The fisheries potential of *Marcusenius pongolensis*, *Oreochromis mossambicus* and *Schilbe intermedius* in Mnjoli Dam, Swaziland

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TABLE OF CONTENTS

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Abstract

This thesis investigates aspects of the diversity, abundance and biology of the fish species inhabiting Mnjoli Dam, an irrigation dam that is located in the rural lowveld region of Swaziland. Specific objectives for this thesis were: to determine the fish species present and select three principal species based on their abundance; to investigate the relative abundance and distribution of the three selected species; and to describe key population parameters, such as growth, maturity, reproductive seasonality and mortality.

The three dominant species were selected on their fisheries potential. These were *Marcusenius pongolensis, Oreochromis mossambicus* and *Schilbe intermedius*. *Marcusenius pongolensis* was the most abundant species in terms of both catch per unit effort and mass. Catch rates were shown to vary according to habitat type.

Age and growth parameters were obtained from sectioned otoliths. Marginal zone analysis showed that annulus formation occurred in winter for all three species. The maximum-recorded ages were 8, 6 and 8 for *M. pongolensis*, *O. mossambicus* and *S. intermedius*, respectively. Growth for the three species was best described by the three parameter von Bertalanffy growth model as $L_t = 188.67(1 - \exp^{-1.48(t+0.67)})$ mm FL for *M. pongolensis*; $L_t = 226.83(1 - \exp^{-0.4(t+2.02)})$ mm TL for *O. mossambicus* and $L_t = 214.59(1 - \exp^{-0.60(t+1.20)})$ mm FL for *S. intermedius*.

Sexual maturity was estimated for male and female *M. pongolensis* at 134 mm FL and 119 mm FL, respectively. *Oreochromis mossambicus* matured at 239 mm TL and *S.*

intermedius at 205 mm FL. Two spawning peaks for *M. pongolensis* and *S. intermedius* were observed, one at the onset of summer (November) and the second at the beginning of autumn (February-March). *Oreochromis mossambicus* also exhibited two spawning peaks, one in spring (September) and the second in autumn (February –March). Mean mortality rate (*Z*), estimated using catch curve analysis was 0.77 $year^{-1}$ for *M. pongolensis*, 0.49 $year^{-1}$ for *O. mossambicus* and 0.79 $year^{-1}$ for *S. intermedius*. Natural mortality was assumed to be equal to *Z* since there is no fishery activity at the dam.

Size specific selectivity curves were developed for each species. Of all the mesh sizes used, the 44 mm mesh size net had the highest catch rates in terms of numbers for *M. pongolensis* and *S. intermedius*. The 75mm mesh caught the highest catch rates for *O. mossambicus*. . The 44mm and 75 mm meshes seem to be the most suitable mesh sizes for harvesting the candidate species.

It is concluded that no commercial fishery should be established on the dam, yet a small subsistence fishery could be a possible option. Management options such as input controls, open and closed seasons and areas and minimum sizes are discussed.

CHAPTER 1

General introduction

The decrease in the viability of utilizing cattle as a source of protein (Hyslop 1994) in Swaziland, due to rampant cattle rustling, outbreak of foot and mouth disease and drought, has created an increased interest in the utilization of freshwater fisheries as a source of protein. In the past, customs and taboos limited fishing activities and fish consumption in those tribes with a cattle-owning tradition (Bruton & Jackson 1983). This included the majority of the Swazi people. However, these taboos have now largely disappeared due to an awareness that has been created that freshwater fisheries can contribute significantly to food security and offer income generation opportunities to communities within the vicinity of inland water bodies such as dams and rivers. The ever-increasing demand for affordable protein, especially in the rural areas (Nthimo 2000) therefore requires the establishment of fisheries development in the dams of Swaziland.

Swaziland has a relatively high rainfall (average = 890 mm per annum) and is traversed by five major perennial rivers, the Lomati, Komati, Usuthu, Mbuluzi and Ngwavuma. The first three rivers originate from South Africa whilst the last two originate within Swaziland. All the rivers drain eastwards into the Indian Ocean. Dams have been constructed on most of the rivers to store water for irrigation, community and industrial water supply and hydro electrical power generation (Table1.1). The small man-made impoundments which are usually for multipurpose use, form the bedrock of fisheries resource and in many countries, like in Swaziland, they are the only inland fishery resource. During the planning and construction of these dams fisheries were never considered, however, the fish populations that usually occupy these new water bodies often prove to be an additional asset to the primary use of the dam. It should be emphasized that, in contrast to non-renewable resources, the failure to utilize freshwater resources constitutes a waste in potential production.

Table 1. 1. Major Dams of Swaziland and their primary use.

Dam	Capacity (Mm^3)	River system	Primary use
Driekoppies	251.0	Lomati	Irrigation
Hawane	2.8	Black Mbuluzi (Mbuluzi)	Domestic water supply
Hendrick van Eck	10.4	Usuthu	Irrigation
Luphohlo	23.6	Lusushwana (Usuthu)	Hydropower generation
Maguga	332.0	Komati	Irrigation & hydropower generation
Magwanyana	6.0	Nyetane (Usuthu)	Irrigation
Mkikomo	2.0	Lusushwana (Usuthu)	Hydropower generation
Mnjoli	152.0	Black Mbuluzi (Mbuluzi)	Irrigation
Sand River Reservoir	50.0	Komati	Irrigation
Sivunga	6.9	Usuthu & Nyetane (Usuthu)	Irrigation

Recent interest in freshwater fisheries has seen the Fisheries Section, which is responsible for all fisheries development in Swaziland, being inundated with application for permits to fish in the country's dams. Most of these people have shown interest to fish at Mnjoli Dam, which is the second largest dam in Swaziland covering an area of 15 km^2. Unfortunately, Swaziland like most African countries does not have historical data on directed catch and effort and length-based or age-based data for the application of stock assessment models for the dams to provide management advice and guide the formulation of legislation. The only available information on Mnjoli Dam and a few other impoundments in Swaziland is within a report by Batchelor (1989) who conducted a preliminary survey on the dams. The aim of the survey was to determine fish species composition and density with a view to decide on the extent to which capture fisheries could be encouraged to ensure proper management of the aquatic resources (Batchelor 1989). The results of the survey indicated that *Marcusenius macrolepidotus* (now *M. pongolensis)* (Peters 1852) and *Schilbe intermedius* (Rüppell 1832) were the most dominant species that could be exploited. The potential yield was estimated using the morphoedaphic index (MEI) (Ryder 1978; Marshall & Maes 1984) and the phosphorus equation (log FC = 0.708 log TP + 0.774; where FC is fish standing stock (kg.ha^{-1}) and TP is total phosphorus (mg.m^{-3})). It was found to be 33 kg ha^{-1}year^{-1} for *M. pongolensis* and 44kg ha^{-1}year^{-1} for *S. intermedius*. The sampling intensity of the survey was extremely short (one night per dam) due to financial constraints. These results do not take into account the biological information of the target fish species and is therefore difficult to base sound decisions on development and management of a fishery at Mnjoli Dam. The scarcity of information on fisheries resources in the man-made impoundments has therefore hindered fisheries development in Swaziland, because the fisheries section does not have all the relevant information to make decisions on fisheries development in dams.

This thesis forms part of a comprehensive fisheries survey project, which was conducted in Swaziland to determine the fish species present throughout the country and their abundance, distribution and seasonal variation. The survey was also conducted to estimate fisheries potential in some of Swaziland’s small water bodies. This thesis, therefore, forms part of the latter objective and focuses on Mnjoli Dam, which is the second largest to Maguga Dam, which is still filling phase.

Aims and Objectives of the thesis

The aim of the thesis is to investigate the abundance, location and specific biological aspects of three dominant fish species in Mnjoli Dam. This information will enable the fisheries section to make rational fisheries development decision and to assist in formulating a fisheries management plan for the dam. The need for detailed information on the biology of the dominant species arises from the interest that has been shown by people applying for permits to fish in this dam as well as the interest shown by the communities living around the dam.

The specific objectives of the study were:

1. determine the fisheries species present and select possible candidate species that can support a fishery,
2. determine the abundance, distribution and seasonality of the candidates
3. describe the reproductive biology of the candidate species,
4. investigate population parameters such as growth, maturity and mortality and assess the resource status of the candidate species, and
5. determine gear selectivity patterns for the three principal species.

To achieve these objectives, this thesis has been divided into seven chapters. Chapter 2 describes the study area and general methods. Chapter 3 describes the distribution, seasonality and relative abundance of the three species. Chapter 4 describes the age and growth of the three species. Chapter 5 describes the reproductive biology of the selected species. Chapter 6 describes gillnet selectivity and mortality rates, of the three species.

Lastly, Chapter 7 discusses general findings and provides fisheries management recommendations for Mnjoli Dam.

CHAPTER 2

Study area and general methods

Study Area

Mnjoli Dam ($26^0$10'S, $31^0$40'E) is an oligotrophic system (Batchelor 1989) located at Manzana, in the Lowveld region of Swaziland. It is a 42 m high rockfill dam constructed in 1980 on the Black Mbuluzi River, which has a catchment area of 3100 km^2, for irrigating sugar cane at the Simunye Sugar Estate. At full capacity of 150 million m^3 the dam stands at 294.5 m a.m.s.l and covers an area of 15 km^2. Due to overgrazing activities upstream, the dam's storage capacity has been reduced to 135 million m^3 through sediment accumulation (Matondo & Dlamini 2000). The maximum draw-down level stands at 280.5 m a.m.s.l.

Water level fluctuations follow the rainfall patterns of the Lowveld region (Figure 2.2). The rainy season occurs over the summer period between October and April, and averages 500 – 900 mm per annum. The dry winter season results in a draw-down. In the draw-down phase, large muddy areas become exposed together with vegetation remains (trees and tree stumps) since the dam area was not cleared when the dam was constructed. There is little vegetation growth on exposed areas. This is due to rocky soils that cannot support extensive vegetative growth. During the study period that is between July 2002 and June 2003 it was drought year as it can be seen on Figure 2.2.

The water level at Mnjoli Dam also depends on the water inflow from the Mbuluzi River as well as the outflow to the canal and back to the river (Figure 2.3). The study was conducted during a drought year and there was more outflow from the dam to irrigate sugarcane. A new sugarcane scheme located close to the dam was established which also utilised water from the Mnjoli Dam thus the increase in outflow compared to the other years.

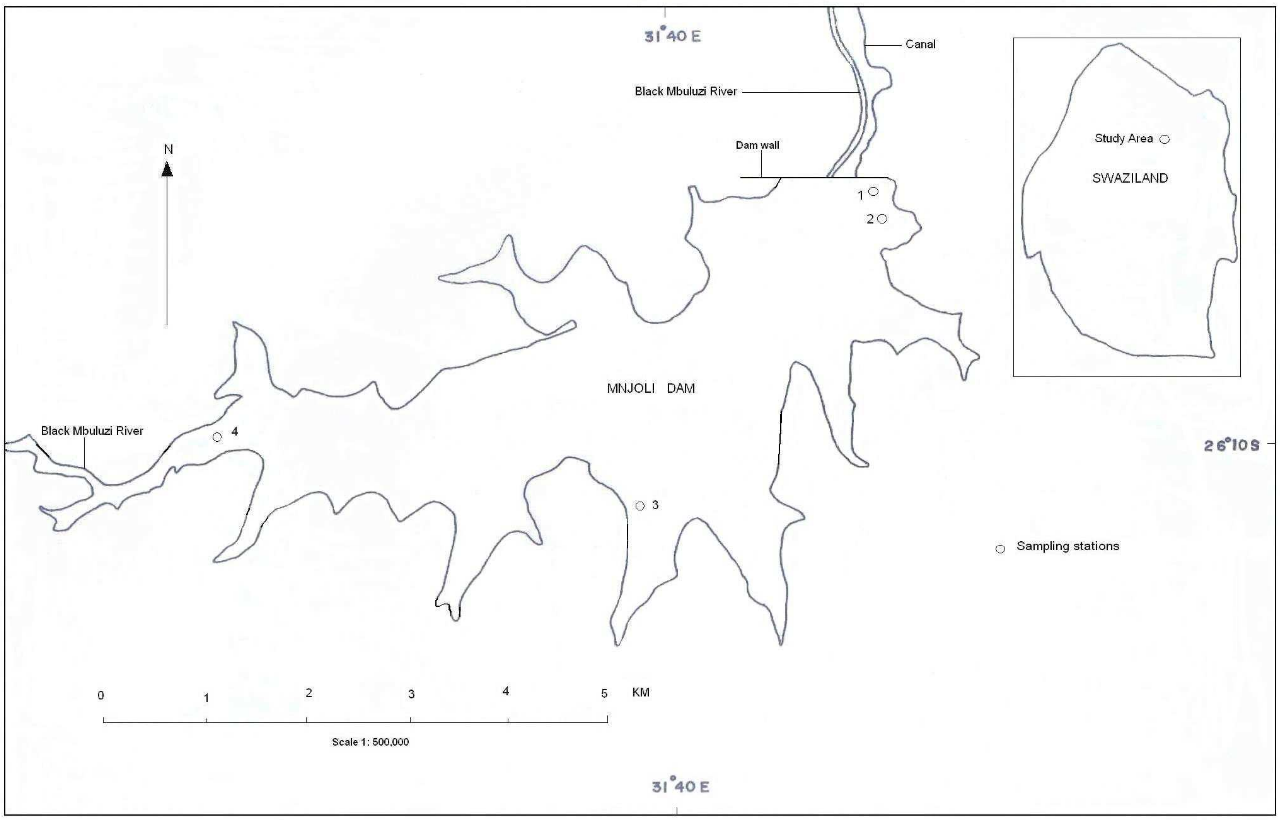

Figure 2.1. Map of Mnjoli Dam, Swaziland.

Sampling stations

Four sampling sites were selected to cover both lentic and transitional zones of the dam (Figure 2.1). Station 1 was situated at the dam wall area and the habitat type in this area consisted of large rocks, Station 2 was at the mouth of the spillway near the dam wall and had a gravel and rock dominated substrate. Station 3 was at the middle area of the dam and had a substrate dominated by mud. Station 4, was initially near an island, which is situated at the middle of the dam. This station was used for the first two months of sampling and was thereafter abandoned for the river inflow area due to the presence of crocodiles on the island, which was a threat to the nets as well as to the research team. The riverine area was dominated by mud. Figures 2.3 and 2.4 provide a visual representation of the habitat types at Station 1 and 4. Table 2.1 provides coordinates of all the sampling stations.

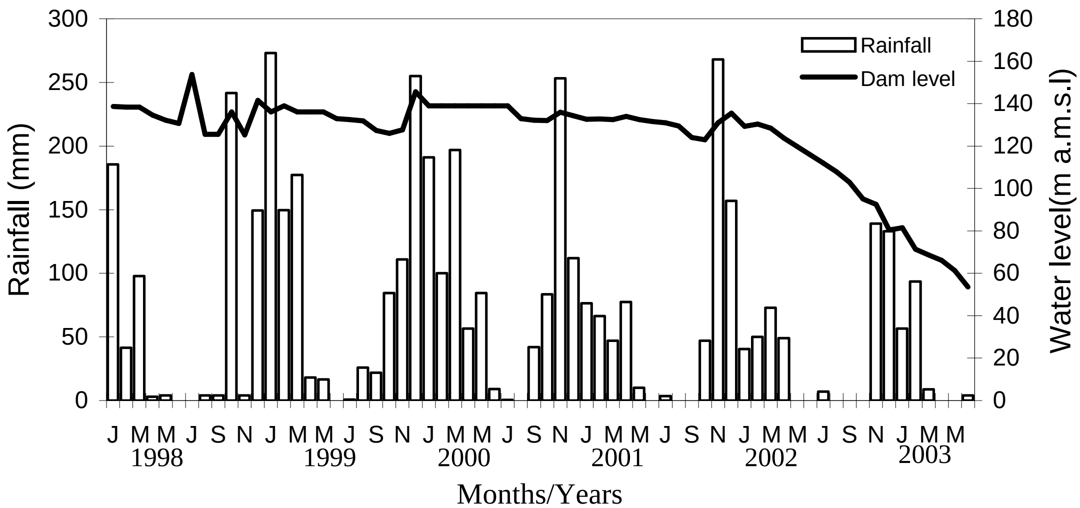

Figure 2.2. Monthly rainfall and water level (m a.m.s.l) from January 1998 to June 2003 in Mnjoli Dam, Swaziland.

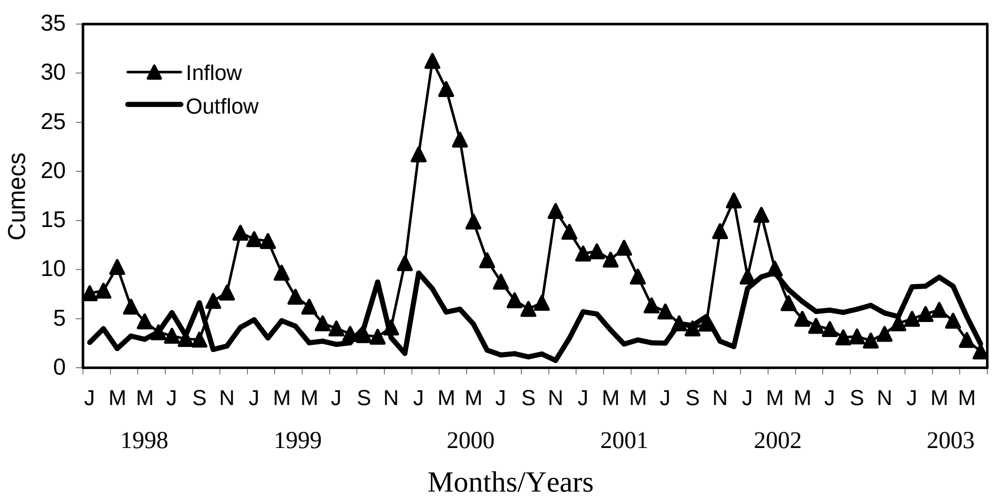

Figure 2.3. Monthly inflow and outflow in Mnjoli Dam, Swaziland from January 1998 to June 2003

Sampling methods

Experimental gill nets were used to collect fish.

Sampling was conducted four nights per month between July 2002 and June 2003 at the sampling stations (Fig.2.1). Top set gillnets were used due to that the vegetation was not cleared when the water was dammed and the nets would have been damaged by the vegetation. Two fleets of multifilament nets 54.61 m long, top set gill nets were used for sampling at each station. Each fleet consisted of six different mesh size panels that were randomly distributed throughout the net, effectively fishing an area of 95.64 m^2. The actual mesh sizes and the manufacturers quoted mesh sizes are shown on Table 2.2. Scrap netting was joined to each end of the experimental gill nets to ensure that there is no "dead space" at the last fishing panels by stretching the outer mesh panels taught. Any fish caught in these end sections were not considered in the study. Gill nets were set between 1600hrs and 1800hrs and retrieved the following morning between 0600hrs and 0800hrs. Nets were set inshore and parallel to the bathymetry at all the sampling stations.

Table 2.1. The location of the four sampling stations at Mnjoli Dam, Swaziland during this study (July 2002-June 2003)

Site Number	Name	Coastline substrate	Co-ordinates
1	Dam wall	Rocky	S 26^0 08'09", E 31^0 40'18"
2	Spillway	Gravel and rocky	S 26^0 08' 48", E 31^0 41'16"
3	Middle area	Muddy	S 26^0 10' 24", E 31^0 41'15"
4	Riverine area	Muddy	S 26^0 10' 01", E 31^0 37'26"
4*	Near island	Rocky	S 26^0 09' 26", E 31^0 40'10"

* Initial location of station 4

Figure 2.3. Researchers pulling a seine net at Station 1, Mnjoli Dam, Swaziland, between July 2002 and June 2003.

Figure 2.4. The fishing team preparing to launch the boat at Station 4, Mnjoli Dam, Swaziland between July 2002 and June 2003.

Fish caught in gill nets were sorted by species measured to both total (TL) and fork length (FL) to the nearest millimeter depending on the species, and weighed to the nearest gram.

Table 2.2. Manufacturers quoted mesh sizes, actual stretch mesh range and gillnet dimensions for the nets used at Mnjoli Dam, Swaziland.

Manufactures Quoted mesh	Stretched mesh size range	Mesh size	Length of Each panel	Depth of each panel
28	28 – 30 mm	29.00 ±1.00 mm	10.00 m	1.53 m
44	44 – 45 mm	44.40 ±0.50 mm	8.00 m	1.84 m
60	60 – 66 mm	63.00 ±3.00 mm	9.73 m	1.88 m
75	70 – 77 mm	73.50 ±3.50 mm	9.88 m	1.43 m
100	95 – 100 mm	97.50 ±2.50 mm	9.00 m	2.00 m
144	170 – 175 mm	159.50 ±15.50 mm	8.00 m	1.90 m

Physical characteristics and species diversity

Surface temperature, pH and Secchi disc depth were measured monthly at all the sampling stations (Fig. 2.1) during the study period. Information on water conductivity was provided by the Water Resources Branch of the Ministry of Natural Resources and Energy who conduct monthly sampling at the mouth and below the wall of the dam.

The water at stations 1 and 2 was perfectly visible since the secchi disc readings ranged from 75cm to 100cm. Both stations were situated near the dam wall. Water transparency was lowest at stations 3 and 4, ranging between 10 cm and 58cm. Station 4 was at the river inlet and the highly turbid Black Mbuluzi River influenced the transparency at this station. Conductivity ranged from 16.7 $\mu S.cm^{-1}$ at the river mouth to 30.8 $\mu S.cm^{-1}$ at the below the dam wall with a mean of 18.7 ± 8.6 μS.cm^{-1} and 27.7 ± 3.9 μS.cm^{-1} respectively. The mean pH during the study was 7.25 ± 0.2.

In general, water temperatures reflected seasonal trends in air temperature. During this study, mean summer water temperature was 26.3°C ranging between 22°C and 29°C. In contrast, mean winter water temperature was 17.6°C ranging between 16°C and 19°C. The lowest temperatures were recorded in June and July, whilst maximum temperatures were recorded in January and February.

Table 2.3. Fish species caught in gill nets at Mnjoli Dam, Swaziland between July 2002 and June 2003.

Species	Common name
Cichlidae	
Oreochromis mossambicus (A. Smith, 1840)	Mozambique tilapia
Tilapia rendalli (Boulenger, 1896)	Redbreast tilapia
Clariidae	
Clarias gariepInus (Burchell, 1822)	African sharptooth catfish
Cyprinidae	
Barbus trimaculatus (Peters 1952)	Threespot barb
Labeo cylindricus (Peters, 1852)	Redeye labeo
Labeo molybdinus (Du Plessis, 1963)	Leaden labeo
Labeobarbus marequensis (A. Smith, 1841)	Largescale yellowfish
Labeo rosae (Steindachner, 1894)	Silver labeo
Mormyridae	
Marcusenius pongolensis (Fowler, 1937)	Southern bulldog
Petrocephalus wesselsi (Kramer & van der Bank, 2000)	Southern churchill
Schilbeidae	
Schilbe Intermedius (Rüppell, 1832)	Silver catfish

A total of 14 species are found in the Black Mbuluzi River system, which supplies water to Mnjoli Dam. A biodiversity survey, using a seine net and an electrofisher, conducted between July 2002 and June 2003 recorded eleven species at the dam wall, eight species at the emergency spillway and 14 species in the river below the dam. A total of 11 species were caught in the dam during the sampling period (Table 2.3). All the fish species are indigenous to the region and are within their natural distribution range (Skelton 2001).

Three species, *Marcusenius pongolensis*, *Oreochromis mossambicus* and *Schilbe intermedius* were chosen for study because they comprised about 75% of the total catch. *O. mossambicus* is a highly valued fish for food. Although *M. pongolensis* and *S. intermedius* are not as valued for food, these three species are significant components of the ichthyofauna of Mnjoli Dam, *M. pongolensis* by virtue of its great abundance. Developing a small-sale fisheries based on these species could possibly improve food security and enable the communities to have access to a cheap source of protein thus improving their nutritional status.

***Marcusenius pongolensis* – Southern bulldog**

Marcusenius pongolensis (Fig.2.5) is widespread and common in the Cunene, Okavango and Zambezi system and east coastal rivers and lakes from the Ruaha (Tanzania) south to the Umhlatuzi in Natal (Skelton 2001). It is a shoaling species and favours well-vegetated, muddy-bottomed marginal habitat of rivers and floodplains.

Figure 2.5. *Marcusenius pongolensis* caught from Mnjoli Dam, Swaziland, between July 2002 and June 2003.

Marcusenius pongolensis is nocturnal (Lowe Mc-Connell 1987) and moves inshore after dark (Skelton 2001). They emit a weak electric discharge for communication (Kenmuir 1984) as an adaptation to nocturnal habits and a life in turbid water (Lowe Mc-Connell 1987). *Marcusenius pongolensis* is classified as insectivorous and feeds on a wide range of benthic invertebrates from the bottom or on vegetation. The species breeds during the rainy season and river migrations (potamodromesis) have been recorded during the breeding season. They are indigenous in the Black Mbuluzi River system.

Oreochromis mossambicus - Mozambique tilapia

Oreochromis mossambicus (Fig. 2.6) occurs naturally along the eastern coast of Africa, in the lower Zambezi and its tributaries, and eastward-flowing rivers and coastal lagoons southward to the Bushman's River, near Port Elizabeth, South Africa (Bruton & Bolt, 1975).

Figure 2.6. *Oreochromis mossambicus* caught from Mnjoli Dam, Swaziland, between July 2002 and June 2003.

It is usually restricted to relatively shallow waters. It is primarily detritivorous species, with diatoms playing an important role in their nutrition (Bowen, 1979; Trewavas, 1983). De Silva *et al*. (1984) found populations in different lakes to differ markedly in their diets. These ranged from almost exclusively detritivorous, to primarily herbivorous and even primarily carnivorous. The Mozambique tilapia is a mouthbrooder, with males constructing nests in areas of sparse to moderately dense vegetation (Bruton & Allanson 1974).

***Schilbe intermedius* - Silver catfish**

Schilbe intermedius (Fig. 2.7) is widely distributed in the Cunene, Okavango, Zambezi systems, southwards to the Phongolo in northern Zululand (Skelton 2001).

Figure 2.7. *Schilbe intermedius* caught from Mnjoli Dam, Swaziland, between July 2002 and June 2003.

S. intermedius is a shoaling species that inhabits stagnant or slow flowing open water. They are classified as piscivorous although they have a varied diet including fish, insects, shrimps and other aquatic organisms. They are generally active at night or in subdued light. They breed during the rainy season. Extensive breeding migrations upstream to suitable spawning areas have been observed by Kenmuir (1984).

CHAPTER 3

Species distribution and abundance

Introduction

Biotic stability in tropical reservoirs is usually achieved between 5 and 15 years after initial impoundment (Henderson *et al.* 1973). Fish population increase, both in terms of number and biomass, parallel the high productivity after the initial filling of the impoundment. As the dam stabilises, only those species that are able to adapt to the newly created lacustrine environment will persist. In 1980/81, soon after the construction and filling of Mnjoli Dam, a preliminary assessment of its fisheries potential was conducted. A total of seven species were noted. These included *C. gariepinus, O. mossambicus, S. intermedius, T. rendalli, L. cylindricus, L. marequensis* and *M. pongolensis.* Catches were dominated by three species, *C. gariepinus*, *S. intermedius* and *O. mossambicus*, contributing 74%, 12% and 9% by mass respectively. Another brief survey to assess the fisheries potential at Mnjoli Dam was conducted by Batchelor (1989). A total of six species were noted; these were *O. mossambicus, S. intermedius, L. marequensis, M. pongolensis* and *B. trimaculatus.* The bulk of the catch by mass was dominated by two species; *M. pongolensis* (50%) and *S. intermedius* (46%).

Mnjoli Dam is now 22 years old, and is assumed to have stabilised. This chapter aims to provide estimates of relative abundance and distribution of all fish species in Mnjoli Dam, and compare changes to the dam’s ichthyofauna over the past two decades.

Materials and Methods

Abundance estimates

Gill net effort was measured on a net. $night^{-1}$ basis, whilst catch was measured in terms of both numbers and mass. Seasonal abundance data were grouped into four periods according the austral seasons for comparison. These were summer (November to January), autumn (February to April), winter (May to July) and spring (August to October). Seasonal catch per unit effort (CPUE) were log-transformed to stabilize variance and seasonal variation was compared using the non-parametric Kruskal-Wallis test on ranks. Spatial variation in CPUE was assessed by comparing CPUE from the different sampling Stations using Kruskal-Wallis test.

The relative abundance, or commonness, of each species in the catch composition was calculated using an index of relative importance (Kolding 1989) as

$$IRI = \sum \left[\frac{(\%W_i + \%N_i) * \%F_i}{(\%W_j + \%N_j) * \%F_j} * 100 \right]$$

where $\%W_i$ and $\%N_i$ is percentage weight and numbers of each species (j) of the total catch, $\%F_i$ is percentage frequency of occurrence of each species in total number of settings, and S is total number of species.

Shannon's Diversity Index, *H*, as a measure of the abundance and evenness of species present in a sample, was calculated at each sampling site. The index is defined (Begon *et al* 1990) as

$$H = -\sum_{i=1}^{S} P_i \ln P_i$$

where P_i is the number of individuals of each species divided by the total number of individuals of all species in each sample and *S* is the total number of individuals of all species. Shannon's evenness index (*J*) was calculated as

$$J = H / \ln S.$$

This index is bounded between 0 and 1, with 1 being complete evenness.

Results

Abundance

In the present study, eleven species were recorded at Mnjoli Dam as compared to six species caught in the 1989 survey by Batchelor. Only five of the ten species (*M. pongolensis*, *P. wesselsi*, *S. intermedius*, *B. trimaculatus* and *O. mossambicus*) were caught on every sampling occasion.

A total of 1092 fish were sampled in Mnjoli Dam during this study. In terms of numbers, *M. pongolensis* was the most numerous, contributing 70% of the total catch. *Petrocephalus wesselsi* was second, *S. intermedius* third, and *B. trimaculatus* was fourth, each contributing 9%, 6% and 6% in terms of numbers, respectively (Table 3.1). *Marcusenius pongolensis* was the most important species, in terms of mass, followed by

C. gariepinus, *S. intermedius* and *O. mossambicus*, accounting for 63%, 19%, 6% and 6%, respectively (Table 3.1).

Table 3.1. Overall percentage contribution by numbers, weight and frequency for the species sampled at Mnjoli Dam, Swaziland between July 2002-June 2003.

Species	% Numbers	% Weight	% Frequency
Marcusenius pongolensis	70.1	59.5	66.7
Schilbe intermedius	6.2	5.7	44.8
Oreochromis mossambicus	4.8	5.6	26.0
Clarias gariepinus	1.1	20.0	8.3
Labeo cylindricus	0.6	0.4	7.3
Labeo molybdinus	0.2	0.6	2.1
Labeobarbus marequensis	1.4	3.7	14.6
Tilapia rendalli	0.6	0.5	5.2
Labeo rosae	0.1	1.5	1.0
Petrocephalus wesselsi	8.8	1.2	31.3
Barbus trimaculatus	6.1	1.2	31.3

Diversity was highest at the river mouth area (Station 4) and decreased towards the dam wall (Station 1). All 11 species were recorded in Mnjoli Dam were represented at the river mouth area, whilst seven were noted at the dam wall and spillway areas. The middle area (Station 3) had eight species. The diversity of fish species calculated from Shannon Diversity Index was H = 1.12, indicating low diversity for the whole dam. Species were proportionally distributed at Station 1 as compared to the other Station (J = 0.35). The lowest of evenness was recorded for Station 4 (J = 0.16).

Highest CPUE, in terms of numbers, was at middle area of the dam (Station 3), where *M. pongolensis* and *P. wesselsi* dominated catches. The highest contribution in numbers of *S. intermedius* to the catches was at the river mouth area (Station 4) where it accounted for 5%, whilst the highest contribution of *O. mossambicus* (5%) was recorded at the middle section of the dam (Station 3).

There was a significant difference in the catch rates at the different Stations (p = 0.01), with Stations 3 and 4 having the highest CPUE as compared to Stations 1 and 2, the dam wall stations (Figure 3.1). There was a significant difference in CPUE between Stations 1 and 3 (p = 0.01), and 1 and 4 (p = 0.05). Differences in CPUE were also recorded between Station 2 and 3 (p = 0.02), and Station 2 and 4 (p = 0.01). There was no significant difference between Station 3 and 4 ($p > 0.05$).

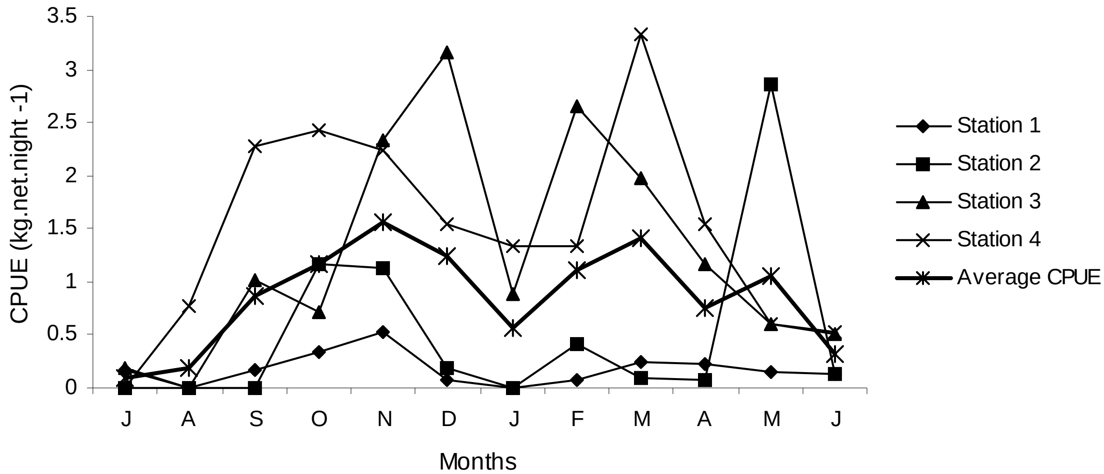

Figure 3.1. Average CPUE for all species at each station and the combined total CPUE for all species sampled at Mnjoli Dam, between July 2002 and June 2003.

Temporal and spatial abundance

Mean monthly CPUE is illustrated in Figure 3.1. Total CPUE varied monthly with three peaks recorded. The first peak in November was the highest with a CPUE of 1.56 kg.net.night^{-1}. The second peak in March had a CPUE of 1.41kg.net.night^{-1} and the third in May was 1.05 kg.net.night^{-1}. The lowest CPUE of 0.08 kg net.night^{-1} was recorded in

July. In all the Stations, *M. pongolensis* contributed the most to the combined total CPUE. There was no significant difference in seasonal CPUE between the various Stations (Kruskal-Wallis, $F = 0.976$, $df = 3$, $p = 0.44$) (Figure 3.1).

Discussion

The gill net data from Mnjoli Dam, sampled between July 2002 and June 2003, forms the longest and probably one of the most reliable data series collected to date. From these data, an index of temporal and spatial change in abundance and species composition was estimated and compared with previous records. The sampling design in this study remained constant over the sampling period and subsequently CPUE could therefore be assumed to be constant throughout the sampling period and likely to be proportional to the abundance of the different species.

The fish population of Mnjoli Dam appears to have changed over the last 15 years. A sample taken between March and April 1989 was dominated by *Clarias gariepinus* (74% by weight), *Oreochromis mossambicus* (9%) and *Schilbe intermedius* (12%) with *Marcusenius pongolensis* accounting for only 4% of the catch (Batchelor 1989). These results should be treated with caution, however, because Batchelor only sampled during one night and his sample may have not therefore been as fully representative as taken more frequently. These results, however, seem to suggest that since the construction of the dam there has been a decrease in the abundance of *C. gariepinus, O. mossambicus, S. intermedius, T. rendalli* and *L. cylindricus* and an increase in *M. pongolensis.* The reduction in certain species could be due to their inability to adapt to the new lacustrine environment or to the low productivity of the dam. The stability of the dam may have also caused the reduction in some species because as the dams stabilise, there is usually a reduction in nutrient levels, which paralleled the initial filling of the dam. Similar observations on changes in species composition have been made for Lake Kariba (Balon 1972). Haplochromis species were the most abundant species in the 1960's in Lake Kariba before it changed to *Lates niloticus* in the late 1970's.

Sampling at the different stations and in different seasons, consistently showed that CPUE for *M. pongolensis* was the highest, indicating this species' ability to colonise the entire dam. With the exception of *T. rendalli, L. cylindricus, L. molybdinus* and *L. rosae,* all the other species were relatively common through out the sampling stations. This suggests that these species, which are relatively common, have adapted to the lacustrine condition and their habitat preferences are sufficiently generalized. Merron (1991) made similar observations that small *Barbu*s species, including *B. barnadi*, *B. radiatus* and *B. thamalakanensis,* as well as *Petrocephalus catostoma, Marcusenius macrolepidotus, Pseudocrenilabrus philander*, *O. andersonii and C. gariepinus* in the Okavango Delta (Botswana), were widespread and common throughout all sampling sites. The absence of *T. rendalli* at the dam wall and spillway areas can be attributed to its preference well-vegetated waters. *L. cylindricus* was found at the spillway and the river mouth areas, while *L. molybdinus* was found at the dam wall and river mouth areas. *Labeo rosae* was only found at the river mouth area. The absence of these species in the other sampling stations can be attributed to their habitat preferences. *S. intermedius* was found throughout the dam at all sampling stations but not as abundant as *M. pongolensis.*

Species diversity was highest at the river mouth area with all eleven species from the dam recorded. By contrast, the lowest diversity was recorded at the dam wall. The observation was not surprising since all the species collected are of riverine origin and Station 4 was at the dam - river interface. The influence of water inflow from the river may have contributed to the high species diversity. Although species richness was high at the river mouth area, individual species distribution was more equitable at the dam wall. At the dam wall the proportion of individual species to the total number of individuals was almost equal, while at the river mouth area the proportion of *M. pongolensis* was highest, masking the contribution from other species.

The abundance of the different species at the different areas appeared to correlate with their habitat preferences. CPUE for *M. pongolensis* was highest at the river mouth area (Station 4) and lowest at the dam wall. The river mouth area was characterized by turbid water and muddy shoreline, which is favourable habitat for *M. pongolensis.* Large catches could also be due to the nocturnal and shoaling behaviour of this species. Their chances of encountering, and being caught, in gill nets was high since the nets were set overnight. *Oreochromis mossambicus* was abundant at the middle station and lowest at the spillway. The middle station was characterized by a muddy shoreline, whilst the spillway was characterized by rocky shoreline. Catch rates for *S. intermedius* were highest at the dam wall (Station 1) and lowest at the middle area (Station 3). *Schilbe intermedius* prefers standing or slow flowing open water, which was characteristic of Station 1. There was a general trend of a decrease in CPUE for this species when moving from the river mouth area towards the dam wall. This could be due to an increase in average depth.

The abundance in terms of catch rates for the combined species varied monthly. Three peaks in CPUE were observed; November, March and May. The highest catch rates were in November and the lowest in June. The peaks in CPUE coincided with the onset of the rainy season, which usually triggers the onset of the breeding season for most of the species. According to Nyman & Degerman (1988), spawning affects fish activity. Since all the species are of river mouth origin, it was not surprising that the highest catch rates were in the transitional zone, at station 4. The peak in May could have been due to adults returning from spawning grounds since most of the fish caught were mature. The lowest catch rates in June could have been due to the cold water conditions since June is the middle of winter, hence fish are less active. Temperature also affects fish activity (Neuman 1974, 1979). The combined catch rates indicated that fish were more active in summer when the temperatures were highest (> 22^0C) and less active when temperatures were low (>18^0C). The difference in catch rates could have been caused by temperature changes. The high CPUE in November and March are therefore associated with the summer season, rains and spawning seasons at Mnjoli Dam.

CHAPTER 4

Age and Growth of *Marcusenius pongolensis*, *Oreochromis mossambicus* and *Schilbe intermedius* in Mnjoli Dam, Swaziland

Introduction

Studies on growth are vital to the understanding of biological cycles in fish populations, as well as the assessment of fish production and levels and the determination of harvesting. Growth is one of the basic parameters required to quantify population dynamics for a particular stock. Seasonality is usually associated with the formation of growth marks in hard structures. These marks are most commonly associated with low winter temperatures in temperate regions, and in the tropics, through seasonality, which is mostly a consequence of wet and dry periods (Welcomme 1967). Other factors such as temperature, water level and turbidity (Campana & Neilson 1980) and gonadal activity (Payne & Collinson 1983) also influence the growth mark formation. A number of calcified tissues have been used for age determination, including scales, opercular bones, fin rays, vertebrae and otoliths (Campana & Neilson 1980). The basic assumption, and one that requires species and area specific validity in the use of otoliths is that growth zones are formed consistently at fixed intervals.

Fish growth is highly flexible, and is influenced by both biotic and abiotic factors therefore allowing the individual an adaptive phenotypic response to a changing environment. Factors that can influence growth can be grouped into exogenous and endogenous factors. Exogenous factors such as temperature, affect both metabolism and ingestion. Generally, growth is relatively faster during the warmer summer months and relatively slower during the colder winter months. These differences are reflected in the hard structures as optically different zones that reflect difference in aragonite deposited during each seasonal event. In summer, translucent zones are wider, and winter zones (opaque) are thinner. The overall result of this type of growth pattern is an alternating series of light and dark zones. The combination of these two bands is referred to as the annual mark, or annulus.

The most frequently used methods for determining age in fishes is the counting of growth zones or zones on bony parts during alternating periods of slow and fast growth (James 1989). One of the main problems in ageing fish is to select the more suitable and accurate structure to use (Machias *et al.* 2002). Scales have been widely used for ageing due to the ease of collection preparation and ease of reading. The use of scales has been criticized primarily because the age of older fish was frequently underestimated (Beamish & McFarlane 1987; Carlander 1987). According to Casselman (1990), otoliths, unlike scales, continue to grow as fish ages. Carlander (1987) suggested that otolith age determination was more accurate because otoliths have a higher priority in the utilisation of calcium. In this chapter otoliths were used for age determination of the three principal species.

Materials and methods

Fish were measured to total (TL) and fork length (FL) to the nearest millimetre and weighed to the nearest gram. The largest pair of otoliths from each species was used for age determination. The lapilliar otoliths were used to age *M. pongolensis*, sagittal in *O. mossambicus* and the astericii in *S. intermedius*. Each otolith pair from each of the different species was removed from the auditory bullae, using a scalpel and fine forceps, dried with a paper towel and stored dry in a numbered gelatin capsule for later age determination.

In the laboratory, one otolith was selected at random from each pair and was mounted in a mould of clear casting resin. The resin rod was sectioned transversely, for *O. mossambicus* and *S intermedius* and longitudinally for *M. pongolensis* using a double-bladed diamond edged saw through the nucleus to a thickness of approximately 0.15 mm. Otolith sections were mounted on labelled glass slides using DPX mountant and were viewed under dissecting microscope at 12x magnification using transmitted light. Age estimates were obtained by counting the number of opaque bands from the nucleus to the margin. Otoliths were read, twice two weeks apart, independently, with no reference to the previous readings and without any knowledge of the length or weight of the fish. A gap of at least 2 weeks between readings was allowed for the primary reader. If the two readings coincided, then this was taken as the number of growth zones. If the two readings did not coincide, a third reading was taken and if two of the three readings coincided that was taken to be the age estimate. If all three readings were different, the otolith was considered unreadable and rejected.

Validation

Validation of annual deposition of bands was evaluated by using the technique of marginal zone analysis (Hecht & Smale 1986; Hyndes *et al.* 1992; Campana 2001). Growth was reflected as alternating opaque and translucent zones. To determine the periodicity of zone formation, the outer margin of otoliths sampled monthly was examined. When readings were taken for each otolith, it was noted whether the growth zone on the margin of each otolith was optically translucent or opaque. The change in relative frequency of each margin type was expressed as a percentage of the monthly sample and provides indirect evidence of seasonality of growth.

Growth Modeling

The von Bertalanffy growth model of the form $L_t = L_\infty \left(1 - \exp^{-K(t-t_0)}\right)$ was chosen to model growth, where L_t is length-at-age t; L_∞ is the predicted asymptotic length; K is the Brody growth coefficient and t_0 is the hypothetical age at which length is zero (Ricker 1975; Punt & Hughes 1992) was chosen to model growth. This growth model was chosen since it provides for a simple description of growth, and can be easily compared with species and populations (Radebe *et al.* 2002). In addition the von Bertalanffy model parameters are commonly used in empirical estimates of natural mortality (Pauly 1980). The first estimate of the maximum theoretical length for all species was estimated by a Ford-Walford plot. These estimates were used as the initial input to the von Bertalanffy growth model which was fitted to the observed age–length data of the species that were aged using non-linear least squares routine. Parameter standard error and confidence intervals were calculated using parametric bootstrap resampling (Efron 1982) with 1000 iterations.

Results

Morphometrics

The slopes (*b*) of the length-weight relationship were not significantly different from three in each species (Table 4.1).

Table 4.1. Relationships between total (TL), fork length (FL) and weight (Wt) of *M. pongolensis*, *O. mossambicus* and *S. intermedius* from Mnjoli Dam, Swaziland.

	Relationship	r^2	n
M. pongolensis			
FL (mm)	= 0.634 + 0.872 × TL (mm)	0.99	748
Wt (g)	= 0.00002 × FL (mm) $^{2.897}$	0.88	732
O. mossambicus			
Wt (g)	= 0.00002 × TL (mm) $^{2.983}$	0.93	53
S. intermedius			
FL (mm)	= – 0.950 + 0.889 × TL (mm)	0.99	68
Wt (g)	= 0.000004 × FL (mm) $^{3.177}$	0.95	67

Ageing of fish

Of the 160 *M. pongolensis*, 43 *O. mossambicus* and 57 *S. intermedius* otoliths examined, 74%, 90% and 72% respectively, yielded interpretable age estimates. The rest of the otoliths were rejected because they were either broken or unreadable. Sectioned otoliths for all species showed clear growth zones (Figure 4.1), with each zone consisting of a wide translucent band and a narrow opaque band for *O. mossambicus* and *S. intermedius* representative of fast and slow growth respectively. By contrast, the opaque bands were wide and the translucent bands were narrow for *M. pongolensis*. Age estimation ranged from 0 to 7 years for *M. pongolensis*, from 1 to 8 years for *S. intermedius* and 0 to 6 years for *O. mossambicus*.

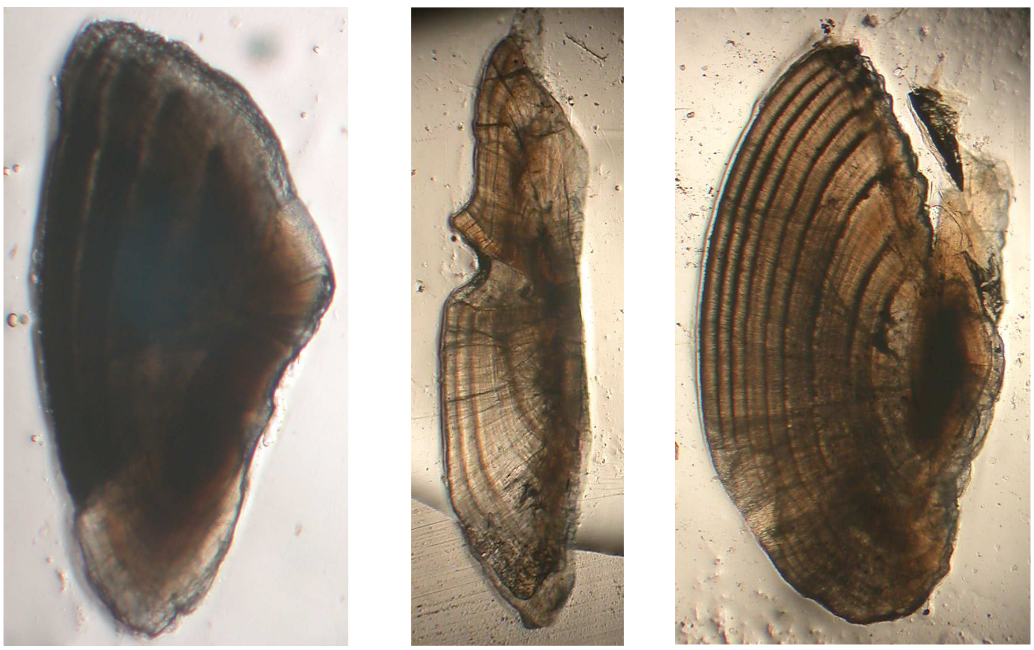

Figure 4.1. Photomicrographs of sectioned otoliths from (a) a 4 year old *M. pongolensis* (b) a 4 year old *O. mossambicus* and (c) a 8 year old *S. intermedius* from Mnjoli Dam, Swaziland.

Validation

The monthly examination of otolith margins revealed that one translucent and one opaque zone was deposited annually in all three species (Figure 4.2). Marginal zone analysis showed that the opaque growth predominates at the outer margin of otoliths of *M. pongolensis* during most of the year and only during the winter (June and July) did a large proportion of otoliths were found to have translucent margins. Although the samples of *O. mossambicus* and *S. intermedius* were small, one translucent and opaque zone was deposited annually. In *O. mossambicus*, the samples did not cover all the months but the data available suggest that the opaque zone predominates the otolith margins between October and December, while in *S. intermedius* it was between November and December.

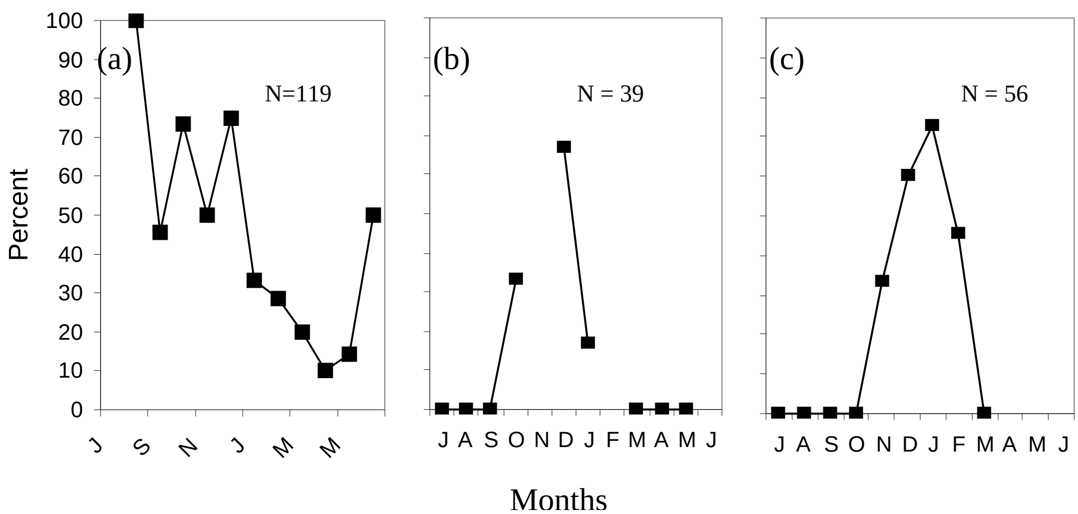

Figure 4.2. The monthly percent occurrence of a translucent margin in otoliths of (a) *Marcusenius pongolensis*, and opaque margin in otoliths of (b) *Oreochromis mossambicus* and (c) *Schilbe intermedius* sampled from Mnjoli Dam, Swaziland.

The von Bertalanffy growth model, fitted to the observed length-at-age data is illustrated in Figure 4.3. The von Bertalanffy growth parameters, variance and standard error estimates are presented in Table 4.2. The growth curves were not differentiated between sexes, as there was insufficient data to test for differences in sexes for *O. mossambicus* and *S. intermedius*, while the *M. pongolensis* the data was combined since the difference between sexes was not significant (p = 0.02). *M. pongolensis* had the fastest growth rate

(K) as compared to the other species, reaching L_∞ in three years. *Oreochromis mossambicus* had the slowest growth rate, reaching L_∞ in about five years.

Table 4.2. Estimates of the parameters of the von Bertalanffy growth equation for the three species, their estimated standard errors (SE) and 95% confidence intervals (CI)

Parameters	Estimate	SE	95% CI
M. pongolensis			
L_∞	188.67 mm FL	1.54	(185.85, 191.79)
K	1.478 year^{-1}	0.171	(1.23, 1.85)
t_0	-0.665	0.33	(-0.81, -0.53)
O. mossambicus			
L_∞	226.83 mm TL	212.67	(200.82, 434.65)
K	0.45 year^{-1}	0.21	(0.058, 0.93)
t_0	-2.023	1.58	(-6.99, -0.94)
S. Intermedius			
L_∞	214.59 mm FL	317.44	(201.15, 1094.58)
K	0.60 year^{-1}	1.52	(0.0075, -19.87)
t_0	-1.20	5.31	(-7.040, 0.79)

Table 4.3. Age-length key for *Oreochromis mossambicus* in Mnjoli Dam, Swaziland.

Length	Age (years)						
(mm TL)	0	1	2	3	4	5	6
100-109							
110-119							
120-129							
130-139	2						
140-149	2						
150-159							
160-169		2					
170-179	2	6					
180-189		5	1				
190-199							
200-209		2	1				
210-219		1	4			1	1
220-229				3	1		
230-239			1	1			
N	6	16	7	4	1	1	1

Table 4.4. Age-length key for *Marcusenius pongolensis* in Mnjoli Dam, Swaziland.

Length	Age (years)							
(mm FL)	1	2	3	4	5	6	7	8
100 – 109	2							
110 – 119	6	2						
120 – 129	3							
130 – 139		1						
140 – 149								
150 – 159			3	3	1			
160 – 169	1	2	7	3	2			
170 – 179	2	1	6	6	2	2		
180 – 189	3	5	4	4	1	1		
190 – 199	2	4	5	10	1			
200 – 209		4	5	2				1
210 – 219			2	2	1			
220 – 229			1					
230 – 239		1	1					
240 – 249			1					
250 – 259			1					
N	19	20	36	30	8	3	0	1

Table 4.5. Age-length key for *Schilbe intermedius* in Mnjoli Dam, Swaziland.

Length	Age (Years)							
FL (mm)	1	2	3	4	5		7	8
110 – 119	1							
120 – 129	2	2						
130 – 139								
140 – 149								
150 – 159								
160 – 169	1	1						
170 – 179					2			
180 – 189					1			
190 – 199		1	3	2	5			
200 – 209				2	4			
210 – 219			1		2	1		1
220 – 229			1	2	1			
230 – 239			1				1	
240 – 249					1			
250 – 259								
260 – 269						1		
270 – 279								
N	4	4	6	6	16	1	1	1

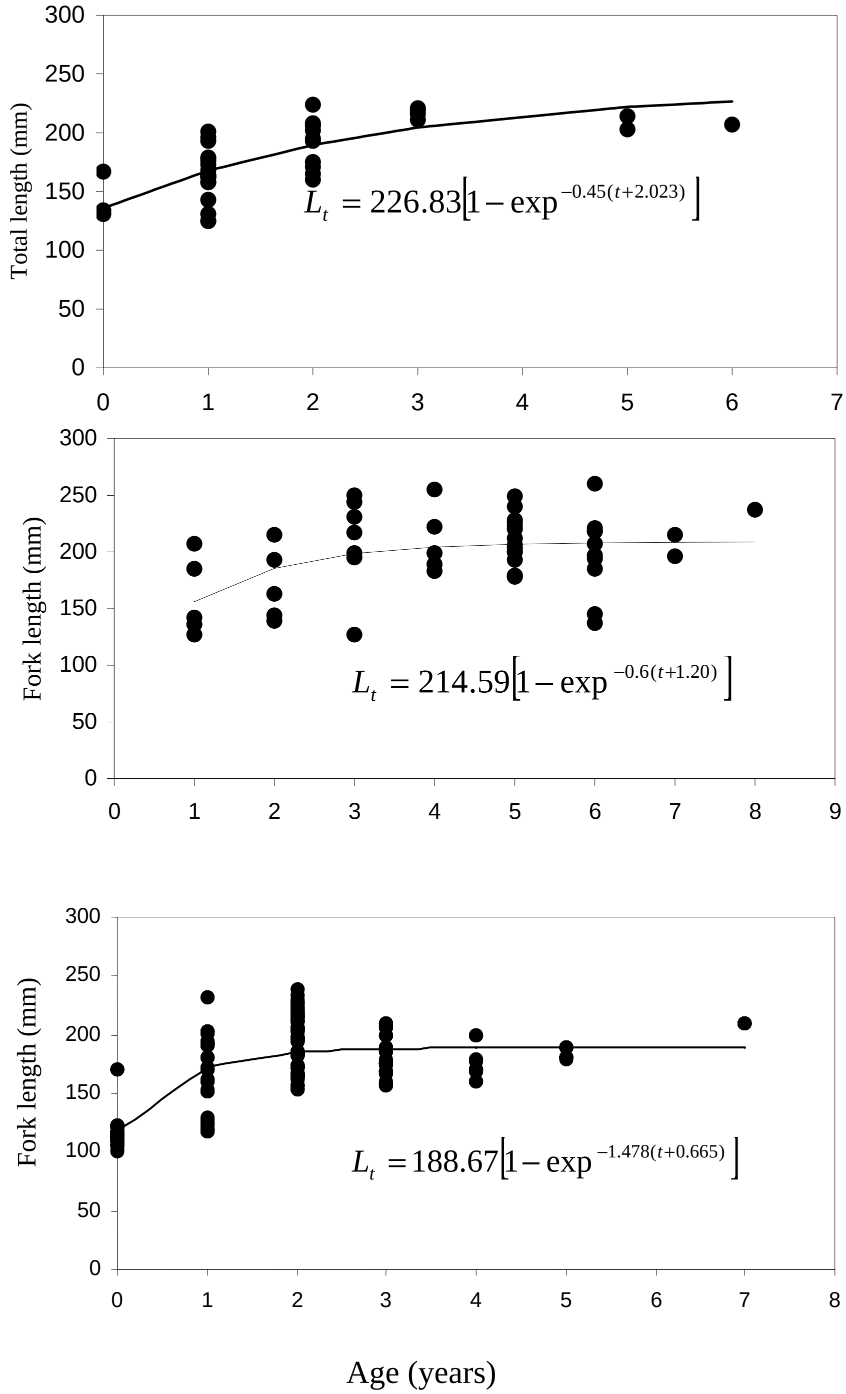

Figure 4.3. Observed length-at-age data of (a) *Oreochromis mossambicus* (b) *Schilbe intermedius* and (c) *Marcusenius pongolensis* fitted to the von Bertalanffy growth model. Samples from Mnjoli Dam, Swaziland between July 2002 and June 2003.

Discussion

Otoliths of *M. pongolensis*, *O. mossambicus* and *S. intermedius* at Mnjoli Dam exhibited a growth zone deposition pattern typical of teleost fishes; annuli comprising one translucent and one opaque zone. The translucent zones were generally broader than the opaque zones suggesting that the translucent zones are deposited during periods of fast growth and the opaque zones during periods of slow growth. By contrast, the opaque zones in *M. pongolensis* were broader than the translucent zones suggesting that in this species fast and slow growth corresponded to the opaque and translucent zones, respectively.

For *M. pongolensis*, the translucent zones are formed in winter (June and July), when the water temperatures are low (<19°C) and the opaque zone during the summer seasons when water temperatures are high (>22°C). There are sufficient differences in water temperatures between summer and winter to result in the deposition of a growth zone. Morales-Nin & Ralston (1990) pointed out that a seasonal temperature difference of 2–3°C might be sufficient to cause ring formation. The winter temperatures may not be the only factor responsible for the opaque ring formation. It is most likely that the combination of low winter temperatures and low water level due to the increased outflow and low inflow also contribute to the formation of translucent zones in this species.

Although samples for *O. mossambicus* were not available for all months, it was evident from marginal zone analysis that *O. mossambicus* deposits a single opaque zone annually. Marginal zone analysis showed that opaque deposition, which is representative of discontinuous or slow growth (Campana & Neilsen 1985), in *O. mossambicus* at Mnjoli Dam was in November and December. This period coincided with the onset of rainfall and an increase in water inflow into the dam. The onset of rains is usually associated with the onset of breeding activities. *O. mossambicus* falls within the reproductive guild of mouth brooders (Balon 1975), and females mouthbrood eggs and juveniles for 14 to 22 days (De Moor & Bruton 1988), which could result in the formation of growth zones. Garrod (1959) attributed the formation of a scale ring in *Tilapia esculenta* in Lake Victoria to breeding activity. During the mouth brooding period, female cichlids do not feed which could be reason enough for the formation of an opaque zone due to slow growth. However, in the Luphehle-Nwanedzi impoundment in South Africa, Hecht (1980) recorded two opaque zones being formed in the *O. mossambicus* population there. One opaque zone was formed in the otolith coinciding with winter and a second opaque ring coincided with the peak reproductive activities. In Lake Chicamba, Mozambique, Weyl & Hecht (1998) recorded a single opaque band being formed in the otoliths of both *O. mossambicus* and *Tilapia rendalli.* The zone coincided with the lowest winter temperatures and the draw down phase of the lake and not with the reproductive activities as observed in this study.

In *S. intermedius* a single opaque zone was formed in the otolith between November and January and it coincided with the end of the dry season and the onset of rains and the summer season. The formation of the opaque zone started in November and was completed (≈75% of specimens had opaque margin) in January. By contrast, Hecht (1980) in Luphehle-Nwanedzi impoundment in South Africa, reported that two opaque and two hyaline zones were found to be deposited on the otoliths of *S. intermedius* in contrast to ring deposition in spines where only a single opaque and hyaline zone were deposited in a year. He reported that one opaque zone was deposited during the breeding season and the second zone during the winter months.

The growth rate of *M. pongolensis* is rapid in early life attaining more than 50% of the asymptotic length in one year. Asymptotic length is however, attained within three years (Figure 4.3). This kind of growth is common to short lived species and *M. pongolensis* from Mnjoli Dam had a life span of seven years. From the length-at-age data, *M. pongolensis* attained 50% sexual maturity at an age of 15 months for females and 18 months for males, but the attainment of asymptotic length does not occur after maturity (Chapter 5). This species continues to grow even after sexual maturity is attained and growth is slowed down after reaching the age of three years. Okedi (1969) observed that growth rates of five small mormyrid fishes of Lake Victoria Basin (*Gnathonemus victoriae, G. longibarbis, Marcusenius grahami, M. nigricans and Petrocephalus catostoma),* was very rapid at early ages but slowed down considerably when the fish attained sexual maturity. In these species maturity was attained at the age of 8-9 months or 14-15 months old, which supports the observations from this study.

For *S. intermedius*, length-at-50% maturity corresponded with an age of two years. The attainment of asymptotic length occurs soon after sexual maturity and reflects a shift from somatic growth to investment in reproduction energy (Weyl & Hecht 1998). Hecht (1980) made similar observations on *S. intermedius* population of Luphehle-Nwanedzi impoundment in South Africa that *S. intermedius* attained sexual maturity at two years age of.

Due to the low sample size obtained for *O. mossambicus*, it was difficult to estimate the length-at-50%-maturity for either female or male fish. From the length-at-age data, asymptotic length corresponded with an age of four years. Population from this study exhibited slow growth, which can be compared to Lake Sibaya's (South Africa) population. Bruton (1979) attributed the slower growth and smaller maximum size of *O. mossambicus* to early maturity and precocious breeding in this abiotically harsh environment. However, variability in growth has been reported for this species in different environmental conditions. Variation in growth rates of *O. mossambicus* has been attributed to reservoir size (De Silva 1986), habitat stability (Balon & Noakes 1983), food availability (Balon & Coche 1974) and the quality of food (Bruton & Allanson 1974; Bowen 1979). At Mnjoli Dam the slow growth rate can be attributed to limited food available in the dam as it is considered to be oligotrophic.

All three species under study have similar longevities ranging from at least six to at least eight years. The oldest age classes found for *M. pongolensis*, *O. mossambicus* and *S. intermedius* were seven, six and eight years, respectively. For *M. pongolensis*, the oldest fish corresponded to a length of 208 mm FL. The seven years recorded for *M. pongolensis* at Mnjoli Dam concurs with observations made by Balon (1974) in Lake Kariba, that specimens of *M. macrolepidotus* older than seven years rarely occurred. At Mnjoli Dam, seven year old *M. pongolensis* constituted only 1.2% of the total gillnet catches of this species. The population structure of *M. pongolensis* was dominated by 2-year-old fish, which contributed 38% to the total annual catch. Although the catches for *O. mossambicus* and *S. intermedius* were low compared to *M. pongolensis,* 1-year old and 5-year old specimens for these species dominated the catches, respectively.

The theoretical asymptotic length for *M. pongolensis* was smaller than the largest recorded fish (189 mm FL vs. 290 mm FL). In *O. mossambicus,* the theoretical asymptotic length was close to the largest specimen observed (226mm TL vs. 225 mm TL), giving a good estimate. The computed value of L_∞ = 226.8 mm for *O. mossambicus* at Mnjoli Dam is comparable with that of *O. mossambicus* (L_∞ = 238.7) from Lake Chicamba Mozambique (Weyl & Hecht 1998), L_∞ = 273 mm from Luphehle-Nwanedzi impoundment, South Africa and Lake Sibaya, South Africa (L_∞ = 260 mm) Bruton &Allanson (1974). The oldest age for this species at Mnjoli Dam was six years, which is comparable with *O. mossambicus* from Lake Sibaya, South Africa, where it had a maximum age of 7 and 8 years (Bruton & Allanson 1974) obtained from scale readings. However, it is far below that of *O. mossambicus* from Lake Chicamba of 10 years (Weyl 1998).

The theoretical asymptotic length calculated for *S. intermedius* was smaller than the largest length recorded for this species. The largest *S. intermedius* recorded in this study was 290 mm FL compared to an asymptotic length of 214 mm FL. The 95% confidence limits for this parameter were wide (Table 4.5). Asymptotic length was comparable with that of *S. intermedius* in the Cross River, Nigeria ($L\infty$ = 275 mm) Etim *et al.* (1999), but it was below that for *E. depressirostris* from Luphehle-Nwanedzi, South Africa (L_∞ = 339 mm) (Hecht 1980). However, it was far below those for *S. mystus* (L_∞ =52.63 cm) from Lake Kariba, (Frank, 1974; *S. mystus* (L_∞ = 33.13 cm) from Lake Kainji, Nigeria and *E. depressirostris* (L_∞ = 47.04 cm) from Lake Kariba (Černy 1974).

The weight–length relationship is a useful tool in fishery assessment, that helps in predicting weight from length required in yield assessments (Garcia *et al*. 1998), and in the calculation of the standing crop biomass (Martin-Smith 1996). According to Pauly & Gayanilo (1997), *b* values may range between 2.5 to 3.5 and the calculated *b* values for the three species fall within this range exhibiting isometric growth (Table 4.1). Estimates of the allometry coefficient can be related to ecological processes and life history (Andrade and Campos 2002). For the three species weight gain is at the same rate as growth in length.

CHAPTER 5

Reproductive biology of *Marcusenius pongolensis*, *Oreochromis mossambicus* and *Schilbe intermedius* in Mnjoli Dam, Swaziland

Introduction

If a species has to be represented genetically in the next generation, it must allocate energy towards reproduction (Wooton 1998). Sustainable fishery development depends on the knowledge and understanding of the reproductive cycle of a species in their environment.

The life history of fishes in different waterbodies is highly variable with respect to growth rate, size at sexual maturity and reproductive periodicity (Lowe McConnell 1987, Hecht 1980a). Depending on the environmental conditions, fish may tend towards a precocial or altricial life-history styles (Man and Hodgkiss 1977). The precocial life-history style is characterized by delayed maturity. Fish exhibit this response generally in large, stable waterbodies. By contrast, an altricial life style is characterised by early maturation at a relatively small size, a life-history style, which is a response to unstable environments.

The formation of man-made waterbodies from existing watercourses usually results in significant changes to the natural riverine conditions; therefore, affecting the reproductive success of certain species. Mnjoli Dam is a man-made dam and the selected species (*M. pongolensis*, *O. mossambicus* and *S. intermedius*) are of riverine origin, and therefore, face challenges of adapting to their new lacustrine environment. Fish are selected to reproduce at the time of the year that will maximise their lifetime production of offspring (Wooton 1998). Fish therefore, display a wide range of lengths at first reproduction; this varies both intraspecifically within a species and among different environments.

The selected species considered here originated from the river system but they seem to have adapted to the dam environment (Chapter 3). The objective of this chapter is to determine the spawning periodicity, size at maturity and possibly elucidate spawning grounds of the selected species.

Materials and methods

Samples of *Marcusenius pongolensis, Schilbe intermedius* and *Oreochromis mossambicus* were collected at four stations monthly at Mnjoli Dam between July 2002 and June 2003 using experimental gill netting procedures (Chapter 2). *Marcusenius pongolensis* and *S. intermedius* were measured to the nearest millimetre total (TL) and fork length (FL). All fish were weighed to the nearest gram. *Oreochromis mossambicus* was measured to the nearest millimetre total length (TL) and weighed wet to the nearest gram. Fish were then dissected, sexed and the gonads removed, weighed, and examined macroscopically and allocated a stage of gonadal development according to the criteria given in Table 5.1; a macroscopic staging key modified from Weyl and Booth (1999).

Table 5.1. Macroscopical criteria used to stage gonadal development in *Marcusenius pongolensis*, *Schilbe intermedius* and *Oreochromis mossambicus* from Mnjoli Dam, Swaziland. Modified from Weyl & Booth (1999).

Gonad stage	Gonad state	Description
I	Immature/Inactive Resting	Not possible to distinguish sex. Gonad appears as a gelatinous strip.
II	Developing	Gonads enlarged, oocytes readily visible, and yellow and testes broadened, change from transparent to cream in colour
III	Ripe	Ovaries very swollen, fills up the abdominal cavity but products do not run out when belly is pressed
IV	Ripe running	Oocytes of maximum size. Yellow and hydrated and products run out when belly is pressed, testes swollen to maximum size.

Gonads from individual fish were weighed and their mass used to calculate the gonadosomatic (GSI). The gonadosomatic index is the weight of the gonads as a percentage of the total weight, and was calculated by:

$$GSI = \frac{GW}{BW} \times 100$$

where *GW* and *BW* = gonad and body weight (g), respectively

For *M. pongolensis*, it was found to be more convenient to only use female fish because only the ovaries develop to a size easily weighed to some accuracy under field sampling conditions. The testes were too small to be weighed with the scales that were available. Due to the low sample size for *O. mossambicus* and *S. intermedius*, it was difficult to calculate *GSI*.

Length at sexual maturity was determined for each species by fitting a logistic ogive to the proportion of reproductively active fish (Stages 3 and 4) sampled during the peak breeding period. Only reproductively active fish were included as the reduced the possibility of including inactive or spent adult fish for juveniles in the analysis. Size at maturity is defined as the length interval when 50% of the adult stock of a species is mature (Paugy 2002). The peak breeding period is selected to ensure that immature fish cannot be mistaken for resting fish. For *O. mossambicus*, samples used were those collected between August and March, *M. pongolensis* between October-November and March, and for *S. intermedius* between December and February. The two-parameter logistic ogive used to describe the length-at-sexual maturity is described by the following equation (Booth & Hecht 1997):

$$P(L) = \frac{1}{1 + e^{-(L - Lm_{50})/\delta}}$$

where *P(L)* is the percentage of mature fish at length *L*, Lm_{50} the length-at-maturity and δ the width of the ogive. Binomial likelihood was used to fit the models. For *O. mossambicus* and *S. intermedius*, the ogive was fitted to combined data of males and females due to the low sample size for these species and for *M. pongolensis*, ogives were constructed separately for males and females.

Sex ratio was estimated from fish greater than the length at maturity and collected during the spawning period. A chi-square test was used to test differences from the expected male-female sex ratio of 1:1.

Results

Size at sexual maturity

Female *M. pongolensis* matured at a smaller size (119 mm FL) than males (134 mm FL) (Figure 5.1a and b). The smallest mature female and male sampled were 100mm and 109 mm FL, respectively. All female fish were mature by 140 mm FL, while for males, all fish were mature by 170 mm FL.

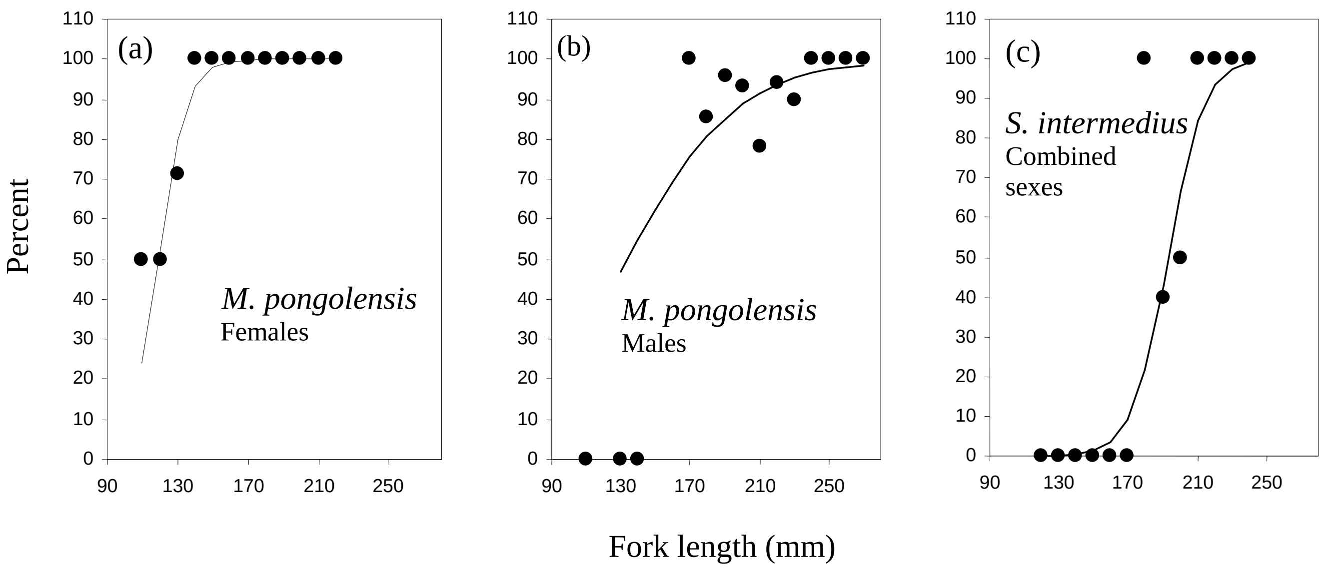

Figure 5.1: Length at 50% sexual maturity in (a) *Marcusenius pongolensis* females (n = 114), (b) *Marcusenius pongolensis* males (n = 139) and (c) *Schilbe intermedius* (n = 19) in Mnjoli Dam as calculated by fitting maturity data to the logistic ogive.

Oreochromis mossambicus matured at 239 mm TL, using combined sex data. Since few data were available for analysis, the length at maturity for each sex was taken to be the length of the smallest sexually mature fish. For females, the smallest fish was 205 mm TL and for males it was 134 mm TL.

From the combined sex data, *S. intermedius* matured at 193 mm FL (Figure 5.1c). For this species, data was few and the smallest mature female and male sampled measured 173mm and 193mm FL, respectively.

Sex ratio

A total of 713 *M. pongolensis* was sampled, of which 48.0% were males and 52.0% were females. The sex ratio of males to females in stages 3 and 4 was 1:1.04 in favour of females. The sex ratio of fish above Lm_{50} (1:1.01) did not differ significantly from unity (χ^2 = 0.407, df = 1, $p > 0.05$).

Of the 27 mature *O. mossambicus* caught between July 2002 and June 2003, 29.6% were females and 70.3% were males. The male to female sex ratio for reproductively active fish was 1:1.7 skewed towards females, whilst for fish above Lm_{50} was 1:0.42, and differed significantly from unity (χ^2 = 4.481, df = 1, $p < 0.05$).

For *S. intermedius*, a total of 49 fish was sampled, of which 43% were males, 57% were females. The sex ratio was 1:3.4 skewed towards females. The sex ratio for fish above Lm_{50} (1:1.02), however, did not differ from unity (χ^2 = 2.00; df = 1; $p > 0.05$).

Spawning periodicity

All individual *M. pongolensis* sampled, both male and females, were characterised by having a single, left gonad. Monthly variation in mean *GSI* showed two distinct peaks for this species (Figure 5.2a), indicating that this species spawned twice a year. The first peak was observed in November and the second peak was in March. The first peak in

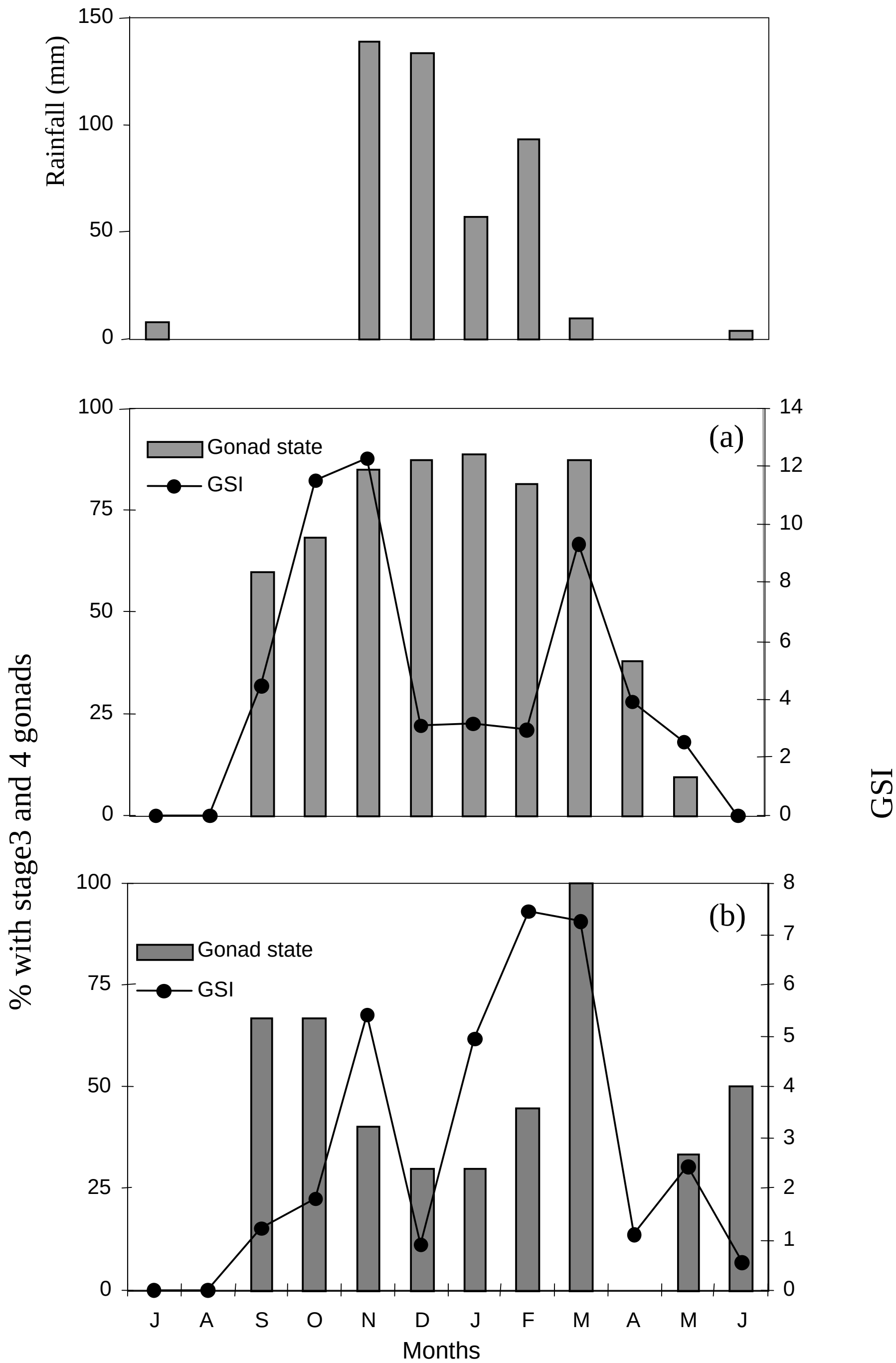

Figure 5.2. The breeding periodicity of (a) *M. pongolensis* and (b) *S. intermedius*, indicated by the GSI, and the proportion of fish with gonads in stages 3 and 4, in relation to rainfall.

November was the highest of the two. These observable changes in *GSI* suggest that gonads began to mature in September, increasing rapidly until it reached peaked at 12% in November. *GSI* decreased in December to 3%. The proportion of fish in stages 3 and 4 also increased from September and only declined in April and by June there were no fishes in stages 3 and 4 (Figure 5.2a). The first breeding peak for this species coincided with the onset of the summer rains and the last peak was just after the last highest rains. The highest proportion (49%) of mature fish in the ripe condition (Stages 3 and 4) were caught at station 4 which was at the river inflow, whilst 51% were caught from all the other three stations. A large proportion of the mature fish caught were in Stage 3 (59%) and fewer fish of Stage 4 (7%).

For *S. intermedius* and *O. mossambicus* there was few data to precisely deduce their spawning periodicity. For *S. intermedius* spawning seemed to occur twice a year; in November and again in February-March (Figure 5.2 b) coinciding with the onset and the end of the summer rains; November and February. It was not possible to determine the spawning periodicity of *O. mossambicus* since there are missing data for some months.

Discussion

Morita and Morita (2002) identified two life-history traits affecting animal fitness; early maturation decreases mortality before maturation and decreases generation time, and late maturation increases body size, which in turn increased fecundity. Male and female *M. pongolensis* attained sexual maturity at different lengths, with females attaining sexual maturity at a smaller size than males. This indicates that this species at Mnjoli Dam matured at a smaller size compared to the mormyrids studied by Okedi (1960) in Lake Victoria Basin. Early maturation of *M. pongolensis* at Mnjoli Dam could have been due to that the study was carried out during a drought year and therefore the species tended towards an atricial life style. Merron (1991) also observed that *M. macrolepidotus* (previously synonymous with *M. pongolensis*) in the Okavango delta, Botswana matured early as a way to decrease mortality before maturation since they were heavily preyed upon by *Clarias gariepinus.*

For *S. intermedius*, males were found to mature at a larger size than females. These observations differ from observations made by Kok (1980), van der Waal (1985) and Merron (1991) who found that males matured at a smaller size than females. At Luphehle-Nwanedzi and Glen Alpine impoundments in Venda (South Africa), Hecht (1980) found that both males and females attained 50% maturity at lengths between 160 and 179 mm FL. The difference observed in this study could be due to the size of the sample and the drought condition. Fish in different localities mature at different sizes due the environment they are in.

Female *O. mossambicus* at Mnjoli Dam was found to mature at a larger size than males. Late maturation in females could be a way of increasing fecundity. *O. mossambicus* exhibit a precocial life-history trait. However, there were few data for this species hence this observation can only be taken with caution. This species did not seem to be affected by the drought condition.

The analysis of the *M. pongolensis* male to female sex ratio showed that the observed ratio does not depart from unity. Okedi (1969) made similar observations on three mormyrid fishes; *Gnathonemus victoriae, G. longibarbis* and *M. grahami*, in the Lake Victoria Basin. Sex ratio for *O. mossambicus*, was skewed towards males, which differs from the sex ratio (0.25: 1) for this species in Lake Sibaya, South Africa (Brutton and Boltt 1975). This difference was attributed to habitat selection by the different sexes. In the present study, the difference in sex ratio of males to females could be due to the small samples used. The sex ratio for reproductively active *S. intermedius*, was skewed towards females. This finding is slightly higher than that recorded for Lake Liambezi (1:2.7; van der Waal, 1985) and the Okavango delta (1:2.3; Merron 1991).

Spawning in *M. pongolensis* occurs from late spring to summer (September to November) where this species is possibly cued by the onset of the summer rains to spawn. Reproduction during this period would therefore provide favourable spawning and rearing conditions. The second spawning peak in March also coincides with the last highest rains and a decline in water inflow to the dam. It seems like high rains trigger spawning in this species. A decrease in rainfall after the peak in November was similarly followed by a decrease in the GSI and a second peak in rainfall was also followed by a peak in GSI. This suggests that spawning in this species is somehow linked to high rains.

The presence of a large number of fish in stage 4 at the river mouth area (station 4), as compared to all the other stations suggest that the spawning grounds for this species is closer to that area. The fish may be breeding in the river as they are of riverine origin.

However, in this study no sampling was done in the river to confirm this. Okedi (1969) observed that the mormyrid fishes of Lake Victoria Basin were potamodromous and riverine ascent took place at the peak of the flood conditions during the rainy seasons. Kirschbaum (1995) noted that at the beginning of the rainy season mormyrids left the dam and migrated into smaller streams. No evidence was available to show *M. pongolensis* did not breed in the dam. The presence of a large proportion of ripe fish (stage 3) from September to May could also mean that maybe the species under normal conditions (without drought), the species might be spawning throughout the summer season. Due to the drought condition and low water level, the fish may have not been able to develop to stage 4 hence their spawning cycle was disrupted and they were unable to spawn. It would be interesting to compare findings of a normal rainfall year with these to ascertain the spawning periodicity of this species.

For *O. mossambicus*, data were insufficient to provide information on the gonadal variation throughout the year. This was due to lack of data for three months when the fish were not caught in the gill nets.

Distinct peaks in mean monthly GSI was observed for *S. intermedius*, suggesting that it spawns twice a year - November and February – within Mnjoli Dam. The first peak coincided with the onset of the summer rains whilst the second peak coincided with the last highest rains suggesting that the spawning of this species seems to be synchronised with increased rains. Similar observations were made by Olutande (1978a) on the schilbeid *S. auritus* in Lake Kainji, Nigeria, and Etim *et al*. (1999) on *S. intermedius* in the Cross River (Nigeria) that the schilbeid species spawned twice a year. According to Etim *et al.* (1999), spawning occurred at the beginning and at the end of the rainy season. Spawning of *S. intermedius* at Mnjoli Dam also occurred at the beginning and the end of the rainy season.

Understanding the length at first maturity, sex ratio and spawning periodicity will enable Fisheries managers to make informed decisions on the proper management of these species at Mnjoli Dam.

CHAPTER 6

Gillnet selectivity patterns and mortality rates of *Marcusenius pongolensis*, *Oreochromis mossambicus* and *Schilbe intermedius* in Mnjoli Dam, Swaziland

Introduction

Various fishing methods are employed to estimate the number of fish species present within a waterbody, their distribution and relative abundance. Within reservoirs and lakes, gillnets are possibly the most commonly used sampling technique (Boy & Crivelli 1998). Gillnets are passive fishing gear and entangle fish by holding them within the mesh webbing. Gillnets are, however, extremely selective in that a specific mesh size catches fishes in a certain optimal length interval. This selectivity introduces a bias when attempts are made to reconstruct the population size distribution from experimental gillnet catches. By taking into account the selectivity of the nets used, the bias is reduced considerably.

The availability of the fish to the gear and their size-selection by gillnets are also affected by factors which are either related to the characteristics of the net or of the fish (Reis & Pawson 1999). Fish characteristics include the body shape, which determines the swimming speed and ability to maneouver, the presence or absence of projections such as spines. Net characteristics include net twine type, net construction and hanging ratio. The probability of fish being captured also depends on its net encounter rate and its ability to avoid it. Both are mainly related to the swimming capability rate of the fish, which in turn, is related to its body size (Regier & Robson 1966).

Precise descriptions of gillnet selectivity for each species are required to determine the efficiency of mesh sizes towards specific fish sizes for the formulation of fisheries management plans. Numerous methods for estimating gill net type selectivity have been developed and can be classified into five categories (Hamley 1975): (1) inferences from girth measurements, (2) size distributions of the catches, (3) direct estimation by comparing catches with known size distributions of the population, (4) use of estimates of mortality for each size class given a time series of catches, and (5) indirect estimation by comparing size distributions of catches of different meshes. Hamley (1975) noted that the most reliable way of estimating gillnet selectivity is by using direct methods. This method involves tagging, that is capture release and recapture of large numbers of fish which is expensive and time consuming. Another direct method involves sampling the population simultaneously with gear of known selectivity patterns (Winters & Wheeler 1990).

Mortality is another basic parameter required to quantify population dynamics for a particular fish stock. King (1995) defined mortality as the loss of individuals in a population through death. It can be divided into two components - natural mortality (*M*) due to natural causes, and fishing mortality (*F*) caused by fishing activity (Sparre *et al.* 1989). Fishing mortality depends on the effectiveness of the fishing gear employed. Therefore, fishing mortality is affected by gear selectivity. It is usually reasonably straightforward to estimate total mortality rate but very difficult to partition total mortality into its natural and fishing components (Hightower *et al.* 2001). The separation into the two components is important so as to assess the value of harvest regulations. The most common method of estimating the total mortality rate (*Z*) is using a catch curves, where the natural logarithm of the number of fish surviving by age is regressed against age (Ricker 1975; King 1995).

In Swaziland fishing using any form of nets is prohibited in the all waterbodies, dams and rivers. Therefore the major fishing activity is recreational fishing, and is too small to significantly affect the fish stock. In view of this, it can be said that there is no existing fishery at Mnjoli Dam. Since there is no intensive fishing activity, total mortality (*Z*) and natural mortality (*M*) will be the same.

Estimates of mortality and gear selectivity are important for the formulation of management plans for the sustainable exploitation of the fishes. These parameters also provide information on life history responses of the species to exploitation. This chapter focuses on estimating gillnet selectivity and natural mortality for *M. pongolensis*, *O. mossambicus* and *S. intermedius* at Mnjoli Dam.

Materials and methods

Estimating gillnet selectivity

Gillnet selectivity was estimated from catches from two fleets of multi-panel gillnets with stretched mesh sizes of 28, 44, 60, 75, 100 and 144 mm. The nets were set at four stations, four times a month between July 2002 and June 2003. Fish captured in the nets were measured to total length (TL), fork length (FL) and gilled girth. Gilled girth was measured from the marks where the fish were enmeshed as not all fish were necessarily enmeshed behind the gills. Gilled girth measurements were taken with tautly streched nylon fishing line, which was then measured on a fish measuring board.

Gillnet selectivity was estimated by employing Sechin's (1969) method which relates the girth measurements of each fish species to the mesh circumference. The basic idea behind Sechin's method is to assume selection is a result of two size dependent processes: a) the fish must be small enough to get its head into the mesh, and b) must be large enough to be retained by the mesh (Hovgård & Lassen 2000). Gilled girth dimensions determine both processes. This method accounts for fish that are either caught gilled (behind the gills) or wedged. Girth (g_L^0) was plotted against length (L) (fork length in the case of *M. pongolensis* and *S. intermedius*, and total length for *O. mossambicus*) and modelled using linear regression of the form $g_L^0 = a + bL$ where a and b are the linear regression parameters.

The Sechin model of the form:

$$S_L = \exp\left(-\frac{1}{2(\sigma_L^m + \sigma_L^g)^2} * (g_L^0 - 2m)^2 \right)$$

where S_L is selectivity at length L, σ_L^m and σ_L^g are the standard deviations of mesh size and girth perimeter at length L, and m the stretched mesh of one bar of gillnetting mesh.

Mortality rate

Total mortality

The instantaneous rate of total mortality (Z) for *M. pongolensis*, *O. mossambicus* and *S. intermedius* were estimated using two methods. Length frequency distributions were converted to an age frequency distribution by means of a length converted catch curve. A first approximation of Z was estimated from the slope of a length converted catch curve (Pauly 1983). The second approximation of Z was from Chapman & Robson's (1960) equation, which is according to Butterworth *et al*. (1989), is a superior estimator of Z. It is described by:

$$Z = \ln\left(1 + \frac{1}{(t_m - t_f)}\right)$$

where t_f denotes the age at full recruitment, t_m denotes the mean age of all fully recruited fish caught estimated from the catch curves of each species.

Results

Gillnet selectivity estimates

Estimates of relative gillnet selectivity are presented in Figure 6.1. Peak selectivity for *M. pongolensis* was found at 120, 170 and 229 mm FL, for the 28, 44 and 60 mm mesh sizes, respectively. For *O. mossambicus*, it was 160, 170 and 210 mm TL for the 44, 60 and 75 mm mesh sizes, while for *S. intermedius* the selectivities were 120, 170 and 220 mm FL for the 28, 44 and 60 mm mesh sizes, respectively.

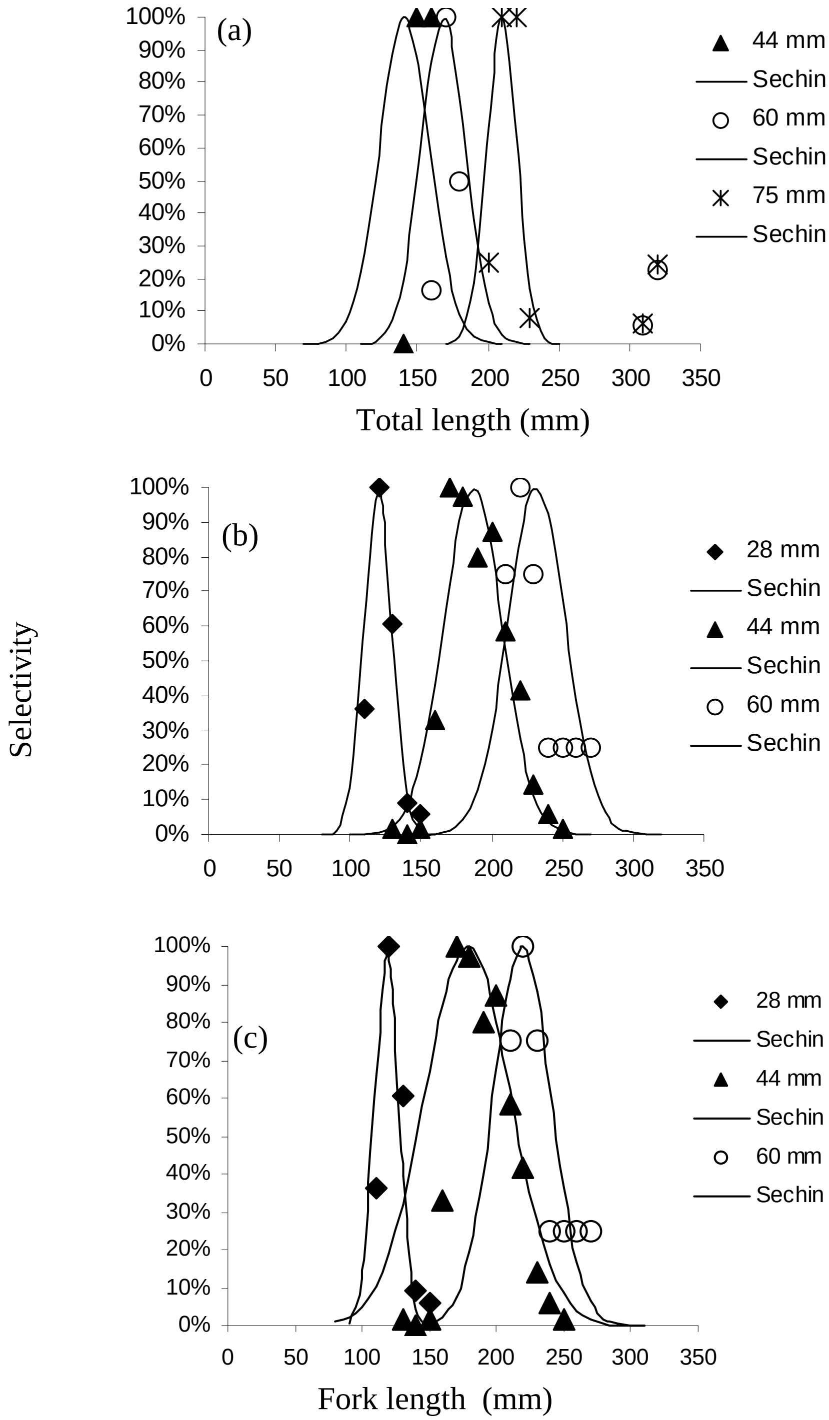

Figure 6.1. Relative selectivity of gillnets of different mesh sizes to a) *Oreochromis mossambicus*, b) *Marcusenius pongolensis* and c) *Schilbe intermedius*, estimated indirectly using Sechins method.

For both *M. pongolensis* and *S. intermedius*, a large number of fish caught of these species were caught in the 44 mm mesh, which accounted for 81% and 54% of the total catch of these species, respectively. Fewer numbers of *M. pongolensis* were caught in the 60 mm whilst for *S. intermedius* fewer numbers were caught in the 28 and 60 mm meshes. For *O. mossambicus*, most of the fish were caught in the 75 mm mesh, which caught 50% of all the fish caught of this species.

Mortality estimates

Total mortality

Length frequency converted catch curves are illustrated on Figure 6.2, and the estimates of total mortality (*Z*) from the catch curves and those calculated from the Butterworth *et al*. (1989) are presented on Table 6.1. Estimates of total mortality (*Z*), estimated from the two techniques were different for all three species. Total mortality, estimated with the Butterworth *et al*. (1989), equation yielded higher values than those estimated from the catch curve for *M. pongolensis* and *O. mossambicus*, whilst for *S. intermedius* it was smaller than the catch curve derived mortality estimate. The values considered were those estimated from the catch curve since they were estimated from the actual sample.

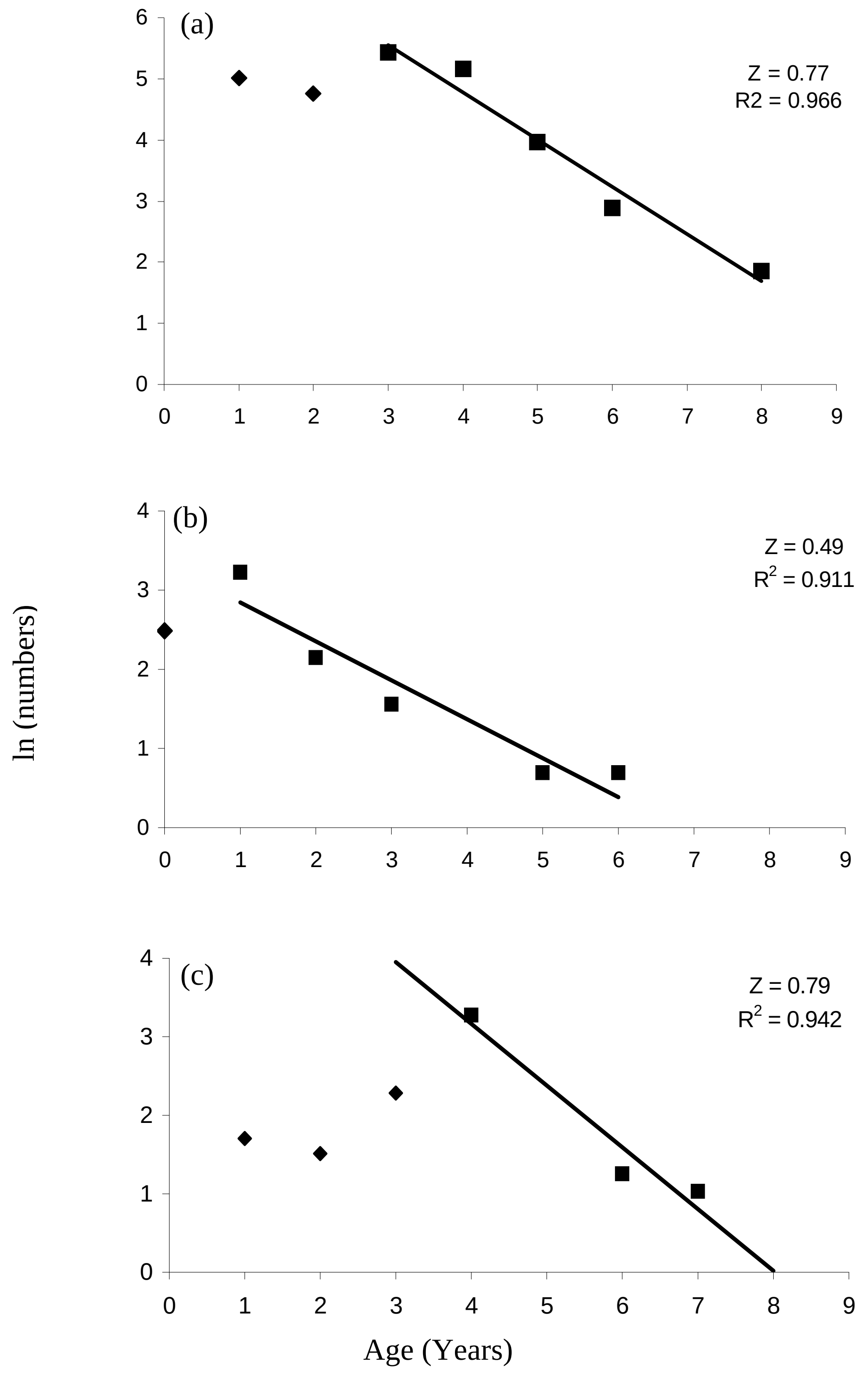

Figure 6.2. Linearized catch curves for estimating total mortality (*Z*) for (a) *Marcusenius pongolensis*, (b) *Oreochromis mossambicus* and (c) *Schilbe intermedius* from Swaziland between July 2002 and June 2003.

Table 6.1. Estimates of instantaneous rate of total mortality (*Z*) for *Marcusenius pongolensis*, *Oreochromis mossambicus* and *Schilbe intermedius* from, Swaziland. Samples were taken between July 2002 and June 2003.

	Total Mortality (Z)	
Species	Catch curve	Butterworth *et al.* (1989)
M. pongolensis	0.77 $year^{-1}$ r^2 = 0.97	0.88 $year^{-1}$
O. mossambicus	0.49 $year^{-1}$ r^2 = 0.91	1.03 $year^{-1}$
S. intermedius	0.79 $year^{-1}$ r^2 = 0.94	0.35 $year^{-1}$

Discussion

The selectivity curves for the three species were typical of gillnet selectivity curves being unimodal, bell-shaped, falling to zero on both sides of a maximum, with selectivity curves for progressively larger mesh being located further to the right (Figure 6.2). The selectivity curve for *S. intermedius* caught in the 44 mm mesh was broader than the other curves. This was due to that most fish were caught tangled by their serrated pectoral spines. According to McCombie & Berst (1969), selectivity curves for fish caught tangled are broader and skewed to the right. None of the other two species were caught tangled, but a fair wedging was common for *M. pongolensis*. Wedging in this species was due to that their body shape is elongate, uniform and the dorsal fin is located posteriorly.

The selectivity of any method of capture depends on the type of gear employed, the way the gear is operated, where and when it is used and the behavior of the individuals in the population to the process of capture (FAO 1975). Visibility of nets may affect the avoidance behaviour of fish towards them. The nets used in this study were green in colour and once in water they were darker. Since the nets were set overnight, it was expected that they would not be visible to fish. The high catches of *M. pongolensis* in the nets could have been due to their nocturnal and shoaling behavior, moving inshore after dark increasing their probability of encountering and being caught in the nets. Turbidity in most of the sampling stations may have also contributed to the decrease in the visibility of nets since stations 3 and 4 were turbid and the highest catches were from these ststions.

The most efficient mesh sizes in terms of number of fish caught were the 44 mm (81%) for *M. pongolensis*, 75mm (50%) for *O. mossambicus* and 44mm (54%) for *S. intermedius*. This could be due to that the other mesh size were either much smaller or much bigger for the fish at Mnjoli Dam. The differences in mesh sizes were quite wide which could have resulted in some fish size classes not being well represented in the catches even though the panels were randomly distributed over each gillnet. This can be investigated using fleets of gillnets of each mesh size that was used during the sampling

Schilbe intermedius had the highest estimate of instantaneous total mortality rate, *M. pongolensis* had the second highest and *O. mossambicus* had the least. It is surprising that *S. intermedius* had the highest *Z* since it is a larger fish as compared to *M. pongolensis*. According to Pauly (1984), natural mortality is correlated with fish size, since larger fish have fewer predators than small fish. Most of the *O. mossambicus* caught were of a larger size and its mortality rate was lowest compared to the other two species.

Errors in estimates of *M* have profound fisheries management implications as both yield and production models require estimates of *M* (Newman 2002). Overestimates of *M* will provide overestimates of the potential yield of fish stocks and this may lead to overexploitation and ultimately recruitment overfishing (Newman *et al*. 2000a). It is clear that *O. mossambicus* and *S. intermedius* cannot sustain a small-scale fishery since natural mortality is higher and also their catches were low. This was not expected because high natural mortality is good for production. If there is an increase in fishing mortality, it could easily lead to overfishing and a stock collapse. Only *M. pongolensis* can sustain a small scale fishery for local communities within the vicinity of the dam who fish for their own consumption

CHAPTER 7

General discussion and conclusion

This thesis documents the first detailed biological study conducted on the dominant fish species of Mnjoli Dam in Swaziland. The results from this thesis contribute to both the understanding of the selected species, and provide important information that will assist in developing and managing the dam's fisheries resources.

There has been a general change in the fish species composition at Mnjoli dam (Chapter 3), a change that is possibly due to some species not being able to adapt to the lacustrine condition. The change could also be due to long-term decrease in productivity, which is common in man-made reservoirs (Jackson 1961). As dams and impoundments mature and stabilize over several years and after the accumulated nutrients from the initial flooding of the system are lost (Jackson *et al*. 1988), productivity declines. Batchelor (1989) classified the dam as being oligitrophic, which suggests that productivity is extremely low. There is unfortunately no long-term catch data to support these observations. However, when comparing results from this study and those from Batchelor's (1989) brief survey, there is an indication of some changes. There is a need to conduct frequent surveys to substantiate these changes in abundance and diversity.

The life history characteristics of fish have been shown to be influenced by environmental conditions. These characteristics include growth (Chapter 4), reproduction (Chapter 5) and rates of mortality (Chapter 6). Inland fisheries are particularly influenced by external environmental conditions. Factors such as drought can affect the life history traits of fish. Fluctuations in water levels in the dam, caused by the combination of drought and from water being drawn for irrigation seems to have disrupted the breeding pattern of the three species at Mnjoli Dam. This factor could have a negative impact on recruitment and may lead to a recruitment failure if the drought conditions persist.

The results from this study have shown that a commercial fishery cannot, and should not in the future, be established at Mnjoli Dam. This is due to the extremely low catches - the highest catch was meagre 1.56 kg set^{-1}. $night^{-1}$. Of the three dominant species in the dam, *M. pongolensis* was present in large enough numbers to support (at most) subsistence fishing by local communities. *M. pongolensis* was found to be more abundant at the river mouth as well as the muddy area site. Therefore, for local communities to realise high catches they would have to set gillnets in these areas. Fishing in these areas can lead to localized overfishing. Since the spawning grounds seem to be around the river mouth area, fishing at this area could result in recruitment failure since the spawning stock would be easily harvested.

Catches of both *O. mossambicus* and *S. intermedius* were extremely low and cannot support fishery, subsistence or otherwise. *O. mossambicus* is one of the most sought after species because of its size as well as that it is preferred by the local community for its taste as compared to the other two species. Due to its value, there is a need to look into responsible stocking of this species in the dam in order to increase stock levels, and after stocking, the stock should be allowed to recover. In addition to stocking of this species, supplementary fertilization to enhance primary or secondary production without changing the biodiversity could also be considered. With improved productivity in the dam, it would take a shorter time for the species to recover to levels that can be exploited. Fertilizing the dam would unfortunately be an extremely costly option due to the size of the dam.

In order to manage a fishery, there are many aspects to be considered. FAO (1997: 8) defines fisheries management as "the integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and accomplishment of fisheries objectives". This study was mainly gathering information on the biological aspects of *M. pongolensis*, *O. mossambicus* and *S. intermedius*, which should be considered in making decisions on the conservation, management and development of a fishery at Mnjoli Dam.

From the results of this study, several tentative management options could be used to achieve the fisheries objective of long-term sustainable use of fisheries resources. Since commercial exploitation is not viable at Mnjoli Dam, the subsistence fisheries that could be allowed should be managed to avoid conflicts and overfishing. Management options could mainly involve controlling fishing mortality by regulating the following:

1) How much is caught?
2) When and where they are caught? and
3) The size at which they are caught?

Option one involves controlling input, which directly regulates the amount of effort that can expended by the fishery. Limiting the number of fishers through a permit system could regulate effort. This would not be a problem since the norm is that people should have a fishing permit in order to fish in any of Swaziland's water bodies. Limiting the number of permits issued may lead to permit holders increasing capacity through using more efficient gears thus increasing the catch rates. This option would, therefore, include the type of gear and fishing methods that the fishers are permitted to use with their fishing permits. Controlling the mass and sizes of fish caught could also help in regulating the amount of effort.

The second option will ensure spawning success for the three species and sustainable recruitment. Therefore, fishing activities could be prohibited during the spawning season and at the spawning areas of these species. The results from this study suggest that spawning grounds for the three species were either up the river or at the river mouth. For conservation purposes this area could be closed from any fishing activities. By closing such areas critical habitats can be preserved as well as the sensitive life stages of species.

The third option is specific to the minimum size and maturity restriction to reduce fishing mortality on life stages of these species, which require protection, such as the juveniles and spawning adults. This could be achieved through restricting the mesh size for the three species based on the length at sexual maturity. The length at first capture should therefore be fish greater than the length at sexual maturity since they would have had a chance to spawn at least once. This is expected to assist in stock enhancement, maximizing future benefits to the fishers.

To manage a fishery, there is a need to take the following factors into consideration. These are: 1) the biological characteristics of the stock, which is provided by this study; 2) the nature of the existing or potential fisheries; and 3) other activities related to or impacting the stock and the potential economic and social contribution of the fishery to local needs. There is no "recipe" for management guidelines but these should apply to the local situation. To develop management plans, stakeholders should be identified and the Fisheries Section will oversee the formulation of management objectives. These management objectives will then be translated to management plans. The Fisheries Section, as a management authority, will then ensure implementation of the plan through monitoring, control and surveillance. The local communities will also take part in the implementation of the management plan.

Fisheries management requires a legal base from which to implement fisheries operations for the management of fisheries resources. Swaziland has an existing Freshwater Fish Protection Act of 1937. This act is however outdated and does not consider these proposed options for fisheries management. It is therefore recommended that the fisheries Act be updated to ensure the implementation of the proposed management options.

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