand fish wellbeing as this would contribute positively to adequate management of these species (Lizamo *et al*., 2002). Condition factors of hake have been studied briefly in recent years (2002 - 2010). So there is a need to study those for earlier years

1994 - 2001. It is very important to have all this information, because it will fill the gap of such information. This information can therefore be used by fisheries managers to establish proper management measures taking into consideration the condition factor of hake to enhance the sustainability of the stock.

1.1.2. Aims of the study

This research aims to analyse changes in the condition factor of the two hake species, *Merluccius capensis* and *Merluccius paradoxus* in the Namibian waters from 1994 until 2001, during summer. Furthermore this study has identified two biological factors that might have influenced the condition factor of the two hake species.

1.1.3. Research objectives

The main objectives of this research are as follows:

a). To analyse changes in the condition factor of *M. capensis* and *M. paradoxus* over the period 1994-2001.

b). To determine the effects of sex and maturity on the condition factor of *M. capensis* and *M. paradoxus*.

1.1.4. Research hypothesis

There are significant changes in the condition factor of *M. capensis* and *M. paradoxus* over the period 1994-2001.

Sex and maturity have significant influence on the condition factor of *M. capensis* and *M. paradoxus.*

1.2. Literature review

1.2.1. Welfare condition of fish

Fisheries play an important role in the economy of most developing countries. Fish provides a very cheap source of highly nutritive protein and also other essential nutrients required by the body (Sikoki and Otobotekere, 1999). According to Huntingford and Kadri (2008), the term welfare is complex and very difficult to define, because it is used in different ways by people from different backgrounds. There is scientific uncertainty with regards to whether fish have the capacity for suffering. Most definitions identify an animal as being in a good state of welfare if one of the following three conditions applies: (a) the animal can adapt to its environment and it is in good health, with all its biological systems working appropriately; (b) the animal is able to live a natural life, and it’s able to meet its behavioural needs; (c) the animal is free of negative experience such as pain, fear and hunger and has access to positive experiences, such as social companionship.

Condition factor, as applied to fish population ecology is described as an indication of fitness, general wellbeing or gonad development of an individual or a group of individuals (Saliu *et al.*, 2007). Individual condition is an important component of performance, survivorship and reproductive success in fish. In energy terms condition factor may be defined as the amount of energy available to an individual that may be allocated to various life functions including reproduction (Huntingford and Kadri, 2008). In fish the condition factor (K) reflects information regarding the physiological state of the fish in relation to its welfare. From a nutritional point of view, there is an accumulation of fat and gonadal development (Le Cren, 1951). From a reproductive point of view, the highest K values are reached in some species (Angelescu *et al.*, 1958).

Condition factor looks at the wellbeing of a fish and is based on the hypothesis that heavier fish of a given length are in better condition (Bagenal and Tesch, 1978). Condition factor decreases with an increase in length and it has been used as an index of growth and feeding intensity (Fagade, 1979). Condition factor can also be used to compare how populations have been living with regard to density, climates and other conditions, when determining the period of gonadal maturity. The study of the condition factor is thus important for understanding the life cycle of fish species and it also contributes to the adequate management of species (Lizama *et al*., 2002).

According to a report by Kainge *et al.*, (2010) *M. paradoxus* has continued to be in a better body condition as compared to *M. capensis* for the period 2002 - 2010. The condition factor of *M. capensis* and *M. paradoxus* for 2010 has decreased as compared to that of 2009. The range of the condition factor which shows the well-being of the fish varies from species to species and for the hake species it is 0.5 – 0.7.

1.2.2. The influence of maturity and sex on the condition factor of fish

In the Namibian waters *M. paradoxus* is believed to undergo a migratory system between spawning and recruitment areas. Based on evidence from surveys and commercial catches the adult *M. paradoxus* migrates to South African waters to spawn and some off-springs migrate or are transported to the Namibian waters where recruitment to the fishery subsequently takes place (Hampton *et al*., 1999). Since 1990 there has been an expansion of this species stocks into the Southern Namibian waters and further North, probably from South African waters (Hampton *et al*., 1999).

M. capensis spawn in the Namibian waters along the coast at Cape Frio, Walvis Bay, Cape Cross and Conception Bay at varying degrees of intensity (Assorov and Berenbeim, 1983), with the area between Conception Bay and Walvis Bay being their most intensive spawning areas (Sedletskaya, 1988). Spawning time for these species starts in September and ends in November. According to Morrison (1990), the reproductive cycles of fish are continuous and it makes it difficult to classify maturity into developmental stages. This classification is done by visual inspection and not evaluated by laboratory examinations of gonads such as image analysis and histology. Condition factor increases during the reproductive period and it decreases again afterwards (Vazzoler and Vazzoler, 1983). The maturity of both *M. capensis* and *M. paradoxus* ranges between 1 and 5. The classifications of these stages are outlined in appendix I.

1.2.3. The biology and distribution of hake species

The Namibian hake species are considered to be top predators. Cannibalism in the hake species is said to account for more than 70% of their diet. Cannibalism among *M. capensis* targeting younger *M. capensis* and younger *M. paradoxus* has been well documented (Macpherson and Gordoa, 1995). The hake species are not separately identified in the commercial catches and landings and are managed as one stock. The north and central areas consists of *M. capensis,* whereas the two species are more evenly represented in catches taken from the south. Both *M. capensis* and *M. paradoxus* have a depth related size distribution, which changes with latitudes. The smaller fish from both species are more present in the shallower water than the larger fish (Van Eck, 1969), in the northern and central part of the region (18 to 22^{o}S); large *M. paradoxus* are present in deeper waters. But they also occur at shallower depths south of 23^{o}S. A larger number of *M. paradoxus* occur together with medium to large *M. capensis* (Botha, 1973).

Areas of high density for *M. capensis* are found almost in the entire coastal shelf of Namibia. In the northern area from Cape Frio to the Orange River, there appears to be high concentrations of these species. Areas of high density for *M. paradoxus* are found in the deeper waters, with the highest concentrations of densities found south of Ambrose Bay, but mainly off Luderitz in the south. There is a low abundance of *M. paradoxus* north of Ambrose Bay, while in 2008 there was more of the species (Kainge *et al*., 2009).

CHAPTER TWO

MATERIALS AND METHODS

2.1. Study species (*M. capensis* and *M. paradoxus)*

M. capensis and *M. paradoxus* are the two species to be analysed in this study. The two species are found off the Namibian coast and are very similar in appearance, but they can be differentiated morphologically with regards to the number and pigmentation of gill rackers, length of the pectoral fins (van Eck, 1969), otolith shape and number of vertebrae (Botha, 1971). The cape hake (*M. capensis*) has 15-20 gill rackers, which are clear without any spots, on the first gill arch while the deep water hake has 18-23 gill rackers, which have black spots, on the first gill arch. The pigmentation on the gill rackers only occurs in adults, in the juveniles the species are differentiated by the count of the vertebra (Botha, 1971). The two species can also be differentiated externally by looking at the anal fins. The anal fins of *M. capensis* are darker while those of *M. paradoxus* are clear (Gordoa *et al*., 1995).

Picture 1: *Merluccius capensis*

Picture 1: *Merluccius paradoxus*

2.2. Study design and data collection

Biological data for *M. capensis* and *M. paradoxus* were collected during survey catches conducted during the period 1994-2001, by NatMIRC. These types of surveys are conducted during summer (mainly January/February) of each year and cover the entire coast of Namibia from the Orange River (30°S) to Kunene River (17°S) (Kainge *et al*, 2009). A total number of 13372 samples of both species were sampled during this period. The information collected from each trawl catch sample included species, length, weight, sex and maturity stage. Latitudes and longitudes where the fish was collected were also recorded. Only the biological data for the years 1994, 1996, 1997, 1999, 2000 and 2001, were used for this study. The missing years were a result of data unavailability during those years.

2.3. Data analysis

The condition factor of each individual fish was calculated in MS Excel spreadsheet using the following formula:

$K= (W/L^3)*100$

- Where: K = Fulton's condition factor, W = whole weight of the fish (g) and L= total length of the fish (cm).

It is believed that the greater the value of K, the better the condition of the fish. For hake the K is expected to range between 0.5 - 0.7. A value below 0.5 would mean that the fish is in a very bad condition and a value above 0.7 would mean that the fish is in a very good condition (Kainge *et al*., 2009).

The K indicates whether an individual is in better or worse condition than an average individual with the same length. At the population level, the average K-indicates whether a population is in better or worse condition than an average population (Lambert and Dutil, 1997). In other words, the condition factor allows the comparison quantitatively of the condition of two or more populations from different localities provided that the year and season of sampling is the same. One of the factors influencing the condition factor of fish is the stage of development of the reproductive organs (Lambert and Dutil, 1997). The Chi-square test using multiple linear models from GENSTAT software was used to test if there are significant changes in the condition factor of the hake species over the years 1994-2001 and if maturity and sex influence condition factor for each species respectively at a significance level of 95%.

CHAPTER THREE

RESULTS

3.1. Condition factor of *M. capensis* and *M. paradoxus*

A total number of 13372 fish were collected with 8418 *M. capensis* and 4954 samples *M. paradoxus* during the period 1994 – 2001 for investigation in the present study. The condition factor of the two species of hake (*M. capensis* and *M. paradoxus*) varied over the years and the values of individual fish ranged between 0.066 – 2.268 for *M. capensis* and 0.216 - 2.778 for *M. paradoxus*.

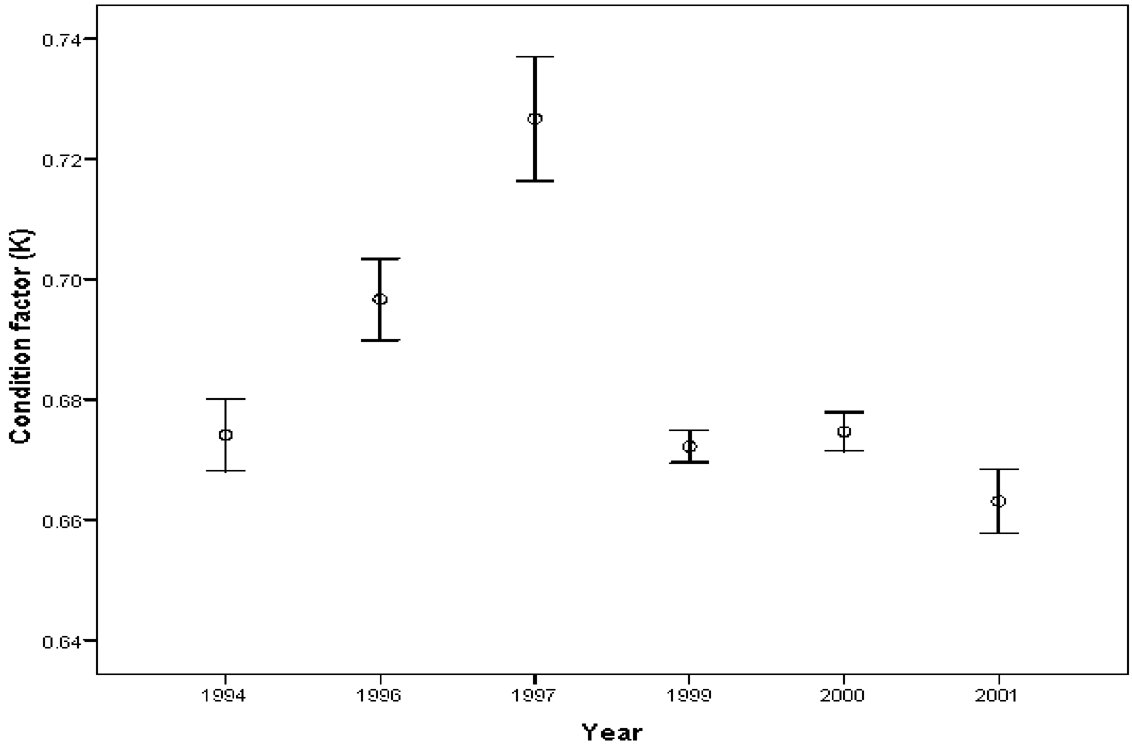

Figure 1: Condition factor of *M. capensis* over the period 1994-2001

The general trends observed in the figure above indicates that the condition factor of *M. capensis* has been increasing since 1994 until reaching the highest peak in 1997, from there it declined reaching the lowest value in 2001. Significant differences in the means of the condition factor of *M. capensis* were observed over the years (p < 0.001). The figure above indicates significant differences in means between the following years: (a) 1994, 1999, 2000, (b) 1996, (c) 1997, and (d) 2001.

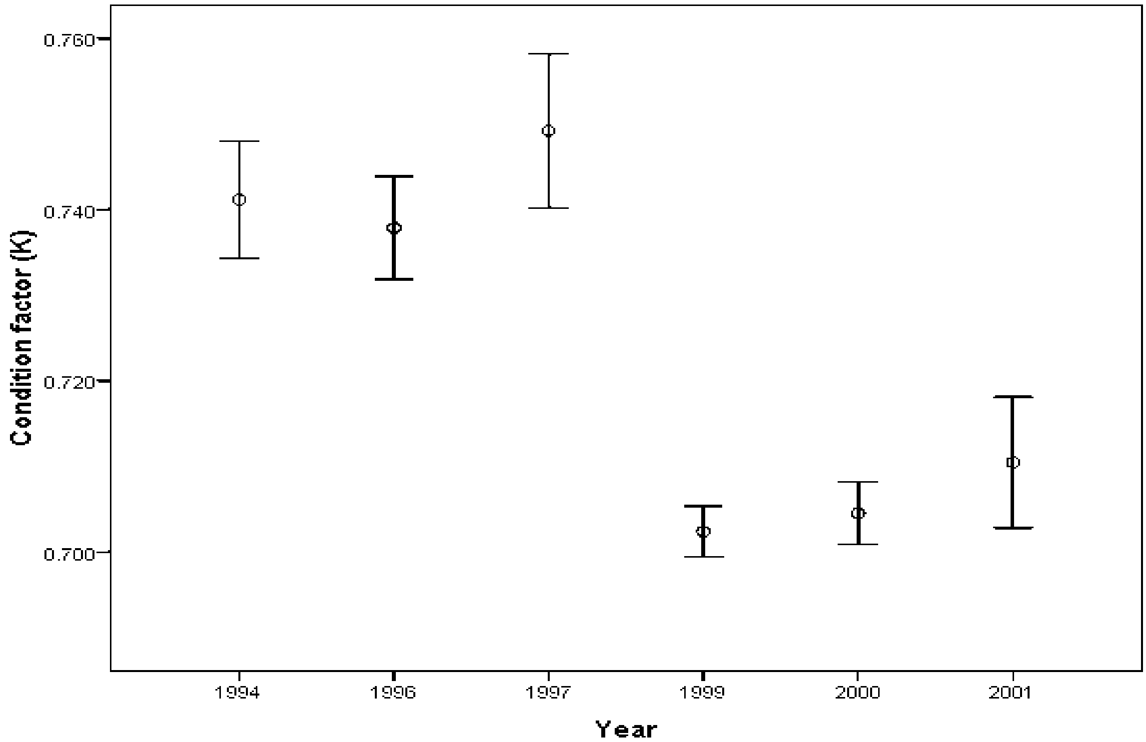

Figure 2: Condition factor of *M. paradoxus* over the period 1994-2001

It is evident from the graph above that the condition factor of *M. paradoxus* was higher during the years 1994 - 1997. The highest peak was in 1997, it then declined reaching its lowest in 1999;

afterwards there have been slight insignificant increases till the year 2001. Significant differences in the mean of condition factor of *M. paradoxus* were observed over the years ($p < 0.001$). The comparison of means in the condition factor of *M. paradoxus* indicated remarkable differences between years. The figure above indicates significant differences in means between the following years: (a) 1994, 1996, 1997 and (b) 1999, 2000, 2001.

3.2. Factors influencing the condition factor of hake species over the period 1993-2001

3.2.1 *M. capensis*

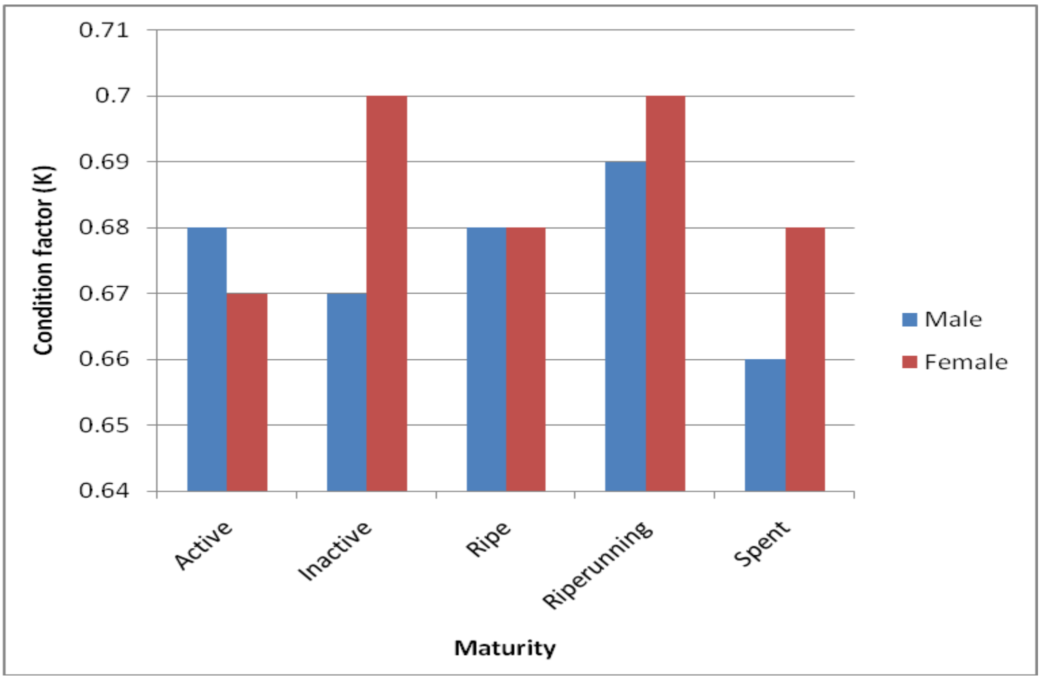

Figure 3: Relationship between condition factor and maturity stages between males and females.

There is no significant interaction between sex and maturity (p = 0.955). In the figure above condition factor shows a non-significant behavioural pattern across maturity stages for the two sexes. Males have a lower condition factor as compared to the females for all maturity stages except for the active stage. The maturity stage ripe and running recorded the highest K values in both males (0.69) and females (0.70). The lowest K value in females is at the maturity stage active and for males it is at spent (0.66).

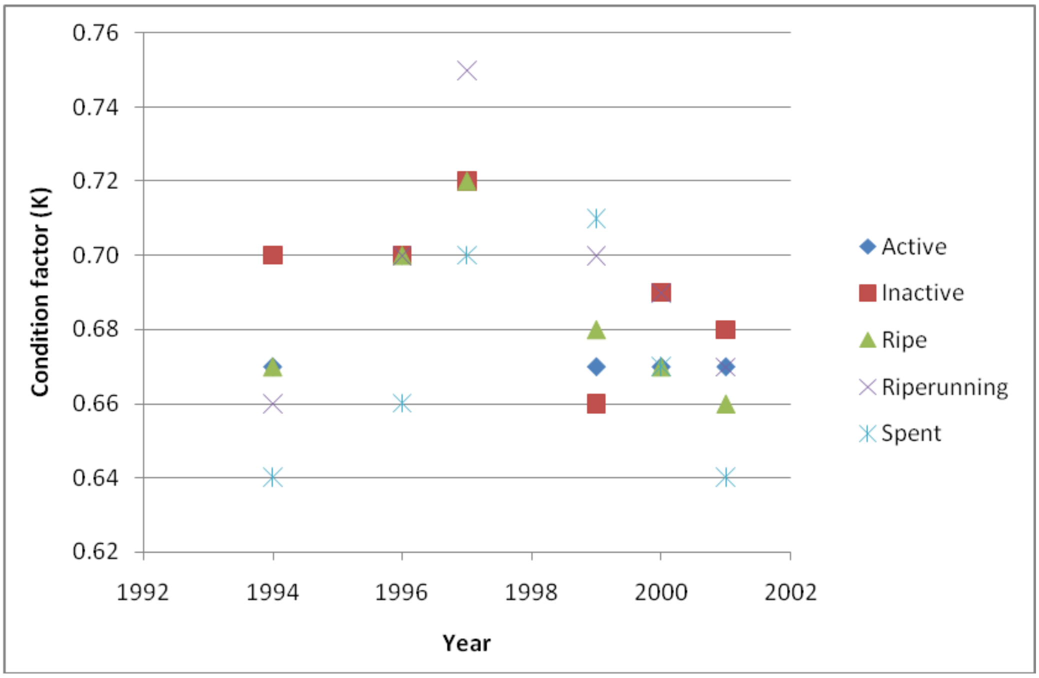

Figure 4: Relationship between condition factor and maturity stages over the years.

There is a significant interaction between year and maturity ($p<0.001$). In the figure above condition factor changes significantly across the years for the different stages of maturity. The maturity stage ripe and running recorded the highest K value (0.75) in 1997. Spent had the least K of 0.64 in 1994 and 2001. In 1996 all the maturity stages had the same K value of 0.70 except for the spent stage.

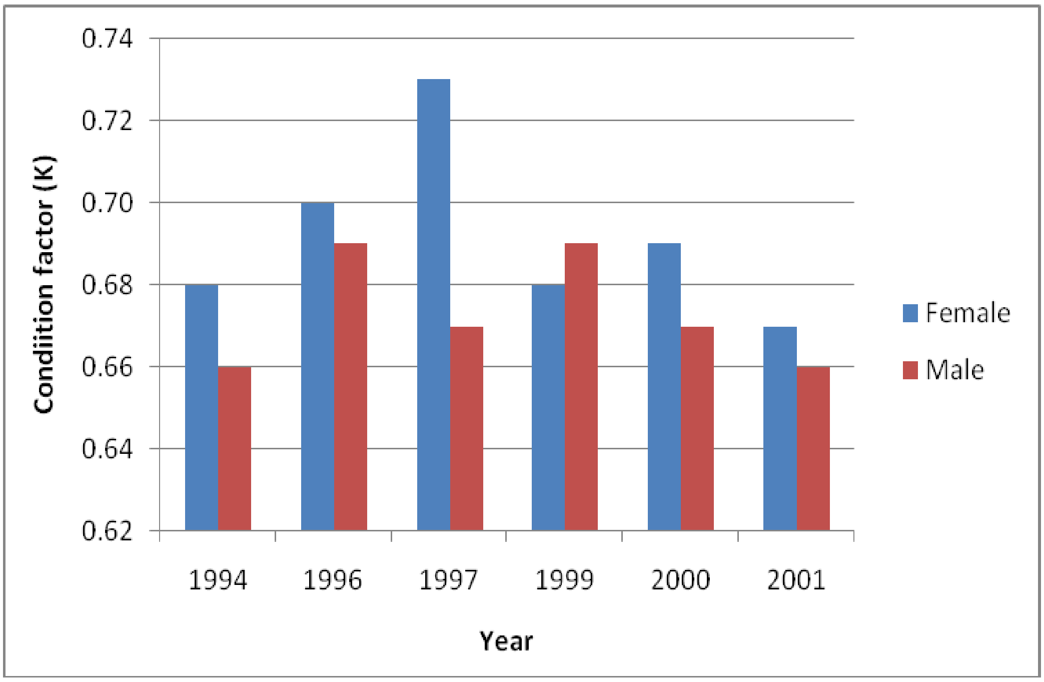

Figure 5: Relationship between condition factor and sex over the years

There is a significant interaction between year and sex (p = 0.005). In the figure above females generally have a higher condition factor than the males, but the pattern changed in 1999, were the males had a higher K value of 0.69. The lowest K values in males were (0.66) in 1994 and 2001 and females (0.67) in 2001.

3.2.2. *M. paradoxus*

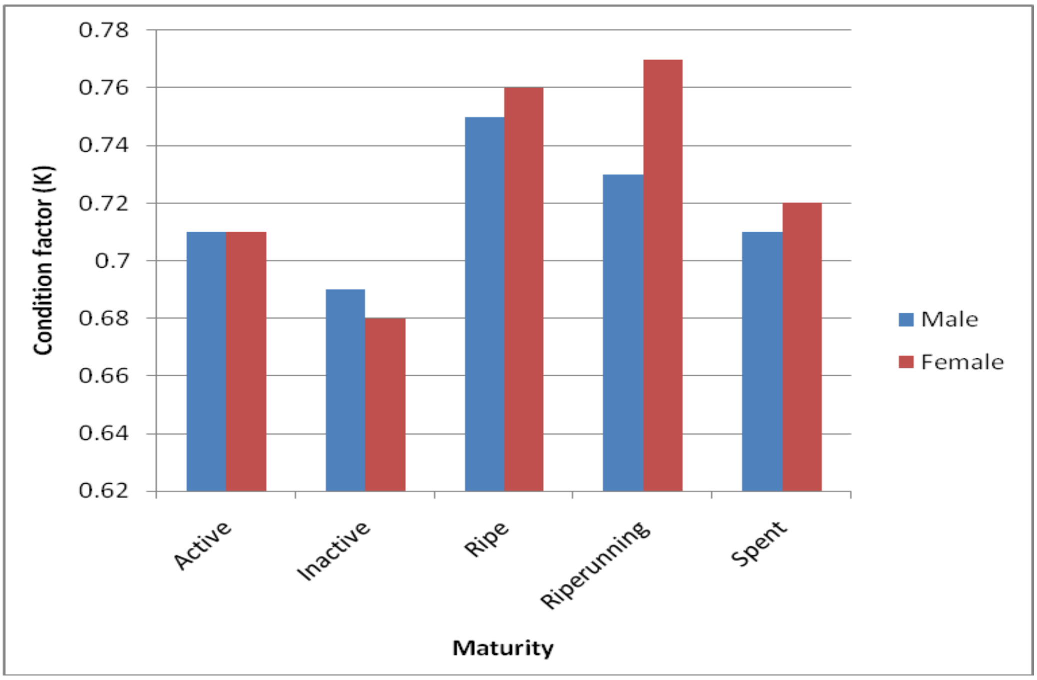

Figure 6: Relationship between the condition factor and maturity stages between males and females.

There is no significant interaction between sex and maturity (p = 0.096). In the figure above it is observed that condition factor shows a non-significant behavioural pattern across maturity stages for the two sexes. Males have a lower condition factor as compared to the females for all maturity stages except for the active and inactive stage. The maturity stage ripe and running recorded the highest K values in females (0.77) and ripe in males (0.73). The lowest K values in both males (0.69) and females (0.68) are at the maturity stage inactive.

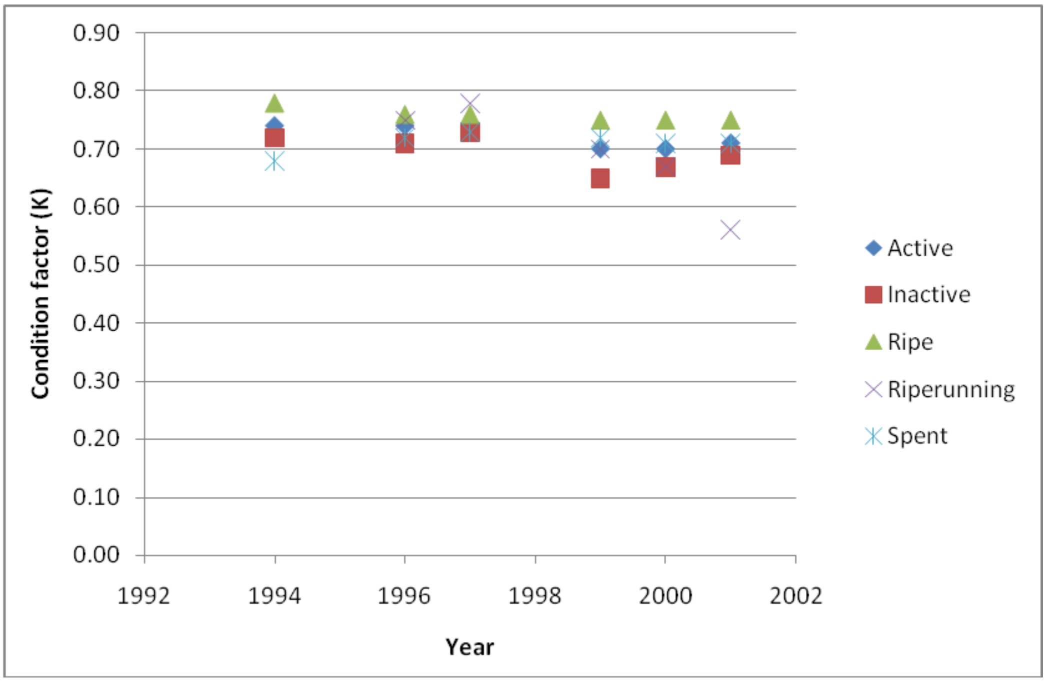

Figure 7: Relationship between the condition factor and maturity stages over the years.

There is a significant interaction between year and maturity ($p<0.001$). In the figure above condition factor changes significantly across the years for the different stages of maturity. The maturity stages ripe and ripe and running had the highest K values (0.78) in 1994 and 1997 respectively. The maturity stage ripe and running also recorded the lowest K value (0.56) in 2001. Most of the maturity stages show a constant trend in K values over the years.

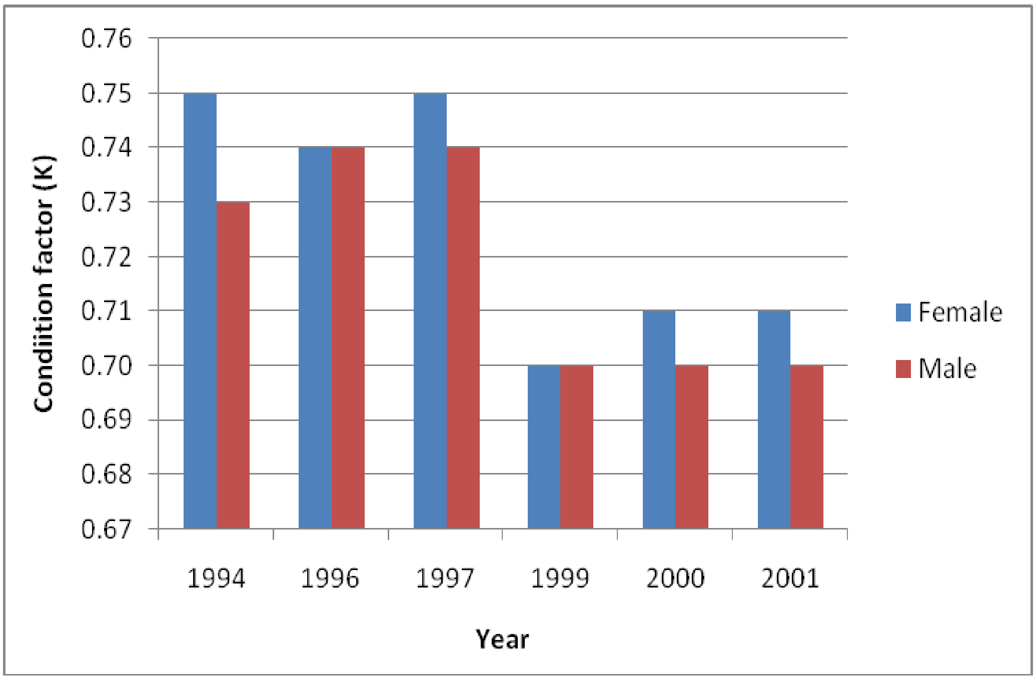

Figure 8: Relationship between condition factor and sex over the years

There is no significant interaction between sex and years (p=0.194). In the figure above condition factor shows a non-significant behavioural pattern across the different sexes over the years. Generally females have a higher condition factor but in 1996, 1997 and1999 it remained the same in both sexes. The highest K values were observed in 1994 and 1997 in females (0.75) and 1996 and 1997 in males (0.74).

CHAPTER FOUR

DISCUSSION, CONCLUSION, CONTRIBUTION TO KOWLEDGE AND STUDY LIMMITATION

4.1. Discussion

This study was designed to determine the changes in condition factor of *M. capensis* and *M. paradoxus* over the period 1994-2001. At the same time biological factors (maturity and sex), were also measured to test whether or not they influenced the condition factor of *M. capensis* and *M. paradoxus* respectively. The results showed a significant interaction between condition factor and years in both species ($p<0.001$).

Fish populations display changes in average condition factor over time (Weatherley, 1972), this is observed in figure 1 and 2, which clearly show that there are changes in condition factor over time in both species. The condition factor for *M. capensis* was increasing well for the period 1994-1997 (Fig. 1) and that of *M. paradoxus* remained relatively high during the same period of time (Fig. 2) this could have been due to the fish making better use of its food sources and favorable conditions that the fish must have been experiencing. The fish during these years can be described as fit and in good health as stated by Saliu *et al.*, (2007) and as having a good accumulation of fat and gonadal development. Condition factor decreases with increases in length (Fagade, 1979), therefore it is safe to say that this years had heavier fish which can also help explain why they are in a good condition. Decreases in condition factor in the period 1999-2001 in both species may have been due to unfavorable conditions in the aquatic environment.

The results obtained from the study indicate that maturity influenced the condition factor in both species. Vazzoler and Vazzoler, (1983) stated that there is normally a gradual increase in condition factor during the reproductive period and normalization occurs immediately afterwards. It is observed that maturity stage 4 (ripe and running) is associated with high K values in both species (Fig. 4 7). However for *M. paradoxus* maturity stage 3 (ripe) was also associated with high K values (Fig. 7). For *M. capensis* maturity stage 2 (inactive) was also associated with high K values (Fig. 4). The increases in the K value at these maturity stages can be due to varies reasons, one being the consumption of fat reserves during the spawning period (Vazzoler and Vazzoler, 1983). The low values in condition factor at the other stages can be due to very high metabolic rates at the start of the spawning period (Vazzoler and Vazzoler, 1983). Condition factor is affected by gonad maturity stage as stated by Parrish and Mallicoate, (1995); this was also evident in results obtained for this two species.

Another factor that was also analyzed in this study is sex, in order to determine its influence on the condition factor of *M. capensis* and *M. paradoxus*. Results showed that there is a significant interaction between sex and condition factor over the years for *M. capensis* (p = 0.005), while in *M. paradoxus* there where no significant differences (p = 0.194). However, the females in both species exhibited higher K values as compared to the males. According to Kainge *et al*., (2009), K is influenced by developmental stage of the reproductive organs. Usually, females have bigger gonads that contribute to fish weight than males, especially during spawning periods.

4.2. Conclusion

This study only represents the events that may occur in summer for the period 1994-2001. The results of this study support the results obtained by other authors on the same subject. It helped depict if there have been significant changes in condition factor in both *M. capensis* and *M. paradoxus* over the period 1994-2001. Furthermore it determined that maturity influenced the condition factor of both species significantly and sex only for *M. capensis* over the years. Irrespective of the increases and decreases in condition factor it is safe to say that both species were in good condition over the period 1994-2001 although it appears to be recently deteriorating.

4.3. Contribution to Knowledge

This study has contributed to the knowledge of the analyser in the sense that it allowed a better understanding of condition factor and its importance and it also exposed investigator to research design, data collection, analysis and interpretation.

4.4. Limitations of the study

Lack of environmental data at the exact areas where the fish was collected prevented condition factor from being related to environmental conditions.

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APPENDICES

Appendix I: The different microscopic maturity stage classifications in both male and female hake species.

The table below shows the different microscopic maturity stage classifications in both male and female hake species that is currently used in the field (Botha, 1986) as cited by Kainge, (2002).

Stage	Females	Males
1	Inactive: Gonads small, slender, transparent, no visible signs of the eggs.	Inactive: Gonads very small, slender, transparent, ribbon like and unlobed
2	Active: Gonads larger and filling with small, pink-orange, opaque and visible eggs	Active: Larger and distended, white opaque, typically lobed
3	Ripe: Gonads very large in relation to fish size, distended and filled with clearly visible opaque eggs-some eggs already translucent; colour of ovaries bright orange to deep pink	Ripe: gonads very large in relation to fish size, white opaque, distended with sperm, with pronounced lobes
4	Ripe and running: Translucent eggs can be extruded through the cloaca with slight abdominal pressure	Ripe and running: Gonads very large and distended, with sperm flowing spontaneously
5	Spent: Gonads visually completely empty, but large, flabby, prominently veined and often bloodshot	Spent: Gonads very large, lobed, flabby but not distended

Appendix II: Chi-square test results for *M. capensis*

Fixed term	Wald statistic	d.f.	Wald/d.f.	Chi-sq prob
Year	221.65	5	44.33	<0.001
Sex	5.93	1	5.93	0.015
Maturity	13.99	4	3.50	0.007
Year.Sex	16.77	5	3.35	0.005
Year.Maturity	75.95	20	3.80	<0.001
Sex.Maturity	0.67	4	0.17	0.955
Year.Sex.Maturity	19.80	20	0.99	0.471

Appendix III: Chi-square test results for *M. paradoxus*

Fixed term	Wald statistic	d.f.	Wald/d.f.	Chi-sq prob
Year	219.56	5	43.91	<0.001
Sex	4.18	1	4.18	0.041
Maturity	332.55	4	83.14	0.001
Year.Sex	7.38	5	1.48	0.194
Year.Maturity	56.73	19	2.99	<0.001
Sex.Maturity	7.87	4	1.97	0.096
Year.Sex.Maturity	37.77	17	2.22	0.003