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Age and Growth of Lake Malawi Salmon *Opsaridium microlepis* (Günther, 1864) in the Linthipe River in Central Malawi Using Otoliths

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Abstract: Ageing data for endemic *Opsaridium microlepis* to Lake Malawi riverine system has mainly been derived from Length Frequency and Distribution Analysis (LFDA). No aspects of the ageing of *O. microlepis* have been investigated using hard parts. Sectioned otoliths were used to estimate the age of *O. microlepis* in the Linthipe River from November 2005 to December 2006. The reproducibility of otoliths readings was described using Average Percentage Error Index (APEI), which was equal to 8.2 %. The age-length data from the sample of 214 fish was described by simple regression model as follows: *Fish total length* (cm) = 12.56 + 6.931* Fish age; $r = 0.799$, $r^2 = 0.639$, ($p<0.01$). The estimated growth rates pattern observed from the study differ from earlier estimates based on LFDA as these appear to have under estimated the ages and growth rate of the species. Results reinforce previous hypotheses that concentrations of *O. microlepis* exploited in Malawian rivers are largely composed of smaller but mature fish that migrate to these rivers during rainy season for spawning.

Key words: Average Percentage Error Index · Marginal Zone Analysis · Otoliths · Simple regression model

INTRODUCTION

Opsaridium microlepis (Günther 1864) is endermic to Lake Malawi. This species migrates for spawning during the rainy season to major affluent rivers. Linthipe River is one of the major rivers, into which *O. microlepis* migrates [1]. Linthipe River is in the southern part of Lake Malawi and its catchment is densely populated around Lake Malawi [2- 4]. Although some aspects of the biology of this fish species have been studied, there is no information on its age and growth using hard parts. Knowledge of age in fish populations is crucial in stock assessment and management [5]. Age information forms the basis for calculations of growth rate, mortality rate and productivity, ranking it among the most influential of biological variables. Aging is most often done by counting rings in hard part of the fish body [6]. Annual ageing is often used in support of harvest calculations and population studies and can be based on any bony structure in the fish [7]. Scales [8], vertebrae [9], fin rays [10], cleithra [7] and opercula [11] have all been used to determine annual age. The aim of this study was therefore, to estimate the age and growth of *O. microlepis* using sectioned otoliths. This study adopted otoliths as these are by far the most commonly sampled and analyzed calcareous structure from fish [12]. Otoliths have been applied over the broadest age range in many species [13]. Information from otoliths combined with data such as fish length, weight and reproductive condition can be used to derive a range of parameters that are useful for managing harvest of a fish stock [12].

MATERIALS AND METHODS

Study Area and Fish Sampling: *Opsaridium microlepis* specimens were collected on monthly basis over a period of three days for 12 months (November 2005 to December 2006) by means of gillnet (survey nets type 'Norden',

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Lundgrens Fiskredskapsfabrik AB, Storkyrobrinken 12, 111 28 Stockholm, Sweden) set across the two selected sites i.e. at a fishing village near the river mouth in Maganga (34°35'E) and near the confluence of Linthipe and Lilongwe Rivers (13°21'E) following Sparre *et al*. [14]. Linthipe River basin is fan shaped and drains an area of 8 641km^2 into Lake Malawi [15]. The study made use of 214 specimens to determine age and growth of *O. microlepis*. Total length (TL) measurements were taken to the nearest (± 0.1cm) using a measuring board [16, 17]. Fish were weighed to the nearest (± 0.01g) using HP - 20 K electronic weighing balance. Otoliths were extracted from the heads of the specimen and stored as described by Kanyerere *et al*. [18].

Determination of Age and Growth of *O. Microlepis:* Age was determined using otoliths [18-22]. Due to difficulties in interpretation of otoliths, an index of readability was used to classify the otoliths according to appearance of the growth zones [23]. This study applied the Index of Average Percent Error (IAPE) to assess 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 [24]. Chang [25] suggested the use of a coefficient of variation (CV) for testing the reproducibility of ageing between readers which was also employed by the study.

Estimation of Growth Parameters from Length Frequency Data: The Length-Weight relationship, $W = aL^b$ [26] was converted into its logarithmic expression. In this formula W is weight in gram and L is total length of fish. Least-squares regression was used to calculate the (a) and (b) parameters, as was the coefficient of determination (R^2). The b value for each species was tested to verify if it was significantly different from 3. A linear regression model was used to model the growth rate [27] and this was attributed to the failure to obtain a sample with big fish encompassing the reported length at infinity [28].

RESULTS

Otolith Ageing: 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.

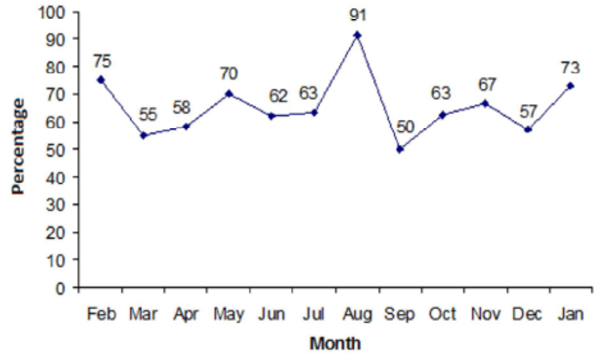

Fig. 1: Monthly percent occurrence of an opaque margin in otoliths of *Opsaridium microlepis* sampled from the Linthipe River

Table 1: Age/Length key for *Opsaridium microlepis* from the Linthipe River

	Age (years)					
Length (cm TL)	1	2	3	4	5	Total
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.

Age estimates 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 %. The monthly examination of the otolith margins revealed that one opaque zone was laid down annually during August (Figure 1). It was concluded that one opaque zone and one translucent zone, constituted an annulus and were counted as such. Five age classes were defined by the transverse surface readings of the otoliths through an age length key (Table 1) which revealed that fish increase in age corresponded to increase in length (Figure 2).

Growth Parameter Estimation: Isometric growth is obtained when b=3 and this results in ideal shape of fish. When the value of b is less than 3.0, the fish experiences a negative allometric growth or if more than 3 fish has a positive allometric growth. When it is equal or nearby 3,

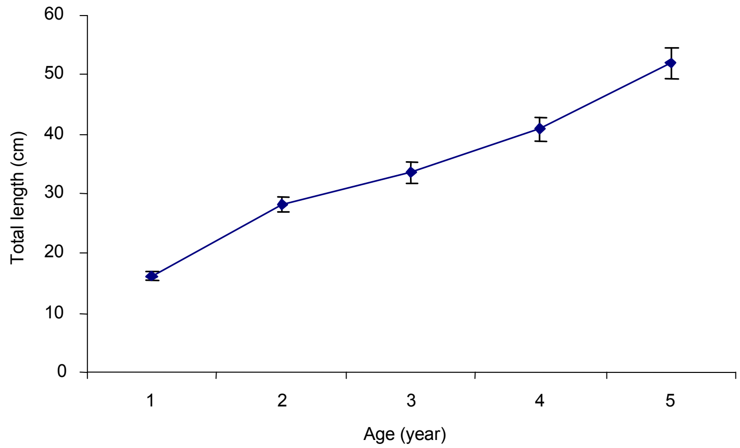

Fig. 2: Mean total length values (±SE) of each age class of *Opsaridium microlepis* constructed using the age length key

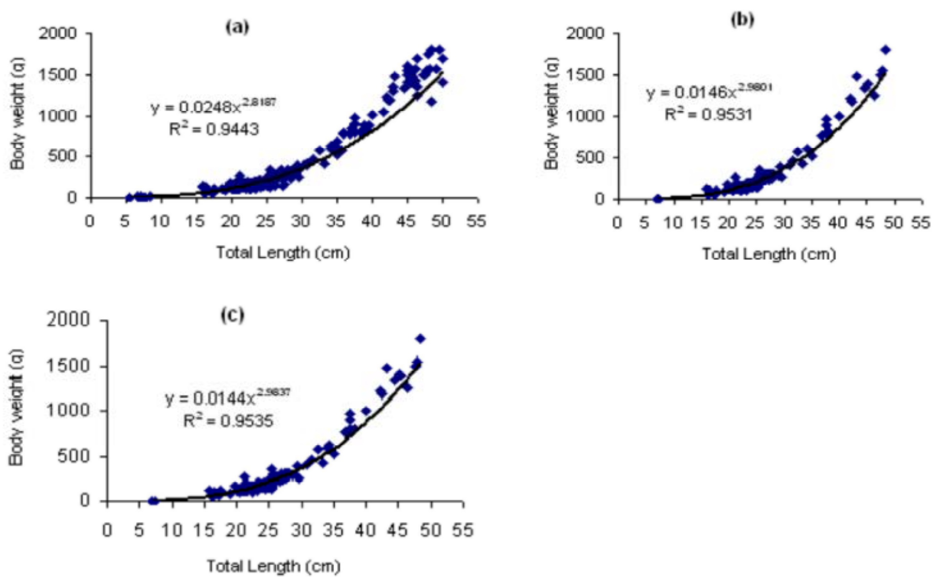

Fig. 3: The relationship between the body weight (g) and total length (cm) for (a) combination of *Opsaridium microlepis* sexes (b) males and (c) females in the Linthipe River

growth of aquatic species is isometric and growth occurs equally in all dimensions [29]. The b values for *O. microlepis* were 2.9837, 2.9801 and 2.8187 for females, males and combined sex respectively Figure 3. The fitted regression line of observed total length (cm) and fish ages (years) growth curve for this study was described by simple regression model as follows: ″*Fish total length* (cm) = 12.56 + 6.931* Fish age; r = 0.799, r^2 = 0.639, p, 0.00″. The r^2 revealed that the variation in the fish growth can be explained by the explanatory variables. The model can be used to determine the growth of *O. microlepis* using ages from sectioned otoliths.

DISCUSSION

The use of hard parts to age tropical fish is supported by several studies that used otoliths to age fishes from Lake Malawi [18, 21]. Several numerical methods have been developed which allow the conversion of length-frequency data into age compositions. However, the final interpretation and reliability of results require availability of some direct age readings [14]. If a sensible interpretation concerning how a species grows from a growth model then the model selection cannot be solely dependent upon quality statistical fit. It should reflect the theoretical viewpoint of growth that is being considered for reasons independent of its statistical fit to data [30]. Despite the earlier failure to age *O. microlepis* using hard parts [1], in this study, clear deposited growth zones were visible in the burnt and sectioned otoliths 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 [10]. Although otolith margins revealed that one opaque zone was laid down annually during August 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 were laid down during the periods of slow growth and this case in August, just as Kaunda and Hecht [21] found for *Bathyclarias nyansensis*.

The estimated ages from sectioned otoliths did differ from earlier estimates based on length frequency analysis [1]. If we assume that otolith-based estimates of age are the most accurate, hence [1] appear to have under estimated the ages of the species [12]. Growth parameters are species and stock specific [14]. In view of the importance of length-weight relationships in understanding growth and stock dynamics of fish populations, it has been extensively studied in several species of fishes distributed in different parts of the world [10]. The study yielded isometric growth of *O. microlepis* depicting good condition for the stock [31].

Age at length was determined with the use linear regression method as absence of big sized fishes (<59cm TL) in the populations encompassing the reported length at infinity or selectivity of the fishing gears [32, 33] and area of sampling [34]. The first estimates for growth rates for *O. microlepis* were from Bua and North Rukuru rivers [1]. These two rivers are very different to the one in which this study was conducted. However, the results on the growth pattern are consistent with Tweddle [35]; 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*. [36] in *Tribolodon nakamurai*, a cyprinid just like *O. microlepis*. The growth rate at 20cm TLyr^{-1}, however agree to Morioka and Kaunda [37] who estimated the growth rate for smaller *O. microlepis*. This growth pattern presents the life history pattern of *O. microlepis* of being riverine or in-shore dwelling, insectivorous fishes, gradually changing to piscivorous, lacustrine, pelagic habits as they approach 20cm in length [38, 39]. Early fast growth rates in *O. microlepis* is heavily supported and sustained by the change of food sources to a more efficient assimilated food [39] and as evidenced in some perch by Quick and Bruton [40].

Failure to obtain a larger sample of more 70 cm TL as reported by Tweddle [35] may be a major worry as it explains why the Von Bertalanffy Growth Function (VBGF) [28] could not be fitted to the data set as the length at infinity could not be estimated. Chen *et al*. [41] found the VBGF to be highly performing than other polynomial equations. This study used a simplified linear regression model as *O. microlepis* did not exhibit an asymptotic maximum length. This suggests that VBGF may not be an appropriate growth model for *O. microlepis*. Roff [42] stated that the choice for VBGF should be dictated by the circumstance. Using VBGF to the current *O. microlepis* stocks in the Linthipe River could yield misleading findings. The disappearance of large fish could have been attributed to overfishing because fishing activities are not controlled in this river. This could also be attributed to environmental degradation because the riverine ecosystem is having an appreciable impact on the population as no larger fish sizes were caught [43]. Findings of the present study highlight the importance of ageing *Opsaridium microlepis* using otoliths and linear regression model in growth estimation as the most accurate method which can be applied to the sustainable fishery management in the Linthipe River and elsewhere in Malawi.

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