

**Determination of age and growth of *Opsaridium microlepis* (mpasa)
and the influence of water quality parameters on its catches in the
Linthipe River in Central Malawi.**

By

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DECLARATION

I, **Moses Limuwa**, declare that the work presented in this thesis is an outcome of my research effort and that it has not been previously submitted to the University of Malawi or any other institution for a degree or any other award. Where other sources of information have been used, acknowledgements have been made accordingly by means of references.

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CERTIFICATE OF APPROVAL

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DEDICATION

This work is entirely dedicated to all those who have supported me since I was born.

Though too many to be mentioned, I salute you!!!

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ABSTRACT

A study on the determination of age and growth of *Opsaridium microlepis*, locally known as the *mpasa*, and the influence of water quality parameters on its catches in the Linthipe River in Central Malawi was conducted between February 2006 and January 2007.

Data collection was carried out at two sampling sites: closer to the river mouth at Mkama and upstream at Kamuzu Bridge. The data collection included: fish catches and duration of net cast, water temperature, dissolved oxygen, salinity, pH, conductivity, turbidity, alkalinity, total hardness, total suspended solids and total dissolved solids. Age of *O. microlepis* was estimated from the sectioned otoliths (lapilli) by counting annuli. Validation of otolith annuli formation was done using the marginal zone analysis. A Catch per Unit Effort (CPUE) and water quality stepwise multiple linear regression model was used in the analysis.

A total of 546 male and female fish ranging from 6 – 53 cm SL were sampled on monthly basis. Growth was best described by simple regression model with the following parameters: $Fish\ total\ length\ (cm) = 12.56 + 6.931 * Fish\ age$; $r = 0.799$, $r^2 = 0.639$, $p = 0.00$. The maximum age for *O. microlepis* was estimated at five years. Marginal zone analysis indicated that otolith annuli (opaque zones), visible in the cross-sectioned otoliths, formed yearly, primarily in August. The age and growth

information showed that this species is short lived and, fast-growing, reaching sexual maturity between one to two years.

The catch per unit effort was influenced by dissolved oxygen, electrical conductivity, and total suspended solids ($p < 0.05$). Dissolved and total suspended solids were positively correlated to the catch per unit effort, while electrical conductivity was negatively correlated, suggesting that river bank cultivation which involves cultivation in the marginal areas of the river is a major factor affecting the total suspended solids levels in the river.

A management strategy for the Linthipe *O. microlepis* fishery has to place emphasis on the control of water quality in the river and its catchment such as total suspended solids and electrical conductivity, which could be due to improper land use practices in the river catchment area.

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LIST OF ACRONYMS

ADD		Agriculture Development Division
ANOVA	:	Analysis of variance
BATWESA	:	Biodiversity Assessment Tools for Inland Water Ecosystems in Southern Africa.
CF	:	Condition factor.
CPUE	:	Catch per Unit Effort.
CV	:	Coefficient of variation.
DO	:	Dissolved oxygen.
DPX	:	Distyrene Plasticizer Xylene
EAD	:	Environmental Affairs Department.
FAO	:	Food and Agriculture Organization.
GOM	:	Government of Malawi.
GSI	:	Gonadosomatic index.
IAPE	:	Index of Average Percent Error.
IUCN	:	International Union for Conservation of Nature.
RUFORUM		Regional Universities Forum for Capacity Building on Agriculture
SL	:	Standard length
SOER	:	State of the Environment Report.
SPSS	:	Statistical Package for Social Scientists
TDS	:	Total dissolved solids.

TL	:	Total length
TSS	:	Total suspended solids.
VBGF	:	Von Bertalanffy Growth Function.

CHAPTER ONE

1.0. INTRODUCTION AND JUSTIFICATION OF THE STUDY

1.1. The status of *Opsaridium microlepis* (mpasa)

Opsaridium microlepis, Günther 1864, locally known as the *mpasa* was not evaluated for the International Union for Conservation of Nature (IUCN) Red List in the 2004 (BATWESA, 2005). However, the species appeared in the 2006 List, (IUCN 2006), after Tweddle (2001) had reported that the species was on its way to extinction. Its appearance in the IUCN list as vulnerable has been attributed to decline in catches (Tweddle, 1983; 1987; 2001) and the environmental degradation of the spawning grounds i.e. the affluent rivers (Tweddle, 1994).

O. microlepis is one of the fish with highest profile in the wild life reserves but very vulnerable to anthropogenic activities in the river character (Tweddle, 1987). *O. microlepis* is a pelagic predator, which spends most of its life in the lake but ascends affluent rivers to spawn during rainy season and part of the dry season. During this spawning period *O. microlepis* is caught in considerable numbers. The male and female *O. microlepis* have similar growth rate (Tweddle, 1987). Growth is relatively fast during the first three years with an annual increase in length of ten centimeters, until maturity is attained at about thirty centimeters in the third year (Lowe, 1952 and Tweddle, 1983). The breeding success of this fish appears to depend mainly on the presence of suitable substrate i.e. gravel sand (Tweddle, 1983).

O. microlepis has 80 to 88 scales in lateral line. The large individuals look silvery while the young ones have numerous dark bars above the lateral line. *O. microlepis* from North Rukuru River, which reaches maturity in their third year at 28.0 cm total length, and that from Bua River which matures at 40 cm (Tweddle, 1983).

O. microlepis is a partial spawner. Each gonad has one apparently more pronounced component, probably representing that which is shed during the peak spawning period (Msiska, 1990; Tweddle, 1983). It lays only a small proportion of its eggs at a time. Eggs are buried in gravel, mainly at the gravel / sand interfaces having filtered down through the interstices in the clean gravel near the surfaces. Eggs remain in the gravel until the yolk sac is absorbed; juveniles remain in the river for several months, and then move to the lake close to the river mouth until their second year. Unlike the juveniles of the Atlantic salmon (*Salmo solar*), which migrate to the sea after a period of up to five years (King, 1995), most juveniles of *O. microlepis* are believed to descend to the river mouth on the set of first rains, at an average age of six months (Tweddle *et al.* 1983).

The overall fecundity of *O. microlepis* from the Bua river was estimated at 34,500 to 65,700 eggs for fish ranging from 54 cm to 57.7 cm with body weights ranging from 1.2 kg to 1.7 kg (Msiska, 1990) while the ovaries of fish caught in North Rukuru River contained 1,381 to 22,077 eggs for fish ranging from 19cm to 55.5cm total length (Tweddle, 1983). Its breeding season extends well in the dry season, when the eggs

and fry are not at a risk of destruction in flash floods; this ensures survival of some batches.

O. microlepis seems to have disappeared from a number of rivers. For example, Lowe-McConnell (1952) reported the species in River Lisangadzi. The river is now a flash flood stream and the species is no longer in the river system. Similarly, the species was reported in Bwanje River (Tweddle, 1981) but is no longer there.

Linthipe River is one of the major rivers, in which *O. microlepis* migrates for spawning during rainy season (Tweddle, 1987). It is the largest river (Fig. 1.1) of the southern part of Lake Malawi and its catchment is one of the most densely populated around the lake (Mkanda and Barber., 1999; Kingdon *et al.*, 1999; Bootsma and Hecky, 1999). The catchment of Linthipe River is characterized by heavy agricultural activities with maize being the most farmed crop (Mkanda, 2002). It seems the river was a hotspot for *O. microlepis* as recorded by Ricardo Bertram *et al.* (1942), that in January 1939 the water in the Linthipe River was said to be ‘boiling’ with *O. microlepis*, hardly an objective scientific statement but probably indicative of a thriving population.

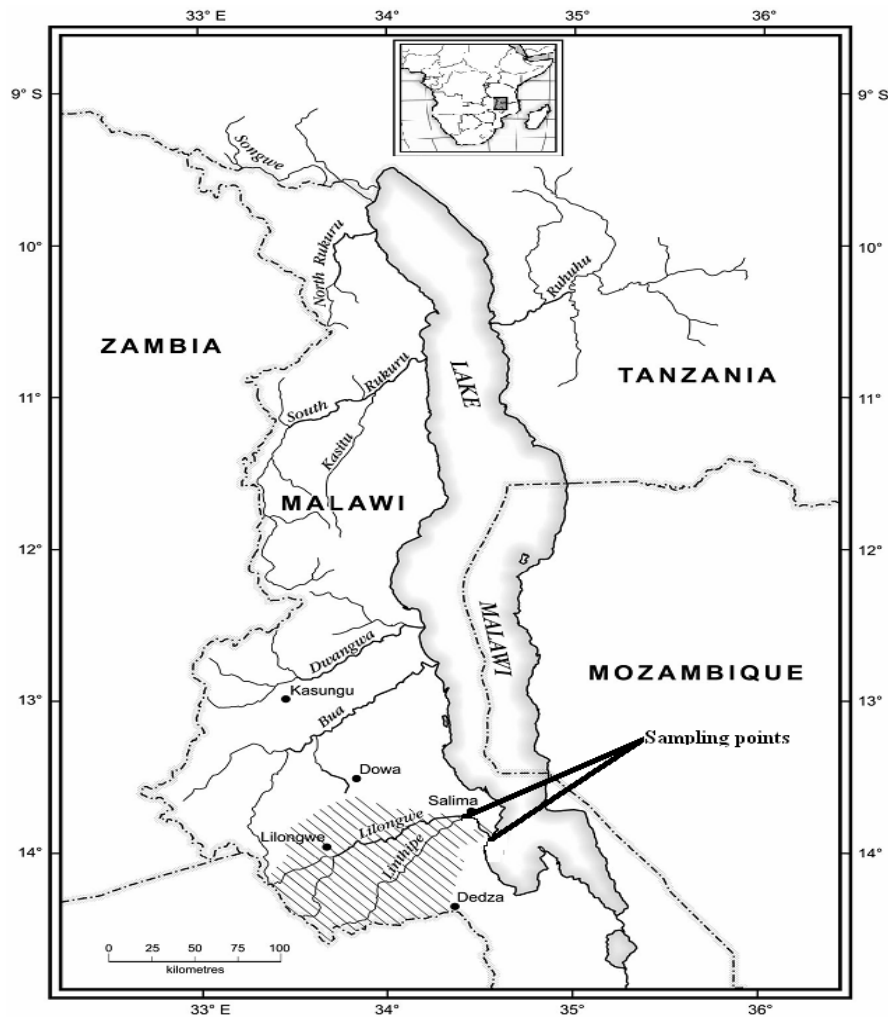


Figure 1.1: Lake Malawi catchment showing major riverine inflows, and the Linthipe River, indicating the two sampling points in the study.

In Malawi, the increasing demographic pressure (Ferguson *et al.*, 1993; Kalipeni, 1996) has recently accelerated the unsustainable land use practices around the lakeshore and its catchments. As a result of deforestation, burning of vegetation, destruction of wetlands in the catchments for agricultural purposes and the cultivation of marginal areas such as steep slopes of hills (Mkanda and Barber, 1999) massive

quantities of sediment eroded from clear-cut watersheds are discharged in the rivers and eventually in the lake (Bootsma and Hecky, 1993).

Erodability factors of the soils in the Linthipe catchment range between 4.5 and 5.5 (Paris, 1990; Lorkeers and Venema, 1991; Lorkeers, 1992). Given that Elwell and Stocking (1982) rated soil erodability on a scale of 1.0–10, the erodability factors of the Linthipe catchment soils imply that they are mostly moderate vulnerable to erosion and low erodability values indicate highly erodible soils (Chakela and Stocking, 1988). Soil losses in the Salima, Kasungu, and Lilongwe Agricultural Development Divisions (ADDs), parts of which lie within the Linthipe catchment area are 16, 20 and 22 tones/ha/yr respectively (World Bank, 1991). These soil-loss rates result in a sediment-discharge rate of about 94.4 g/m (3.28 tones/ha/yr) at the river mouth, which is only surpassed by that of the Ruhuhu River (143.2 4 g/m or 4.97 tones/ha/yr) on the Tanzanian side (Kingdon *et al.*, 1999).

Currently, some natural resources have been depleted, while others face a threat of extinction (EAD, 2001). Expansion of agriculture and the concomitant deforestation in recent decades have led to considerable soil erosion, siltation of streams and rivers, and changes in flow regimes. Apparently, riverbanks have relatively richer soils, hence cultivating in these areas becomes an alternative to the highly priced fertilizers and scarce compost manure.

Firm evidence on changes in rivers as a result of man's agricultural activities, and the effects of those changes on the dependent fish stocks, is lacking, though the problem is widely recognized (Lowe-McConnell, 1952; Bowmaker *et al.*, 1978; Jackson and Coetzee, 1982). However, the negative impact of excess sedimentation and water turbidity on the diversity and ecology of aquatic communities has been reported for other lakes (Waters, 1995; Evans *et al.*, 1996).

It is also known that changes in water quality resulting from human activities (such as riverbank cultivation) within the lakes' watersheds can seriously affect fisheries production and biodiversity as experienced in the Laurentian Great Lake of North America and with Africa (Bootsma and Hecky, 1999). Riverine water quality and sediment loads may have effects on fish migration and spawning success of some riverine freshwater fishes (Jamu *et al.*, 2003). Thus the understanding of the physico-chemical environment would explain the altitudinal distribution of biological organisms, particularly fish, which is the main biological resource targeted by the local population for food (Busulwa and Bailey, 2004). Since *O. microlepis* goes upstream into the freshwater river to breed, it is easy to conceive that changes in water quality and gravel deposition as a result of anthropogenic activities would affect its catches and reproduction.

Considerable volume of data on *O. microlepis* is mainly from other rivers i.e. Bua and North Rukuru Rivers (Tweddle, 1983; 1987 and Msiska, 1990), but much less on Linthipe River. Fish catches from the rivers in Malawi are recorded as part of the Lake

Malawi catches (SOER 1998) and many fishermen fish down the river and make good catches which go completely unrecorded (Tweddle *et al.*, 1995). It is therefore difficult to understand the life history traits and survival rates of *O. microlepis* in relation to its environment in the Linthipe River. Lack of data, leads to challenges in the designing and implementing programmes that provide for societal water needs and water needs of aquatic and riparian biota (Naiman *et al.*, 2002; Richter *et al.*, 2003). At the same time, the majority of stock-recruit relationships that have been documented for freshwater fish populations have been derived from stable lake environments while relationships in tropical rivers and floodplains are less well understood (Welcomme, 2001). It is on these premises, that a study on age and growth of *O. microlepis* and the influence of water quality parameters on the catches of *O. microlepis* was conceived.

1.2. STATEMENT OF RESEARCH OBJECTIVES

1.2.1 Overall objective of the study

The general objective of the study was to investigate some life history traits mainly; age and growth, reproductive seasonality and condition factor of *O. microlepis* and the influence of water quality parameters on *O. microlepis* catches in the Linthipe River, in Central Malawi.

1.2.2. Specific Objectives

Specific objective of the study were to;

- i. estimate age and growth parameters of *O. microlepis* in the Linthipe River.

- ii. determine the reproductive seasonality and condition factor of *O. microlepis* in the Linthipe River.
- iii. determine the influence of some water quality parameters (water temperature, dissolved oxygen, salinity, pH, electrical conductivity, turbidity, alkalinity, total hardness, total suspended solids and total dissolved solids) on catches of *O. microlepis* in the Linthipe River.

1.2.3. Study hypotheses

The study hypotheses were:

- i. the age and growth of *O. microlepis* in the Linthipe River is the same as reported by Tweddle (1987) i.e. 11 cm TL/yr.
- ii. the reproductive seasonality and condition factor of *O. microlepis* is similar to what was reported by Morioka and Kaunda (2004); Tweddle (1983).
- iii. there are no correlations between water quality parameters and *O. microlepis* catches in the Linthipe River.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. The genus *Opsaridium*

Opsaridium is a small genus containing 13 species belonging to the family of Cyprinidae, order Cypriniformes, class Osteichthyes and sub class Actinopterygii (ray-finned fishes) (www.taxonomy.nl/main/classification/191525.htm). The genus *Opsaridium* was erected by Peters in 1852 and, *O. microlepis* (Fig. 2.1) together with *Opsaridium microcephalum* locally known as *Sanjika* are endemic to Lake Malawi. These two species were described by Günther in 1864 (Skelton, 1993).



Figure 2.1: *O. microlepis* male, TL = 560 mm. (Photo: Moses Limuwa).

2.2. Biology and distribution of *O. microlepis*

Tweddle (1982) observed that not all *O. microlepis* run upriver with the first heavy rains, but build up in numbers off the mouths of the rivers during the rainy season. The

majority apparently runs up when there is a late flood season. Most spawning activity takes place following the rains in May and June, as large numbers of larvae just past the yolk sac stage can be seen in the shallow water in June and July. There is reduction in the breeding activities during the cold season.

2.3. Growth of *O. microlepis*

O. microlepis attains an average weight of at least 4 Kg and is the largest of all the bariliine cyprinids (Tweddle and Lewis, 1983). The growth of *O. microlepis* has been found to be variable, Tweddle (1987) in both Bua and North Rukuru Rivers showing that the species reaches about 11 cm total length in its first year. Morioka and Kaunda (2001) reported that *O. microlepis* juvenile reaches 181.60 mm TL in 221 days after hatching and 131.40 mm TL in 151 days. However, Morioka and Kaunda (2004) made another study on which the growth pattern displayed indicated that *O. microlepis* could reach 20 cm TL within a year of hatching demonstrating that *O. microlepis* growth is variable depending on many factors.

2.4. Breeding behavior, spawning strategies and fecundity of *Opsaridium microlepis*

The breeding behavior of *O. microlepis* was described by Tweddle (1983) based on the observations made in Bua River in June 1982. Males guard the territories in shallow, gravel-bottomed areas and chase rival males, which intrude on to their territories. The closest distance between adjacent territories can be about 2 m. In each spawning cycle, females follow the male nose to tail for 30 seconds to 2 minutes. The females take up a

position facing into the current at the center of the territory and the male move along the left side of the female. Both fish erect their fins, angled their bodies so that their vents are almost touching and, lying very close to the gravel substratum, and begin to quiver rapidly. The spawning act lasts about 8-10 seconds on average.

Unlike many other cyprinids such as *Labeo mesops* locally known as *nchila*, *O. microlepis* has a flexible spawning strategy; it is a “partial spawner”, i.e. lays only a small proportion of ripe eggs at a time (Tweddle, 1983). This may give the advantages in survival in the unpredictable riverine habitats that are used for spawning. *O. microlepis* breeds in large rivers and not in temporary streams, and stay in the river for several months laying many batches of a few thousand eggs at a time over a period of time (Msiska, 1990). Its breeding season extends well into the dry season, when the eggs and larvae or juveniles are not at risk of destruction in flash floods. Thus, if conditions are bad for some batches of same as above, there are numerous other batches with a chance of survival. However, since partial spawners breed several times during any one season it is therefore difficult to estimate the total fecundity of the fish. The overall fecundity of *O. microlepis* from the Bua River was estimated by Msiska (1990) at 34, 000 to 66, 000 eggs for fish from 54-58 cm in length, while Tweddle (1983) presented similar figures to those given by Msiska (1990) for North Rukuru larger fish. Evidence from tagging shows that many fish make more than one spawning run in their lives (Tweddle, 1987). Breeding period of *O. microlepis* estimated with the use of otoliths (lapilli) was found to be from the latter half of the dry season and the beginning of the rainy season (September to December). This

indicates that the breeding season of *O. microlepis* may extend from July to December (Morioka and Kaunda, 2001; Morioka and Kaunda, 2004). However, the sexually mature adults were captured in earlier months (July and August) (Kataya, *pers. comm. cit. in* Morioka and Kaunda (2001).

2.5. Climatic conditions around Linthipe River

The water temperature in Linthipe River over the period of February to March ranged from 25 to 32°C; and density due to temperature alone ranged from 0.9970 to 0.9950 g/cm³, or twice the density range encountered in the top 50 m of Lake Malawi (0.9971 to 0.9960 g/cm³) (McCullough, 1999). The actual density range was even greater, because total suspended solids at the maximum observed concentration added another 0.002 g.cm⁻³ to the river (McCullough, 1999). Bad farming practices have resulted in surface-runoff rates of 41 m³/s (GOM, 1994).

Most parts of the Linthipe River basin, especially the Lilongwe Plain receives an annual rainfall ranging from 800 - 1000 mm. In the lakeshore areas around Linthipe River estuary, rainfall increases up to 1400 mm (GOM, 1986). The resultant rainfall energy, which is an important factor in soil-particle detachment and entrainment (Hudson, 1995), is high; ranging from 15000 j m⁻² in the Lilongwe Plain to 18000 j m⁻² in the Lakeshore (Mkanda and Barber, 1999). The rainy season extends generally from November to April during which period the basin receives an average of over 95 % its annual rainfall. Most of the parts of the basin reach their monthly maximum rainfall in January, but a few of them do so in December or February (Rimington, 1963; GOM,

1986; Lorkeers and Venema, 1991). Most of the catchment's drainage systems lie in the Lilongwe Plain, the main tributary being the Lilongwe River.

2.6. Use of hard parts to age fish

Knowledge of age in fish populations is crucial in stock assessment and management (Bermejo, 2007). Age information forms the basis for calculations of growth rate, mortality rate and productivity, ranking it among the most influential of biological variables. In most cases, periodic growth increments are counted to estimate the age. Several calcified structures produce periodic growth increments useful for age determination in fish. Scales (Robillard and Marsden, 1996), vertebrae (Brown and Gruber, 1988), fin rays (Cass and Beamish, 1983), cleithra (Casselman, 1990) and opercula (Baker and Timmons, 1991) have all been used to determine annual age. However, otoliths are applied over the broadest age range in many species (Secor *et al.*, 1995a). Campana and Thorrold (2001) estimated that over one million fish were aged worldwide in 1999, most of which were aged using scales and otoliths. Annual ageing is often used in support of harvest calculations and population studies, and can be based on any bony structure in the fish (Casselman, 1990). In contrast, daily ageing based on the otolith microstructure tends to be targeted more at recruitment questions and studies of young fish (Pannella, 1971; Campana and Neilson, 1985). There are many instances in which ageing error has contributed to the serious overexploitation of a population or species (van den Broek, 1983; Smith *et al.*, 1995; Chilton and Beamish, 1982; Campana *et al.*, 1990; Beamish and McFarlane, 1995).

Validation is important in determining the age of first increment formation. Ageing by identifying annuli (or daily increments) in calcareous structures must be validated as such structures frequently show false annuli or checks that can be misinterpreted as true annuli (Campana, 2001). There is a hypothesis that states the existence of an annual succession of an optically opaque zone corresponding to the period of rapid growth, followed by a translucent zone corresponding to the period of slow growth (Dupouy *et al.*, 1986). This hypothesis was tested by means of optical observations using transmitted light. The assumption of one growth zone by indirectly validating the ages was justified by Banda (1992) on *Oreochromis* spp. When a comparison was made between the observed and the length – frequency results that were obtained in an independent study, it was shown that the results from the two methods were similar. Validating a method of fish age determination is extremely important in fisheries biology, without which estimates may be inaccurate (Singini, 2006).

As observed in other cyprinids (Hoff *et al.*, 1997), the lapilli are apparently superior to other otolith bones for the increment counts with the consecutive readability of increments. The lapilli in cyprinids are superior on daily increment of rings (Hoff *et al.*, 1997; Morioka and Kaunda, 2001) and in other species (Morioka and Machinandiarena, 2001). In many teleosts, the sagittae, being the largest otolith element, is frequently used for growth analysis. However, the sagittae is elongated and in cyprinids it is not appropriate for growth analysis because of its spearhead shape and fragility (Morioka and Kaunda, 2001; Imai *et al.*, 2002).

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. The study area

The study was conducted in the Linthipe River, from the confluence of Linthipe and Lilongwe River going down stream to Kamuzu Bridge on M5 road and at the river mouth in Traditional Authority (TA) Maganga (Fig. 1.1). These two sampling sites fall in the lakeshore plain of the river in the five categories of the river basin (Rimmington, 1963; GOM, 1986). Linthipe River catchment lies in the Central Region of Malawi between latitudes 13°21'E and 34°35'E. The river basin is fan shaped and drains an area of 8 641 km² into Lake Malawi. Most parts of the Linthipe River basin lie between 500 m and 1500 m above mean sea level (GOM, 1994). The river slope gradient is gentle (1–6%) in the Lilongwe and Lakeshore plains, moderate to steep (6.1–50%) in the Scarp and Dowa Regions (Mkanda and Barber, 1999). Erodability factors of the dominant soils in the catchment range between 4.5 and 5.5 (Paris, 1990; Lorkeers and Venema, 1991; Lorkeers, 1992). The Linthipe River estuary swampy areas have the usual swampy grassland (GOM, 1986).

3.2. Fish sampling program

Specimens of *O. microlepis* were collected once per month over a period of three days by means of gillnets set across the river from the two selected sites, i.e. at a fishing village near the river mouth in Maganga (Mkama site) and near the confluence of

Linthipe and Lilongwe Rivers going down stream up to Kamuzu Bridge on M5 road, (thereafter, Kamuzu Bridge site). Each sampling site was geographically positioned using a hand-held Global Positioning System (GPS) (GPS 72 personal navigator, Garmin). Sampling was conducted by two fishermen using a multimesh gillnet (survey nets type 'Norden', Lundgrens Fiskredskapsfabrik AB, Storkyrobrinken 12, 111 28 Stockholm, Sweden), consisting of 12 randomly distributed panels of various mesh sizes, ranging from 5 mm to 55 mm which was laid across the river. The net was 30 m x 1.5 m and was set for a night between 18:00 hours and 6:00 hours (Mattson and Mutale, 1992). The duration of casting and the number of fish specimens were recorded following guidelines outlined by Sparre *et al.* (1998). The net was then removed from the river, and *O. microlepis* specimens were collected and placed in plastic buckets containing water from the river. The fish were preserved in ice. Fork length (FL), Standard length (SL) and Total length (TL) measurements were taken to the nearest (± 0.1 cm) using a measuring board. Fish were weighed to the nearest (± 0.01 g) using HP – 20 K and gonads to (± 0.001 g) using HF – 3000 electronic weighing balance. These measurements were taken after preservation in the ice and all heads were preserved in deep freezer for otolith extraction.

3.3. Determination of age and growth of *O. microlepis*

The fish were held upside down and cut through the gill arches and isthmus to expose the roof of the mouth. The fish were cut three-quarters through the roof of the mouth (parasphenoid bone) where the first gill arches join the roof of the mouth.

While holding the head of the fish, the backbone was broken downwards where the cut was made in the roof of the mouth. This exposed the otolith bones within membranous sacs on either side of the mid-line at the posterior ventral portion of the brain cavity. The otoliths were extracted or removed unbroken, as clean as possible, using small forceps. Both bones were removed and stored in small, labeled manila envelopes (Singini, 2006). Preparation of the otoliths followed methods described by Griffiths and Hecht (1995); Booth and Merron (1996).

Both lapilli were weighed to the nearest 0.001 mg on a sensitive microbalance, AND HR-200. Otolith diameter and length were measured to the nearest 0.01 mm using an ocular scale on the microscope (Olympus BX 50). Otolith length, which is the distance from the anterior tip to the posterior tip, and the otolith width, which is the distance from the dorsal edge to the ventral edge across the nucleus perpendicular to the otolith length were measured. These measurements were made as close as possible through the nucleus (Singini, 2006).

Left or right lapilli from each fish were arbitrarily selected for ageing. To enhance otolith growth zones visibility, a technique used by Kaunda (2000); Kanyerere (2003); Chimatiro (2004); Singini (2006) was employed. Each otolith was lightly burned to a light brown color using a double electric hot plate with adjustable heat settings. To avoid charring, a specially designed tray was used to hold the otoliths about 5 cm above the heating element. Burnt otoliths were embedded in clear fiberglass casting resin, and sectioned to a thickness of about 0.5 mm through the nucleus using a double-bladed diamond saw (Fig. 3.1).

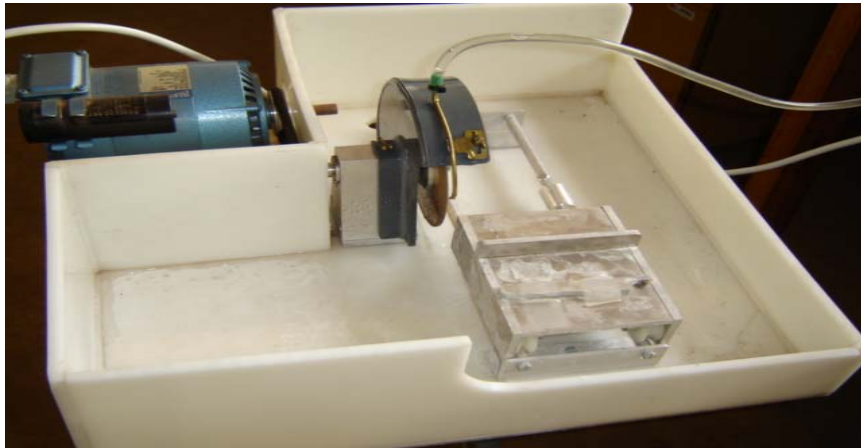


Figure 3.1: An otolith cutter used for cutting thin transverse sections of *Opsaridium microlepis* lapilli otoliths (Photo: Wales Singini).

Sections were cleaned of excess water and residues prior to mounting on microscope slides with Distyrene Plasticizer Xylene (DPX) mountant and viewed with a light microscope (Olympus BX 50) under transmitted light using variable magnification (Kaunda, 2000; Kanyerere, 2003; Chimatiro, 2004; Singini, 2006).

Under transmitted light, the opaque zones appear as dark shadowy rings, while the translucent zones appear as bright light rings (Williams and Bedford, 1973). A translucent and opaque zone together constituted a complete growth zone. Due to difficulties in interpretation of otoliths, an index of readability (Table 3.1) was used to classify the otoliths according to appearance of the growth zones (Fossen *et al.*, 2002).

Table 3.1: Criteria for classifying otolith readability

Readability	Growth zone appearance
1	Believed to be reliable, good definition between translucent and opaque zones
2	Relatively clear zonation but not well defined, the error margin is expected to be ± 0.5 year i.e. ± 1 ring
3	

Source: Fossen *et al.*, 2002.

Age assessment from calcified structures is strongly subjective (Weatherley and Gill, 1987). This study applied the average percent error method. The Index of Average Percent Error (*IAPPE*) was suggested to be the better method for assessing the precision of age determinations compared to the percent agreement method, since the latter does not equally evaluate the degree of precision for all species (Beamish and Fournier, 1981). The average percent error method was calculated for age determination by the same reader or different readers and does not necessarily imply that the age estimates are accurate, but only relates to the consistency between the age readings.

Average percent error and the percent agreement method are two methods used to minimize subjectivity in age determination. Chang (1982) suggested the use of a coefficient of variation (CV) for testing the reproducibility of ageing between readers. While structure comparisons are very useful during the selection of a preferred ageing

method, consistency among within-fish growth structures is the rule rather than the exception. This is not surprising given that the growth of all structures within a given fish tends to be influenced by the same environmental and physiological factors (Campana, 2001).

If N fish are aged and R is the number of times each fish is aged then X_{ij} is the i th age determination of the j th fish and X_j is the average age calculated for the j th fish.

$$X_j = \frac{1}{R} \sum_{i=1}^R X_{ij}$$

The Index of Average Percent Error for all fish in this sample was calculated as:

$$\text{IAPE} = \frac{1}{N} \sum_{j=1}^N \left[\frac{1}{R} \sum_{i=1}^R \frac{|X_{ij} - X_j|}{X_j} \right] \times 100$$

The outer margins of otoliths sampled at monthly intervals were examined and the composition of the outer margin (either opaque or translucent) was expressed as a percentage of the monthly sample. Marginal zone analyses (Mannoch, 1982) was used to validate the observed growth zones as annuli and were therefore used to estimate the age of the species. The recommended length frequency analysis as an alternative method of ageing fish (Pitcher and Hart, 1982) was also used to compare with the observed results from the otolith as justified by Banda (1992) working on *Oreochromis karongae*.

The relationship of otolith length to total length was estimated using the formula by Griffiths and Hecht (1995) as below:

$$OL = aL + b$$

Where OL = Otolith length (mm)

L = Total length (mm)

a and b are constants

Power function was used to model the relationship between weight and fish total length (Pitcher and Hart, 1982). The relationships were described by regression equations, which were fitted to the data. Equations for lines of best fit were determined by least squares regression.

Weights of the extracted otoliths ranged from 0.001g to 0.0021g, while otolith width (radius) ranged from 0.6 mm to 0.8 mm.

3.4. Estimates of growth parameters from length frequency data

Growth parameters are species and stock specific (Sparre *et al.*, 1998). Among the several growth models, the set values of parameters are plotted in VBGF to get the length frequency plots. The VBGF model is used for the following reasons: 1. For African fish species it provides a good fit of the data (de Merona *et al.*, 1988, Moreau *et al.*, 1992) and 2. It proves useful for comparative purposes as it has been largely utilized for African Fresh Water Species (de Merona *et al.*, 1983; 1988. Ndamala (2006) used the VBGF to study the same species (*O. microlepis*). Although the VBGF

has been used in several studies. Morioka and Kaunda (2004) used a logistic model with an assumption of total length of 4.00 mm at hatching time in the examination of *O. microlepis* of less than one year. In this study the linear regression was used to model the growth rate and this was attributed to the failure to obtain a sample with big fish encompassing the reported length at infinity.

3.5. Gonadosomatic index and condition factor

Condition factor and gonadosomatic index of *O. microlepis* were determined as follows:

The Gonadosomatic index was expressed following the formula by (King, 1995) as.

$$GSI = 100\% * \frac{\text{Weight of gonads}}{\text{Weight of fish}}$$

Fish condition factor was determined following the formula by King (1995) as:

$$\text{c.f.} = (W/L^3) * 100$$

Where W is the weight of the fish in grams and L is the total length of the fish in cm and L^3 is a power function.

3.6. Catch per unit effort of *O. microlepis*

Fish specimen sampled at the two sampling sites was used to obtain total catch.

CPUE was calculated as the total weight of fish in grams per duration of the net cast

in hours. CPUE is used in fisheries stock assessments and it is assumed to be proportional to abundance and therefore included in the stock assessment as a relative index of abundance (Sparre *et al.*, 1998).

3.7. Physico - chemical water quality parameters

Water temperature, Dissolved Oxygen, Salinity, pH, Electrical Conductivity, and Turbidity were measured on sites using Horiba U-10 Multiparameter Water Quality Meter. For Alkalinity, Total Hardiness, Total Suspended Solids and Total Dissolved Solids; water samples were collected at each sampling site for analysis in the laboratory at Bunda College, while flow rate was measured using vernier flow meter. All the parameters were analysed according to standard methods (APHA, 1989). All water quality parameters were collected early in the morning before the sunrise.

3.8. Data analysis

Stepwise multiple regression analysis using SPSS version 15.0 computer package was used to identify the water quality parameters which were correlated with catch per unit effort (CPUE) of *O. microlepis*. The water quality parameters used in the model were: water temperature, flow rate, dissolved oxygen, salinity, pH, electrical conductivity, turbidity, alkalinity, total hardness, total suspended solids and total dissolved solids. A model of the following expression was used:

$$Y = f(b_1X_1, b_2X_2, \dots, b_{11}X_{11})$$

Where: Y = catch/effort; X_1 = Water temperature; X_2 = Dissolved oxygen; X_3 = Salinity; X_4 = pH; X_5 = Electrical conductivity; X_6 = Turbidity; X_7 = Alkalinity; X_8

= Total hardness; X_9 = Total Suspended Solids; X_{10} = Flow rate; X_{11} = Total dissolved solids while $b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_9, b_{10}$ and b_{11} are the coefficient of the parameters $X_1 \dots X_{11}$.

The regressions were compared in order to select one with the best fit. The selection of the best model was based on the magnitude of the R^2 values, levels of significance and the correlations of the water quality parameters to CPUE. Differences in CPUE between months and sampling sites were studied using t-test and ANOVA tests (Delaney, 2005; Hyvärinen and Salojärvi, 1998).

To determine the relationship between water quality parameters and CPUE, multicollinearity was checked using the Variance Inflation Factor (VIF) of the predictor variables (Macuiane, 2006). A low tolerance of less than 0.1 indicates that the predictor variable is correlated with one or more of the other predicting variables, while VIF values greater than 10 show strong collinearity (Quinn and Keough, 2002).

ANOVA was applied to monthly data of male and female mean Gonadosomatic Index (GSI) and Condition Factors (CF) to determine if they varied significantly between the year (Delaney, 2005). Chi-square (χ^2) was applied to determine the sex ratios (Kaunda, 2000). Simple linear regression analysis model in (SPSS 15.0) was used to fit the growth model.

CHAPTER FOUR

4.0. RESULTS

4.1. Age estimation of *O. microlepis*

Out of the 260 pairs of otolith that were collected over the 12 months, 214 (82.3%) were sectioned and aged while 46 (17.7%) were discarded, as they were broken before preparation. Of the 214 sectioned otoliths, one hundred and sixty-eight (78.5%) yielded useful age estimates. Eleven (5.1%) were rejected due to disagreement between replicate counts. No otoliths were discarded due to difficulties in reading the zones. Growth zones on lapilli were reflected as alternating opaque and translucent zones. The transverse sections of the otoliths showed distinct opaque and translucent zones (Fig. 4.1).



Figure 4.1: Photomicrograph of lapillus otolith with 4 opaque zones from a 43 cm TL *Opsaridium microlepis*.

Age estimate ranged from 1+ to 5+ years. Aging precision estimates yielded: Average percent error (APE) of 8.2%, coefficient of variation (CV) of 5.8% and Index of precision (D) of 4.1 %.

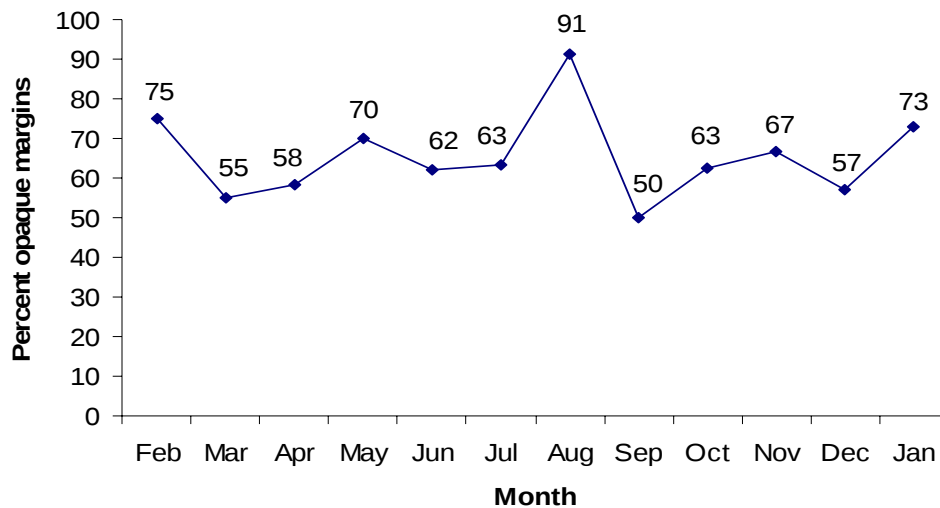


Figure 4.2: Monthly percent occurrence of an opaque margin in otoliths of *Opsaridium microlepis* sampled from the Linthipe River.

The monthly examination of the otolith margins revealed that one opaque zone is laid down annually during August (Fig. 4.2). Therefore, it was concluded that one opaque zone and one translucent zone, constitute an annulus and were counted as such. A length-at-age key for *O. microlepis* is presented in (Table 4.1). Five age classes were defined by the transverse surface readings of the otoliths.

It was observed that, as the fish grew in length, the number of age classes involved increased (Table 4.1).

Table 4.1: Age/Length key for *Opsaridium microlepis* from the Linthipe River.

Length (cm TL)	Age (years)					Total
	1	2	3	4	5	
0-4						
5-9	1					
10-14	1	1				
15-19	4	3				
20-24	1	15				
25-29		51	25			
30-34		26	38	5		
35-39			10	7		
40-44			1	6		
45-49				6	4	
50-54					6	
55-59					3	
N	7	96	74	24	13	214

Note: The numbers in the table represent the number of fish in the given length that were found within the given age group.

The mean total length of each age class was plotted using the age length key (Table 4.1) where it is clear that as the fish increase in age, there was corresponding increase in length (Fig. 4.3).

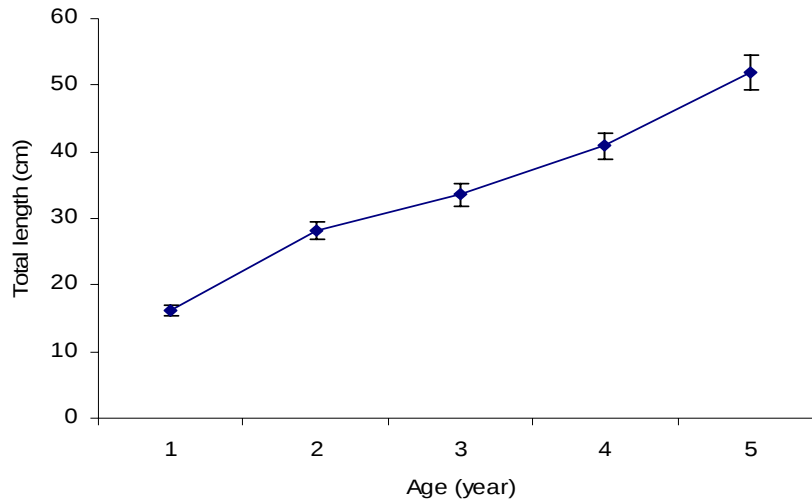


Figure 4.3: Mean total length values ($\pm$ SE) of each age class of *Opsaridium microlepis* constructed using the age length key

4.2. Length-Weight Relationship

The relationship between length and weight of *O. microlepis* is summarized by equations in Table 4.2 and shown in (Fig. 4.4).

Table 4.2: Length – weight relationship for *Opsaridium microlepis* from Linthipe River.

Relationship	Sex	N	aL ^b	r ²
Wt(g)	Combined	546	= (0.0248)*TL ^{2.8187}	0.9443
Wt(g)	Male	282	= (0.0145)*TL ^{2.9801}	0.9531
Wt(g)	Female	264	= (0.0144)*TL ^{2.9837}	0.9535

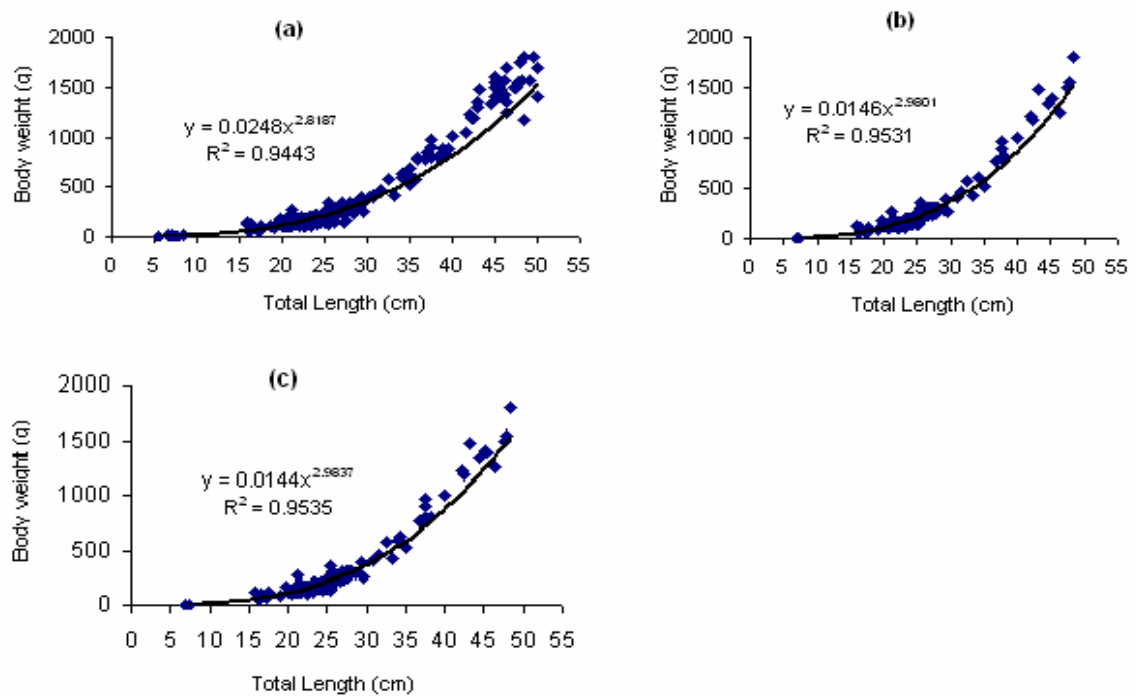


Figure 4.4: The relationship between the body weight (g) and total length (cm) for (a) combination of *Opsaridium microlepis* sexes (b) males and (c) females in the Linthipe River

4.3. Otolith dimension and fish length relationship

The relationships between fish total length and otolith dimensions (otolith weight, length and width) are summarized in Table 4.3. Otolith length and width were linearly related to the total length of fish.

Table 4.3: Relationships of otolith dimensions of *Opsaridium microlepis* to fish total length.

Parameter	Relationship	R ²	P
Owt (g)	$= 0.0005 * e^{0.0311 * TL}$	0.59	<0.05
OL (mm)	$= 0.0133 * TL + 0.958$	0.50	<0.05
OW (mm)	$= 0.0.127 * TL + 0.386$	0.56	<0.05

TL = total length, Owt = otolith weight, OL = otolith length, OW = otolith width, R² = coefficient of determination, p = level of significance.

4.3. Growth parameter estimation

Figure 4.5 show the fitted regression line of observed total length (cm) and fish ages (years) growth curve for this study. The regression model parameters are given in Table 4.4.

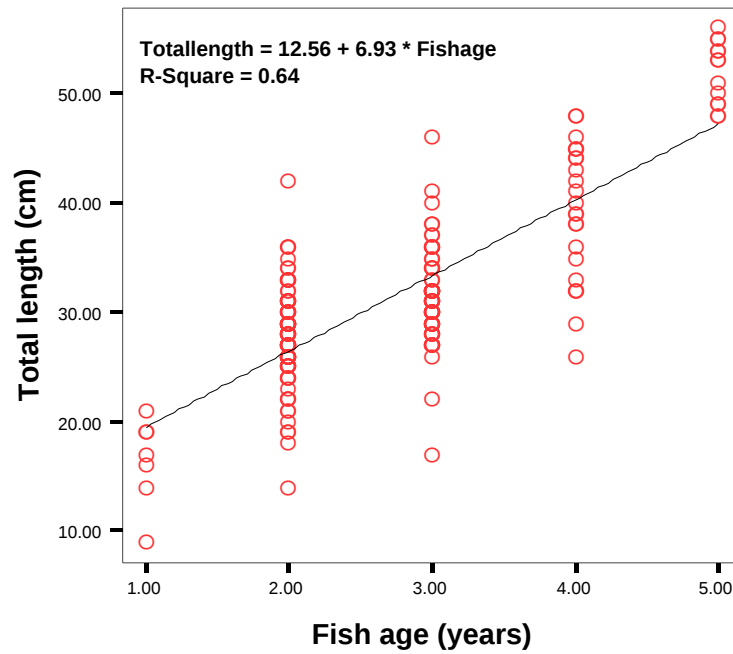


Figure 4.5: Fitted growth model for *Opsaridium microlepis*; using total length and fish ages derived from otoliths.

Table 4.4: Simple linear regression results of fish total lengths and ages of *Opsaridium microlepis* in the Linthipe River.

Variable	Coefficient	S.E	p-value
Constant	12.56	1.026	0.000
Fish age (years)	6.931	0.357	0.000
$R=0.799, R^2 = 0.639, p=0.000$			

4.6. Gonadosomatic index (GSI)

The GSI for *O. microlepis* fluctuated throughout the year (Fig. 4.6). The GSI ranged between 5.6 to 13 % for females and between 0.3 to 1.4 % for males respectively. GSI variation between the months was significantly different (One-way ANOVA, $p < 0.05$).

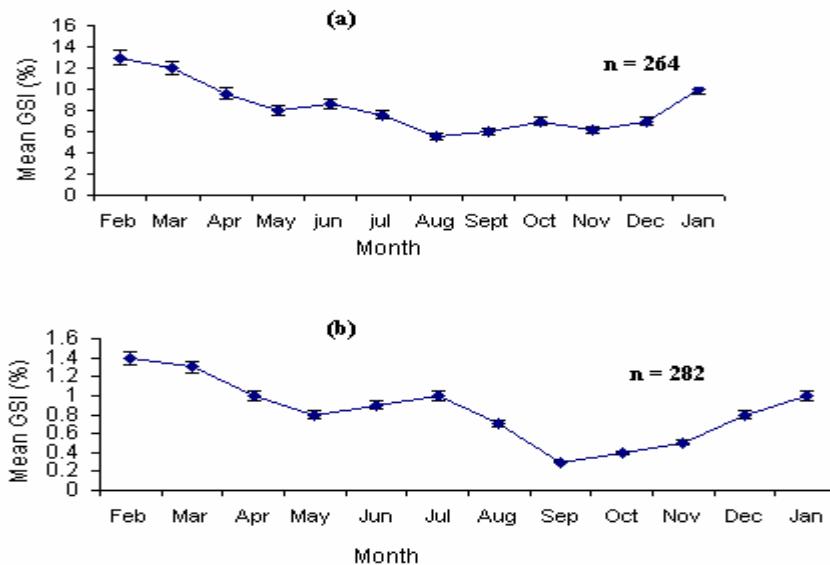


Figure 4.6: Mean monthly GSI values ($\pm$ SE) for *Opsaridium microlepis* (a) female and (b) male caught in the Linthipe River (February 2006 – January 2007).

A summary of the mean weights, condition factor and GSI are presented in Table 4.5.

Table 4.5: Mean body weights, condition factor and GSI for *Opsaridium microlepis* from Linthipe River (February 2006 – January 2007).

Parameter	Female		Male	
	Value	Month	Value	Month
Mean highest body weight (g)	1831.8	February	1176	February
Mean lowest body weight (g)	62.1	November	76.4	October
Mean highest condition factor (%)	1.4	February	1.3	February
Mean lowest condition factor (%)	0.6	August	0.6	August
Mean highest GSI (%)	13	February	1.4	February
Mean lowest GSI (%)	5.5	August	0.3	September

4.7. Sex ratios

The overall sex ratio was 1: 1.068182 males to females, which was not significantly different from unity ($\chi^2 = 0.022$, $df = 1$, $p > 0.05$).

4.8. Condition factor

The condition factor was significantly different (One-way ANOVA, $p < 0.05$) amongst months but was not significantly different between sexes (t-test, $p > 0.05$). The condition factor ranged from 0.6 to 1.4 with peak of 1.4 in February. The lowest condition factor of 0.6 was in the month of August (Fig. 4.7).

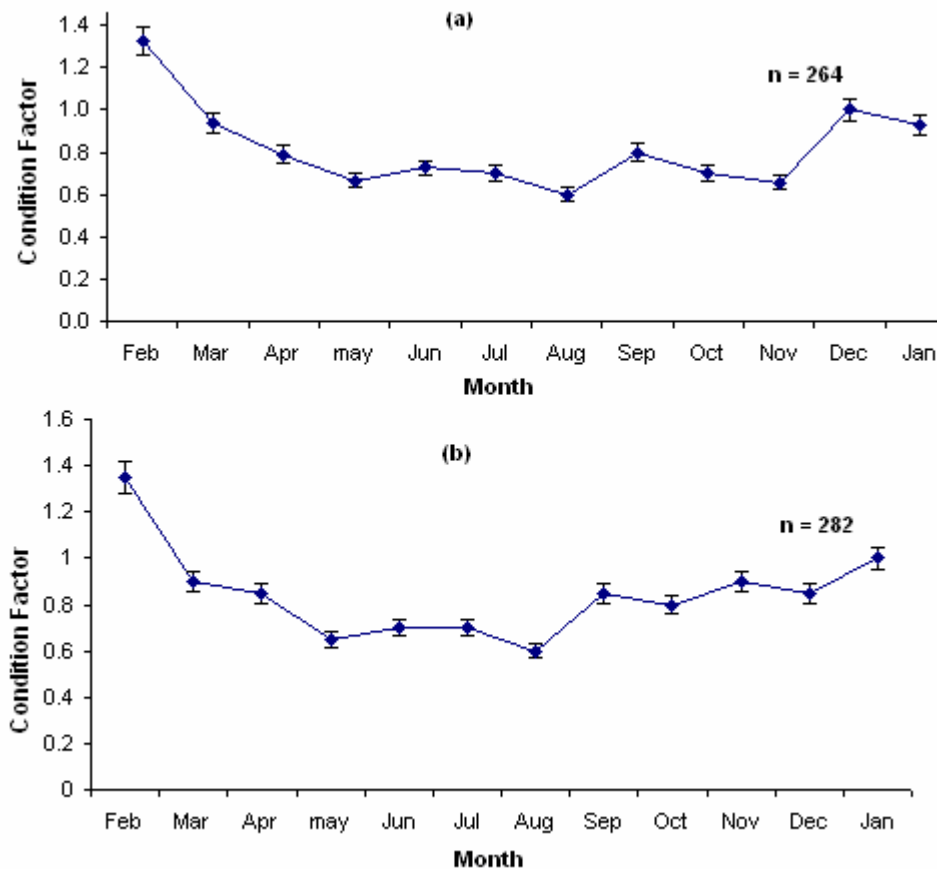


Figure 4.7: Mean monthly condition factor values ($\pm$ SE) for *Opsaridium microlepis* (a) female and (b) male caught in the Linthipe River (February 2006 – January 2007).

4.9. Catch per unit effort of *O. microlepis*

Catches ranged between 0.006Kg/hr in November to 0.611Kg/hr in February. There was a similar trend of *O. microlepis* for CPUE for the two sites. The highest CPUE value was observed in February, (Fig. 4.8). CPUE for the two sites was not significantly different (t-test, $p > 0.05$).

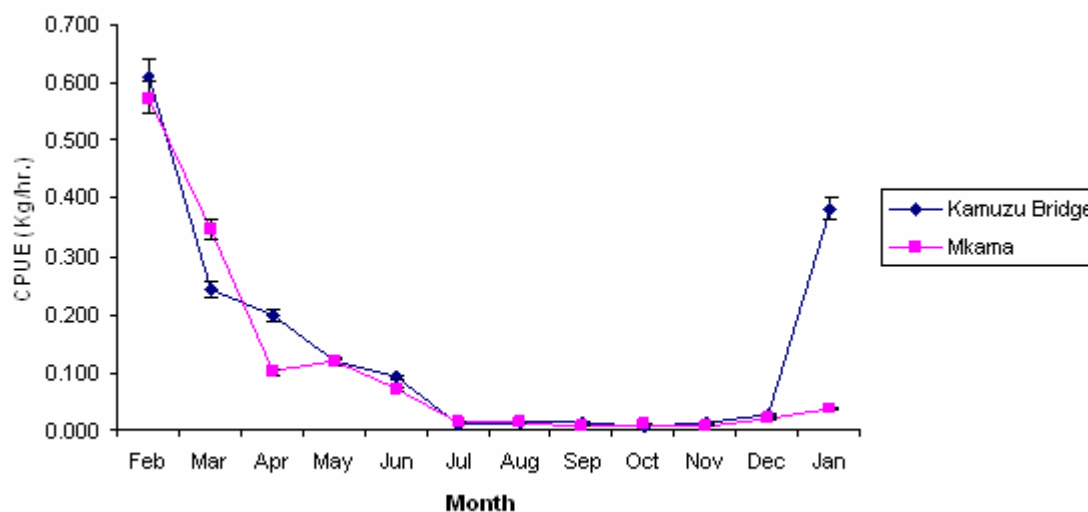


Figure 4.8: Mean monthly CPUE values ($\pm$ SE) for *Opsaridium microlepis* sampled in the Linthipe River at two sites (Kamuzu Bridge and Mkama).

4.10. Water quality

The means, ranges and standard error of water quality monitoring in the Linthipe River (February 2006 – January 2007) are summarized in Table 4.6. Values for alkalinity ranged between 9.5 mg/L to 33.00 mg/L while dissolved oxygen ranged between 3.5 mg/L to 14.06 mg/L. Values for electrical conductivity ranged between 0.23 ms/m to 0.61 ms/m and those of salinity ranged between 0 ppt to 0.02 ppt while total dissolved solids ranged between 1.4 mg/L to 18.00 mg/L. On the other hand, Total suspended solids ranged from 1.0 mg/L to 29.6 mg/L, turbidity ranged from 200 mg/L to 999 mg/L, flow rate ranged from 0.7 m/s to 1.9 m/s and water temperature ranged from 21.7 °C to 29.7 °C. All the water quality parameters in the river were significantly

different between the sampling months (ANOVA, $p < 0.05$), but not significantly different between the sampling sites (t-test, $p > 0.05$).

Table 4.6: Results of water quality analysis (mean $\pm$ SE) for Linthipe River (February 2006 – January 2007).

Name of parameter	Mean	Range	$\pm$ SE
Alkalinity (mg/L)	17.76	9.5 - 33.00	2.38
Dissolved oxygen (mgO ₂ /L)	7.67	3.5 - 14.06	1.18
Electrical conductivity (ms/m)	0.42	0.23 - 0.61	0.04
pH		6.15 - 8.9	
Salinity (ppt)	0.01	0.00 - 0.02	0.002
Total dissolved solids (mg/L)	7.30	1.4 - 18.00	1.83
Total Hardiness (mg/L)	141.56	87.0 - 261.0	14.86
Total suspended solids (mg/L)	8.4	1.0 - 29.6	3.14
Turbidity (mg/L)	555.17	200 - 999	103.08
Flow rate (m/s)	1.24	0.7 - 1.9	0.14
Water temperature (°C)	25.34	21.71 - 29.72	0.74

Partial correlation was used to explore the relationship between *O. microlepis* catches (CPUE) and water quality parameters (water temperature, dissolved oxygen, salinity, pH, electrical conductivity, turbidity, alkalinity, total hardness, total suspended solids flow rate and total dissolved solids). Dissolved oxygen and total suspended solids were positively correlated with *O. microlepis* catches (Dissolved oxygen ($r = 0.821$, $p < 0.05$);

total suspended solids ($r = 0.592$, $p < 0.05$), while electrical conductivity was negatively correlated ($r = -0.673$, $p < 0.05$).

Partial correlation showed that of all the parameters, dissolved oxygen, total suspended solids and electrical conductivity were significantly ($p < 0.05$) correlated to *O. microlepis* catches. Since multicollinearity was detected: electrical conductivity and dissolved oxygen were separated and two multiple linear regression models were developed. Dissolved oxygen and total suspended solids were significantly correlated ($p < 0.05$) to CPUE Table 4.7, while electrical conductivity was significantly correlated ($p < 0.05$) to CPUE (Table 4.8).

Table 4.7: Multiple regression results of dissolved oxygen and total suspended solids on CPUE of *Opsaridium microlepis* in the Linthipe River.

Variable	Coefficient	S.E	p-value
Constant	-0.171	0.046	0.005
Dissolved oxygen	0.031	0.005	0.000
Total suspended solids	0.007	0.002	0.006
$R=0.929$, $R^2 = 0.864$, $p=0.006$			

From Table 4.7, dissolved oxygen and total suspended solids were significantly correlated ($p < 0.05$) to *O. microlepis* CPUE.

Table 4.8: Multiple regression results of electrical conductivity on CPUE of *Opsaridium microlepis* in the Linthipe River

Variable	Coefficient	S.E	p-value
Constant	0.473	0.126	0.004
Electrical conductivity	-0.828	0.288	0.016
$R=0.673, R^2 = 0.453, p=0.016$			

From Table 4.8, electrical conductivity was significantly correlated ($p<0.05$) to *O. microlepis* CPUE.

Figure 4.9a shows that, electrical conductivity was highest between August and November when CPUE was low, and when dissolved oxygen and total suspended solids were also low. Dissolved oxygen and total suspended solids were high in February (14.1mg/L and 29.9 mg/L) respectively when CPUE was also high (Figs.4.9 b and c).

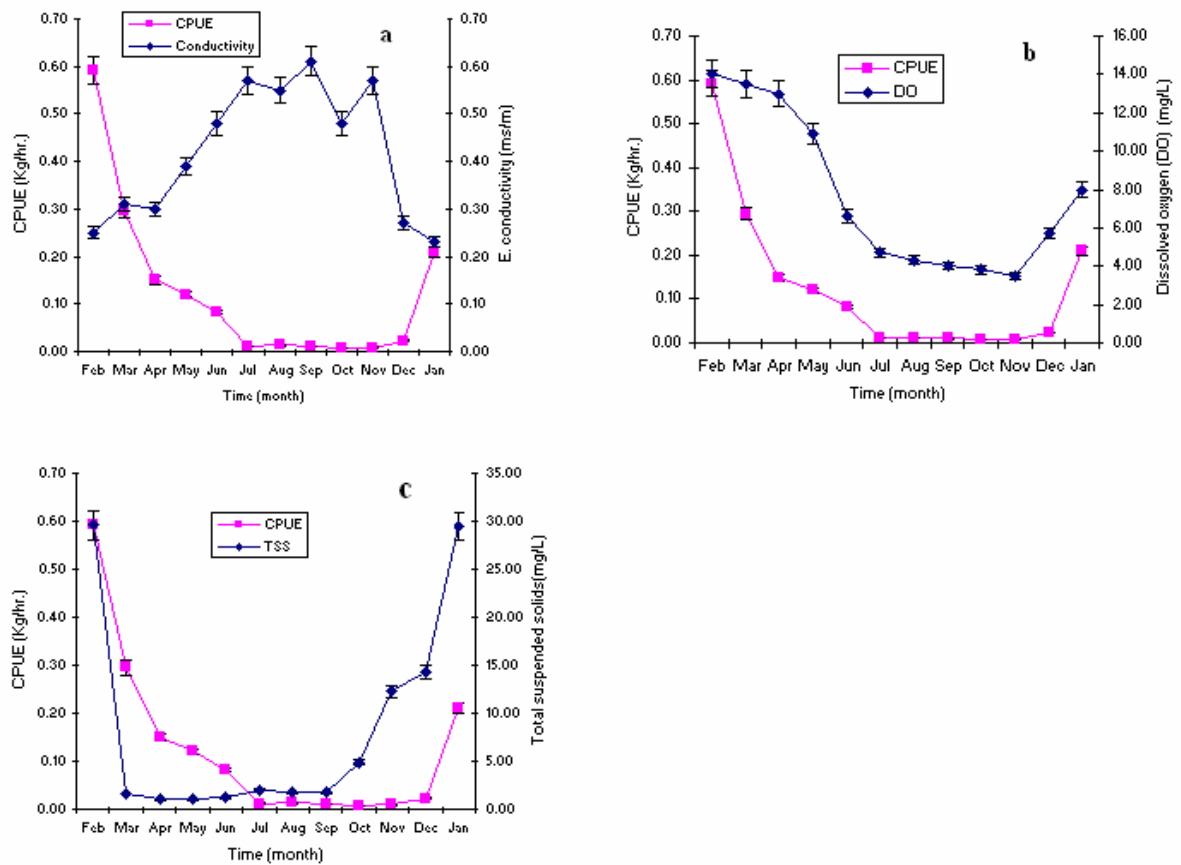


Figure 4.9: CPUE of *Opsaridium microlepis* and electrical conductivity (a), dissolved oxygen (b) and total suspended solids (c) in the Linthipe River between February 2006 and January 2007.

CHAPTER FIVE

5.0. DISCUSSION

5.1. Discussion

5.1.1. Age and growth of *Opsaridium microlepis*

The use of age-based data for fish stock assessment and fisheries management maintains the pragmatic requirement for otolith research (Begg *et al.*, 2005). Growth checks on hard structures such as scales, otoliths and spines are formed as a response to one or more environmental variables that reduce metabolic rate and result in a slowing of the growth rate (Gauldie and Nelson, 1988). Age and growth history of fish are encoded in the microstructure of these organs (Jones, 2000). Although the period of annulus formation has been reported to be variable in fishes of tropical and sub-tropical waters (Booth and Merron, 1996), there is a strong indication that the formation of a single opaque zone in otoliths occurs at the end of winter, when either temperature or water level are low (Weyl and Hecht, 1998). The growth of the otolith continues throughout a fish's lifetime and is based on a genetically guided mechanism (Gauldie and Nelson, 1988).

Despite the earlier failure to age *O. microlepis* using hard parts (Tweddle, 1987), in this study, clear deposited growth zones were visible in the burnt and sectioned lapilli (Fig. 4.1), leading to the first hard-part based estimate of annular age and growth for this species. The precision of age estimates of the study indicated a good

reproducibility i.e. Average Percent Error (APE) = 8.2%, Coefficient of Variation (CV) 5.8% and Index of precision (D) 4.1 %. Ageing studies can be carried out with a CV of less than 7.6%, corresponding to an APE of 5.5. A CV of 5% serves as a reference point for many fishes of moderate longevity and reading complexity (Campana, 2001). Therefore, the results from the study were in a good range and could be reliably used.

The use of hard parts to age tropical fish is supported by several studies that used sagittae to age fishes from Lake Malawi (Kaunda, 2000; Kanyerere, 2003; Chimatiro, 2004; Singini, 2006). Although otolith margins revealed that one opaque zone is laid down annually during August (Fig. 4.2), a high percentage of the samples (average 65%) had opaque zones in all the months, suggesting that there may be more than one ring formed in each year. Opaque zones observed under transmitted light are laid down during the periods of slow growth, and this case in August, just as Kaunda and Hetch (2003) found for *Bathyclarius nyansensis*.

Otolith growth is very sensitive to temperature in a number of species as temperature fluctuations have a major influence on annuli formation (Brothers, 1981). Although carbon anhydrase regulated system is also said to be responsible for otolith formation, the system requires temperature as its external controlling factor (Gauldie and Nelson, 1990a). In addition, food availability is also known to affect fish growth (Weatherley and Gill, 1987), a reduction in feeding activity leads to an increase in the gonad maturation which is known to cause a depletion of peritoneal fat reserves causing the

opaque zone formation (Jepsen *et al.*, 1999). In this study, opaque zone deposition on otoliths seem to have corresponded to a period of high temperature, high GSI and low fish condition factor of *O. microlepis* (Fig. 4.6 and 4.7). This period of annuli formation could have been a period of active feeding after termination of spawning activity and abundance of feed which coincides with the time when the south east winds blow strongly causing an upwelling of nutrient-rich water leading to a peak in primary productivity (Patterson and Kachinjika, 1995).

The estimated growth rates from sectioned lapilli did differ from earlier estimates based on length frequency analysis (Tweddle, 1987). If we assume that otolith-based estimates of age are the most accurate, hence Tweddle (1987) appear to have underestimated the growth rate of the species. However, the results agree with Tweedle (1983) who reported the growth in length of *O. microlepis* is approximately linear until at least five years of age. Linear growth of fish has been reported by Imai *et al.* (2002) in *Tribolodon nakamurai*, which is a cyprinid like *O. microlepis*. The growth rate at 20cm TL/ year, however agree with Morioka and Kaunda (2004) who estimated the growth rate for smaller fish.

Perhaps the major worry with the findings is the failure to obtain a larger sample of more 70 cm TL as reported by Tweddle (1983). This may explain the reason why the VBGF the most used growth model for fisheries (Sparre *et al.*, 1998) could not be fitted to the data set as the length at infinity could not be estimated. This led to the use of the linear regression. The disappearing of large specimens could imply the

environmental problems with the catchment degradation (Mkanda 2002) or overfishing of the stock

5.1.2. Reproductive seasonality and condition factor of *Opsaridium microlepis*

Some investigations on the reproductive biology of *O. microlepis* have been done (Tweddle, 1983; Msiska, 1990; Morioka and Kaunda, 2001; Morioka and Kaunda, 2004). In this study, breeding season of *O. microlepis* from the Linthipe River occurred between November and July with a peak of activity between January and April and a decline in August (Fig. 4.6). The highest GSI was observed in the month of February at the start of the rainy season while the lowest in the month of August when rains have ceased. The breeding season observed is in line to that reported by Tweddle, (1983); Morioka and Kaunda, (2001). The peak-breeding season coincided with the rainy season. During this period suspended and dissolved solids are washed away to the lake (McCullough, 1999), and this has been known to have an effect on when *O. microlepis* should start migrating to the rivers for breeding (Tweddle, 1987). Turner (2004 b) reported that during the start of the rainy season, temperatures are cool. This could also imply that *O. microlepis* breed during the rainy season when the surface water temperatures are low and just before upwelling of nutrient waters.

These results are in line with Morioka and Kaunda (2001) who reported on the throughout the year breeding of some cyprinids in the Lake Malawi. This continuous breeding observed in the study might entail the existence of the plural stocks of *O. microlepis*, that is, the different stocks adapting to the different optimum temperature,

in Lake Malawi (Patterson and Kachinjika 1995), for reproduction of the cyprinids as observed by Morioka and Kaunda (2001).

During the peak breeding season the condition factor of the fish was highest. The condition factor increased with increase in the spawning activities (Fig. 4.7). Condition factor is a frequently used index for fish biology studies. It furnishes important information related to fish physiological state (Bolger and Connolly, 1989). The high condition factor observed in the study entails that the quality of the environment during the peak breeding season was good (Braga, 1986). Though the condition factor between the months was significantly different (One-way ANOVA, $p < 0.05$), this might have been due to the fluctuation of the GSI value (Fig. 4.6). This could be so because condition factor is heavily influenced by season, stage of maturation, fullness of the gut, type of food (Bolger and Connolly, 1989). The condition factor was not significantly different between the sexes (t-test, $p > 0.05$), the values of female condition factor did not decrease rapidly as expected (Singini, 2006). The reason for a gradual decrease may be attributed to the spawning behavior of *O. microlepis* as reported by Msiska (1990), i.e. *O. microlepis* stays in the river for several months laying many batches of a few thousand eggs at a time over a period.

5.1.3. Relationship between catch per unit effort and water quality parameters

Variation of CPUE is of concern to people who rely on the resources for their daily lives (Chifamba, 2000). Farming systems contribute to soil erosion because of several sub-optimal land use practices that include improper alignment of contour ridges, and

failure to control gully formation (World Bank, 1991). Soil loss in most parts of the Linthipe catchment area range between 16 - 22 t ha⁻¹ yr⁻¹ (World Bank, 1991). These soil-loss rates result in a sediment-discharge rate of about 94.4 g/m (3.28 t ha⁻¹ yr⁻¹) at the river mouth, which is only surpassed by that of the Ruhuhu River (143.2 4 g/m or 4.97 t ha⁻¹ yr⁻¹) on the Tanzanian side (Kingdon *et al.*, 1999). As Total suspended solids (TSS) increases with high flow of rate and erosion (Bootsma and Hecky, 1999), these high soil losses are likely to result in high TSS values in the Linthipe River. Incidentally, the TSS and EC values reported in this study (8.4 ± 3.14 mg/L and 0.42 ± 0.04 ms/m, respectively) are much higher than what were reported previously (1.6 mg/L and 0.12 ms/m, respectively) by McCullough (1999) and Gomani (2007). The changes in TSS value could imply increased degradation of land (Welcomme, 2003; Gomani, 2007).

The significant correlation ($p < 0.05$) between CPUE and TSS should be a cause for concern as this implies that there is an increased efficiency in catching fish as TSS increases. Total suspended solids (TSS) cause turbidity, which limit light penetration (Bootsma and Hecky, 1999), and which may reduce visibility of fishing gears and thereby making fish more susceptible to capture. Similar results were reported by Kim and Wardle (1998a and b); Rosland and Giske (1994) who found that fish catches were high in less visible waters. Degree of soil erosion which results in high TSS has been found to significantly correlate with the amount of cultivated farmland (Mkanda, 2002), and more land is being cultivated due to land pressure in Malawi (Ferguson *et al.*, 1993; Kalipeni, 1996). Hence, total suspended solids (TSS) is bound to increase

with time, implying that stock of *O. microlepis* may rapidly decrease due to increased CPUE.

The negative correlation between EC and CPUE could be a reflection of the rainfall pattern. In Malawi, the rainy season starts around December and stops in April (Patterson and Kachinjika, 1995). Since evaporation of water from the surface of a water body concentrates the dissolved solids in the remaining water resulting in a higher EC (Rosland and Giske, 1994), it is easy to see that with the onset of dry season in July the EC went up and dropped down as the rainy season commenced in December (Figure 4.9a). In fact the data that was obtained during the study show that the rainfall was 475 mm in January and dropped to 0 mm in July.

CHAPTER SIX

6.0. Conclusion and Recommendations

6.1. Conclusions

- Aging was possible with the use of lapilli. It was observed that the deposition of a growth zone occurred when the fish's condition was poor. The variation in the water quality parameters might have led to the deposition of an annular ring in the otoliths.. Most of the fish specimens caught during the study period were estimated to be between 2-3 years. Growth was linear and different from that reported by Tweddle (1987). The growth rate was estimated at 20 cm TL/yr.
- Peak breeding activity was observed between January to April. This was at the onset of rainy season. This was similar to that reported by Tweddle, 1983; Morioka and Kaunda, 2004 while the condition factor of *O. microlepis* was found to be variable with lowest value in the month of August.
- *O. microlepis* catches between the two sampling sites followed a similar trend and were affected by water quality. Of the sampled water quality parameters; total suspended solids, dissolved oxygen and electrical conductivity were significantly affecting the catches. Total suspended solids and dissolved oxygen were positively correlated to the catches while electrical conductivity was negatively correlated.

6.2. Recommendations

The following recommendations were generated from the study:

- The impacts of the positive correlation of TSS with CPUE, entails that a lot fish are captured. Therefore, measures to reduce soil erosion due to bad land use practices should be enforced.
- Closed fishing season and area should be instituted in the Linthipe River. This should be done during the peak-breeding season i.e. January to April.
- Other studies must be taken in the Linthipe River catchment to evaluate the impacts of land use practices on the riverine fishes.
- Gear selectivity studies must be carried out in order to know the mesh size which can sustainably catch *O. microlepis*.

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