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ASPECTS OF THE REPRODUCTIVE BIOLOGY AND FISHERY OF THE BLUE  
MARBLED PARROT FISH *LEPTOSCARUS VAIGIENSIS* (QUOY AND  
GAIMARDI, 1824) IN KENYA SHALLOW INSHORE WATERS

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## DECLARATION

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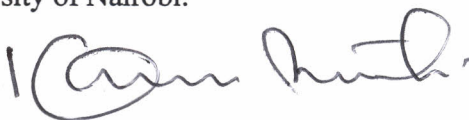
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## DEDICATION

This thesis is dedicated to my late sister PERIS MUTHONI who gave me a lot of support and encouragement. This work is in memory of her.

## ACKNOWLEDGEMENT

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I wish to express my sincere gratitude to all those people who made this work possible. Special thanks go to my Supervisor Dr. M. J. Ntiba whose interest, encouragement and criticism made this thesis what it is. I would also wish to thank Dr. Ezekiel Okemwa, Director of Kenya Marine and Fisheries Research Institute who granted me study leave and encouraged me throughout the study period. Thanks go to Dr. J. M. Kazungu, the EEC STD 3 project coordinator, who accorded me logistical support throughout the study. His enthusiasm and interest in this work is highly acknowledged. Messers Boaz Orembo, Rashid Anam, C. Gonda and Kuria helped me in field and laboratory. I wish to personally thank them for their support. Many thanks also go to my wife Esther Warao and loving daughter Susan Kagendo for their patience and understanding. I would also like to pay tribute to my parents who brought me to the person I am today. Thanks also are due to all those people, who are not mentioned individually but contributed significantly in making sure that the work was completed successfully. Phyllis Mutere tirelessly and meticulously typed this thesis.

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**ABSTRACT**

The reproductive biology, growth parameters, mortalities and exploitation rate of *Leptoscarus vaigiensis* were investigated in a shallow inshore lagoon in the south coast of Kenya. The overall male to female sex ratio was 1:1.4. Statistical analysis by Chi-square showed that there is no significant difference from the 1:1 ratio ( $P > 0.05$ ). The monthly male to female sex ratio did not show any consistent trend that could have been related to the reproductive cycle.

Oocyte- size-frequency distribution coupled with histological analysis of the ovary indicated unimodal distribution of oocytes in stages 1,2,3 and 6. A bimodal distribution of oocytes is evident in ovaries at maturity stages 4 and 5. The bimodal distribution included one mode of mature oocytes and the other mode made of immature oocytes. These modes were not completely separated from the immature stock, and some intermediate oocytes were evident between the two modes. However, these oocytes contained cytoplasmic vacuoles meaning that such oocyte will mature and will be spawned together with the large sized ones. There is no progression of the mature oocytes in ovaries in stage 6 of sexual maturity. At this stage, the ovaries contained only immature stock of oocytes, with few degenerating oocytes. It was inferred that an individual fish probably spawns only once during the year of study. However, the GSI and  $K_n$  calculated for the fish population, showed that there were two peak spawning times during the year of study, one between March and June with a peak in April, and the other between November and December. These months fall within the two intermonsoon periods that are experienced in the East African region. There is therefore a possibility

that there are two breeding populations of *L. vaigiensis* at the area of study with each having peak spawning at a specific intermonsoon period.

In the present study, the potential fecundity of *L. vaigiensis* ranged between 186,000 to 1,806,000 eggs. A mean potential fecundity of 674,000 eggs per female was determined. Fecundity was significantly related to body weight and body length. The fish became sexually mature at 16.8 cm, total length.

The length-weight relationships calculated for males and females were not significantly different (ANCOVA:  $F = 14.9$ ;  $P = 0.68$ ) and a single regression was calculated which adequately described the length-weight relationship of this species. The relationship obtained was  $\text{Log}_{10} W = 2.86 \text{ Log}_{10} L - 1.595$ . Growth and mortalities were determined from length frequency data. The growth constants were estimated as  $K = 1.5$  per year,  $L_{\infty} = 28.9$  cm and  $\phi^1 = 3.10$ . Natural mortality was estimated from Pauly's empirical formula (Pauly 1980) which was found to be 2.30. Total ( $Z$ ) and fishing mortality ( $F$ ) were estimated as 3.52 and 1.15 respectively. The estimated exploitation rate ( $F/Z$ ) estimated to be 0.33 is below the optimum exploitation rate of 0.5. This could be an indication that the stock is not optimally exploited, though growth overfishing was deduced to be taking place since the recruitment into the fishery occurs when the fish is only 11.7 cm (total length) and the fish seems to mature at 16.8 cm (total length).

# CHAPTER 1

## GENERAL INTRODUCTION

### 1.0 Introduction

The demersal marine fishery in Kenya is concentrated in the shallow part of the continental shelf, close to the shore and the outer edge of the continental shelf. This resource is commonly exploited by the artisanal fishermen and a small industrial fleet of commercial trawlers, which is found in the northern Kenya banks around the Malindi.

The main fishing along the Kenya coast is mainly artisanal and supports approximately 6,500 fishermen. Artisanal fishermen employ the following gears of fishing; lines, beach seines, gillnets, bottom lines, local traps, diving for lobsters and in some cases spear-fishing. Fishermen use canoes and outrigger boats that may be powered by sails, oars or engines.

The Kenyan coastline is characterized by shallow (< 5 m deep, relative to extreme lowest spring tide) reef lagoons consisting of a body of water enclosed by the fringing reef and land backing. These coastal marine systems are usually oriented parallel to the coast yet separated from the ocean by one or more restricted inlets which remain open at least intermittently (Kirugara, 1997). Along the entire coastline of Kenya, the artisanal fishing activities takes place in these shallow reef lagoons (de Souza, 1988). The simple gears and crafts used by artisanal fishermen limits their operations to the shallow waters.

Eighty per cent of the total marine fish landed by the artisanal fishermen is made up of the fish families' scaridae, nemipteridae, siganidae, lethrinidae and lutjanidae. The

scaridae (parrotfishes) contribute significantly to the total landings of the artisanal fisherfolks as it is the third most important catch (in terms of weight). The significant contribution of parrot fishes to the total marine and coastal fish landings can clearly be demonstrated by the fish landings statistics collected by the Kenya Department of Fisheries over the years. In 1995, for example, 172 metric tones of parrotfishes were landed, out of a total of 6700 metric tones. In 1996 and 1997, 187 and 166 metric tones of parrot fishes were landed out of a total landing of 7074 and 6878 metric tones respectively (Kenya Fisheries Department, 1995, 1996 & 1997). In 1995, a total of 157 metric tones of fish were landed at the Msambweni landing site. Out of this, parrotfishes contributed 8.6 metric tones (Kenya Fisheries Department, 1995). Msambweni fish landing site was my sampling station.

Coral reefs and coastal lagoon fishes are more vulnerable to over exploitation. Their vulnerability can be attributed to certain life history traits of reef fishes living in such environments and presumed trophodynamics characteristics of coral reefs (Russ, 1991). Fishes living in these environments are usually restricted to their habitats with limited ranges of habitat and depth preferences. The coral reef fishes are often territorial or have small home ranges (Munro & Williams, 1985). It has been suggested that, despite the high primary productivity and the high standing stocks of reef fishes (Russ, 1984), the harvestable component of the stock is quite limited and can be exhausted quite rapidly by intensive exploitation (Stevenson & Marshall, 1974).

The blue marbled parrotfish, *Leptoscarus vaigiensis*, is abundant in the shallow lagoons of seagrass beds, coral reefs and along the rocky shores. These areas are the operation zones of artisanal fishery because they can be accessed easily. This, therefore, does not

only make *L. vaigiensis* an important catch of the artisanal fishermen but also highly susceptible to overexploitation.

Recruitment and growth are the two most important factors responsible of maintaining a fish stock at equilibrium if the physico-chemical factors remain favorable. The factors, which are responsible for recruitment, include mating success, availability of a spawning stock, fecundity and recruitment success. These factors pertain to the reproductive biology of any stock. Recruitment and growth maintains a stock by compensating for the losses through natural and fishing mortalities. In cases where the total mortality is more than the self-generating capacity of the fish stock then eventual depletion of the stock will occur. In many cases, excessive fishing is the main cause of this. Excessive fishing can deplete the population or stock of a given fish species, disrupt the marine ecosystem and damage a coastal ecosystem overall economy (Johness, 1992).

In order to guard against this kind of scenario, recruitment and growth should be well understood for a given stock. Unfortunately, studies on fish stock, reproduction biology, growth and mortality for many tropical fishes are still few. Such studies are mostly concentrated in the temperate waters (Abu Hekima, 1984; Cyrus & Blaber, 1984). For judicious fishery management policies to be formulated there is need to collect sufficient biological data, which allows for the characterisation of the exploited population of fish. This information is also lacking for *L. vaigiensis*, especially in Kenya where very scanty information exists.

## 1.2 Literature review

Smith and Heemstra (1986) reports that members of the family scaridae found in the waters of the Indo Pacific Ocean consists of thirteen species. These are *Scarus festirus*, *Scarus ghobban*, *Scarus cyanescens*, *Scarus russelli*, *Scarus scaber*, *Scarus sordidus*, *Scarus tricolor*, *Calatomous spinidens*, *Hipposcarus harid*, *Scarus atrehumula*, *Scarus caudofasciatus* and *Leptoscarus vaigiensis*. These species belong to two genera; sparisomatinae and scarinae (Bruce and Randall 1985). *Leptoscarus vaigiensis* is listed in the genera sparomatinae.

Many workers who have worked on this family have concentrated their interest on the color changes and sex reversal (Robertson, 1982; Robertson *et al.*; 1982, Bruce & Randall, 1985). They have observed that in the parrotfishes and wrasses sex reversal occurs. In this condition, some males are derived from females and are regarded as secondary males, and those males which do not pass through a female phase and are born as males are known as primary males. The advantages and disadvantages of sex reversal have has been discussed on by various authors (Robertson *et al.* 1982; Smith and Heemstra, 1986; Bruce & Randall, 1985). While working on the sexual behavior of scarids and wrasses the authors concluded that among all the Scarids, it is only *L. vaigiensis* which does not undergo sex reversal. The considerable interest in scarid sexual behavior and classification of sexes could have been motivated by the need to understand this behavior because of the great effect sex reversal has on growth and exploitation of such population. Sex change results with some individuals concentrating more of their energy on reproduction and thus achieving very limited growth. This population behavior offers a great challenge on the best way to exploit such a resource.

For example, a question may arise pertaining to the minimum size of fish recruiting into the fishery while there is a differential growth because of a reproductive strategy. Since males in species that tend to exhibit sex reversal are larger, older and less than the females, fishing may selectively remove more males than females.

Although in the temperate waters, where large amount of data are available on the reproduction biology of the teleost fishes, this unfortunately is not the case in the tropics (Ntiba & Jaccarini, 1990). Data on the reproduction of tropical fish is scanty and limited and a large number of the tropical water fishes remain unstudied. Reproduction and recruitment are important parameters of any given fish stock. The two are intertwined in such a way that failure of a stock to reproduce leads to recruitment failure and the stock may either diminish or even collapse. In cases where overfishing is experienced, there is a decline in the average size of fish and disappearance of large specimens. This in effect reduces the stock reproductive potential and so fewer and fewer fish are available for fishing from one year to the next. One method of detecting whether this phenomenon is happening in fishery is to look at the minimum size at sexual maturity, which in effect will show two things. First, it will indicate whether the fish is maturing earlier, and secondly whether fishing mortality is focussed on fishes which have not attained sexual maturity leading to growth overfishing. In other cases some fish spawn on restricted areas and forms heavy concentrations in the spawning area. Knowledge of such behaviour is important for exploitation and conservation purposes.

An estimate of the number of mature fish in a particular population in an area can also be predicted when the following are known: (1) fecundity/length or weight relationship, (2) mean length or weight of mature females, (3) sex ratio and (4) the total egg production



for the season. If the weight/length relationship is also known, the population size in number can be converted to weight using this procedure from which then an estimate of the population can be made (Cushing, 1957).

Although information on reproduction and ecology of a given fish offers the basic information required for its proper utilisation and exploitation, little of this is known for *L. vaigiensis* in the Kenyan waters. Some aspects of reproduction of *L. vaigiensis* have been reported. This includes work carried out at the Aldabra Atoll in the granitic Seychelles and on the coast of Kenya (Robertson et al. 1982) and at the coast of Tanzania (Rubindamayugi, 1983). The study of Robertson et al (1982), on the reproductive behaviour of *L. vaigiensis* concentrated on the spawning behaviour and it covered only a part of the year. Robertson et al (1982) observed pair and group spawning in the shallow waters above sea grass flats during the falling tide and spawning occurring in September through November. Rubindamayugi (1983) carried out a study on the biology and the fishery potential of *L. vaigiensis* in Tanzania. He observed that there was high occurrence of fish in ripening, ripe and spent gonadal maturity conditions during April to September, which would suggest that the majority of fish spawn during this period with a peak in June/July. From the ova-diameter frequency distribution *L. vaigiensis* seems to have one extended spawning season during the Southeast monsoon. However, this study failed to carry out a detailed analysis of the reproductive organs, since it is only based on gonadic index and the examination of ova diameters distribution which are only gross indicators of reproductive activity of a fish species. The methods employed by Rubindamayugi (1983) are probably not accurate enough to establish the stage of gonadal development, or to detect subtle differences between gonads and failed to use histological analysis

which would have permitted the correct determination of gonad development and maturation especially in the case of multiple spawners (Hunter *et al.*, 1985).

Collins and Bell (1991) studied the aspects of spawning of scarid fishes at Enewetak Atoll, Marshall Islands and observed that many species of scarids spawn throughout the year. The data used to draw this conclusion was limited and, unfortunately, did not include *L. vaigiensis*. In Jamaican reefs, spawning of scarids appears to be confined to the period January – June with a February – March peak (Lowe – McConnell, 1979). However, Sale (1978) pointed out that fishes with pelagic eggs such as labrids, scarids and acanthurids are in many cases multiple spawners with extended spawning periods, extending sometimes throughout the year. Again *L. vaigiensis* was not one of the species studied to form this general conclusion on scarids reproductive biology.

In fishery biology, the knowledge of age, growth, and mortality are used to determine the effects of fishing on stocks, the efficacy of management policies, to understand life history events and to maximise yield while still ensuring the future of the resource (Johness, 1992). Growth rate data are essential for predicting estimates, identification of exploitable species, description of the population structure, determination of the timing and frequency of spawning, individual and population growth responses to environmental changes such as population density or habitat alteration and annual or short term variation in recruitment success. These data, whether of a basic nature or directly applicable to fishery statistics, contribute to the understanding of the biology of fishes. Furthermore, in a more applied sense we can extend this age and growth information to examine past responses and predict future changes in relation to a variety of exploitation schemes

(Brothers, 1980). Age specific parameters such as growth rate, mortality and fecundity are therefore central for fishery analysis using dynamic population models. Unfortunately, comparatively little of these parameters is known for the tropical fishes (Pauly, 1981).

#### The length based :-

There are basically three broad methods of studying age and growth of fishes. These include: (1) direct measurement of growth in certain individuals and extrapolating to the population for example: mark recapture studies or growth in confinement; (2) statistical approach for example: length frequency analysis; and (3) ageing on the basis of regular periodic markers in hard structures (usually calcified), such as scales, otoliths and bones.

#### from length :-

The use of anatomical method for ageing fish gives precise results and has been widely applied. In tropics, this method is faced with some weakness. The most widely recognised factor is that in the tropics, fish live in environments, which on the average show less seasonal variation in such biotic and abiotic factors such as temperature, salinity and productivity. This makes it difficult to recognise zones on scales or otoliths reflecting such variations. The zones reflecting these variations on scales and otoliths are either poorly developed or even absent. In such cases great care is required to count the rings since there can be a substantial amount of subjectivity involved in discriminating what are considered to be "true" time markers and also to validate the results.

#### coral reef :-

Tag recapture studies where the calcified structures themselves are also marked using chemicals such as tetracycline are powerful tools of studying age and growth, but requires a lot of effort in time, energy and money. This method as well as that of holding

fish in captivity require relatively long periods of time before results are meaningful, and they are also subject to the various biases introduced by tagging and/or artificial confinement.

The length based methods rely on catch statistics and under the right circumstances, form the basis for age and growth analysis (Brothers, 1980). Generally variability in recruitment, growth rate, differential fishing effort could all be sources of bias, but the application of length-frequency approach for growth related analysis for the estimation of mortality do not lead to fatal misinterpretation of the parameter estimated (Pauly & Morgan, 1987). Unlike the other methods, it is easier to collect data for growth estimates from length frequency analysis and also the method is less complicated and requires less sophisticated equipments for its analysis. It is also possible to estimate other population parameters such as mortality and recruitment. These factors make this method more versatile and to have a wider application in stock assessment. For these reasons, the length frequency method was chosen for the estimation of the growth and mortalities of *L. vaigiensis* in this study.

The literature search showed that there is scanty data on the growth rates of the scarid fishes. Munro and Williams (1985) looked at the growth rate of *sparisoma viride* in the *Virgin Island and Kitalong and Dalzell (1994) did an assessment of the status of inshore coral reef fish stocks in Palau and gave growth estimates of *Bolbometopon muricatum* and *Hipposcarus longiceps*. The only available estimate of the growth rate of *L. vaigiensis* is that given by Benno (1992), in the coastal waters of Tanzania. In order to assess the fishing pressure in any given area, it is necessary to estimate growth and*

mortality. Growth and mortalities estimates indicate the fishing pressure in a given area for a specific stock of fish. Such information is lacking for our local stock of *L. vaigiensis*.

This study was to

### 1.3 Aims and objectives

The main aim of this study was to investigate the reproductive biology and fishery of *L. vaigiensis* in order to give descriptive biological information necessary for the proper management of this species. The following objectives were set to achieve this:

- (1) To define the gonadal development, spawning times and frequency of spawning in *L. vaigiensis*
- (2) To define the population structure of *L. vaigiensis*
- (3) To estimate the fecundity of *L. vaigiensis*
- (4) To estimate growth and mortality parameters of *L. vaigiensis*.
- (5) To estimate the exploitation rates of *L. vaigiensis*

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### 2.0 GENERAL MATERIALS AND METHODS

#### 2.1 Study area

This study was carried out at Msambweni Lagoon located around at 4°25'S, 39°30'E on the southern Kenyan coast, 50 km south of Mombasa island (Fig. 1). This area is a shallow lagoon with an expanse seagrass bed dominated by *Thalassia hemprichii* in association with *Cymodocea rotunda*; *C. serrulata* and *Halimeda opunter* and *Glacillera corticata*. The seaweed *Halimeda mucrolaba* and *Avrainvillea obscura* dominate from mean low water to approximately 1 meter depth, beyond which *Thalassodesdron ciliatum* is locally, replaced by *Enhalus acroides* (Kimani *et al.* 1996). To the north of the lagoon, there is a 6.61 km<sup>2</sup> of mangrove forest dominated by *Sonneratia alba* and *Rhizophora mucronata*. A continuous fringing reef, which is between 0.5 and 2 km offshore marks the end of the lagoon to the south.

The Msambweni lagoon is an unprotected area. Intensive and indiscriminate fishing activities are carried out by artisanal fisherfolks in this shallow lagoon and around the coral reef unlike in other lagoons which have been put under some management regimes in order to control the fishing activities. Such include; areas that have been designated as national marine parks, and national marine reserves. The marine parks and reserves are gazetted areas. Any type of fishing is not allowed in the marine parks whereas in the marine reserves only traditional fishing methods are allowed. Indiscriminate fishing is common in the unprotected reefs occasioned by the poor policing and surveillance capabilities. It is also common to find such area experiencing high fishing pressure that is mostly undocumented. Plans are underway by Kenya Wildlife service to gazette this area

as a protected Marine Reserve. It is therefore of great interest to check the state of fishery in this area. The information gathered in this study will form the baseline data that can be compared with information gathered after the creation of the marine reserve. Such comparison can be used to evaluate the success and benefits of the creation of a marine reserve in this area.

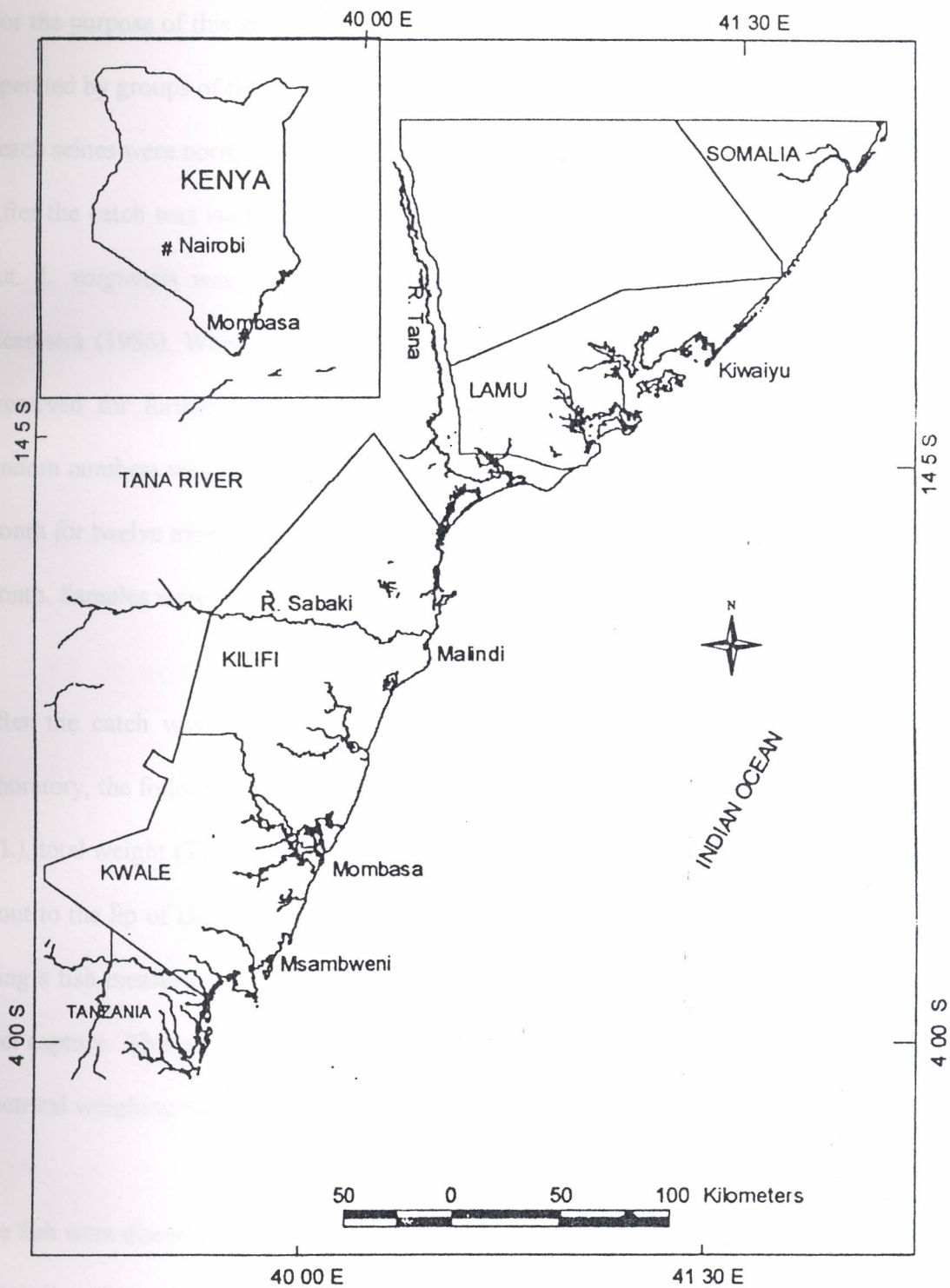


Figure 1. A map of the Kenyan coastline showing the location of Mswambweni (Map prepared by the UNEP database project, KMFRI Mombasa, 5<sup>th</sup> June 1998).



## 2.2 Fish samples collection

For the purpose of this study, the fish samples were collected from three boats that were operated by groups of fishermen using beach seines at Msambweni fish landing site. This beach seines were normally operated in the lagoons and around the coral reefs.

After the catch was landed from the three boats, all *Leptoscarus vaigiensis* were sorted out. *L. vaigiensis* was identified using the fishing identification guide of Smith and Heemstra (1986). When the number of *L. vaigiensis* landed was less than 50, all were preserved for further analysis. When the number exceeded 50, a sub-sample using random numbers was carried out. A minimum of fifty specimens was analysed in every month for twelve months. Sampling was done twice per month at mid and the end of the month. Samples were collected from January to December 1995.

### 2.3.2 Results

After the catch was sorted out, the specimens were taken to the laboratory. In the laboratory, the following general measurements were taken; this included the total length (TL), total weight (TWT), sex and maturity stage. TL was taken as the distance from the snout to the lip of the caudal fin. The measurement was recorded to the nearest 0.1 cm using a fish measuring board. TWT was recorded as wet weight of the fish immediately after capture. This parameter was recorded to the nearest 0.01 grams using a "Sartorius" electrical weighing balance.

The fish were dissected, sexed and the gonads assigned to a maturity stage determined by inspection of macroscopic features. The whole gonad was then weighed to the nearest 0.01 gram on a "sartorius" electrical weighing balance. For the ovary, one lobe was weighed and preserved in Gilson's fluid for oocyte counts and the other was preserved in

Bouin's fixative for a period of twenty four hours and then transferred to 70% ethanol. This material was used for histological analyses of the internal organisation of the ovary.

## **2.3.0 Physical and chemical parameters**

### **2.3.1 Materials and methods**

Measured physical- chemical parameters were water salinity and temperature. These measurements determined in the field each time the fish samples were collected. Salinity was determined using an Atago hand held refractometer. Temperature was measured using a temperature- salinity Sond. Rainfall data was gathered from Msambweni Meteorological Station.

### **2.3.2 Results**

The physical chemical parameters at the sampling area are shown in figure 2. The monthly rainfall for this area is shown in figure 3. Salinity and temperature fluctuates little through the year. There are two rainfall peaks in this area, a major one occurring in April-May and a minor one in October-November.

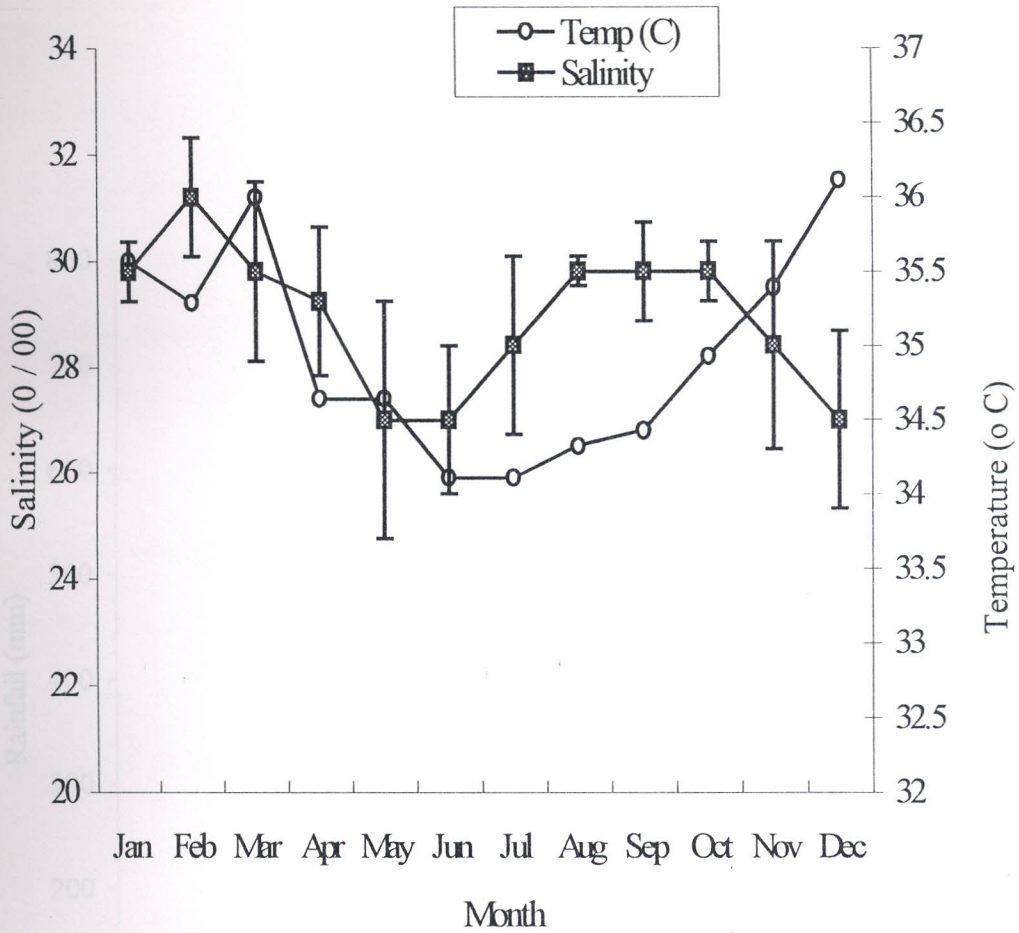


Figure 2. The mean monthly temperature and salinity at Msambweni, south coast of Kenya.

### 3.5.3 Discussion

Tropical savanna ecosystems have

but in East Africa some

ecology

comparisons

monsoon

between

run-off

low

The inter-

The post-

periods

experienced

Nitrogen being the

period.

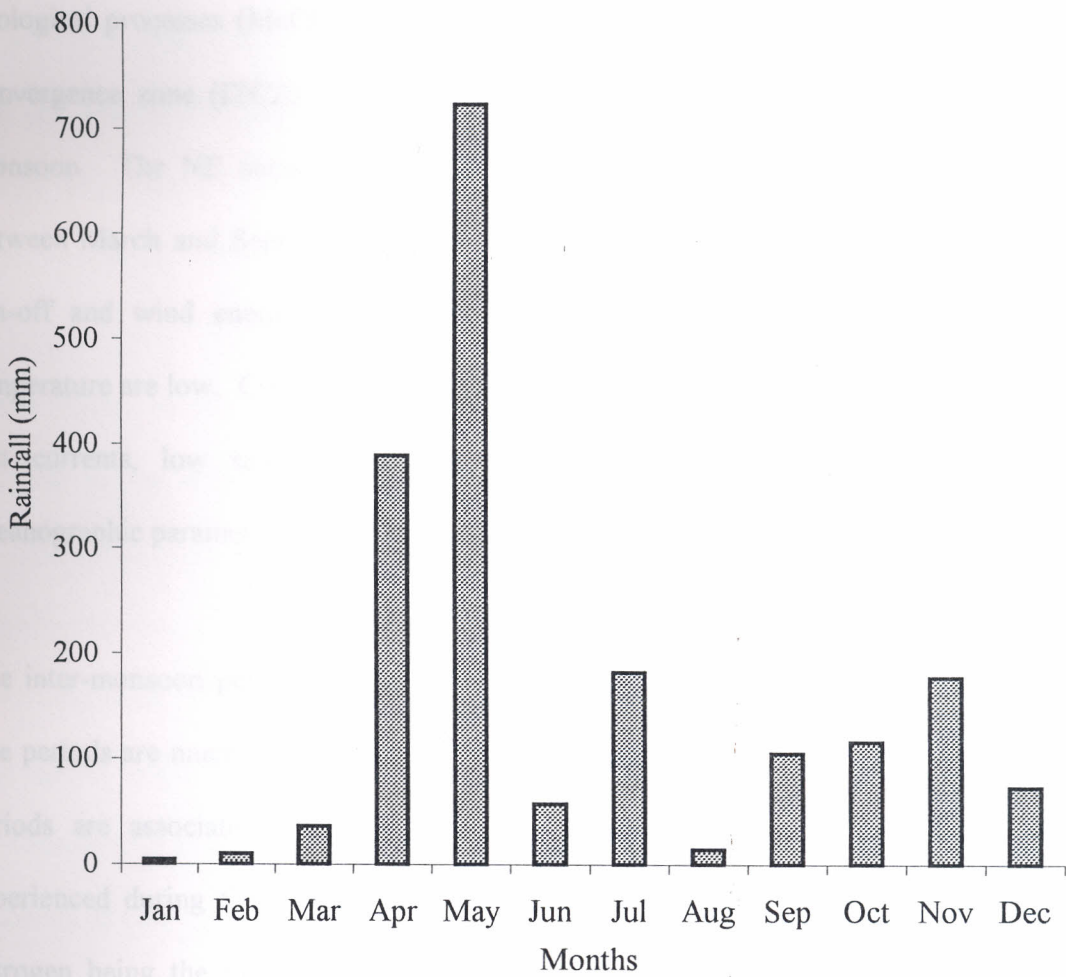


Figure 3. Monthly rainfall in Msambweni area. Source: Msambweni Meteorological Station, Kenya Meteorological Department

### 2.3.3 Discussion

Tropical marine ecosystems have been noted for minor seasonal changes or aseasonality but in East Africa some large seasonal changes occur which in turn control many ecological processes (McClanahan, 1988). The annual migrations of the inter-tropical convergence zone (ITCZ) create two seasons; the northeast (NE) and southeast (SE) monsoon. The NE occurs between September and March and SE monsoon occurs between March and September. High cloud cover, rainfall, river discharge, terrestrial run-off and wind energy characterize the SE monsoon while solar insolation and temperature are low. Cool water, deep thermocline, high water mixing and wave energy, fast currents, low salinity and high phosphorous characterize the SE monsoon oceanographic parameters. These parameters are reversed during the NE monsoon.

The inter-monsoon periods are basically transitional periods between the two systems. The periods are much calmer since the wind is changing directions. The intermonsoon periods are associated with the two rainy seasons. The long and short rains are experienced during the periods, March – July and October – November respectively. Nitrogen being the major source of nutrients is also high during the inter-monsoon period.

## CHAPTER III

### 3.0 LENGTH WEIGHT RELATIONSHIP AND CONDITION FACTOR

#### 3.1 Introduction

According to Le Cren (1957), the analysis of length – weight relationship data is usually done with two objectives. First is to describe mathematically the relationship between length and weight. Secondly is to measure the variation from the expected weight for length of individual fish or relevant groups of individuals as an indication of fatness, general “well being” and gonad development.

In many cases, lengths of fish are easier to measure than weight. It is therefore convenient to be able to determine weight where only lengths are known and occasionally it is more convenient to reverse this process. It is obviously desirable to have some expression for the relationship of weight and length in fish. The change in the relative magnitude of these variables implies growth. In most fishes, relationships of weight against length will reveal a power curve of exponential growth whose slope may differ considerably amongst species, populations, or by seasons for the same population (Weatherley & Gill 1987).

Another important and, undeniably, more useful derivative of growth in fish population is the condition factor (K). Condition factor is applied as a rigorous but general term for length weight relationship as a measure of variation from the expected weight for length of individual fish or groups of individual. It is used as an indication of normal seasonal fluctuations in their metabolic balance, and also in the pattern of maturation and subsequent release of reproductive products. In many species of fish

significant permanent sex differences in K occur after maturity (Weatherley & Gill, 1987).

According to Le Gren (1957), length is a linear measure and weight is a measure of volume, the relationship between length and weight can be expressed by the hypothetical cube law of the form;

$$W = CL^3 \dots\dots\dots 1$$

Where,

W = weight of fish,

L = the length of fish and,

C = a constant of the equation

Le Cren (1957) noted that length weight relationship in fish can be expressed by the following equation;

$$W = a L^n \dots\dots\dots 2$$

Where,

W = weight of fish,

L = length of fish and,

n = a exponent of the equation

The length-weight relationship can be expressed graphically by plotting the logarithms of observed weights as a scatter diagram. The fish having the same relationship will tend to lie along a straight line, though with some scatter due to individual variation. Beverton and Holt ( 1957) noted that this line adequately represents the equation.

Where,

$$\text{Log}_{10}W = \text{log}_{10} a + b \text{ log}_{10} L \dots\dots\dots 3$$

b = is the slope of the line and,

$\text{Log}_{10} a =$  is the intercept of the equation

The equation of the line is computed by regression method of least squares. As long as the data from which length-weight relationship is calculated has not been subjected to any selection for weight against length, for example gill nets which select the fatter among the shorter fish and the thinner among the long fish, the relationship should adequately describe the length-weight relationship of the population.

In any material body there exists a linear relationship between the linear dimension of the body and weight. Walford (1932) showed that this relationship can be explained in the following equation;

$$K = W/L^3 \dots\dots\dots 4$$

Where,

K = condition factor

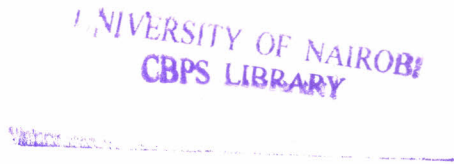
W = weight in grams

L = length in centimetres



Walford (1932) also showed this relationship can be explained by the following expression;

$$K = 100W/L^3 \dots\dots\dots 5$$



Relation 4 and 5 assume an ideal fish where  $W$  is approximately equal to  $L^3$ . However, Le Cren (1957) noted that in many instances the cube law fails to apply. Thus  $b \neq 3$  for a population, which, as a whole, will include a range of size classes. He therefore suggested that relative condition factor ( $K_n$ ) can be calculated for fish length-weight relationship which does not follow the cube law. This can be expressed as

$$K_n = W/W^o \dots\dots\dots 6$$

Where,

$W$  = observed weight, and

$W^o$  = expected weight

The expected weight of each individual fish was calculated following Equation 3.

$K_n$  is a measure of a deviation for given fish from the mean weight-for-length of its size group, section of a population, or species, whereas  $K$  is an individual deviation from a hypothetical ideal fish shape. Relative condition factor ( $K_n$ ) is therefore a better index to reflect changes in the fish population especially changes occurring due to breeding cycles. Relative condition factor ( $K_n$ ) was therefore used to reflect these changes in *L. vaigiensis*

## 3.1 MATERIALS AND METHODS

### 3.2.1 Length-Weight relationships

720 fishes were grouped into sexes and total lengths (cm) were used to determine length-weight relationship for the two sexes.

The length-weight relationship was calculated by regression method of least squares. To test whether there was a significant difference between the slopes of the two sexes, a test of equality of the two population correlation coefficients was carried out. An analysis of covariance (ANCOVA) showed homogeneity in the two correlation coefficients ( $P > 0.5$ ). The length-weight relationship of the population was therefore calculated using the pooled data.

Many growth models used in fish population dynamics assume the exponent 'b' of the length-weight relationship is equal to 3. The exponents calculated for the blue marbled parrotfish were therefore tested for significant different from 3 (test of isometry) following Pauly (1983). This is done by calculating a statistic ( $t^{\wedge}$ ) using the equation

$$t^{\wedge} = (SD_x / SD_y) (b - 3) / \sqrt{(1 - r^2) / (n - 2)} \dots \dots \dots 7$$

Where,

$SD_x$  = Standard deviation of  $\log_{10}$  of monthly lengths

$SD_y$  = Standard deviation of  $\log_{10}$  monthly weights

n = number of fish used in analysis and

$r^2$  = coefficient of determinations

Statistic ( $t^{\wedge}$ ) is significantly different from 3 if its value is greater than the tabulated value of  $t$  (in the  $t$ -table) at  $n-2$  degrees.

### 3.2.2 Relative Condition Factor ( $k_n$ )

$K_n$  was calculated for individual female and males and a mean calculated for every month following Equation 5.

### 3.3 RESULTS

The overall parabolic equation for all 720 length weight growth of *L. vaigiensis* (Fig. 4) is expressed as;

$$W = 0.025 L^{2.9} (r = 0.97; n = 720) \dots\dots\dots 8$$

The relationship of weight against length reveals a form close to the cube law of exponential growth.

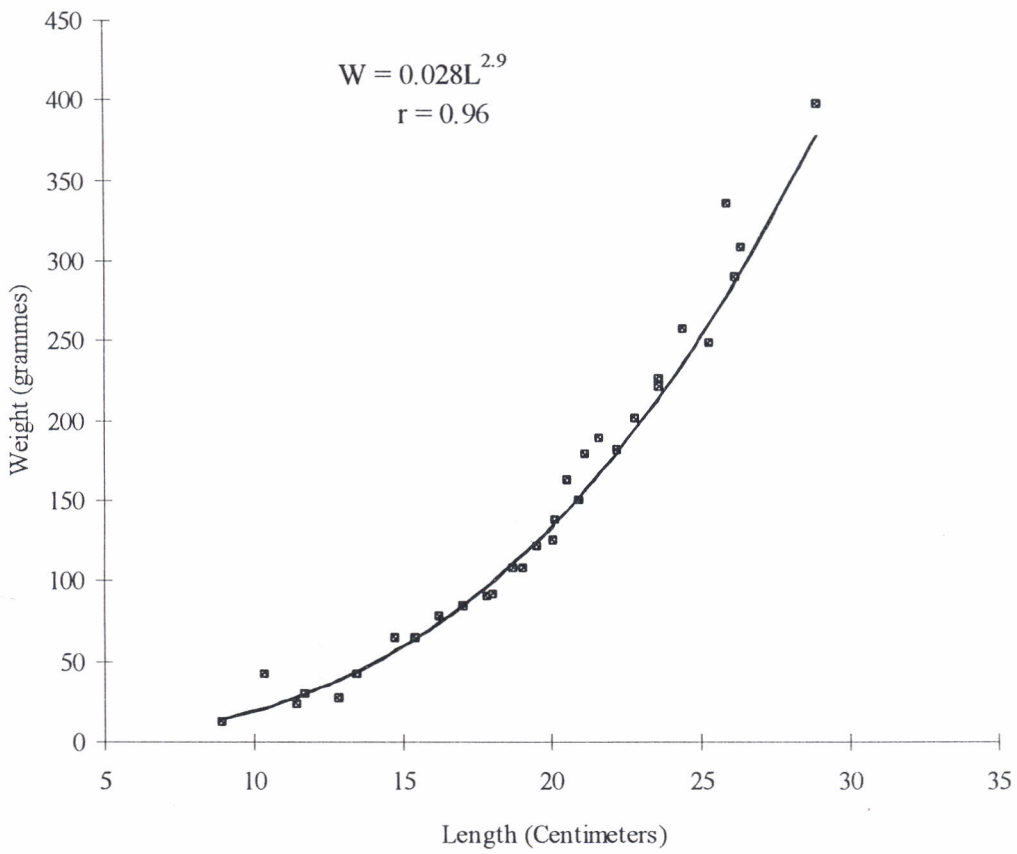


Figure 4. The length – weight relationship of *L. vaigiensis*

The logarithmic relationship was linear (fig 5), and explained by the equation;

$\text{Log}_{10} W = 2.86 \text{ log}_{10} L - 1.595$ ;  $r = 0.97$ ;  $\text{SE} = 0.05$ .....9

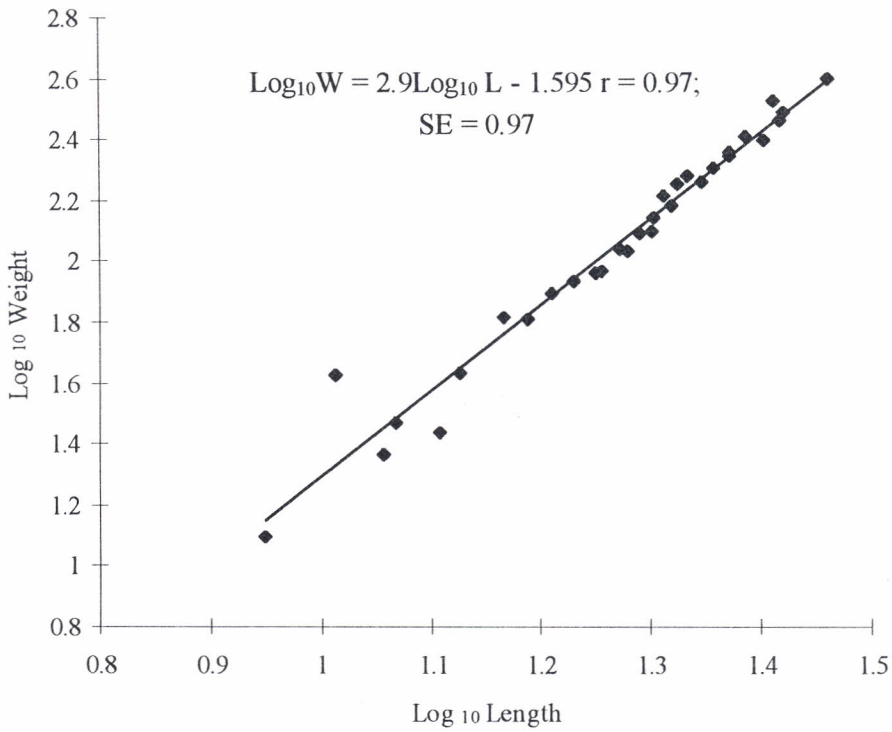


Figure 5. The linear Length –Weight relationship of *L. vaigiensis*

Test of isometry for both sexes and monthly length-weight relationship in given in Table

1.

**Table 1.** Test of isometry for the monthly length - weight regression for males and females. (\* Significant at 5% level)

Month (1995)	Sex	N	DF	b	r <sup>2</sup>	t <sup>^</sup>	t <sub>0.05, n-2</sub>
Jan.	M	10	8	2.66	0.97	1.39	2.306
	F	12	10	2.89	0.98	0.43	2.229
Feb.	M	27	25	2.99	0.99	0.09	2.060
	F	27	25	3.08	0.99	0.43	2.060
March	M	44	42	3.33	0.90	6.20*	2.018
	F	32	30	3.2	0.99	3.44*	2.042
Apr.	M	26	24	2.5	0.61	2.49*	2.064
	F	59	57	2.6	0.8	4.15*	2.001
May	M	16	14	2.52	0.8	1.54	2.145
	F	33	31	2.72	0.9	1.90	2.040
June	M	56	54	2.98	0.99	0.49	2.005
	F	62	60	2.78	0.8	1.31	2.000
July	M	9	7	2.62	0.99	1.95	2.365
	F	12	10	2.83	0.9	0.28	2.128
Aug.	M	12	10	2.92	0.8	0.22	2.228
	F	27	25	2.99	0.7	0.02	2.06
Sep.	M	32	30	2.66	0.68	0.65	2.042
	F	8	6	3.06	0.99	1.55	2.447
Oct.	M	27	25	3.1	0.98	1.12	2.06
	F	26	24	2.77	0.91	1.28	2.06
Nov.	M	12	10	2.85	0.99	1.70	2.22
	F	23	21	2.55	0.94	3.02*	2.08
Dec.	M	22	20	3.08	0.98	0.80	2.08
	F	13	11	3.06	0.98	0.47	2.2
	F	327	325	2.88	0.9	0.87	1.96
	M	286	284	2.89	0.93	0.9	1.96
Overall		613	611	2.86	0.92	1.41	1.9

All the correlations were highly significant ( $P < 0.05$ ) with coefficient of determination ranging from 70 to 99%. The mean exponent ( $b = 2.86$ ) was not significantly different from 3 for the female population ( $t^* = 0.87$ ;  $P > 0.05$ ) and for the male population ( $t^* = 0.9$ ,  $P > 0.05$ ). The monthly exponent were significantly greater than 3 in March for both sexes. It was significantly less than 3 in April for both sexes and in November for females.

The monthly trend of relative condition factor for the males and females of *L. vaigiensis* is given in fig. 6.

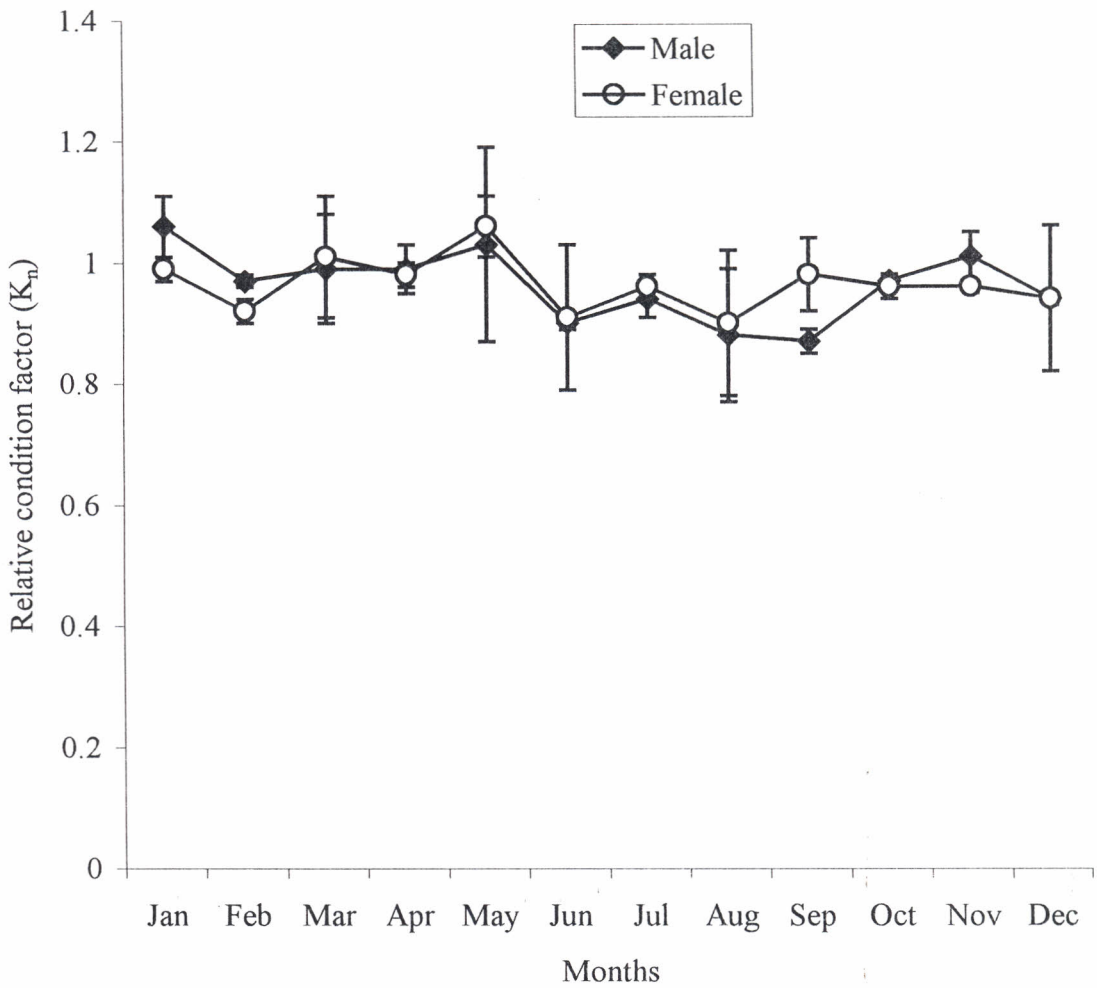


Figure 6. The mean monthly variation of relative condition factor in *L. vaigiensis* ( $\pm$  SEM)

Relative condition factor ( $K_n$ ) for both males and females followed the same general trend. There was an increase in March - May, a drop between June and August. Another minor increase was discernible between September and November.



### 3.4 Discussion

This study has shown that there is no significant difference in the length-weight relationship between males and females *L. vaigiensis* (ANCOVA:  $P > 0.05$ ) in the Kenya coastal waters. This regression can be described by a single equation of the form;

$$\text{Log}_{10}W = 2.86 \text{Log}_{10}L - 1.595$$

The mean exponent ( $b = 2.86$ ) is not significantly different from 3 ( $t^{\wedge} = 1.14$ ,  $df = 611$ ,  $P > 0.05$ ). The population of *L. vaigiensis* therefore exhibits an isometric length-weight relationship.

In many fishes, the slope lies between 2.5 and 4.0. (Lagler *et al.*, 1977). The positive allometry exhibited by the fish in the months of March could be as a result of the gonad accumulating material prior to spawning. The fish losing weight due to spawning may cause the negative allometry in April and November. However the current data can not be used to make a conclusive statement.

With the Windemere perch, *Perca fluviatilis*, the changes in the values  $K_n$  observed throughout the year in the mature males and females and immature fish were attributed to sexual changes i.e. change in gonad size (Le Cren, 1957). There was a massive and rapid loss in relative condition factor at spring spawning when large quantities of ova were released. Spring and summer peaks were evident just before spawning occurred. Ntiba and Jaccarini (1990) used the variation of relative condition to describe the spawning

pattern of *Siganus sutor* off the coastal waters of Kenya. In the current study the relative condition factor ranged between 0.9 to 1.05 throughout the year. This indicated that the fish was in good condition throughout the year, as a  $K_n$  value of around 1 is considered to reflect good condition in the fish. However, a relative increase in  $K_n$  was discernible in the period of March-May and another weaker one in September and November. Increase in  $K_n$  can be attributed to the sexual cycle, that is, change of gonad size (Le Cren 1957; Weatherly 1987). The increase in gonad weights in the period March-May and September-October reflects the maturation of the gonads. Likewise, a drop in  $K_n$  in June-August and February-March is a reflection of the gonad losing weight following release of ova and sperm.

## CHAPTER IV

### 4.0 REPRODUCTION AND BREEDING CYCLE

#### 4.1 Introduction

Knowledge of the reproduction of fish is of importance in the successfully management of fisheries. Reproduction can be used to study the effects of several management strategies on a fish population. Reproductive strategies and tactics seen in a population of fish also exemplify a wide range of life history modification to environmental capacity and predictability. Fonda *et al* (1993) studied the reproductive biology of two closely related species of fish in Lake Timsah, and demonstrated that the two species coexist by one adapting to summer spawning and the other to spring spawning. In many fish species the separation in breeding season contributes to the partitioning of the available resources and maximization of the niches (Fonda *et al.*, 1993).

In species where sequential hermaphroditism is exhibited, the management of a fishery is considerably complicated since males in protogynous species tend to be larger, older and less numerous than females so that fishing tends to remove more males than females (Shapiro, 1987; Bannerot *et al.*, 1987). It is therefore crucial to carry out detailed studies of species that have not been previously studied in order to determine their mode of reproduction for management purposes. Reproductive studies are of enormous importance when considering a species for aquaculture as information on their reproduction information is required to manage the aquaculture system successfully.

In order to gather information on the reproductive biology of *L. vaigiensis*, a number of factors were studied. First, there was obsolete need to know how the reproductive organs of this species mature in order to explain its mode of spawning. Analysis of the occurrence of maturity stages in the fish population sampled, and use of gonadosomatic index and relative condition factor over the whole year, were used to give an indication of the duration and time of the year when spawning take place. The size when this fish becomes sexually mature, and the annual potential fecundity of an individual fish and hence the population were evaluated. Knowledge of the annual potential fecundity of a given fish population is the surest way of assessing a fishery potential (Macer 1974).

Detailed approaches were used in order to come up with information of the fish reproductive biology that is more comprehensive. Staging of the gonads maturity stages was studied using gross anatomical criteria, calculating the gonadosomatic indexes (GSI), estimating the ova diameter distribution, and classifying the ovary histologically amongst others. Histological approaches can be extremely useful when studying multiple spawning fish populations since one can, with some degree of accuracy, describe the frequency of spawning using the presence of post ovulatory follicles (Hunter & Goldberg 1980). By using the presence of cytoplasmic vacuoles (Macer 1974; Ntiba & Jaccarini, 1990) accurate determination of fecundity can be made. Histological criteria can also be used to determine the extent of oocyte re-absorption, a process known as atresia (Macer, 1974).

## 4.2 Materials and methods

The growth of the gonad was expressed in terms of the Gonadosomatic Index (GSI). GSI was determined using the equation

$$GSI = \frac{Gonad\ Weight(g)}{Body\ Weight(g) - Gonad\ Weight(g)} \times 100 \dots\dots\dots 10$$

Mean GSI was calculated for maturity stages 1-6. The description of the maturity stages used is given in table 3

The minimum size at sexual maturity was determined by drawing a percent cumulative curve for each sex. The size at which 50% of the population is mature was taken to present the minimum size at sexual maturity.

Oocyte counts was determined from Gilson's preserved material. Ovaries in all stages of maturity were preserved in Gilson's fluid for a period of two months. The material was periodically shaken in order to release eggs from the ovarian tissue. Those oocytes that were not fully liberated from the ovarian tissue were released by careful teasing using dissecting needles. The liberated oocytes were then transferred into a clean beaker and rinsed several times in distilled water. After each rinse, oocytes were allowed to settle before decanting excess water. The supernatant was checked under a dissecting microscope for any oocytes before being discarded. If any oocytes were noticed, the supernatant was allowed to settle and the procedure repeated over again.

After the oocytes were thoroughly cleaned, a known volume of water was added. Using an electric stirrer, the whole mixture was vigorously stirred for 30 seconds to have an even distribution of oocytes in the suspension. A 1 ml stempel pipette fitted with a spring mechanism was used to take samples.

The sample was poured into grinded petri dishes and the oocytes counted and their diameter measured under a microscope fitted with an eye piece graticule at a magnification of X40. The maximum horizontal diameter of the oocytes was taken regardless of the shape of the oocyte.

An initial test of the homogeneity of oocyte distribution in portions taken from the left and right lobes of the ovaries and along the antero-posterior axis was made by the analysis of variance (ANOVA). There was no significant difference ( $P = 0.46$ ) in oocyte distribution from the different location of the ovary and between the right and the left lobes. This shows that there is no relationship between any stage of oocyte development and its location in the ovary. However, all materials for Gilson's count of oocytes were cut from the middle portion of either lobe of the ovary.

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The total number (N) of oocytes in the ovary was calculated as follows:

$$N = \frac{V}{V1} \times n \times \frac{W}{W1} \dots\dots\dots 11$$

Where;

n = Number of oocytes of a given size class in the sub sample

V = Volume of sample

V1 = Volume of the sub sample

W = Weight of whole ovary

W1 = Weight of a portion of the ovary

Fecundity estimate was determined from the Gilson's counts of twenty-five stage 4 ovaries.

Materials used for histological analysis were preserved in Bouin's solution for 24 hours and then preserved in 70% alcohol, to avoid the chances of the material becoming brittle. The samples were dehydrated in graded alcohol, cleared in xylene and embedded in paraffin wax. Using a rotary microtome sections were then cut at between 5-10  $\mu$ m and stained in Haematoxylin and Eosin (H&E).

The slides were then examined under a standard microscope to study the internal appearance of the ovaries at different stages of sexual maturity.

To measure the size of oocytes in the histologically prepared material, the slide was moved along the x-axis on the microscope fitted with an eye piece graticule. The oocytes were measured at a total magnification of 40. Only those oocytes, which were sectioned through the nucleus were measured. The cells had different shapes and the diameter measurements were standardized by adopting the following procedure; the diameters of spherical oocytes were directly measured. The oocytes having an oval shape the longest and shortest axis were measured and the mean of the two was taken to be the diameter. The oocytes in each size class were counted and the numbers were expressed as a percentage of the total oocyte counts in all ovaries at the same stage of sexual maturity. The sections were analyzed for other features in order to describe the internal features of the ovary.

### **4.3.0 RESULTS**

#### **4.3.1 Sex ratio**

The percentage occurrence of males and females of *L. vaigiensis* in monthly collections are given in Table 2.



MONTH												
SEX	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MALE	12	27	44	26	16	52	20	12	32	27	12	22
FEMALE	18	27	32	69	33	62	32	27	28	27	23	13
SEX RATIO	1:1.5	1:1	1:0.7	1:2.3	1:2.1	1:1.2	1:1.6	1:2.3	1:0.8	1:1	1:1.9	1:0.6
CHI SQUARE	1.2	0	1.8	12.8	5.89	0.8	2.8	5.7	0.3	0	3.45	2.31
REMARK				+	+			+				

Table 2. The monthly variation of sex ratio of *L. vaiigiensis* (+ indicates significance Difference: Chi-square,  $P < 0.05$ )

There was dominance of females in most months apart from March and September. Chi square test showed that the sex ratio differed significantly ( $P < 0.05$ ) from the 1:1 ratio in the months of April, May and August. There was no significant differences ( $P > 0.05$ ) in all the other months and the different size ranges.

#### 4.3.2 Size at sexual maturity

The percent cumulative curves showed the minimum size at sexual maturity was 16.8 cm (Fig. 7).

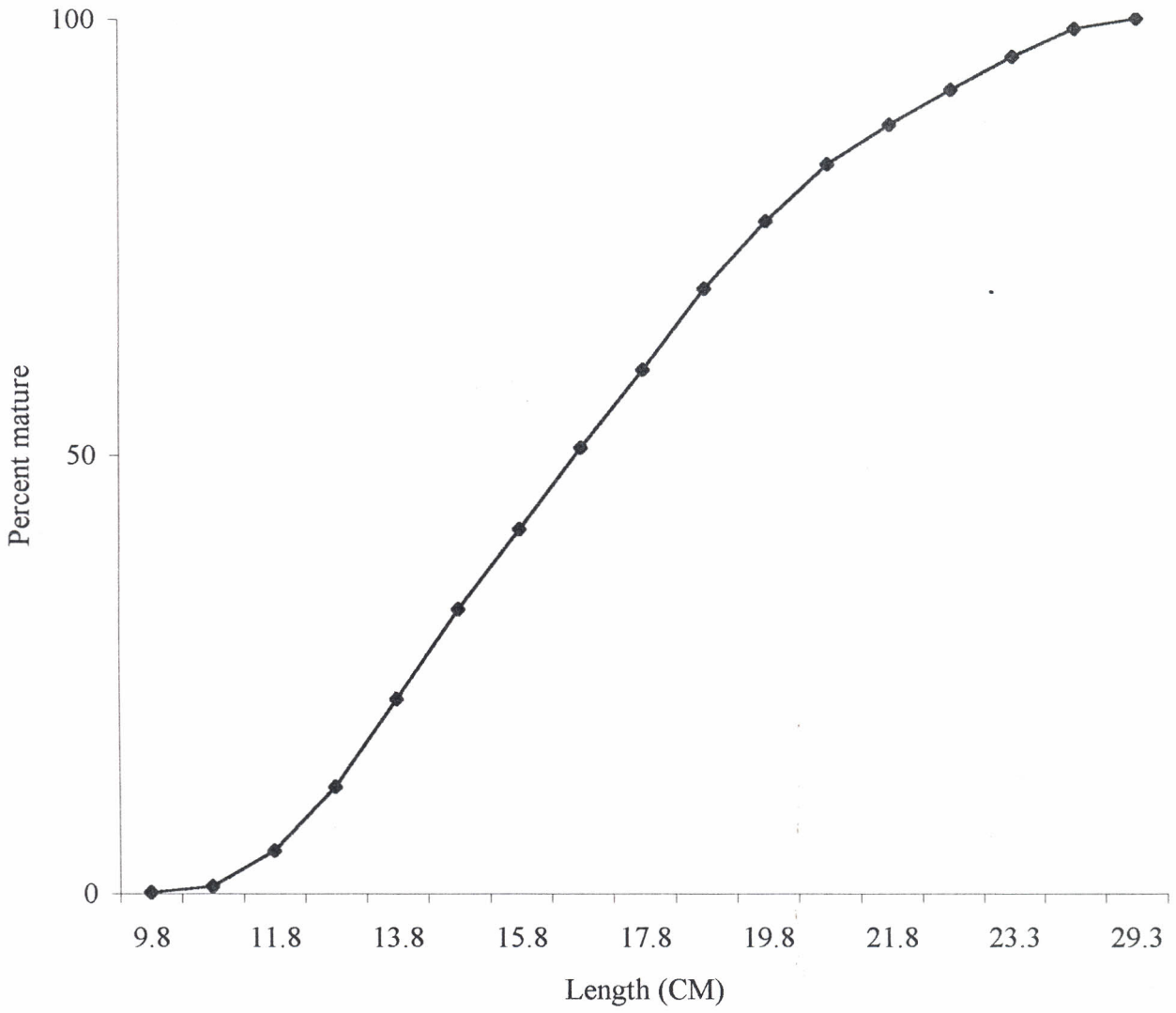
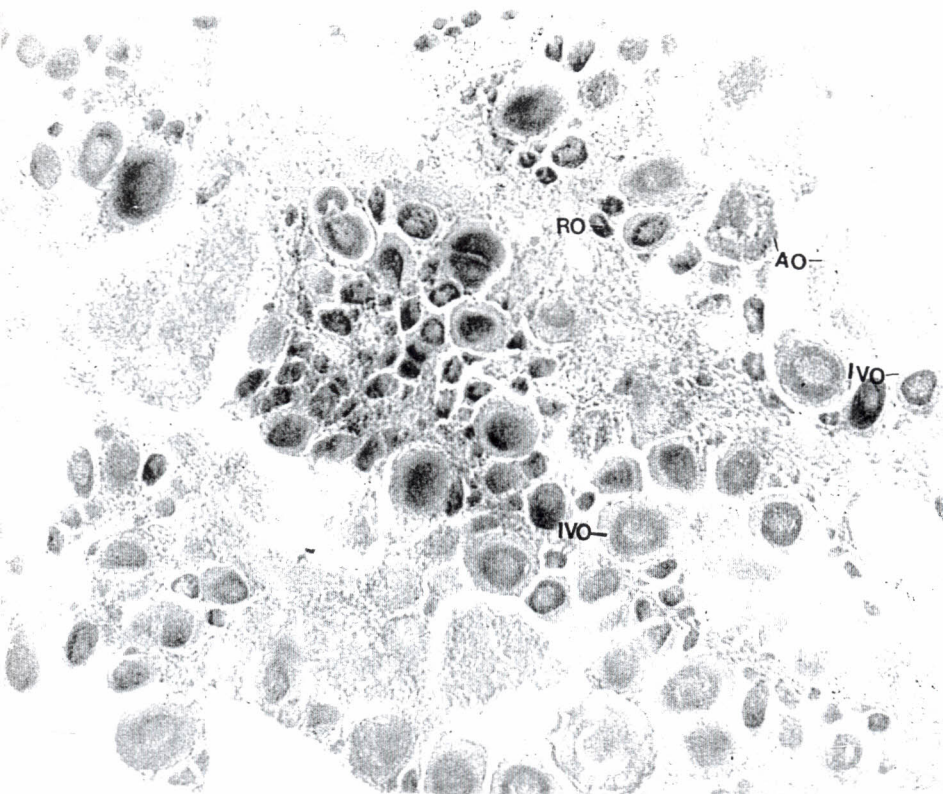


Figure 7. A percentage cumulative curve showing the minimum size at sexual maturity of *L. vaigiensis*

#### **4.3.3.0 GROWTH OF GONADS**

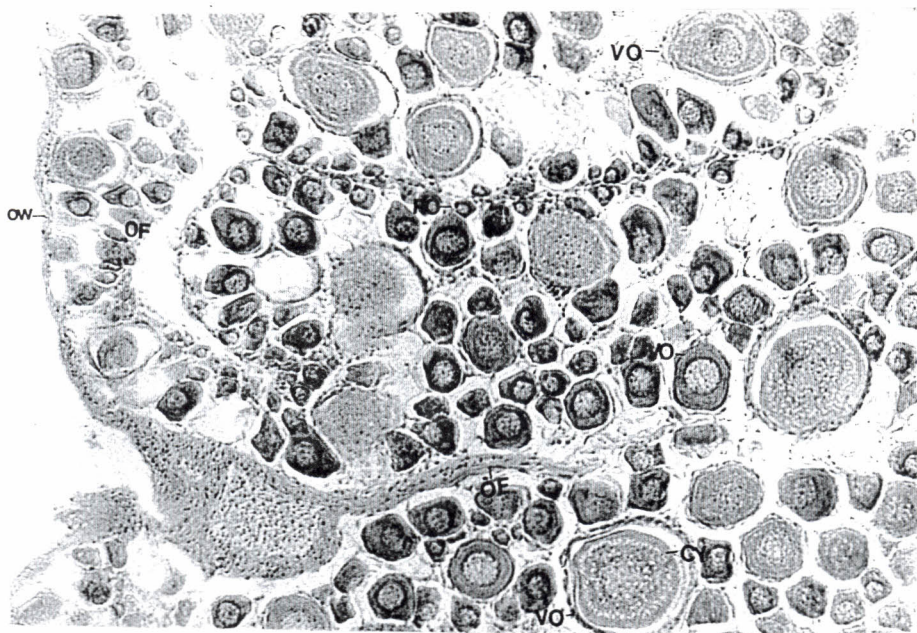
##### **4.3.3.1 Description of the gonads**

The detailed microscopic appearances of the gonads are shown in plate 1 (a-f), and the descriptions of the maturity stages used in this study are given in table 3.



82  $\mu\text{m}$

Plate 1 a. A photomicrograph of a stage 2b ovary from *L. vaigiensis* showing a recovering ovary. AO = atretic oocytes; IVO = initial vitellogenic oocyte; R.O = resting oocyte.



161  $\mu\text{m}$

Plate 1 b. A photomicrograph of a stage 3 ovary from *L. vaigiensis* showing a developing ovary with vitellogenic oocytes having cytoplasmic vacuoles. OW = ovary wall; CV = cytoplasmic vacuole; VO = vitellogenic oocytes; OF = ovigerous fold.

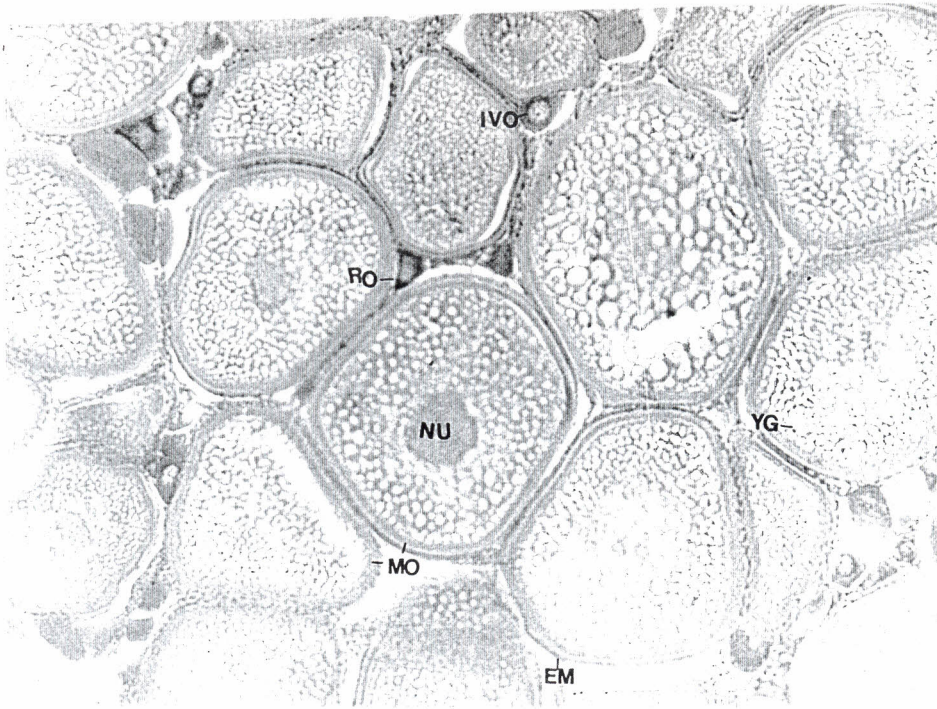


Plate 1 c. A photomicrograph of a stage 4 ovary from *L. vaigiensis* showing a mature ovary. There is presence of mature oocytes containing cytoplasmic granules and initial vitellogenic oocytes. EM = egg membrane; NU = nucleus; IVO = initial vitellogenic oocytes; MO = mature oocyte; Ro = resting oocyte; YG = yolk granules AO = atretic oocytes; IVO = initial vitellogenetic oocyte; R.O = resting oocyte.

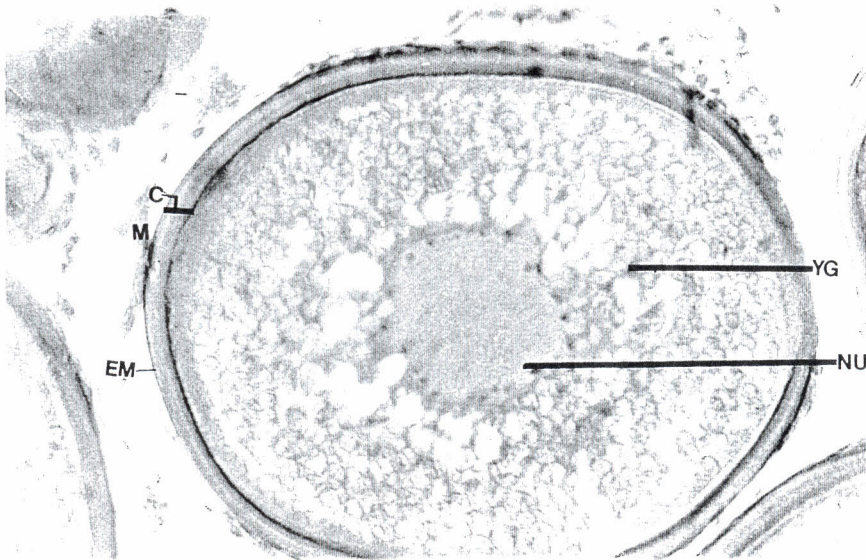


Plate 1 d. A photomicrograph of a typical stage 4 oocyte in *L. vaigiensis* showing a well stratiated cell membrane and chorion that develops during stage 4. EM = egg membrane; YG = yolk granules; NU = nucleus; C = chorion.

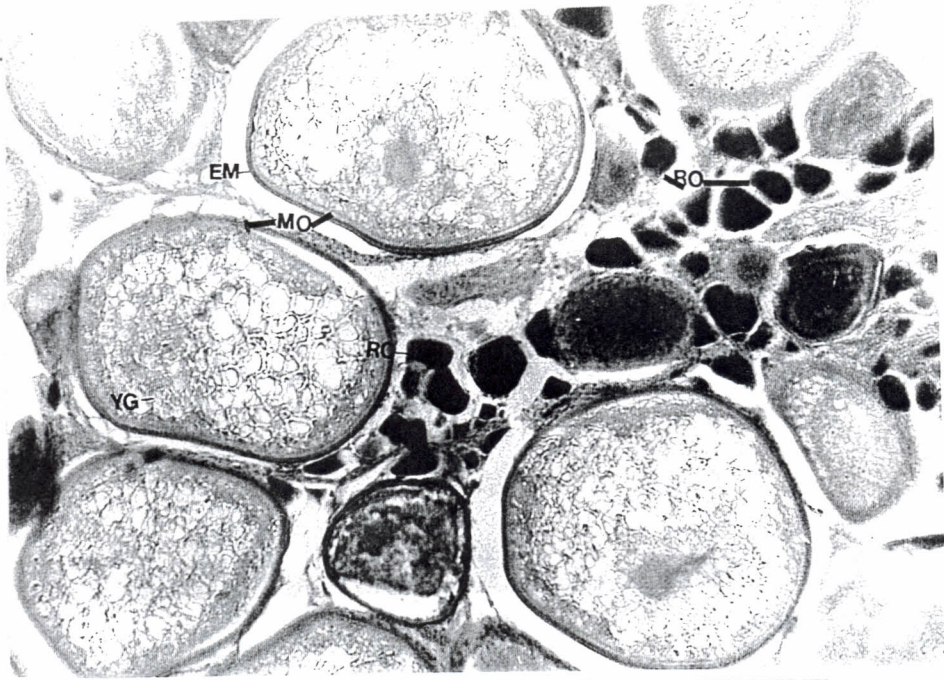


Plate 1 e. A photomicrograph of a stage 5 ovary from *L. vaigiensis* showing a ripe ovary with cytoplasmic granules. YG = yolk granules; RO = resting oocytes; MO = mature oocyte.

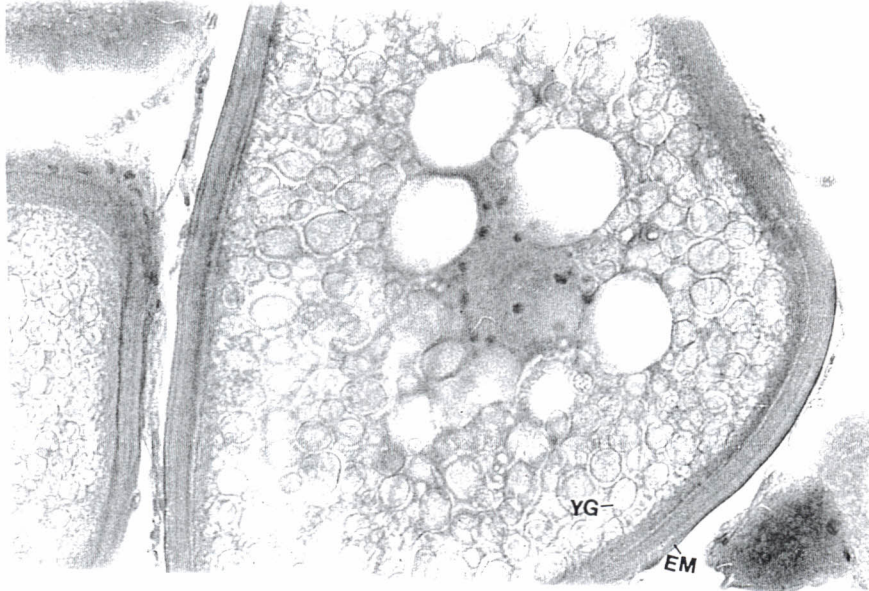


Plate 1 f. A photomicrograph of a stage 5 ovary from *L. vaigiensis* showing a typical stage 5 oocyte with well formed cytoplasmic vacuoles. YG = yolk granules; EG = egg membrane.

Table 3. The maturity stages of the gonad of *L. vaigiensis* (Adopted and modified from Ntiba & Jaccarini , 1990).

MATURITY STAGE	MACROSCOPIC APPEARANCE OF TESTIS	OVARY	
		MACROSCOPIC APPEARANCE	MICROSCOPIC CRITERIA
1 Immature	The testes are slender and thread like, translucent; colorless to light grey. They occupy about one-fifth of the body cavity	The ovary is slender, thread like, white and semitransparent, occupying less than one quarter of the body cavity. No oocytes visible through the ovary wall and no blood vessels. The ova are transparent and spherical without yolk	Few oocytes larger than 69µm. Small cells which are strongly stained with haematoxylin. The cells are irregular in shape and have no defined cell membrane. Ovary wall >12 µm thick
2a Developing virgin	Testes are white but more flattened and enlarged than in the previous stage, occupying about two-fifths of the body cavity. Tiny blood cells start forming.	The ovaries are larger and broader, occupying almost one-half of the body cavity, translucent with tiny blood cells forming internally. Larger ova are opaque and light yellow due to the commencement of yolk formation and the younger are colorless and transparent.	Few oocytes larger than 92 µm. The largest ova measure about 138 µm. Many cells have large nucleus. The cells are irregularly shaped but a few are rounded and visible between the resting oocytes. Ovary wall about 20µm.
2b Recovered spent	As in 2a but tough in texture, deep brown in color. The gonad is slightly larger than in 2a.	Soft and flappy with a cavity at the centre of the gonad. Greyish in color and no oocytes visible through ovary wall.	Same as 2a but residual oocytes present

<p>3 Early developing</p>	<p>Becoming broader, smooth, light brown. Watery milt exudes on a cutting. Blood vessels (internal visible through testes wall. Gonad extends for about half of the body cavity</p>	<p>Ovaries are larger and occupy almost three quarters of the body cavity. Tiny oocytes visible through ovary wall. Dense network of blood vessels visible internally through the ovary wall.</p>	<p>Few oocytes larger than 115µm. The oocytes are lightly stained; non homogenous denoting the formation of vitellogenic substances but some are characterised by distinct cytoplasmic vacuoles. Stage 1,2,3 oocytes present. The ovary wall is richly supplied by blood vessels. Ovary wall about 60 µm thick</p>
<p>4 Late developing</p>	<p>Broad and firm in texture; smooth flat, light grey; exudes thick bloody milk on cutting. They have lobulators over the outer surface. The testes occupy about three fifths of the body cavity</p>	<p>The ovaries are further enlarged and occupy almost the entire body cavity, they are bright yellow, with a brownish tinge. The ovary is turgid and slight pressure can break the outer membrane. A heavy network of blood vessels now appear externally on the surface of the ovary wall.</p>	<p>Many oocytes between 207-253µm in Gilson's count. The ova have well defined cell membrane. Stage 2,3,4 and present. Many cells with cytoplasmic vacuoles; large oocytes (stage 4) filled with yolk granules. Very few oocytes in stage 5 present. Ovary wall 110µm</p>
<p>5 Ripe and sometimes running</p>	<p>Broadest, mostly firm but some were flacid. Flat, smooth and highly lobulated. Ivory coloured. No blood vessels and thick milk exudes with on slight pressure. The testes cover about three fifths of the body cavity.</p>	<p>Broadest and firm where sheddings of egg has not yet commenced, otherwise soft, rounded and with a rough granular surface. Blood vessels coalesce to form larger ones</p>	<p>Many oocytes between 207-345µm. A mode of large oocytes at 270 µm. Many oocytes are in stage 2 and 5 and</p>



<p>6 Spent</p>	<p>Reduced in size and sometimes very small, flaccid and walls hard in texture. Flat, lobules disappearing. Dark brown in color and no blood vessels visible; no milt. Gonad extends for almost half of the abdominal cavity</p>	<p>on the external surface of the ovary wall. Yellowish in colour possibly due to the large yellow oocytes that are visible through ovary wall. The ovary extends almost the entire cavity</p> <p>Reduced in size, flaccid but ovary wall is tough and smooth (no granulation). Round to ovoid in shape. Reddish in color. Residual oocytes are visible through flabby wall. Gonad extends for 50% of the abdominal cavity.</p>	<p>a few others at stages 3 and 4. The vitellogenic granules are forming amorphous plagues of large size. The vitellogenic granules are conspicuous and well distributed. The size of these oocytes ranged between 230-390<math>\mu</math>m. Atretic oocytes were present but quite rare. Ovary wall about 153<math>\mu</math>m thick</p> <p>Many oocytes between 23-69<math>\mu</math>m. Small oocytes have a thin densely staining cytoplasm. A few atretic residual oocytes present. Septum disorganized; no definite empty follicular coats.</p>
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### 4.3.3.2 Mean Gonadosomatic index

Figure 8 shows the changes in mean gonadosomatic indexes of males and females gonads at different stages of sexual maturity. The mean gonadosomatic index increases continuously for both sexes from stage 1 of sexual maturity reaching the maximum in stage 4 and 5 for females and males respectively. GSI values falls for both sexes at stage 6 of sexual maturity due to the gonads losing weight after spawning. The GSI for females is always higher than that of males apart from stage 5 of sexual maturity when the GSI for females has already started the decline trend. GSI of females' start the decline trend at stage 4 and this is caused by the female gonad starting to release ova at stage 4 at the start of the spawning process. The maturity stages chosen do fit an expected and logical pattern of weight changes in the gonad, providing an additional degree of confidence in the maturity assessment.

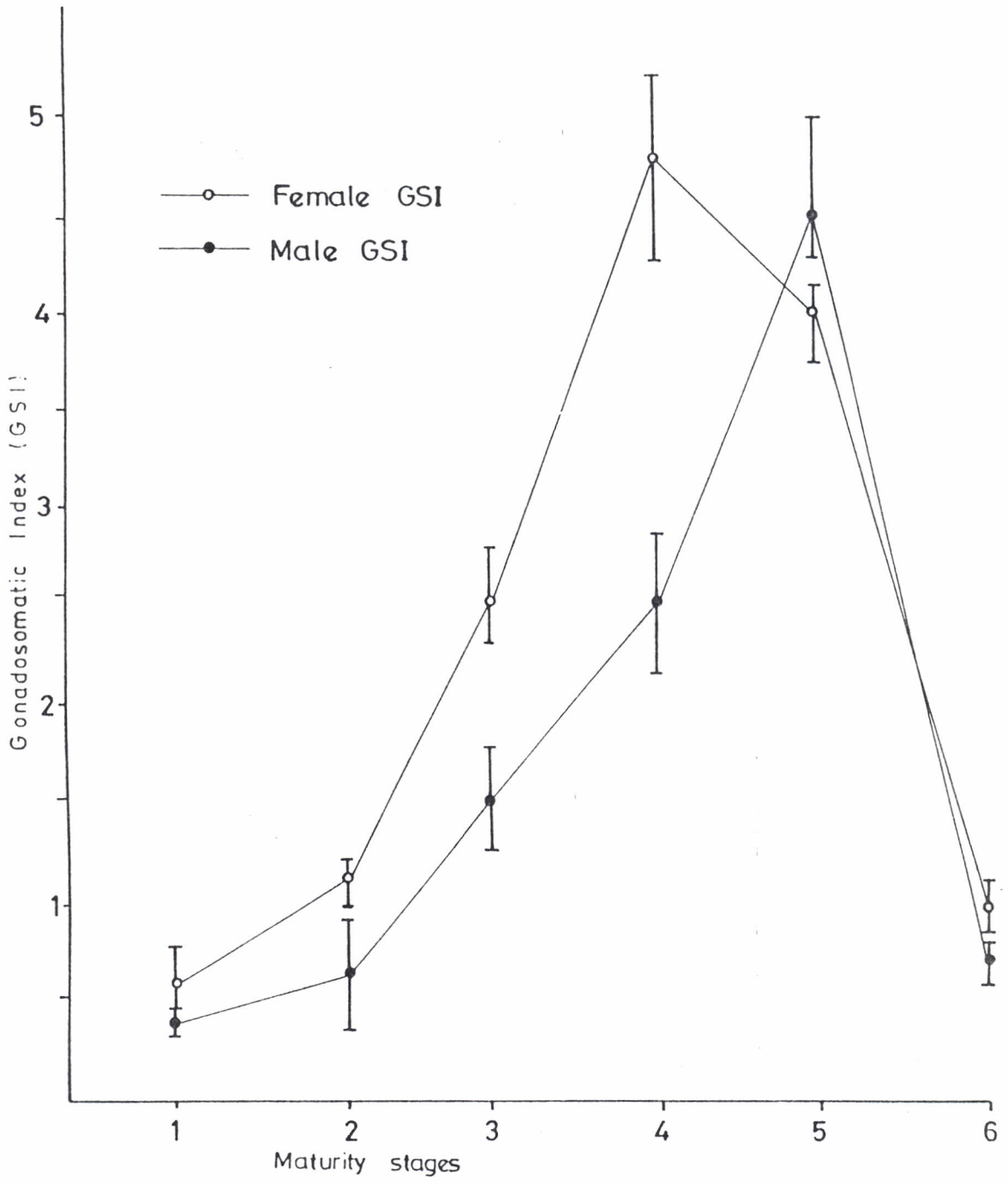


Figure 8. The mean GSI of male and female *L. vaigiensis* ( $\pm$  SEM) at various maturity stages.

#### **4.3.3.3 Oocyte distribution**

The size frequency distribution of Gilson's isolated oocytes of ovaries in stages 1 – 6 of maturity development are shown in figure 9. The results indicate that at stage 4 and 5 there are two distinct modal classes of oocytes. Only one modal class of the ova at 23-92  $\mu\text{m}$  size class is apparent in stages 2, 3 and 6 ovaries. In stage 4 distinct modal classes are discernible between 26-69  $\mu\text{m}$  and 184-230 $\mu\text{m}$  and at 26-69  $\mu\text{m}$  and 253-299 $\mu\text{m}$  in stage 5 ovaries.

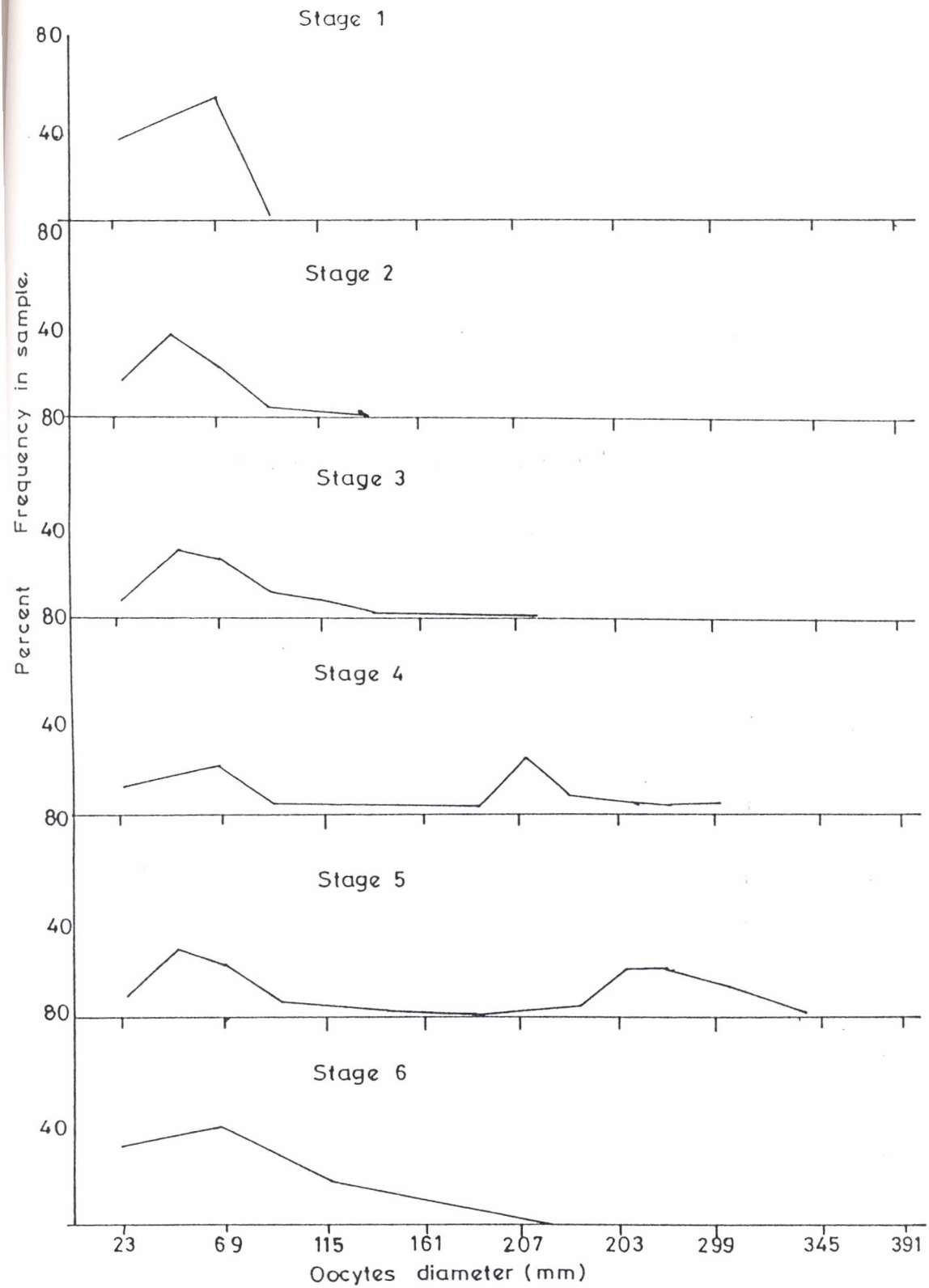


Figure 9. Size frequency of oocytes preserved in Gilson's fluid from ovaries of *L. vaigiensis* at various maturity stages

#### 4.3.4.0 BREEDING CYCLE

##### 4.3.4.1 Temporal variation of Gonadosomatic index

The monthly mean GSI variation is shown in figure 10.

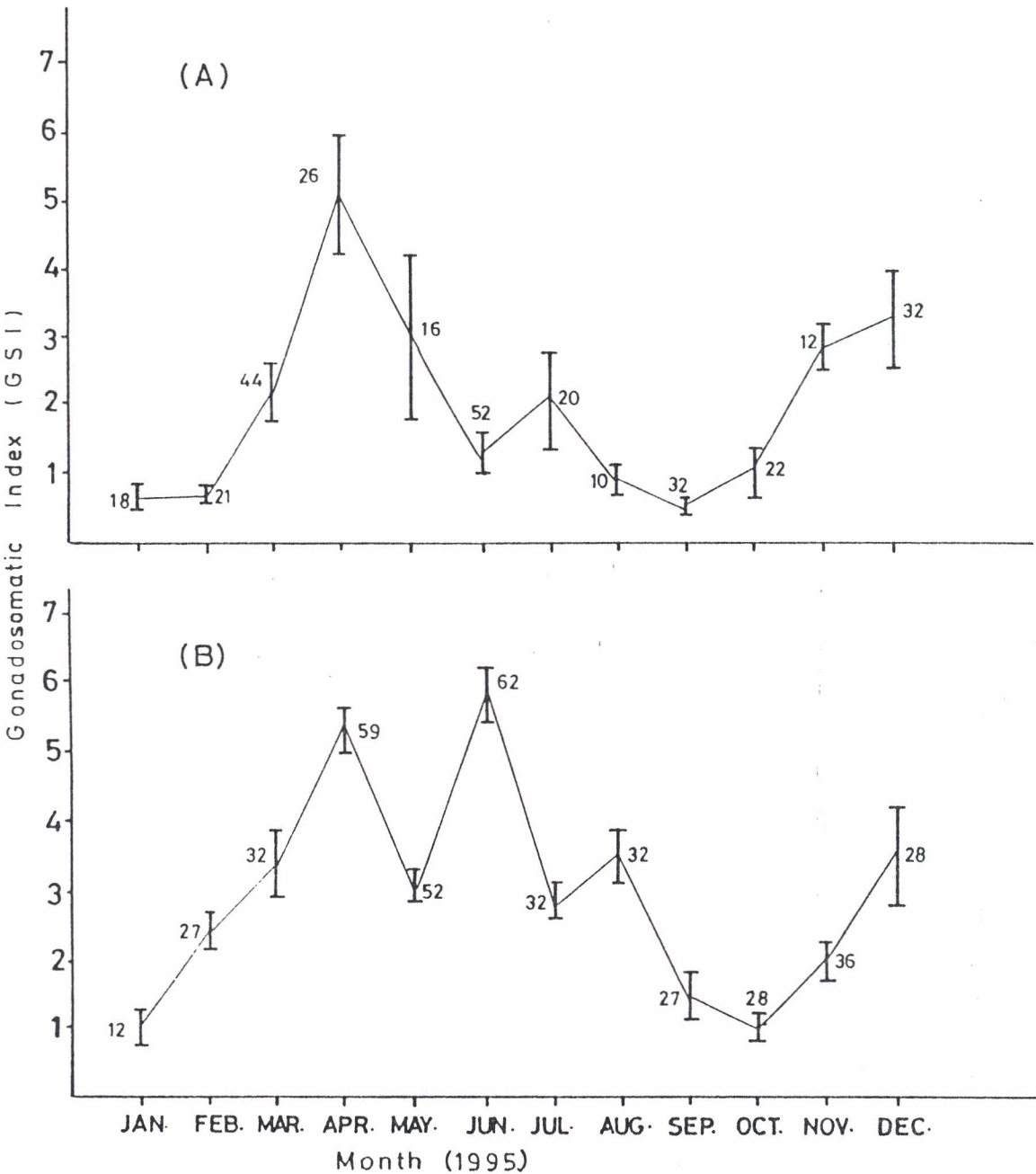


Figure 10. The temporal variation of GSI in male (A) and female (B) in *L. vaigiensis* (number indicates the sample size; vertical bar  $\pm$  SEM).

Mean GSI values for female *L. vaigiensis* is highest in maximum in April and June, declines between April and May, June- July and August- October before rising again from October to December. The Male GSI values increases from February reaching a maximum in April. It decreases from July to October and increases again between October and December.

#### **4.3.4.2 Monthly occurrence of maturity stages**

The monthly occurrence of fish at different stages of maturity is shown in figure 11.

Fish with ripe gonads (stage 4 and 5) occur throughout the year. A high percentage of fish in maturity stage 5 occur in March - July and again in November - December. Stage six gonads are present in appreciable numbers in December.

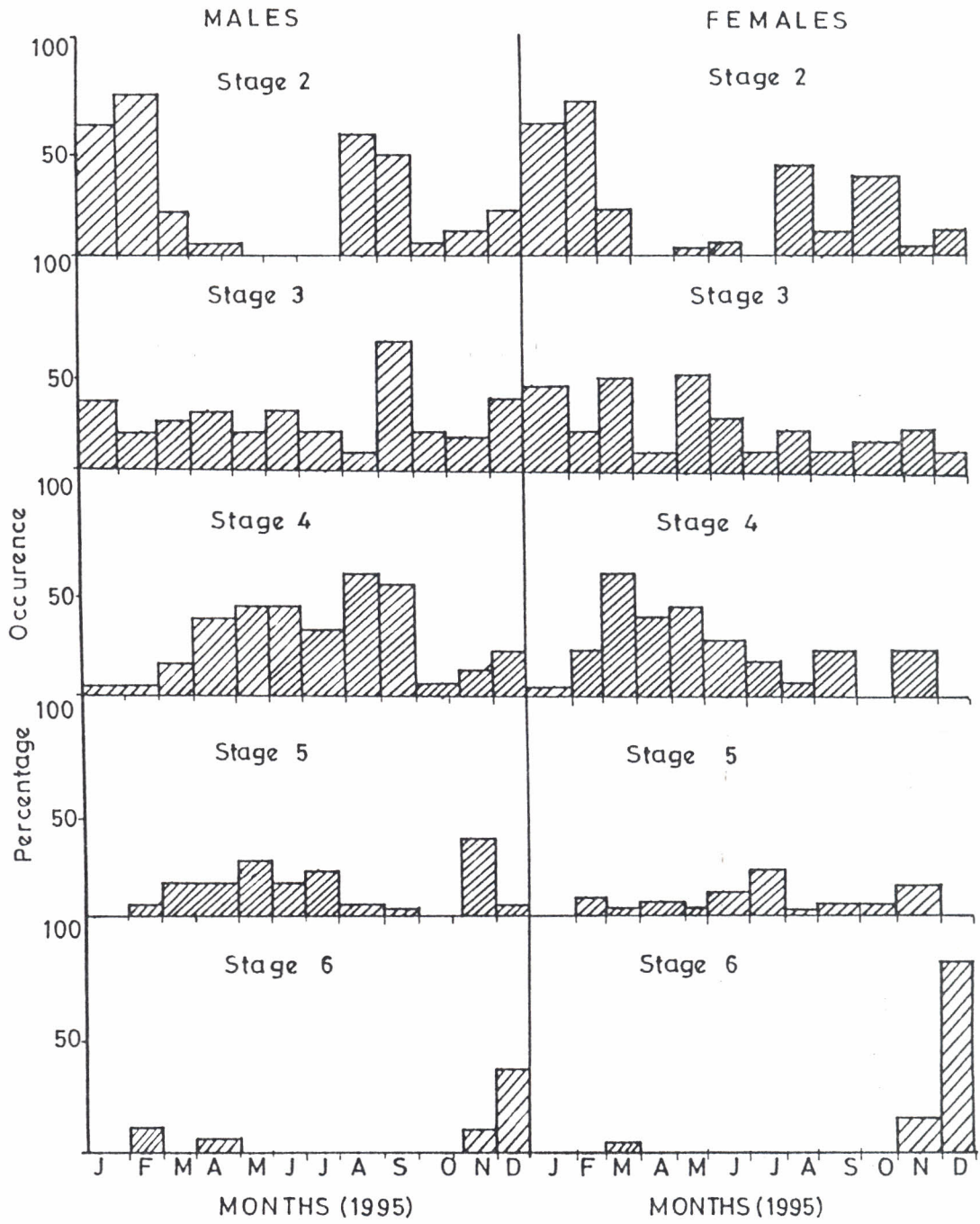


Figure 11. Monthly occurrence of *L. vaigiensis* in different maturity stages in the sample (N = 641).



### 4.3.5 Fecundity estimates

Fecundity estimates based only on counting all yolked oocytes (Nzioka, 1985; Fonda *et al.*, 1993) usually is an underestimate of the potential fecundity. This is because in stages 4 and 5 there are some unyolked and developing oocytes, which contain cytoplasmic vacuoles and are going to be spawned together with the yolked oocytes. Appearance of cytoplasmic vacuoles in oocytes, is a sure indication that such oocytes would grow and be spawned together with the larger ones. (Macer 1974; Ntiba & Jaccarini 1990). Therefore, to determine the fecundity, oocytes with cytoplasmic vacuoles were measured and counted in six stage 4 ovaries. The size frequency distribution of oocytes containing cytoplasmic vacuoles is shown in figure 12.

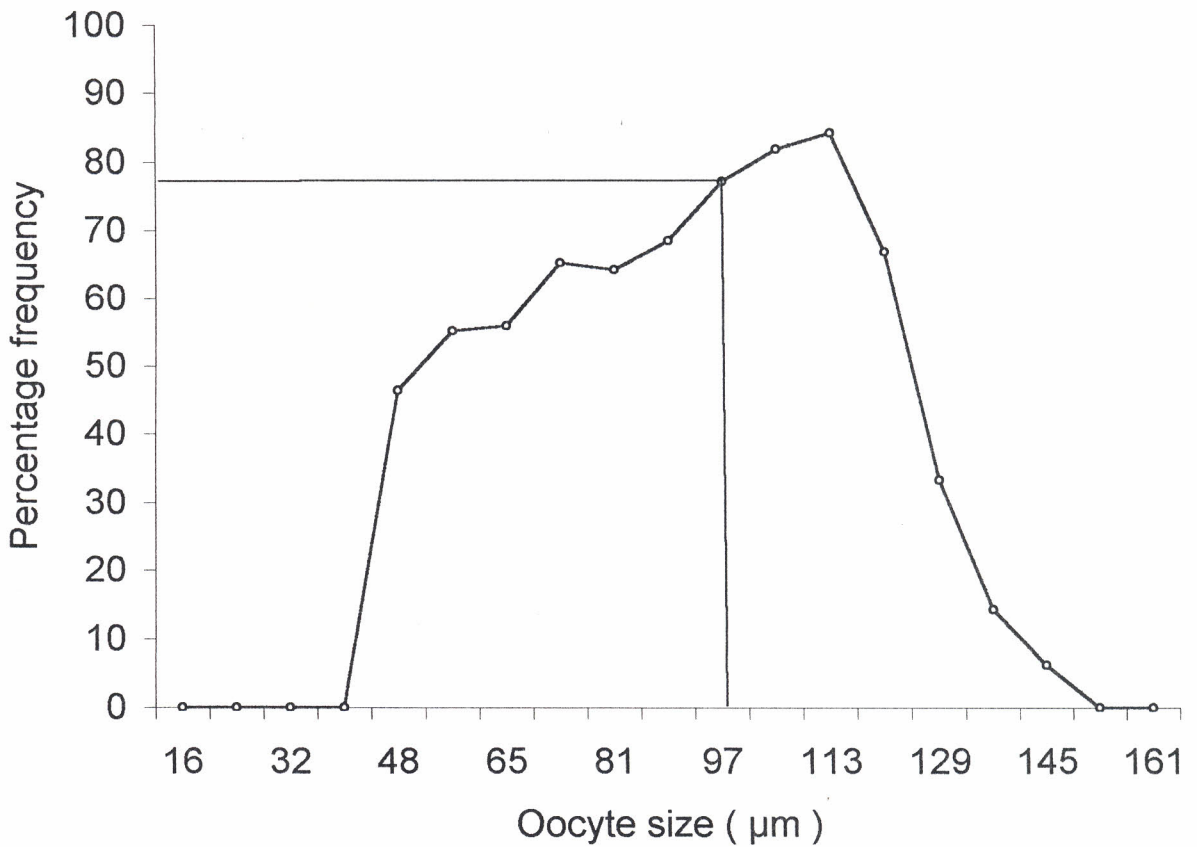


Figure 12. The frequency occurrence of oocytes having cytoplasmic vacuoles in stage 4 ovaries in *L. vaigiensis*.

It appears that at 45 μm the oocytes have started developing cytoplasmic vacuoles. At 97 μm, about 77% of the oocytes have developed cytoplasmic vacuoles. For fecundity estimates therefore all oocytes greater than 97 μm were counted, as these oocytes have matured and they are going to be released the season after capture. Potential fecundity thus determined ranged from 186,000 to 1,806,000. The fish size ranged between 14 to 29 cm, total length. The average fecundity of this fish was estimated to be 674,000.

The relationship between fecundity with length and weight in *L. vaigiensis* is shown in figure 13 & figure 14.

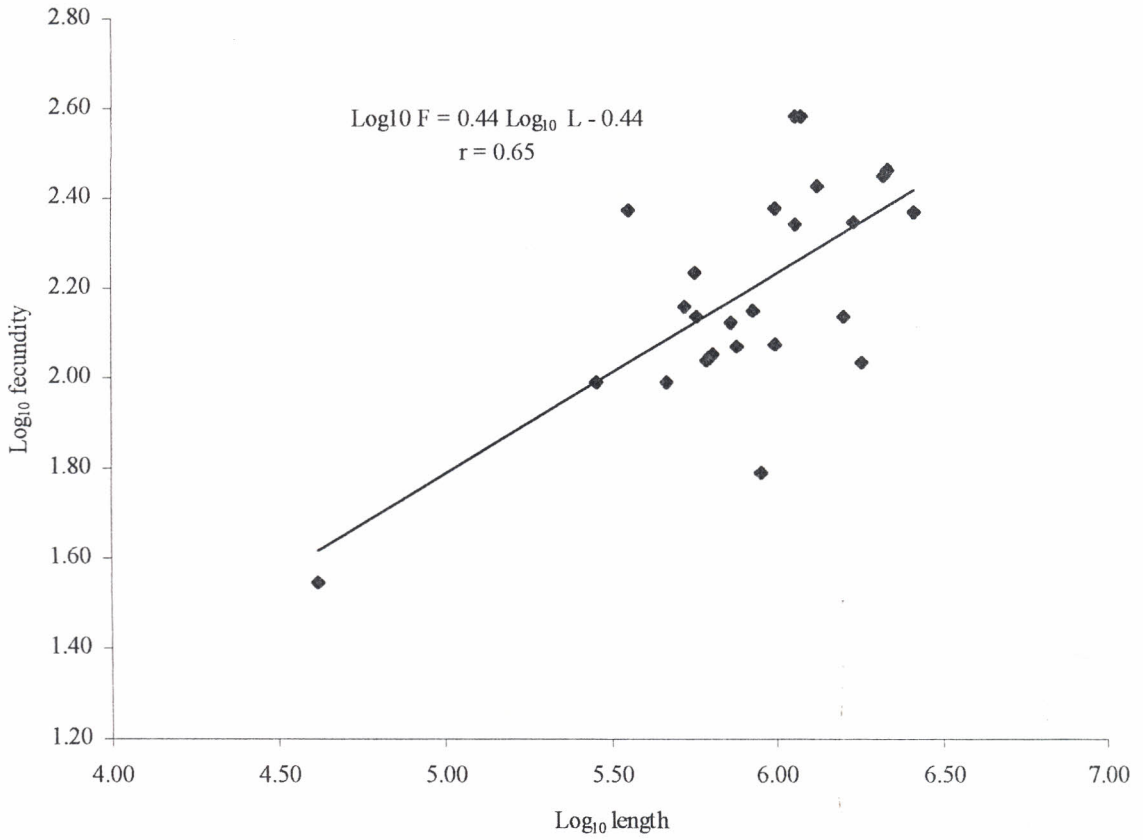


Figure 13. The relationship between fecundity and length in *L. vaigiensis*

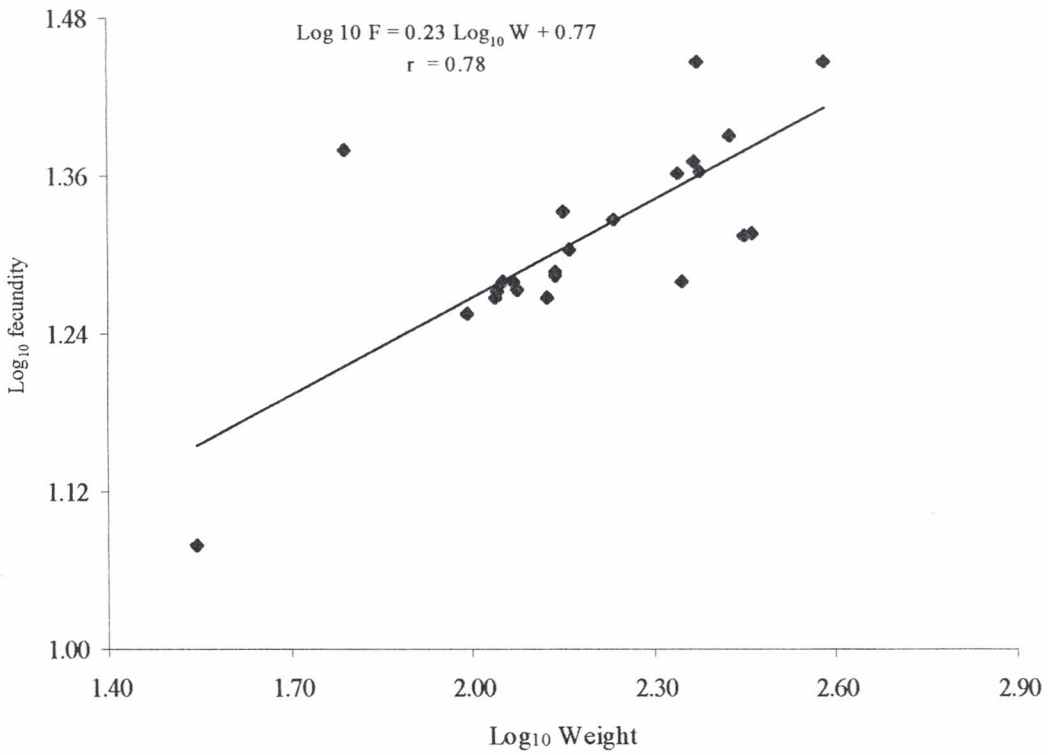


Figure 14. The relation between fecundity and body weight of *L. vaigiensis*.

Fecundity showed a linear relationship with fish length and body weight( Fig. 13 & 14). The log-log plot of fecundity versus body weight gave a slightly higher correlation coefficient ( $r = 0.78$ ) than fecundity versus length ( $r = 0.65$ ).

#### 4.3.6 DISCUSSION

The stages of gonad development in fish are classified using different criteria such as size of gonad in relation to body cavity, ova diameter, fat content and gonadosomatic index (Nzioka, 1981). General appearance of the whole sections of gonads, taking into account vascularization, ovarian membrane thickness, and the relative abundance of the different stages of oocytes have been used (Elorduy-Garay & Ramirez-luna, 1992). The criteria used by Ntiba and Jaccarini (1990) was found adequate and applicable in staging the gonads of *L. vaigiensis*.

In the histological section, two batches of oocyte were recognized in stage 4 and 5 ovaries. At these stages, there are post vitellogenic oocytes that are at an advanced level of maturation, and a second lot made of previtellogenic oocytes. In addition, counts made from the Gilson's preserved samples showed that there were two modal classes in the distribution of oocytes in stage 4 and 5 ovaries. Only one modal class made up of previtellogenic oocytes is discernible in stage 1, 2, 3 and 6 ovaries. A single modal class of immature oocytes noted in stage 6 shows that the batch of post vitellogenic oocytes noted in stage 4 and 5 has already been released at spawning. This indicates that the batch of ripe oocytes is clearly separated from the batch of immature oocyte before spawning takes place. The mature oocytes are all released by the time the ovaries reach stage 6 of sexual maturity. *L. vaigiensis* can therefore be classified as a batch spawner whereby a single batch of oocyte is released per spawning period.

Ripe gonads occurred throughout the year (Fig. 12) indicating the population of *L. vaigiensis* is capable of spawning throughout the year. However, evidence from GSI and

relative condition factor show a clear pattern in which there are two distinct peak spawning times. These peak spawning times occur in March through June and again during the period November/December. There seems to be a definite seasonality in the breeding cycle of this fish species in the Kenya waters. There is a likelihood that there are two breeding populations of *L. vaigiensis* in this area with each having a peak spawning activity at the different periods (March-June and November/December) of the year. This could not be totally ascertained using the current data and thus requires further research.

According to Rosemary (1979), scarids have extended spawning seasons, which may go on throughout the year. At Enewak atoll, Marshal Island, ripe ovaries were recorded throughout the year (Collin & Bell, 1991). In Kenya, spawning in *L. vaigiensis* was observed to occur in September through November (Robertson *et al.*, 1982). Females with vitellogenic ovaries were observed in January, May and July through December and ripe ones were recorded in September – November. The other months of the year were not sampled. The salient point which comes out the study of Robertson *et al* (1982) is that either vitellogenic, ripe ovaries or spawning activity was noted in all the months sampled, showing that there is a possibility of the population of *L. vaigiensis* to spawn all year round. Similar observations have been made in this study. Rubindamayugi (1983) reported one breeding season for *L. vaigiensis* during the SE monsoon period in the coastal waters of Tanzania, observation that is at variance with current one.

Seasonality in spawning has been shown to be common in temperate marine fish (Sherman *et al.*, 1984; Lambert & Ware 1984; Checkley *et al* 1988) and in tropical marine fish (Walsh, 1987; Gladstone & Westoby 1988; Nzioka 1981,1982 & 1985 and

Ntiba & Jaccarini, 1990). Seasonality in spawning is influenced by environmental conditions that favor larval survival, juvenile and the adult growth. Johannes (1978) argued that there are correlations between spawning patterns and the gross environment that favors the larval survival. Watson & Leis (1974) showed that there is synchronization of spawning with periods of reduced currents. Reduced currents favor larvae survival by making it possible for the larval to develop and metamorphose before they are swept off to the sea (Watson & Leis, 1974). In the present study, the peak spawning activities corresponds fairly well with the intermonsoon periods. Intermonsoon periods (March – July and October – November) are associated with the wet seasons and calmer currents. These periods are also associated with high nutrients and primary production (Kitheka *et al.*, 1996). This means that these periods tend to favor larvae survival by ensuring that development and metamorphosis are allowed to take place before the powerful currents carry the larvae offshore as argued by Leis (1974). Several observations indicate that peak spawning in many areas occurs in the times of the year when prevailing currents or winds are weakest (see also table 4). Suffice to say that this is could be one of the underlying reason for the synchronization of the two peak spawning seasons with the intermonsoon periods. However, there is a need to understand the many ocean processes and the biology of fish in this area before a very definite reason can be advanced.

In other studies, spawning patterns have been shown to follow seasonal changes in the suitability of environment in terms of changes in food and the physical stress (Ochi, 1986; Robertson, 1991). The area sampled during the present study has been shown in separate studies to be characterised by high levels of inorganic nutrients, high rates of

primary production and zooplankton biomass during the wet season (Kitheka et al., 1996). Since high productivity would probably mean more food for juvenile fish, it can be concluded that the availability of abundant food is cueing the spawning behavior of this fish and probably other fish in this part of the Indian Ocean. More studies on these lines should be undertaken.

Table 4: Collective spawning months for shallow water tropical marine teleosts.  
(Modified from Johannes, 1978).

LOCATION	MONTHS	SOURCE
Madagascar	April-May & Oct-Nov.	Fourmanoir (1963)
Madras, East India	Late Dec. through January	Basheeruddin & Nayar (1962)
Madapam, S.E. Asia	March & Nov.	Bapat (1955), Prasad (1958)
South China sea	March - April	Vatanachi (1972)
Micronesia	Feb - June	Johannes (1978)
Hawaii	March-May and October	Watson & Leis (1974)
Caracao	March-May & Sept-Nov	Luckhurst & luckhurst(1977)
Barnados	March-May & Aug-Oct	Powles (1975)
Jamaica	Feb-April	Munro et al (1973)
Kenya & Tanzania Kenya	Oct-March (NE Monsoon) May & October	McClanahan (1988)
Kenya	March – May & Sept.- Nov	Nzioka (1982), Nzioka (1985)
Kenya	Jan – Feb & May - June	Ntiba & Jaccarini (1990)



The purpose of calculating the sex ratio was to check for change in population structure which could be related to growth and reproduction. The results showed no consistent trend in the change of sex ratio. The overall sex ratio was 1: 1.4 and is to 1:1 sex ratio. The length distribution by sex was not significantly different meaning the population structure does not change because of breeding cycle.

Estimation of fecundity in fishes is as a means of evaluating the reproductive and fishery potential of a particular species (Macer 1974). A comparison of data on fecundity and recruitment is used to indicate levels of mortalities. This is done by determining the fecundity of individual fish during the spawning season, the mortality of egg and larvae and knowledge of the recruitment strength. These parameters determine the success of a given fish stock. The potential fecundity of *L. vaigiensis* was determined to be 670,000. This estimate compares well with other tropical demersal fish with pelagic eggs where fecundity is high due to high predation. There was significant correlation between fecundity, length and weight of fish. The fecundity increases with weight and length of the fish. There is a stronger correlation between fecundity and weight, and this equation can be used to predict the potential fecundity of *L. vaigiensis*.

## CHAPTER V

### 5.0 THE FISHERY OF *L. VAIGIENSIS*

#### 5.1 Introduction

Fisheries exploit wild stocks that are living in their natural environments. In order to exploit these stocks in a manner which is both sustainable and economically or biologically optimally, it is important to assess the condition of a stock at a given point in time, and the effects on these stocks of particular fishing strategies.

It is important to study stock-recruitment relationships because this forms the basis of the stock in future. To achieve this it is imperative to collect data on the biological characteristics of the stock. For stock assessment, this involves determination of rates of growth, mortality and recruitment. This information makes it possible to make estimates of expected yield under different condition of fishing pressure. A common approach used in many such estimates is the yield – per – recruit model. A yield-per-recruit analysis considers the fate of a brood of a year class once they have been recruited into the fishery. Estimates of yield (biomass) from a given year class of recruits can be calculated on the knowledge of their rates of growth and mortality. Yield per recruit models enables the calculation of exploitation rates under different conditions of fishing mortality (F) or size (or age) at first capture. This information will indicate the situation of the stock, whether under-exploited or overexploited. With information reflecting the state of exploitation, it is possible to offer advice to the resource manager and indicate the recommended fishing mortality to be applied to the stock and on the size (or age) at first capture to maximize yield from the stock. Whereby a stock is a sub – set of one species

having the same growth and mortality parameters, and inhabiting a particular geographic area. These predictive models, have proved to be extremely useful in some pelagic and most demersal fisheries for fish and shrimps (Sparre & Venema, 1993), but not on certain stocks especially for small pelagic species occurring in upwelling areas, whose fisheries depend on environmental factors which are beyond the interference of any human influence (Sharp & Csirke, 1984).

To estimate these stock parameters, methods using length-frequency analysis to infer the growth patterns are commonly applied (Pauly, 1983). These methods have found wide applications because of their robustness and easiness. For example although aging of fish using hand plates is of great importance, when the resource under investigation consists of small, short-lived fish that can be aged only by counting daily rings, routine assessments based exclusively on age-structured models in quite impractical, especially in a multispecies situation (Pauly & Morgan, 1987). Length-frequency analysis find great use when trying to model size related processes such as predation, food conversion efficiency, gear selection, recruitment to fishing grounds and marketability and price of fish.

The computer based length-frequency models to estimate growth and mortalities have been used by several authors in the tropic to give reliable estimates since the 1980's. Their applications have not involved fatal misinterpretation of the program features or output (Pauly, 1983). With the advancement of technology, length weight analysis is now carried out using computer programs. One of such computer based programs is the Fish

Stock Assessment Tools (FiSAT) (Ganyanilo *et al.* 1994). This computer based program was used in the current study.

## 5.2 Materials and methods

Length frequency data collected from catches of the beach seine in the seagrass and coral reef lagoon in Msambweni was pooled by months for the length frequency analysis. A size class of 0.5 cm was used in all the analysis.

The use of length-frequency data for the estimation of  $L_{\infty}$  and K (Ricker, 1977; Gulland, 1983; Samb, 1988 and Pauly, 1983) assumes that:

- (a) The length-frequency data are representative of population
- (b) The growth parameters are repeated each year
- (c) The von Bertalanffy growth formula (VBGF) describes the growth of the population;
- (d) All sample have the same growth parameters and that
- (e) Length frequency data obtained from fish (unless they are collected with a highly selective gear such as line and hook) usually contains modes pertaining to one of two major cohorts per year even if they were sampled from females which spawn throughout the year.

The von Bertalanffy growth function was used to estimate growth constant (K) and asymptotic growth ( $L_{\infty}$ ). The equation is expressed as: -

$$L_t = L_{\infty} (1 - e^{-K(t-t_0)}) \dots\dots\dots 12$$

Where;

$L_t$  is predicted length at age  $t$

$L_\infty$  is the asymptotic length, i.e. the mean length the fish of a given stock would reach if they were to grow forever;

$K$  is a growth constant (stress factor); and

$t_0$  is the "age" the fish would have had at zero if they had always grown in the manner predicted by the equation.

The least square method is used to estimate  $L_\infty$ ,  $K$  and  $t_0$ . The advantage of using this method, is that the sum of squares of deviation from the model and the observation is minimized.

### 5.2.1 Estimates of $L_\infty$ and $Z/K$

The Powell-Wetherall Plot (Gayanillo *et al*, 1994) allows the estimation of  $L_\infty$  and  $Z/K$  ratio in a steady state population, using a time series data of length-frequency. This is expressed by the model.

$$\overline{L} = \frac{(L_\infty + L^1)}{L_t(Z/K)} \dots\dots\dots 13$$

From which

$$L_\infty = -a/b, \text{ and}$$

$$Z/K = -(I+b)/b$$

$$\phi^1 = \log_{10} (K) / 2 \log_{10} (L_\infty)$$

Where

- $Z$  is the instantaneous rate of total mortality
- $\bar{L}$  is the mean length computed from  $L^1$  upwards
- $L^1$  is the smaller length fully represented in the sample
- $a$  is the y-intercept
- $b$  is the slope of a linear regression.
- $\phi$  is a length based index of growth performance.

The basic assumptions in this model are:

- (a) A steady state population;
- (b) Growth is assumed to follow the deterministic von Bertalanffy curve with parameters  $K$  and  $L_\infty$ ; and
- (c) The curve location parameter,  $t$ , usually included in other models using length frequency analysis, is omitted since it does not influence length frequency distribution;

Successful use of the Wetheral method for estimating  $L_\infty$  and  $Z/K$  for tropical fish has been demonstrated ( Djama, 1988). This method was used to estimate these parameters for *L. vaigiensis* in the present study.

### 5.2.2 Estimation of mortality

Natural mortality ( $M$ ) of fish have been known to have a strong relationship with their growth parameter (Beverton & Holt, 1959). Pauly (1986), accounted for the partial correlation between  $M$  and  $l_\infty$  on one hand, and  $M$  and  $K$  on the other and showed that  $M$

is strongly correlated with mean environmental temperature. He derived an empirical formula to calculate natural mortality where:

$$\ln (M) = -0.0152 - 0.279 \ln (l_{\infty}) + 0.6543 + \ln (K) + 0.463 \ln (T) \dots \dots \dots 14$$

Where T is the mean annual temperature and the other parameters are as previously defined. This equation was used to estimate the natural maturity in

*L. vaigiensis*.

The Z (total mortality) was estimated using the length "converted catch curves". This method uses length frequency samples and thus no need of ages. The mortality is estimated with the assumption that:-

- (a) Z is the same in all age groups used in the plot;
- (b) All age group used in the plot were recruited with the same abundance (or recruitment) fluctuations which are small and of random character;
- (c) All age groups used in the plot are equally vulnerable to the gear used in the sampling; and
- (d) The sample used is large and lengths cover enough age groups to effectively represent the average population structure of the period of time considered.

With these assumptions the instantaneous rate of total mortality (Z), was obtained by the length converted catch curve analysis assuming as steady state population, (Pauly, 1990).

This takes the form

$$\ln (N_i/\Delta t_i) = a + b.t_i \dots \dots \dots 15$$

Where,

$N$  is the number of fish in length class  $I$ ;

$\Delta t$  is the time needed for fish to grow through length class  $I$ ; and

$t$  is the age (or the relative age, computed with  $t_0 = 0$ ) corresponding to the mid length of class  $b$ , with sign changed and  $I$  is an estimate of  $Z$ .

### 5.2.3 Fishing mortality and exploitation rates

The fishing mortality ( $F$ ) was calculated by subtracting natural mortality from total mortality ( $F = Z - M$ ) and the exploitation rate ( $E$ ) was estimated by dividing fishing mortality by the total mortality ( $E = F/Z$ ). The probability of capture, is estimated from the catch curve analysis through backward projection of the number that would be expected if no selectivity had taken place ( $N^?_i$ ), using the expression

$$N^?_{i-I} = N^?_i \cdot \text{Exp} (Z\Delta t) \dots \dots \dots 16$$

### 5.2.4 Yield - Per- Recruit estimates

The yield-per-recruit model to estimate yield was first proposed by Beverton and Holt (1959) and has recently been modified Pauly & Soriano (1986). The modified model is of the form:-

$$Y/R = EU^{M/K} \left[ 1 - \frac{3U}{(1+M)} + \frac{3U^2}{(1+2M)} - \frac{U^3}{(1+3M)} \right] \dots \dots \dots 17$$

Where  $U = 1 - L_c/L_\infty$

$$M = (1-E) / (M/K) = (K/Z)$$

$$E = F/Z$$



The relative yield per recruit ( $Y^1/R$ ) is described by two characteristics of the fish i.e.  $M/K$ , and the characteristic of the fishery ( $E$ .)

Several computer programs exists (Pauly & Morgan, 1987) for these models and their use has been demonstrated in several tropical fish species (Boonraksa, 1988; Gayanillo *et al.* 1994). The analysis was carried out using FiSAT (Fish Stock Assessment Tools) computer software developed by ICLARM & FAO (1996). The program was run on an IBM "Itech" 486 computer.

### 5.3 RESULTS

The Powell-Wetheral plot (Gayanillo *et al.*, 1994) estimated  $L_\infty$  and  $Z/K$  as 28.9 and 2.409 respectively (Fig. 15). These results were then applied to estimate the growth performance ( $\theta^1$ ) and growth constant ( $K$ ) by the shepherd method and ELEFAN method (Gayanillo *et al.* 1994) Using these methods,  $K$  and  $\theta^1$  were estimated as  $1.5 \text{ yr}^{-1}$  and 3.10 respectively.

Pauly's empirical formula was used to estimate natural mortality. Natural mortality ( $M$ ) was estimated to be 2.37. The mean surface water temperature for Msambweni lagoon is  $28.5^\circ \text{ C}$  and this was used in these calculations.

Length converted catch curves method was used to estimate  $Z$ ,  $F$ ,  $E$  and the selection curve. The catch curve graph is shown in figure 16 and the selection curve in figure 17. The mortalities and exploitation rates were estimated as  $Z = 3.52$ ,  $F=1.15$  and  $E = 0.33$ . From yield-per-recruit model the exploitation level which maximizes yield-per-recruit, ( $E_{\text{max}}$ ) and the exploitation level which result in a reduction of the unexploited biomass by

50% ( $E_{0.5}$ ) were estimated as 0.70 and 0.56 respectively. The calculated exploitation rate (E) (figure 18) of this fish is 0.33.

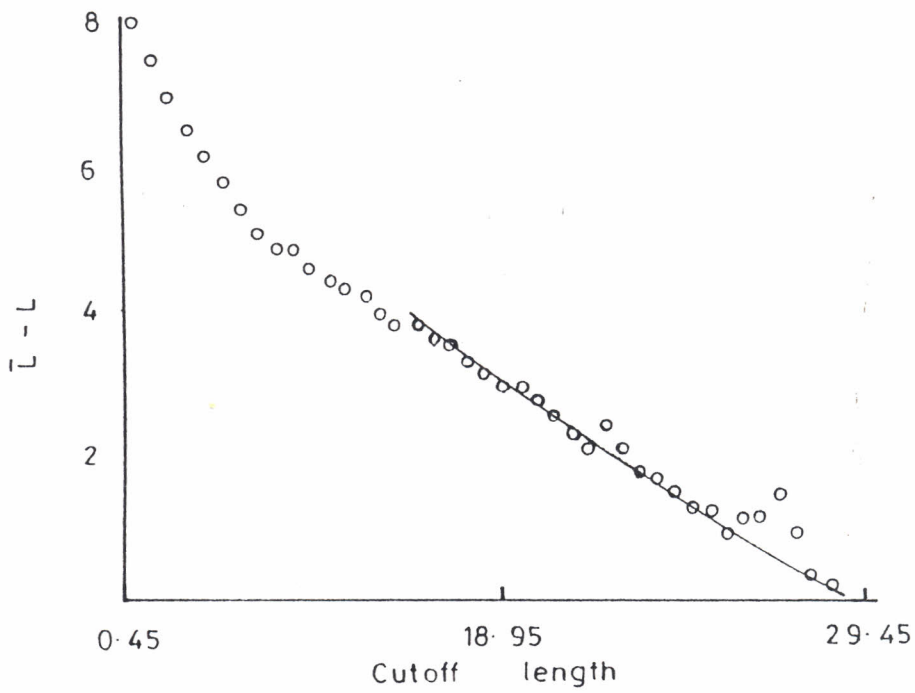


Figure 15. The Powell plot for the estimation of  $L_{\infty}$  and  $Z/K$  of *L. Vaigiensis* ( $L_{\infty}=28.9$ ;  $Y=-0.29$ ;  $r=0.95$ ).

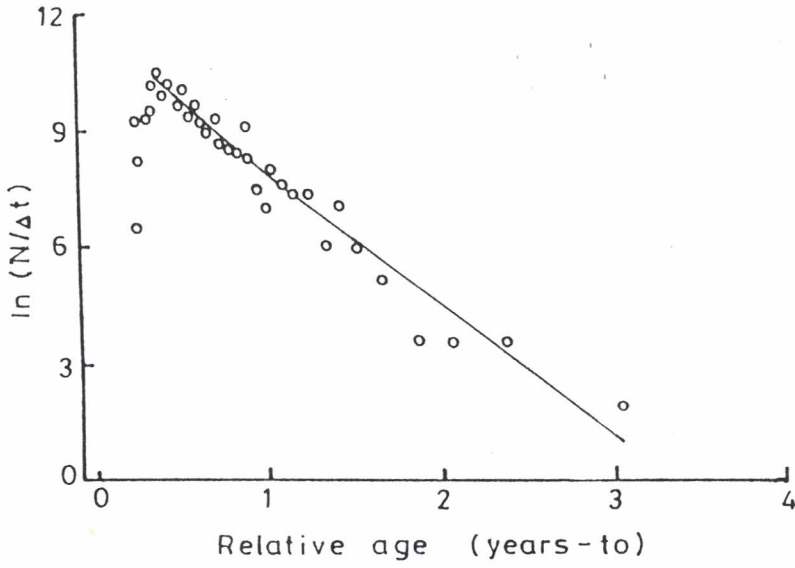


Figure 16. The catch curve of *L. vaigiensis*. The ascending part of the curve has been ignored.

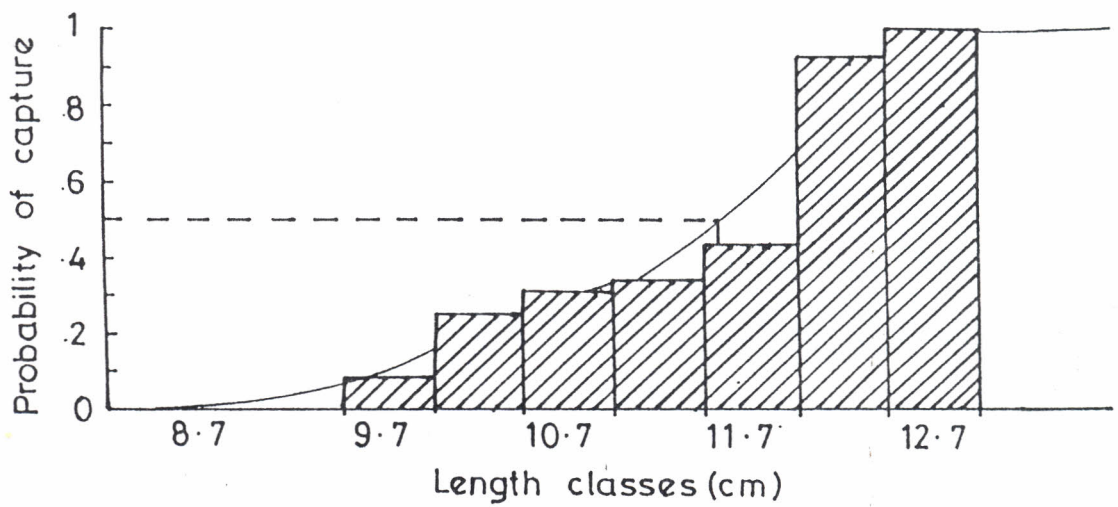


Figure 17. The probability of capture of *L. vaigiensis*. ( $L_{\infty} = 28.9$ ;  $K = 1.50$  and  $L - 50 = 11.6$ )

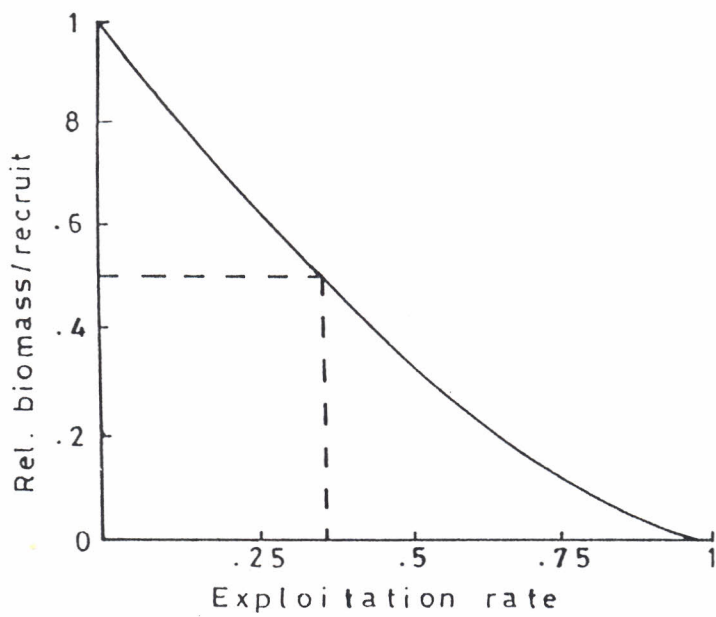


Figure 18. The relative yield per recruit curve of *L. Vaigiensis* ( $L/C=0.48$ ;  $M/K = 1.58$  and  $E_{Max} = 0.7$ ).

## DISCUSSION

The parameter estimated from models of length frequency data provide direct indications of  $K$ ,  $L_{\infty}$  and  $t_0$ , which are always in good agreement with those from more conventional subjective methods and those based on age determination where it has been tested (Shepherd, 1987). Therefore the length frequency based methods are objective and do not overestimate the growth and mortality parameters of temperate and tropical fishes. The von Bertalanffy growth curve is a curve of the decaying exponential type that has widely been used as a model of growth where a growth curve is a mathematical relation between the size of an animal and time.

The circumstances where methodologies as length-frequency analysis might apply are, for example, the preliminary stages of development of an assessment program or for a resource on which the investigation is just beginning (Csirke et al., 1987). In these estimates the main possible source of bias is introduced by the selective capture of larger sizes or older age groups due to fishing mortality, thereby reducing the average age of given fish.

The Wetheral-plot (Gayanillo *et al*, 1994) used to estimate  $L_{\infty}$  and  $Z/K$  in this study is a more objective and reliable compared to the other methods since it does not rely on resolving length frequency into normally distributed components. The estimated value of  $L_{\infty} = 28.9$  cm and  $Z/K = 2.4$  are reliable. There is evidence to this because the calculated ratio of  $M/K$  lies within the recommended value of between 1.5 and 2.5 (Beverton and Holt, 1959). Invariably other estimated parameters are correct as  $L_{\infty}$  and  $Z/K$  from the Wetheral plot were used to run other programs.

Phi- Prime values are similar within related taxa and have narrow distribution (Pauly, 1979). The overall growth performance of 3.10 calculated for *L. vaigiensis* compares well with the values given for other scarids. This ranges between 2.9 to 3.4 (Fishbase, 1994). The high values of  $K$ , and  $\phi^1$  compare favorable well with results achieved for other tropical fishes. Benno (1992) calculated  $K = 2.30$ , and  $\phi^1 = 3.4$  for *L. vaigiensis* and  $K = 1.0$  and  $\phi^1 = 2.335$  for *Calotomus spinidens* another scarid in Tanzania coastal waters. In the tropics,  $K$  and  $\phi^1$  values are always higher than that for the temperate fishes, since tropical fishes are short lived and fast growing (Pauly, 1979).

Fishing obviously impose an extra component of mortality on populations, and comparison of mortalities can be successfully used to determine the level of exploitation, (Raltson, 1987; Wright *et al.*, 1986; Russ & St. John, 1988). Based solely on length frequency data obtained from the *L. Vaigiensis* stock in this study it was principally possible to assess whether the stock is overfished for  $E_{opt} = 0.5$ . The calculated fishing mortality ( $E$ ) of 0.33 indicate that the level of the current fishing mortality results in an exploitation rate which is below the optimum rate ( $E_{opt} = 0.5$ ). A level of  $E_{opt} = 0.5$  is considered to be the level of exploitation necessary in order for fishing mortality to compete with natural mortality (Gulland, 1983). At  $E_{opt} = 0.5$ , maximum benefit is achieved from the fishery as there is no waste of the resource. At the current exploitation rate of  $E = 0.33$  the fishery of *L. vaigiensis* is under-exploited; as we have not reached the optimum level of  $F$  which is 0.5. From the selection curve of *L vaigiensis* (Fig. 17), the length at which 50% of the fish has already recruited into the fishery is at 11.7 cm. It has also been determined that the minimum size at which 50% of the fish has reached sexual

maturity is 16.8 cm (Fig. 7). It is apparent that *L. vaigiensis* recruits into the fishery before attaining sexual maturity. In Kenya, the Fisheries department recommends the use of beach seines with mesh sizes of more than 5 cm. Artisanal fishermen do not observe this regulation especially in the unprotected coastal lagoons and reefs. Fishermen using beach seines with cod ends of 2.5 cm were commonly encountered in the study site (Peers. Observation). The fish specimens used in this study were caught using such gears. Therefore such gears, which have small mesh sizes catch immature fishes in high proportions. The phenomenon whereby fish recruit into the fishery before attaining sexual maturity is known as growth overfishing (Russ & Alcala, 1989). Growth overfishing can result with a substantial reduction in the proportion of large size classes. It can also reduce the size of adult stock, whereby the production of larvae and subsequent recruitment is impaired. Nzioka (1985) has shown that growth overfishing do occur in coastal lagoons and coral reefs of northern Kenyan banks. This problem needs to be seriously addressed. Alternative management option should be explored in order to minimize the operation of illegal fishing gears in the coastal lagoons and coral reefs. The artisanal fisherfolks are people of low incomes and as such they require financial assistance to facilitate them acquire fishing facilities that can enable them venture into offshore fishing. Stock enhancement programs can be introduced in order to help in diverting the fishing pressure from the current traditional fishing grounds and give them time to recover. The fishermen should be educated on the benefits of sound fishing practices so that they can ultimately manage their resources sustainably. A continuous monitoring of the coastal fishery is also recommended.



## CHAPTER VI

### 5.0 CONCLUSION

Teleostean fishes have been observed to exhibit different spawning habits and based on their spawning they can be classified into four major groups (Kareka & Bal 1960). These groups are:

- Group I: Fishes with a short spawning season. The mature ovaries contain two separate batches of ova, immature and mature.
- Group II: Includes fishes which spawn once, but over a long period. The size of mature eggs will approximately represent half of the total range of the entire egg component.
- Group III: Fishes which spawn twice a year. The ovaries contain mature eggs and a batch of maturing eggs.
- Group IV: Fishes which spawn intermittently over a prolonged period. The ovaries may contain batches of eggs which cannot be differentiated from each other.

The oocyte size frequency distribution (Fig. 9) and histological studies (Plate 1) revealed two batches of oocytes in ovaries in stage 4 and 5. One batch contained immature oocytes and the other batch contained mature oocytes. The oocytes encountered in between the two modes contained cytoplasmic vacuoles, a clear indication that these would grow and be released together with the oocytes in the mature mode. The batch of mature oocytes is almost half of the entire egg component ( Fig. 9, stage 4 & 5). Hence *L. vaigiensis* belongs to category II as described by Kareka & Bal (1960). An individual

*L. vaigiensis* fish therefore capable spawns once in a breeding season, but over an extended period.

The monthly GSI plots for *L. vaigiensis* demonstrated that *L. vaigiensis* population in the inshore waters of Kenya have two peak spawning seasons. One period falling between March-June and the other occurring in November-December. Fish with mature gonads (Stage 4 & 5) were present in the sample throughout the year (Fig. 11) a clear indication that the fish population breeds throughout the year. However, the high values of gonadosomatic index realised during the period March-June and November-December is a reflection of usually large number of individuals reproducing and as such this fish shows breeding seasonality whereby there are two peak spawning seasons in the year.

Breeding habits of fish are associated with the suitability of the environment that suits the biology of the fish, and survival of the progeny. In lower latitudes, seasons which favour spawning are longer (Quasim 1995; Harden-Jones 1968). In the tropics however, there are the monsoon seasons which are generally distinguished on the basis of wind, precipitation, current patterns, concentration of nutrient, primary and secondary productivity (especially in nearshore waters). During the intermonsoon period there are calmer winds, heavy rainfall, high nitrogen and phosphate concentrations resulting with high primary and secondary production (Kitheka et al. 1996). The peak spawning season of this fish occurs during these periods. The conditions prevailing during the intermonsoon could be favouring breeding and survival of larvae and juvenile fish, but more research is needed to confirm this.

Rubindamayugi (1983) showed that *L. vaigiensis* has extended spawning season during the SE monsoon. Johannes (1978) has described scarids as non-migratory fish which exhibit multiple spawning. This study has given information showing that the population of *L. vaigiensis* is capable of spawning throughout the year, but with two peak spawning times in a year when a large number of individuals were in reproduction activity. It has been reported that in the tropics, smaller fractions of populations of many fish species spawn periodically over longer portions of the year with specific times when a large number of individuals are in reproduction activity (Johannes, 1978). This seems to be the case with the population of *L. vaigiensis* investigated in this study. Other studies of tropical fish species have also shown seasonality in their breeding patterns (Nzioka, 1981, 1982; McClanahan, 1988; Ntiba & Jaccarini, 1990). Nzioka (1981) also observed that the breeding season of *Scolopsis bimaculatus* coincides with the intermonsoon season.

The growth rates observed in this study compare fairly well with the observed rates of  $K=2.3$  and  $\phi^1=3.4$  in the Tanzanian water for the same fish (Benno, 1992). The similarity in the growth characteristics of *L. vaigiensis* in Kenyan and Tanzanian coast probably implies that the level of exploitation is similar. The fishing mortality in this study has been estimated to be below the  $E_{max}$  indicating that the stock is under-exploited. The current exploitation rate can at least be increased to 0.5, which is the  $E_{opt}$ , without having an advance effect on the fishery. However, the current fishing method, especially by seines, need to be reviewed as it has been shown in this study that they remove a very high proportion of sexually immature *L. vaigiensis* which leads to growth overfishing. Growth overfishing has been shown to occur widely in near shore waters (Nzioka, 1985).

The local fishermen should be encouraged to use beach seines with larger mesh sizes.

The current fishing method whereby the nets are fitted with cod-end liners of 2.5 cm should be discouraged. Meshes of less than 5 cm are prohibited in Kenyan waters under the fisheries act. This law should be observed and strengthened. Fish nets of mesh sizes less than 2 cm are also in use in the other areas despite their illegality (McClanahan et al. 1997). The seagrass beds are important nursery grounds for many commercial fish (Kimani et al., 1996) and so overfishing in this area can lead to poor recruitment and collapse of the fishery.

Intensive fishing pressure in Central Philippines has been shown to alter the pattern of zonation of large herbivorous reef fishes on a scale of hundred of meters (Russ & Alcala, 1989). The herbivorous fishes especially scarids moved from the shallow reef flat to the reef crest or slope. This type of movements could be occurring here as intense fishing has been observed in the shallow reef flat. There is a need to confirm whether this phenomenon is apparent in Kenya coastal waters. Nonetheless, the fishermen should be encouraged and facilitated to use recommended gear and also to diversify their fishing. Possibly fishing in deeper waters would realise a better catch and reduce the current growth overfishing which has been demonstrated here. A credit facility can be initiated for the fishermen to be able to purchase better fishing gears which are user friendly to the whole ecosystem. Community participation in the resource management could achieve better utilisation and sustainable utilisation of coastal marine fisheries.

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