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Research Article

A COMPARISON OF LIFE HISTORY TRAITS OF MPASA, *OPSARIDIUM MICROLEPIS* (GÜNTHE 1864), (PISCES: CYPRINIDAE) FROM BUA AND LINTHIPE RIVERS IN CENTRAL MALAWI

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ABSTRACT
A study on life history aspects of mpasa, *Opsaridium microlepis* from Bua and Linthipe Rivers in Central Malawi was conducted between March 2007 and February 2008. A total of 301 mpasa (82 from Bua and 219 from Linthipe) were sampled monthly using trawled gill nets. The sampled mpasa fish ranged between 181 and 452 mm SL in Bua River and 106 and 446 mm SL in Linthipe River. Age was estimated using lapillus otoliths while annual rings validation of marginal zone analysis was used to validate formation of annual rings. Principal Component Analysis (PCA) was used to compare the morphology of mpasa from two rivers.
Growth of fish from the two rivers was described by simple linear regression model with the following parameters: *Total length (mm) = 197.41 + 27.22× Age;* r^2*=67%, P = 0.001* for Bua River and *Total length (mm) = 237.68 + 12.57× Age;* r^2*=41%, P = 0.001* for Linthipe River. Maximum age for *O. microlepis* was 10 years for Bua River fish specimens and 12 years for Linthipe River fish specimens. Marginal zone analysis showed that annuli were formed yearly in March and September for Bua and Linthipe, respectively. PCA showed that there were minor morphological differences between the stocks indicating that *O. microlepis* in these rivers might belong to different stocks. From these results a recommendation was made regarding adoption of proper catchment management and sustainable exploitation of *O. microlepis* in order to conserve stock diversity.

Key Words: *Life History, Mpasa (Opsaridium Microlepis), Otolith, Age, Growth, Bua River, Linthipe River, Water Quality*

INTRODUCTION
Knowledge about fish life history traits can be useful in fisheries management. Information about fish age is of primary importance in studies of fish biology and for determination of management strategies of fish stocks. Age-determined parameters such as mortality and growth underlie the population dynamics models used in fishery analyses. Age studies can furnish other basic data such as stock age structure, age at first maturity, spawning frequency, individual and stock responses to changes in the habitat and recruitment success. Age and growth data also permit the determination of population changes due to fishing rates (Taylor *et al.*, 2000; Morales-Nin, 1986a)
Studies of life history traits such as growth and reproductive biology are indispensable for successful management of natural fishery. The catch that can be taken from a fishery depends largely on growth of fish in the exploited population and fish are recruited into a fishery through reproduction. Calculation of age structure and growth rate in a fish population can be made if the age of fish sampled is accurately determined.
Different river systems have different nutrient levels. For example, (Kingdon *et al.,* 1999) reported that densely populated regions such as Linthipe have higher average nutrient loading resulting from agricultural development, deforestation and seasonal burning in their catchments. This is not the case with low populated rivers like Bua whose course flows in a protected Nkhotakota Game Reserve. Bua and Linthipe Rivers inhabits Mpasa, *Opsaridium microlepis* (Günther, 1864) during breeding season.

Opsaridium microlepis is endemic to Lake Malawi and its affluent rivers. Mpasa is commonly caught in the northern and central regions of Malawi, where it ascends rivers to breed. It has been suggested that *O. microlepis* catches have been on the decline (Tweddle, 1981, 1983). During the spawning migrations, *O. microlepis* is heavily exploited by gillnets set near river mouths and other fishing methods used in the rivers. *O. microlepis* no longer exists in some river in-flows where it used to be abundant some time back due to ecosystem degradation and overfishing during migration (Ndamala, 2006). Human population density and climate change in the areas surrounding the rivers are some of the causes for disappearance of *O. microlepis* in many inflow rivers of Lake Malawi (Kingdon *et al.,* 1999). This study aimed at comparing life history traits of *O. microlepis* from Linthipe and Bua Rivers as a response to the intensity of nutrient loading and suspended solids.

MATERIALS AND METHODS

Fish Sampling

Between March 2007 and February 2008. *O. microlepis* specimens were sampled in Bua and Linthipe Rivers using trawled gillnet set across the rivers from the selected sites. Sampling was conducted by two fishermen using a multimesh gillnet, 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 (Limuwa, 2008). The duration of casting and the number of fish specimens were recorded following guidelines outlined by (Limuwa, 2008). 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. Morphometric measurements were taken (± 0.1cm) using a measuring board and caliper. Fish were weighed to the nearest (± 0.01g) using HP – 20 K and gonad weight to (± 0.001g) using HF – 3000 electronic weighing balance. Egg diameter was recorded. These measurements were taken after preservation in the ice and all heads were preserved in deep freezer for otolith extraction.

Age and Growth

Lapillus otoliths were removed and stored dry in well labeled envelopes. One of the lapillus otoliths (left or right) from each fish was weighed to the nearest 0.01mg on a microbalance, AND HR-200, and length and width were measured to the nearest 0.01mm using a microscope (Olympus BX 50) on the ocular scale. Otolith length was measured as the distance from the anterior tip to the posterior tip, and the otolith width was measured as distance from the dorsal edge to the ventral edge across the nucleus perpendicular to the otolith length. The otoliths were cut into 0.5 mm thick sections and were mounted on a microscope slide. Annuli were counted on the section through the core by using a compound microscope.

To enhance otolith growth zones visibility, a technique used by (Kanyerere, 2003; Morales-Nin, 1986a) was employed. To avoid charring, a specially designed tray was used to hold the otoliths about 5cm above the heating element. Otoliths were burned over a low intensity ethanol flame until they turned pale brown. Each otolith was then embedded in a block of clear fibre glass resin and sectioned transversely through the core using a dual blade high-speed diamond saw. The sectioned otoliths were mounted on glass slides with DPX mountant and were viewed with the aid of a dissecting microscope under transmitted light using variable magnification. The number of opaque zones was read on three occasions without reference to fish's size. A reading was accepted only if two of the three readings were the same and an average was used if three readings differed by a year.

Average percent error (APE) method for precision was applied because it is a better method for assessing the precision of age determinations than the percent agreement method, since the latter does not evaluate the degree of precision equally for all species (Beamish and Mcfarlane, 1995).

Growth zone deposition periodicity was identified by plotting a graph of monthly percentage of otoliths with opaque, narrow and wide hyaline zones as a function of time.

Simple regression model of total length on age was fitted to determine the growth of fish from both rivers. Student's t-test was used to differentiate two growth models.

Condition Factor, Egg Diameter, Fecundity and GSI

Condition factor for 301 fish from Linthipe and Bua Rivers was calculated using the following formula:

$$K = \frac{(10)^5 W}{L^3}$$

Where K is the condition factor
W is the weight of fish (g)
L is the length of fish (mm)

Gonads were used to determine temporal reproductive activity of *O. microlepis*. Gonads were extracted from mature specimens, weighed to the nearest 0.01g using HF – 3000 electronic weighing balance and preserved in histological solution. Gonads were fixed in Bouin's solution made up of picric acid (75%), formalin (25mL) and glacial acetic acid (5mL) was used as the ultimate histological solution. After fixation, gonad tissues were rinsed and stored in 70% alcohol. Fish total length (TL) and standard length (SL) were measured to the nearest millimeter and weight of the whole fish to the nearest 0.1g using a length board and microbalance (HP – 20 K), respectively. These measurements were taken on fresh specimens from the field to avoid changes in some of these measurements due to freezing. GSI for each sex of *O. microlepis* was calculated using the following formula:

GSI = ((gonad weight/somatic weight) × 100)

Where somatic weight = (total weight - gonad weight)

Relative fecundity was determined by weighing all the eggs in the ovaries and counting 10 sub samples of 0.15 g of eggs from different parts of the ovaries. The average number of eggs per g of preserved wet weight was calculated and multiplied by the total weight of each ovary n order to get the total number of eggs per ovary.

Egg diameter was measured as the distance from the dorsal edge to the ventral edge across the yolk perpendicular to the egg length, to the nearest 0.01 mm, by using the ocular scale on microscope.

Two-way ANOVA was used to analyze the temporal and spatial difference of parameters of the two river sites.

In order to isolate groups that differed from one another, Duncan's Multiple Range Test was performed for normal data. GSI was not normal even after log-transformation; as a result Games-Howell was used to separate means.

Morphology

Principal Component Analysis (PCA) in JMP was done on 13 morphometric measurements {Total length (TL), Forkal length (FL), Standard length (SL), Body depth (BD), Head length (HL), Dorsal fin base length (DFB), Anal fin base length (AFB), Predorsal distance (PRD), Preanal distance (PRA), Prepectroral distance (PRP), Prepelvic distance (PRV), Eye diameter (ED), Preorbital distance (PD)} obtained from *O. microlepis* (N = 60). Fish specimens of almost the same size (236-283mm, SL), 30 specimens from Bua and 30 from Linthipe, were used for morphometric comparisons. The original values were log-transformed to normalize variances (Kassam *et al.*, 2000). The covariance matrix was then subjected to PCA.

RESULTS

Age Estimation and Growth

The age estimate for *O. microlepis* ranged from 1 to 10 years for Bua and 1 to 12 years for Linthipe *O. microlepis specimens*. CV values (Table 1) for both sites indicates that insignificant errors (10.4 and 10.0 for Bua and Linthipe Rivers respectively) were incurred during the ageing process.

Table 1: Age estimates of *O. microlepis* from Bua and Linthipe Rivers.

Site	Average Percent Error (APE %)	Coefficient of Variation (CV %)	Index of Precision (D)
Bua	10.4	7.7	4.5
Linthipe	10.0	7.5	4.3

Monthly examination of the otolith margins show that one opaque zone was laid down annually in March for Bua stock (Figure 1a) and in September for Linthipe stock (Figure 1b). Therefore, one opaque zone and one translucent zone constitute an annulus.

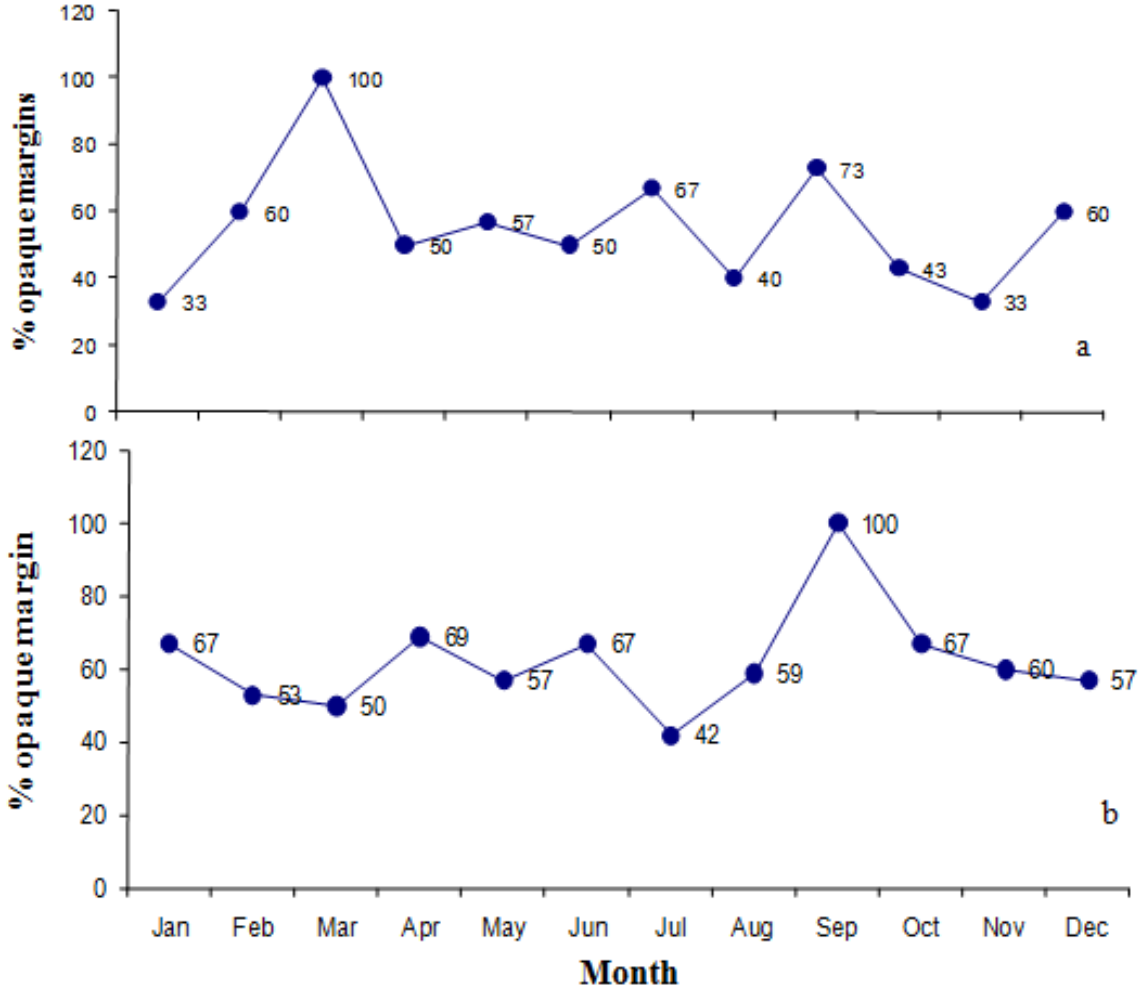

Figure 1: The monthly percent occurrence of an opaque margin in otoliths of *O. microlepis* sampled from a) Bua, N = 47 and **b)** Linthipe, N = 150.

The relationship between total length and age was described by the equation $Y = 27.221Fish\ age + 197.409$ ($r^2 = 0.670$) and $Y = 12.568Fish\ age + 237.678$ ($r^2 = 0.0407$) for Bua and Linthipe respectively were significant at $P = 0.001$ (Figure 2). Growth models showed a significant linear relationship between fish length and age ($P < 0.10$).

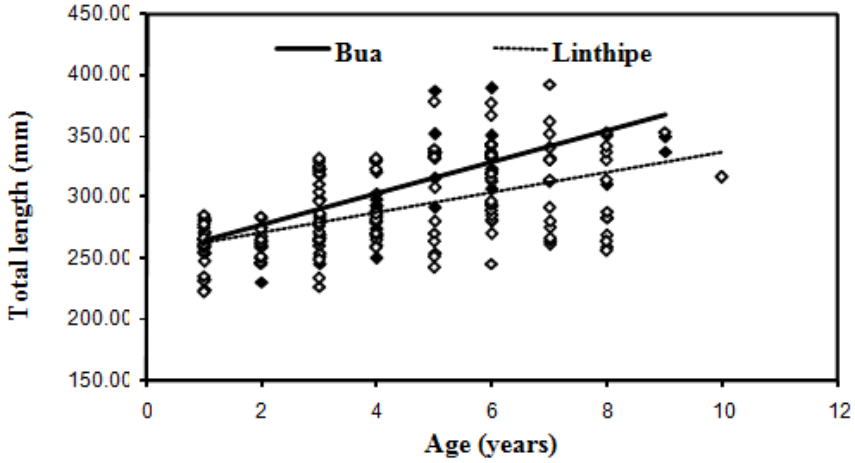

Figure 2: Length-at-age of *O. microlepis* from Bua (—) and Linthipe (---) Rivers. Fitted growth model using total lengths and fish ages derived from lapillus otoliths.

Gonadosomatic Index, Egg Diameter, Relative Fecundity and Condition Factor

Female mpasa bred throughout the year with peaks in August and October for Bua (Figure 4a) and Linthipe (Figure 4b), respectively. One-way ANOVA showed that GSI was significantly different ($P < 0.05$) between months and not between sites. Males' GSI increased in June with peak in October for both stocks. Relative fecundity was not \significantly different ($P > 0.05$) between the sites and months.

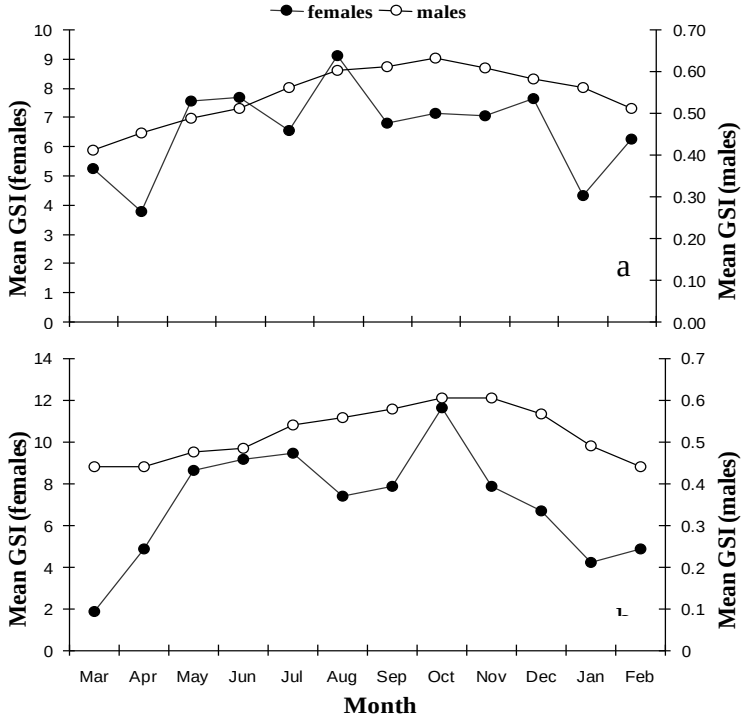

Figure 3: Mean Gonadosomatic Index values of *O. microlepis* in different months (March, 07 to February, 08) from Bua (a). and Linthipe (b). Rivers.

Condition factor and egg diameter were significantly different ($P < 0.05$) between Linthipe and Bua (Table 2). Fish in Bua had higher average condition factor than in Linthipe while egg diameter was generally higher in Linthipe than in Bua. Egg diameter was also significantly different ($P < 0.05$) between months (Table 3) for Bua stocks but not for Linthipe stocks. The largest eggs were obtained in January while the smallest in September in Bua River.

Table 2: Mean Condition Factor and Egg Diameter of *O. microlepis* from Bua and Linthipe Rivers.

Sampling Site	Condition Factor (C.F) (Mean ± SE)	# of Fish Specimens
Bua	0.90 ± 0.011	82
Linthipe	0.83 ± 0.008	219

Table 3: Mean Egg Diameter of *O. microlepis* from Bua and Linthipe Rivers in different months of the year (March, 07 - February, 08). Means within same column not sharing same superscript(s) are significantly different ($P < 0.05$).

Month	Bua	Linthipe
	Egg Diameter (mm) (Mean ± SD)	Egg Diameter (mm) (Mean ± SD)
March	1.47 ± 0.11^{abcd}	1.57 ± 0.021
April	1.30 ± 0.14^{abc}	1.48 ± 0.26
May	1.67 ± 0.21^{cd}	1.49 ± 0.10
June	1.45 ± 0.22^{abcd}	1.58 ± 0.23
July	1.45 ± 0.13^{abcd}	1.59 ± 0.02
August	1.30 ± 0.03^{abc}	1.60 ± 0.19
September	1.22 ± 0.02^{ab}	1.72 ± 0.13
October	1.16 ± 0.02^{a}	1.57 ± 0.14
November	1.35 ± 0.21^{abcd}	1.73 ± 0.11
December	1.58 ± 0.32^{bcd}	1.63 ± 0.19
January	1.70 ± 0.19^{d}	1.72 ± 0.18
February	1.56 ± 0.16^{bcd}	1.66 ± 0.15
All Months Combined	1.43 ± 0.024	1.61 ± 0.030

Morphology

Results from PCA comparing morphometric measurements of the Bua and Linthipe River stocks showed that PC I contributed 62.2% of morphological variation among *O. microlepis* from Bua and Linthipe Rivers (Table 4). PC II and PC III contributed 23.1% of the total variance (Table 4). PC 1 is strongly correlated with overall size and it cannot help to discriminate the fish in the two sites, therefore it was not plotted for morphometric discrimination.

PCII is mainly defined by total length (TL), head length (HL), prepectoral distance (PRP) and eye diameter (ED), PCIII is defined by eye diameter (ED) and anal fin base (AFB) (Table 4). These characters may be used to discriminate the fish between sites since the plots did show some partial differentiation

among specimens (N = 60) from both sites, but there is no clear-cut segregation (Figure 4). *O. microlepis* from Bua overlap with those of Linthipe River implying that they may be the same stocks. Tables 5 and 6 show the factor loadings for the characters of the fish from Bua and Linthipe Rivers.

Table 4: Principal Component loadings of the log-transformed variables on the first three axes for *Opsaridium micolepis* Bua (N = 30) and Linthipe (N = 30) Rivers.

Character	PC I	PC II	PC III
TL	0.27132	0.36790	-0.14277
FL	0.30588	0.28990	-0.17151
SL	0.30695	0.28516	-0.14471
BD	0.28842	-0.29780	0.17849
HL	0.22113	-0.46682	-0.12852
DFB	0.27476	-0.13884	0.09068
AFB	0.27128	-0.28062	0.20681
PRD	0.33706	0.13374	-0.04633
PRA	0.33327	0.14588	-0.04878
PRP	0.28545	-0.35162	0.15716
PRV	0.30352	-0.06213	-0.02047
ED	0.05277	0.32448	0.88967
PD	0.23741	0.15070	-0.09345
% Variance	**62.1647**	**16.0072**	**7.1212**

Table 5: Principal Component loadings of the log-transformed variables on the first three axes for *Opsaridium microlepis* from Bua River.

Character	PC I	PC II	PC III
TL	0.25274	-0.31783	0.13238
FL	0.29009	-0.31223	-0.09058
SL	0.27025	-0.33102	-0.09840
BD	0.27519	0.31769	-0.24510
HL	0.12114	0.46945	-0.01760
DFB	0.26955	0.16151	0.27832
AFB	0.30365	0.23675	0.17722
PRD	0.36826	-0.08642	-0.14429
PRA	0.37140	-0.12259	-0.15326
PRP	0.25248	0.37199	-0.16851
PRV	0.34271	0.16290	0.01588
ED	0.17050	-0.30097	-0.30118
PD	0.19963	-0.10238	0.79478
% Variance	**49.4390**	**29.4317**	**6.7384**

Table 6: Principal Component loadings of the log-transformed variables on the first three axes for *Opsaridium microlepis* from Linthipe River.

Character	PC I	PC II	PC III
TL	0.30909	0.10133	-0.09875
FL	0.30937	0.09624	-0.06621
SL	0.30850	0.09508	-0.01637
BD	0.28937	-0.07950	0.23299
HL	0.28105	-0.13592	-0.30446
DFB	0.27690	-0.06453	0.27393
AFB	0.24901	-0.25803	0.53401
PRD	0.31246	0.10251	-0.06036
PRA	0.30877	0.10251	-0.00241
PRP	0.29615	-0.11118	0.12832
PRV	0.27081	-0.06417	-0.04873
ED	0.00334	0.89163	0.33799
PD	0.24113	0.22820	-0.58453
% Variance	**75.4155**	**8.4642**	**6.4277**

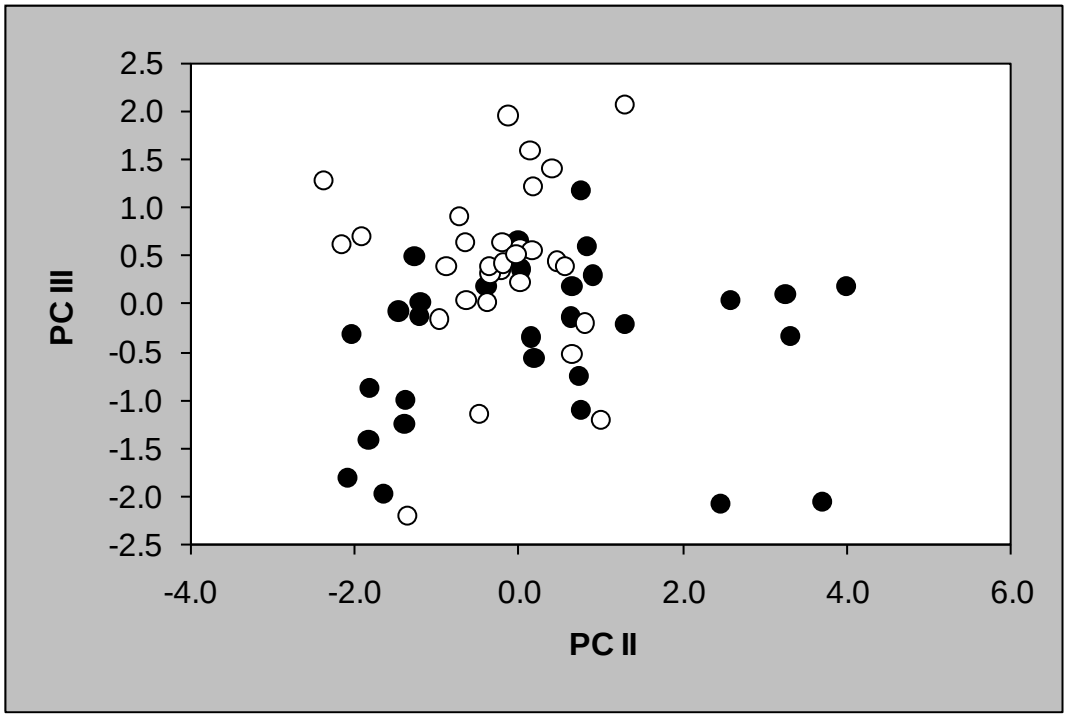

Figure 4: Scatter plots of the scores on the first three components and standard length of a PCA of log transformed measurement of *Opsaridium microlepis* from Bua (N = 30) and Linthipe (N = 30) Rivers. Filled circles: *Opsaridium microlepis* from Bua River; open circles: from Linthipe River.

Water Quality Parameters

Chlorophyll *a*, EC, salinity, TDS, total hardness, TSS and temperature were significantly different between Bua and Linthipe Rivers (Table 5). Chlorophyll *a*, electrical conductivity, TDS, turbidity and temperature were significantly higher in Bua River than in Linthipe River. TSS was significantly lower in Bua River than in Linthipe River

Table 7: Results of water quality analysis for Bua and Linthipe Rivers (March 2007-February 2008).

Name of Parameter	Bua		Linthipe		*P*-Value
	Mean ± SE	Range	Mean ± SE	Range	
Alkalinity (mg/L)	187.62±2.05	156.00-212.00	183.90±1.68	140.00-239.00	0.219
Chlorophyll *a* (mg/L)	5.41±0.14	2.90-7.70	4.57±0.07	2.50-6.70	0.000
DO (mg/L)	11.92±0.12	9.50-14.00	11.99±0.04	11.00-14.00	0.464
EC (ms/m)	0.19±0.01	0.14-0.23	0.46±0.21	0.21-0.69	0.000
Ph	6.85	6.50-7.70	6.75	6.60-7.80	
Salinity (mg/L)	0.01±0.00		0.01±0.00	0.01-0.03	
TDS (mg/L)	6.26±0.56	1.00-20.0	3.85±0.22	0.93-13.00	0.000
Total Hardness (mg/L)	61.77±1.24	43.00-82.00	58.53±0.89	39.00-85.00	0.050
TSS (mg/L)	4.64±0.21	1.00-13.00	6.78±0.14	1.40-13.00	0.000
Turbidity (mg/L)	41.55±10.11	6.00-121.00	20.83±7.14	10.00-195.00	0.090
Temperature (^{0}C)	25.25±0.38	23.00-27.00	23.78±0.36	19.00-29.00	0.019

DISCUSSION

Ageing tropical fishes has previously been assumed to be virtually impossible due to continuous spawning and the absence of growth cycles (Maruyama *et al.*, 2004; Tweddle, 1983). Several authors do, however, mention the presence of annual growth rings in tropical fish by burning and sectioning the otoliths (Chimatiro, 2004; Limuwa, 2008; Morioka and Kaunda, 2001; Singini, 2006). The deposition of annual growth rings (annulae) in the calcified tissues of bony fishes is at least partly caused by seasonal changes in the environment. These periodic changes (temperature cycles and available food) are less regular and less severe in tropical than in temperate zones. Some of these authors link the causes of growth rings to spawning periods and others to water temperature changes. The latter cause might be true because growth rings are also found in immature fish.

Otolith margins revealed that one opaque zone is laid down annually during March for Bua stocks and September for Linthipe stocks. In this case one opaque zone represent one year of growth for both stocks. The deposition of opaque zone during March is similar to what (Kaunda, 2000) found in *Bathyclarias nyassensis* that opaque zones were laid down during March and August. On the other hand, (Limuwa, 2008) found that opaque zones were laid once during August for the Mpasa in Linthipe River. Otoliths of teleost fish are composed of calcium carbonate and organic matter. The opaque zone is laid down when calcium deposition slows down (slow growth), and the hyaline/transparent zone is laid down when calcium deposition speeds up (fast growth). We can only observe that a new zone has been laid down when the change in calcium deposition is great enough to produce a change in the optical density of the otolith substance that can be detected visually (Tomas *et al.*, 2005). Opaque and transparent zones coincided with minimum water temperature and spawning associated loss in condition.

Reliable age estimates are essential for all aspects of fishery research including studies of growth, production, population structure and dynamics (Kanyerere, 2003). Ageing precision estimates obtained in this study compare well with those of Kaunda (2000); Kanyerere (2003); Limuwa (2008). Kaunda (2000) using sectioned sagittal otoliths to age *B. nyasensis*, obtained an APE of 14.2%, CV of 10% and a precision estimate (D) of 7.1. Kanyerere (2003) found APE of 10.5%, CV of 7.4% and a precision estimate of about 5.3 using sagittal otoliths in ageing *Diplotaxodon limnothrissa*. Limuwa (2008) used lapillus otoliths to age *O. microlepis* and obtained an APE of 8.2%, CV of 5.8% and precision estimate of 4.1. The estimates obtained in this study were an APE of 10.4%, CV of 7.7% and a precision estimate of about 4.5 and APE of 10.0%, CV of 7.5% and precision estimate of about 4.3 for Bua and Linthipe

Rivers, respectively. 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 this study were in a good range and could be reliably used.

Results of *O. microlepis* age estimates suggest that Bua stocks attain a maximum age of 10years at 532mm mean length, while Linthipe stocks attain maximum age of 12years at 524mm mean length though this study did not sample all age and size groups. Previously the maximum age for Mpasa in Linthipe was estimated to be 5 years (52cm, TL) for *O. microlepis* (Limuwa, 2008). Two possible reasons may account for these differences. Firstly, it is possible that different cohorts were sampled between the years the current study and that of Limuwa, 2008) were conducted. This is possible as Tweddle (1981) also found fish of two different ages at different times in the same year but of the same size. Secondly, age determination using hard parts in cyprinids is largely objective and subjective (Campana, 2001). The results may also have been compounded due to error associated with age determination from calcified fish parts. Age assessment from calcified structures is strongly subjective.

However growth models for fish from both rivers showed a significant linear relationship between fish length and age ($P < 0.10$). Different growth models between fish stocks from two rivers might imply that the stocks from these rivers are different as suggested by Tweddle (1981) that different rivers host different Mpasa stocks during breeding season. Variation of age in fish of same size can be temporal or spatial depending on the ecological opportunity provided by the habitat, including food availability (Chimatiro, 2004). Rivers and floodplains are dynamic environments and habitats that strongly influence the life-histories of the fishes. Deposition of annual growth rings as mentioned previously is caused by seasonal changes in environment (food availability and temperature cycles); therefore this may be the other reason for more years in this study as compared to those reported by 17 in *O. microlepis.*

Breeding seasonality of Mpasa stocks in rivers sites was not significantly different. Differences were observed along the months. GSI suggested that female Mpasa has a definite peak spawning period between August and October for Bua and Linthipe River, respectively. Results about breeding seasonality agree with Morioka and Kaunda (2001) who reported July to December as the breeding season for this fish species and Tweddle (1983) who reported breeding season of May to December. In Malawi warm months start from August to December hence spawning in Mpasa may be triggered by warm temperatures as in other Lake Malawi fish species such as *Bathyclarias nyassensis* (Kaunda, 2000), *Clarias gariepinu*s and *Oreochromis mossambicus* (Chimatiro, 2004).

While the condition factors of fish in the two rivers were significantly different, in both cases the C.F dropped during breeding season suggesting that fish may be diverting energy for breeding in these months (Kaunda, 2000). The differences in condition factors of the two stocks may suggest the differences in food availability (Froese, 2006) or water levels (Chimatiro, 2004) in the two rivers. Primary production which starts in a food chain is indicated by chlorophyll *a* content. Chlorophyll *a* was significantly higher ($P < 0.005$) in Bua River than in Linthipe, perhaps explaining the better C.F of stocks in Bua River. TSS was significantly higher in Linthipe which can also be the reason for lower condition factor in the river. These suspended sediments cause turbidity, thereby limiting penetration of light, which is essential for primary productivity (Bootsma and Hecky, 1999).

It is also of interest to note that egg diameter of mpasa in Linthipe was significantly higher than in Bua River. Egg diameter is a function of female size, either in length or weight (Li-Junior *et al.*, 2002; Trojnar and Fuiman, 1980), spawner age, time of spawning season, temperature, salinity (Cheng-Sheng, 1981) and availability of high nutritious food (Maruyama *et al.*, 2004). Large egg diameter is associated with larger fish (Trojnar and Fuiman, 1980). Since average weights of females were 207±10.10g and 498.69±80.34g in Linthipe and Bua Rivers respectively, egg diameter was affected by other factors than size of fish. The egg diameters tend to decrease with increasing water temperature (Cheng-Sheng, 1981). Water temperature was significantly higher in Bua (25.25±0.38) than in Linthipe (23.78±0.36), hence explaining smaller egg sizes in Bua River.

The positive and significant ($P < 0.05$) correlation between TSS and male GSI in both Bua and Linthipe suggests breeding is induced by higher TSS. Similarly, the positive correlation of turbidity with female GSI in Linthipe could imply that breeding is induced by onset of rains as higher TSS is associated with rainy season. Similar results were obtained by Jamu and Brummet (1999) who found that TSS and electrical conductivity were positively correlated to GSI of adult *Barbus*. In this study TSS and food availability (chlorophyll *a*) had a significant correlation with GSI of *O. microlepis.* TSS was significantly higher (6.78±0.14) in Linthipe River than in Bua River (4.64±0.21). There was correlation between TSS and GSI of fish from Linthipe River while for Bua River there was no such correlation. It seems probable that large vegetation cover in Bua's catchment which is well protected in the Game Reserve reduce the amount of TSS. On the other hand Linthipe River had higher TSS because the river has catchment areas which mainly comprises of arable land.

Negative correlation existed between TDS and relative fecundity in Bua River and there was no such relationship in Linthipe River, while a positive relationship existed between alkalinity and egg diameter in both rivers. Alkalinity is the total concentration of basic minerals and alkaline waters are more productive. Waters low in total alkalinity are poorly buffered against pH changes although most of these parameters are not a problem in natural waters. High or low alkalinity restricts the availability of carbon dioxide which leads to low primary production (Blakely and Hrusa, 1989). Therefore the diameter of eggs increases with increase in alkalinity in both rivers. Minerals like calcium are some of the components of eggs, therefore the more the total alkalinity, the wider the size of egg in *O. microlepis*. In their study,Trojnar and Fuiman (1980) found that calcium was directly related to egg diameter of white suckers (*Catostomus commersoni*) and inversely with conductance and sodium concentration. However some studies by Potts and Rudy (1969); Chatto (1981); Patino and Sullivan (2002) showed that calcium, and to a lesser extent sodium ions delay the formation of, reduce the rate of formation, and reduce the final volume of perivitelline fluid in some teleost fish.

Morphometric analysis is used to establish phylogenetic relationship among stocks and can also be applied to assess the environmental impacts on the morphological structures. Tweddle (1981) suggested that stocks of mpasa are specific to each river system with little or no intermingling. Indeed it has been established in this study that minor morphological differences between stocks from Bua and Linthipe Rivers do occur. Li *et al* (1993) reported that morphological differences may be due to both genetic and environmental differences. Morphological differences and similarities of the stocks may reflect their phylogeny rather than the adaptation to environmental degradation in these rivers (Kassam *et al.,* 2002). Whether or not this morphological differentiation has resulted from prolonged geographical isolation or unusual genetic events is not known. The answer to such a question can be provided through genetic studies. However, environmental factors like water quality and differences in river habitats could partly influence the morphological variation noted in this study.

The scatter plots on factor loadings showed that morphological characters for *O. microlepis* from Bua and Linthipe Rivers are different. The observed morphological differences between stocks from Bua and Linthipe were significant for total length, head length, prepectoral distance, eye diameter and anal fin base. Environmental factors that affect fish morphology are temperature and velocity of water, for example, Marcil *et al* (2006) found that temperature and velocity of water had an effect on morphology of Atlantic cod, *Gadus morhua.* In this study, temperature was a likely factor affecting fish morphology among Bua River stocks where temperatures were significantly higher and fish had deeper body. In their study, Marcil *et al* (2006) found that Atlantic cod raised in higher temperatures had deeper body, larger head and shorter caudal fin. Other studies have provided evidence that there is genetic basis to swimming performance in fishes that would be unrelated to morphology (Nicoletto, 1995; Garenc *et al.*, 1998; Hanson *et al.*, 2007).

Findings of this study partly support the hypothesis of Tweddle (1981), that different rivers like Bua and Linthipe are inhabited by different stocks of Mpasa species during breeding period. This might imply that mpasa do not intermingle during breeding, suggesting that the species of the two rivers belong to different

stocks hence stock diversity. However, the permanence of differences in stocks can only be ascertained through genetic studies. If these differences are consistent, there is need therefore to sustain this stock diversity. Proper catchment management should be practiced to sustain breeding habitats for the stocks. There is also need to keep the stocks at sustainable exploitation levels.

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