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Original Article

Some aspects of the reproductive biology of *Labeo victorianus* (Boulenger, 1901) from Kuja-Migori River basin, Kenya

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Abstract
Labeo victorianus is an endemic species to Lake Victoria basin and also a species threatened with extinction status. This study investigated reproductive biology of *L. victorianus* from Kuja- Migori River basin, Kenya with a view to determining the length weight relationship (LWR), condition factor, fecundity, egg diameter gonado-somatic index (GSI), length at 50% maturity (L_{M50}) and sex ratio. Sampling was done by electrofishing from January 2018 to June 2019. The LWR showed a negative allometric pattern ($p < 0.05$). The mean condition factor for combined sexes was 1.02. Fecundity ranged from 47842 – 101902 eggs (mean ± SD: 83663 ± 2605 eggs) and correlated highly with body size ($r^2 = 0.9137$). Egg diameter ranged from 0.5 – 0.7 mm. Mean GSI was 6.3 ± 1.6 and 2.8 ± 0.45 for females and males respectively. The L_{M50} was estimated at 18 cm total length (TL) and 20 cm TL for males and females respectively. Sex ratio did not differ from the expected 1:1. This species has a high fecundity with small sized eggs and males attain sexual maturity earlier than females. The findings of this study provide useful information towards sustainable conservation of *L. victorianus* in the Lake Victoria basin.

Keywords: Endangered; endemic; fecundity; GSI; L_{M50}; *Labeo victorianus*; Lake Victoria; LWR; potamodromous

1 | INTRODUCTION

The threatened African carp, *Labeo victorianus* (Boulenger, 1901), locally known as 'Ningu' is a freshwater fish species endemic to Lake Victoria basin (Rutaisire and Booth 2005). It belongs to the family Cyprinidae which displays a potamodromous behaviour by migrating up the rivers to spawn (Kibaara 1981). In Uganda, with the onset of rains *L. victorianus* move up to Rivers Kagera and Sio to breed (Rutaisire and Booth 2005). In Kenya, it migrates upstream to Migori and Sondu Miriu to spawn (Ochumba and Manyala 1992). Similar observations have been made in some species of the same genus such as Labeo horie in Lake Turkana, Kenya, which migrates upstream to River Omo to spawn (Dadebo et al., 2003). Fish that belong to the genus *Labeo* are of commercial importance in many African countries and have had a significant contribution to fisheries (Ogutu-Ohwayo 1990; Weyl and Booth 1999, Njiru *et al.* 2005). However, they are known to be susceptible to overfishing, for example, the collapse of the fishery of *Labeo mesops* and *Labeo altivelis* in Lake Malawi and Lake Mweru respectively (Anteneh *et al.* 2012).

Labeo victorianus is highly cherished by the riparian communities of Lake Victoria as a food fish (Ochumba and Manyala 1992). It was distributed widely in the rivers flowing into Lake Victoria and used to support commercial fishery up to the late 1950s, but it has long declined in population (Kibaara 1981; Rutaisire and Booth 2004). Today, *L. victorianus* appear on the red list of the International Union for Conservation of Nature (Froese and Pauly 2021) as a Critically Endangered species of Lake Victoria basin. Predation from Nile perch, *Lates niloticus*, competition for similar food items with other fish species, ecosystem degradation, illegal fishing methods, and over-exploitation have been cited as the major reasons of disappearance of this species from the Lake Victoria basin (Greboval and Mannini 1992).

Length - weight relationship (LWR) is useful when estimating the rate of growth of fish, length and age structures, the mean weight at a given length class and the status of fish health (Miranda *et al.* 2009; Moradinasab *et al.* 2012). It enables fisheries researchers to convert equations of growth in length to growth in weight in fish stock assessment models to estimate biomass from length frequency distributions, and compare fish life histories and morphological aspect of populations inhabiting different regions (Froese *et al.* 2014; Sarkar *et al.* 2006). Condition factor is used to indicate the general wellbeing of fish in their habitat and it is assumed that a good condition exists in heavier fish than in lighter ones at a certain length (Dadebo *et al.* 2003; Ogamba *et al.* 2014). Poor condition slows down the growth rate of a fish, reduces the fish's potential to produce eggs and sperms and can negatively affect survivorship or reduce its longevity. When the condition factor is close or equal to one it depicts an overall good fitness of a fish (Abobi 2015; Nazek *et al.* 2018). In fisheries biology, fecundity measurements are important in exploring dynamics in reproduction and energetics of spawning of a fish stock in order to estimate its yearly reproductive output (Mohammed and Patahk 2011). In addition, fecundity estimation is important in appraising spawning biomass through the egg production (Ganias *et al.* 2014). Further, knowledge on fecundity is essential to determine the potential for spawning and its success (Murua *et al.* 2003; Ojutiku *et al.* 2012). The GSI is an important index describing energy allocation in fish (Mohammad and Pathak 2011). It provides information concerning fish spawning and it is a crucial parameter used to determine the degree of maturity of the ovaries (Mishra and Saksena 2012; Manal *et al.* 2017).

Earlier studies focused on Lake Victoria fishes while riverine fishes, in particular, *L. victorianus* has rarely been studied (Masese *et al.* 2020). Some work has been done on captive breeding and culture (Orina *et al.* 2014, Kembenya *et al.* 2016) but none has worked on the reproductive aspects of this species covered in the present study. The aim of this paper was to determine the LWR, condition factor, fecundity, egg diameter, GSI, L_{M50} and sex ratio of *L. victorianus* from Kuja- Migori River. Information from this study can be employed in formulating regulations aimed at managing the riverine fishery and develop adequate conservation strategies to prevent further decline of this species.

2 | METHODOLOGY

2.1 Study area

Fish samples were collected from five sampling stations S1 to S5 (Figure 1). The Kuja- Migori River takes its source from Trans- Mara Forest and drains into Lake Victoria, Kenya. The basin has an equatorial climate that receives rainfall in two seasons. The long rains begin in March through June while short rains begin to fall between October and November. Hence the rain falls in a bimodal pattern with an average of 1800 mm year^{-1} and a peak of 2230 mm year^{-1} (Kizza *et al.* 2009). The headwaters of the river are small and rocky while in the middle and lower reaches, the river is wide and deeper, with fine sediment at the bottom.

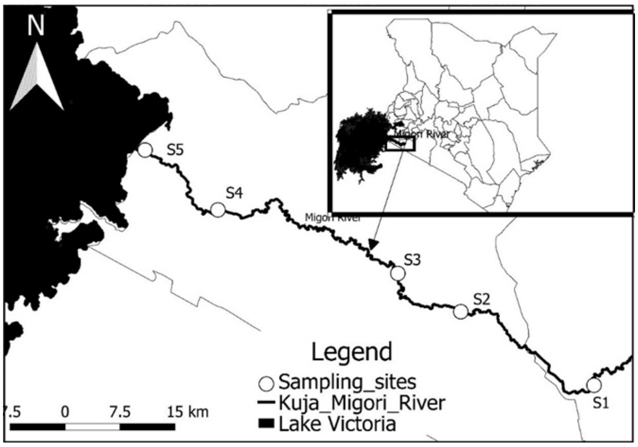

FIGURE 1 Sampling stations on Kuja- Migori River basin, Kenya.

2.2 Sampling and data collection

The fish specimens (n = 319) were collected using a 400 V and 10 A electrofishing equipment with a 50 m long electric cable, model Electra catch Wolvampton W.O 580 Winchester procurement limited on wadable areas along the Kuja-Migori River from January 2018 to June 2019. The sampled fish specimens were put in a cool box of ice soon after capture and taken to the laboratory. The total length (TL, cm) and total weight (TW, g) were measured and recorded. The gonad maturity stages were determined according to a procedure developed by King (1995).

Fecundity was estimated from the formula of Yelden and Avsar (2000): F = nG/g; where F = fecundity, n = number of eggs in the sub-sample, G = total weight of the ovaries and g = weight of the sub-sample in g.

The gonado-somatic index (GSI) was calculated as: GSI = (GW / W) × 100; where GW is the weight of gonads and W is the fish weight in g.

The condition factor (K) for each individual fish was calculated according to Le Cren (1951) as: K = W / aLb; where W is the body weight, L is the total length and a and b are the length weight relationship parameters.

Length at which 50% of the fish were mature (L_{M50}) was estimated by fitting frequency data of mature individuals by length to a logistic curve.

2.3 Data analysis

Chi square was used to test if there was a deviation from the theoretical sex ratio of 1 : 1. Student's *t*-test comparison was employed to verify whether the parameter *b* was significantly different from the predicted isometric growth of (b = 3) for fishes. The analyses were performed using Statgraphics software (version 19) at an α significance level of 0.05.

3 | RESULTS

3.1 Length weight relationship and condition factor

There was a high positive correlation between the total length and body weight (r^2 = 0.83) for both male and female *L. victorianus* (Table 1). The parameter *b* was a statistically significant from three (*t*-test: p < 0.05) which shows a negative allometric growth in *L. victorianus*.

TABLE 1 Length weight relationship and condition factor of *Labeo victorianus* from Kuja - Migori River sampled between January 2018 and June 2019.

Sex	*n*	*a*	*b*	r^2	Equations	*K*
Male	145	–1.87	2.92	0.79	W = 2.92 TL – 1.87	0.98
Female	174	–1.85	2.92	0.88	W = 2.92 TL – 1.85	1.07
Pooled	319	–1.86	2.92	0.83	W = 2.92 TL – 1.86	1. 02

n, sample size; *a*, intercept; *b*, slope; r^2, coefficient of determination; *K*, condition factor.

3.2 Fecundity

The smallest female fish used to estimate fecundity was measuring 22.1 cm TL, whereas the biggest measured 35.5 cm TL. Fecundity ranged from 47842 – 101902 eggs (mean ± SD: 83663 ± 2605 eggs). The fecundity increased with unit increase in total length of female fish (R^2 = 0.9137) (Figure 2).

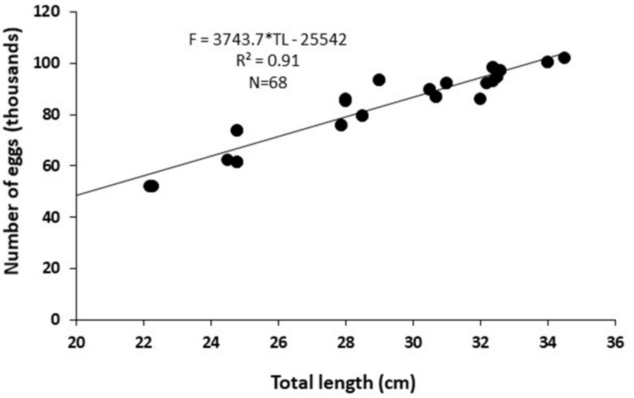

FIGURE 2 Regression of total length versus fecundity of *Labeo victorianus*, in Kuja-Migori River.

3.3 Gonadosomatic index (GSI) and egg diameter

Mean GSI for females ranged from 2.5 – 10.3 with a mean (± SD) of 6.3 ± 1.6 while that of males ranged from 2 – 4.1 with a mean of 2.8 ± 0.45. An increase in GSI with increase in maturity stage was apparent in both sexes of *L. victorianus* (Figure 3). Egg diameter ranged from 0.5 mm to 0.7 mm in maturity stage five with a mean of 0.65 ± 0.002.

3.4 Length at 50% (L_{M50}) maturity

The males of *L. victorianus* attained sexual maturity earlier than females. The L_{M50} was estimated at 18 cm TL for males and 20 cm TL for females (Figure 4).

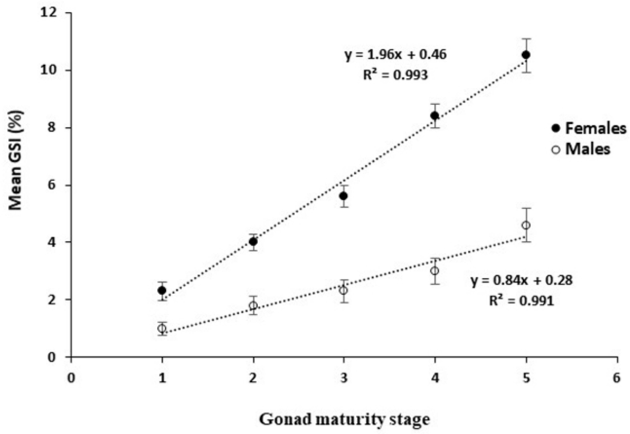

FIGURE 3 Regression of gonad maturity stages against mean Gonadosomatic index of pooled sexes of *Labeo victorianus*, in Kuja – Migori River (vertical bars represent standard error).

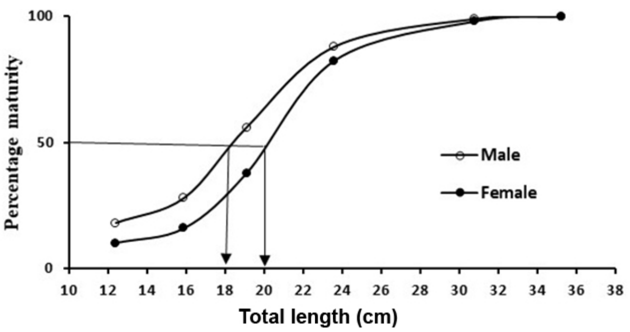

FIGURE 4 Maturity ogives for male and female *Labeo victorianus* in Kuja - Migori River. The ogive was fitted to estimate length at 50% maturity in females and males represented by arrows.

3.5 Sex ratio

A total of 319 specimens of *L. victorianus* constituting 145 males and 174 females were analysed. This gave a male to female sex ratio of 1 : 1.2 which was not statistically different from the expected ratio of 1:1 (χ^2: p > 0.05).

4 | DISCUSSION

4.1 Length weight relationship and condition factor

In this study, there was a linear relationship between length and weight which was in line with the general formula that express the relationship between the length and weight of fishes (Ogamba *et al.* 2014; Abobi 2015). The values of *b* for both sexes were within the range of two to four recommended by Bagenal and Tesch (1978). The coefficient of determination values obtained were higher which indicates a good linear regression prediction for this fish species (Froese 2006). Therefore, extrapolation is possible for similar fish size ranges in future catches of this species on the river basin. The growth showed a negative allometry where fish became slender as they increased in length (Lederoun *et al.* 2020). This is attributable to the body shape of *L. victorianus* which appear long than wide rather than its condition. However, this may be an indication that this fish species has a relatively slow growth rate (Nazek *et al.* 2018).

Condition factor is used to estimate the general wellbeing of fish in their habitat and it is assumed that a good condition exists in heavier fish than in lighter ones at a certain length (Dadebo *et al.* 2003; Ogamba *et al.* 2014). When the condition factor is close or equal to one it depicts an overall fitness of a fish (Abobi 2015; Nazek *et al.* 2018). The mean condition factor recorded in this study was greater than one, which shows that fish in the river were physiologically stable during the study period. Condition factor is affected by changes in the availability and abundance of food in the environment, feeding intensity of the fish and reproduction status (Abobi 2015; Yongo *et al.* 2019). However, variation of condition factor observed among individual fish in this study may be associated with differences in food availability and foraging ability (Abdul *et al.* 2016).

4.2 Fecundity

Fecundity showed a positive and significant correlation with fish total length. This concurs with the findings of Rutaisire and Booth (2004) on *L. victorianus* of river Kagera and river Sio in Uganda. The increase of fecundity with increase in size of the fish suggests that larger individuals contain more eggs compared to smaller individuals. In the present study, the mean fecundity for females was higher than that obtained by Orina *et al*. (2014) for *L. victorianus* from Kenyan rivers (e.g. Yala, Mara, Migori and Nyando) and studies of Kembenya *et al.* (2016) on *L. victorianus* from river Mara. This difference may be attributed to the fact that the number of eggs spawned by a fish varies with size, age and adaptations to environmental habitats (Nazek *et al.* 2018; Yongo *et al.* 2019). The high fecundity of *L. victorianus* could be attributed to the fact that this particular fish species does not exhibit parental care and therefore, produces many eggs as a strategy to increase the chances of off-spring survival (Yongo *et al.* 2019).

4.3 Gonadosomatic index and egg size

The GSI is used to describe the maturity status of fish by the expression of the weight of gonads as a percentage of fish weight (Shoko *et al.* 2015). The GSI increase as gonad development reaches maturity; then it begins to decrease towards spawning (Maskill *et al.* 2017). The GSI provides information concerning fish spawning and it is a crucial parameter used to determine the degree of maturity of the ovaries (Manal *et al.* 2018). It is also used to formulate suitable breeding policies in fisheries management. The high values of GSI observed in the present study concur with that of Sindhe and Kulkarni (2004) who reported that GSI more than two is an indication that fish are ready for spawning activity. The GSI obtained in this study were comparable to those of *L. victorianus* from River Kagera but lower than those of victorianus from River Sio in Uganda (Rutaisire and Booth 2004). The difference can be attributed to variation in the geographical locations of the rivers. The GSI of females had a significant correlation with TL and was higher compared to the one of males in all stages of gonad maturation. This could be attributed to the fact the presence of ovaries alters the weight of female fish at the time of breeding (Lederoun *et al.* 2020).

The females of *L. victorianus* have small eggs as seen in this study, an indication that this fish species has little investment in eggs which is a common trend in fish that do not exhibit parental care. The offspring that develop from small eggs are tiny due to low amount of stored nutrients for the development and growth of larvae. Reduced egg size slow down the rate of development of fish larvae thus extending the overall period of larval growth (Rahman *et al.* 2013). In this study, there was a weak relationship of egg size and the weight of fish. However, the size of eggs has been found to increase with fish size in other species of fish.

4.4 Length at 50% (L_{M50}) maturity

The L_{M50} in the current study was lower in both sexes than those obtained by Rutaisire and Booth (2004) on *L. victorianus* from River Kagera but higher than those from River Sio. Further, in this study the males attained sexual maturity earlier than females while in Rutaisire and Booth (2004) the females attained sexual maturity earlier than males. This may be attributed to variation in phenotypic responses and differences in environmental conditions.

4.5 Sex ratio

The male to female ratio of *L. victorianus* did not differ from the expected 1 : 1. In most cases, such deviation of sex ratio is rarely observed in fishes. Fertilisation success greatly depends on sex ratio and bias on either sex can cause behavioural, biological and physiological changes of fish, which may affect success in reproduction (Manal *et al.* 2017; Maskill *et al.* 2017). In addition, fish behaviour such as competition for food, selection of mates during breeding, and aggression are affected by sex ratio (Weir 2013). High ratio of males to females can lead to stress brought about by competition during courtship thus preventing spawning from taking place and decreased fertilization success (Maskill *et al.* 2017).

5 | CONCLUSIONS

The results from this study reveals that the African Carp, *L. victorianus* exhibits a negative allometric growth and has a good condition in its riverine environment as established from the length weight relationships. This species has small sized eggs with a high fecundity and the sex ratio did not deviate from the expected. It was also found that males attain sexual maturity earlier than females. The findings of this study on the biological aspects of *L. victorianus* provide useful information towards its sustainable conservation and management. Future research work should focus on how environmental conditions and their seasonality affect the biological aspects of *L. victorianus*.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

EK participated in data collection, analysis and drafting the manuscript. **AG**, **JN** and **RO** participated in conceptualizing and editing the manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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