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Condition Factor and Length-Weight Relationship of *Labeo victorianus* (Boulenger, 1901) in the Selected Rivers of the Lake Victoria Basin, Kenya

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Abstract

We studied the length-weight relationship (LWR) and condition factor of Labeo victorianus (Boulanger, 1901) in four rivers (Awach, Mara, Nyando and Sondu-Miriu) in Lake Victoria Basin, Kenya. A total of 421 fish individuals of the species were measured for length and weighed. There was no significant variation in mean relative condition (K_n) of L. victorianus (ANOVA F= 0.54, df=3, p=0.65) in the rivers. The species from Mara and Sondu Miriu showed positive allometric growth while those from Awach and Nyando rivers showed negative allometric growth. The lowest mean condition factor K was recorded for females in the Mara and Nyando rivers (0.975 and 0.872 respectively). The length (ANOVA F=64.20, df=3, p<0.001) and weight (ANOVA F= 25.56, df=3, p< 0.001) were significantly different in Mara River. The relative condition factor showed significant variation with the total length (p<0.0001 and VIF <1). Variations in the length-weight relationship indicates the degree of environmental degradation to which the fish species is subjected to in the rivers of the LVB. This study recommends that environmental management should be considered as one of the strategies for conserving this and other threatened species in the LVB.

Keywords: Allometric Growth**,** Anthropogenic Influence, Riverine Fishes, Environmental Degradation, Threatened Species

INTRODUCTION

The Lake Victoria Basin (LVB) holds one of the most flourishing and diverse aquatic biodiversity in tropical Africa but has undergone significant environmental and ecological changes over the years (Witte *et al.*, 1991; Ogutu-Ohwayo, 2001; Verschuren *et al.*, 2002, Balirwa *et al.*, 2003; Sayer *et al.*, 2018). Growth in urbanization, agriculture expansion, overfishing and introduced exotic species have been identified as the major causes of ecological changes in the LVB (Hecky, 2002; Masese & McClain, 2012; Achieng *et al.*, 2020). This has resulted in deterioration of the aquatic ecosystems and the disappearance of some endemic species in rivers and the Lake Victoria (Vershuren *et al.*, 2002; Ojwang *et al.*, 2007; Masese et al, 2014; Nyamweya *et al.*, 2020).

Labeo victorianus (Boulenger, 1901*)* or "Ningu" as locally known, is an endemic fish species to the Lake Victoria Basin. Historically, the species formed an important part of the lake and riverine fisheries depended upon by the local community (Kibaara, 1986; Ochumba and Manyala, 1992, Ogutu-Ohwayo, 2001). However, for decades, the captured population has declined drastically both in the lake and in influent rivers because of the intensive harvesting of gravid females and males during the rainy season when migrating to spawn (Cadwalladr, 1965; Balirwa *et al.*, 2003). Additionally, emergence of dense papyrus vegetation at river mouths prohibited recently hatched larvae (fry) to swim actively back to the lake from the river where they were hatched, predisposing them to heavy predation and mortality at river mouths (Ochumba & Manyala, 1992). The species is currently listed in the IUCN Red list of the threatened species (IUCN, 2018) because of overexploitation, pollution and ecological changes (Ochumba & Manyala, 1992; Balirwa, 2003).

Studies of length-weight relationships (LWR) and condition factor are used in fisheries management to assess fish growth and well-being of fishes in a given aquatic ecosystem (Lizama *et al.,* 2002; Muchlisin *et al.,* 2010). The relationship utilizes a mathematic equation to predict the weight of a fish from its length and *vice versa*, estimating the condition of the fish in a given ecosystem by assuming that the heavier the fish the better the condition for a given length (Muzzalifah *et al.*, 2015; Ondhoro *et al.*, 2016). The LWR and condition factor are also used to assess the morphological comparison between fish populations from different geographical regions (Lizama *et al.*, 2002; Kuriakose, 2017). As they grow in size, fish increase both in length and weight as their growth is influenced by the natural environment such as fluctuations in the physico-chemical parameters of water. Sex, size, age, health status, stage of maturity, food composition and availability also influence fish growth (Ogutu-Ohwayo, 2001; Cornelissen *et al.,* 2018; Kuriakose, 2017). According to Lloret *et al.* (2002), fish populations display different condition in response to variations in ecosystem health. Thus, the better the ecosystem quality, the better the condition of fish.

The LVB rivers are a refuge for fish species that migrate from the Lake Victoria for breeding during the wet season (Masese & McClain, 2012). Recent studies show that *L victorianus* is now restricted to major rivers of the LVB (Achieng et al, 2020) and the populations in the lake have plummeted (Nyamweya *et al.,* 2020). Besides, rivers and streams are being altered both by land use change, damming and anthropogenic activities including urbanization and industrialization (Corbet, 1961; Lytle and Poff, 2004; Ojwang *et al.*, 2007, Masese *et al.*, 2020a). These changes in the rivers and streams are followed by fluctuations in the water quality parameters that may affect the physiological interactions of fishes (Lizama *et al.,* 2002; Achieng *et al.,* 2020).

Recent investigations on LWR of *L. victorianus* include those of Kembenya *et al.* (2017) in the Migori River. However, little attention is paid to both the LWR and condition of *L. victorianus* and how the two variables are affected by spatial changes in environmental conditions in the rivers of the LVB, considering that the fish species is under threat. The present study examined the spatial variation in the length-weight relationship of *L. victorianus* in selected rivers of the LVB in order to estimate the relative condition and robustness of individuals of the fish in these rivers. This is useful to contribute to the knowledge on endangered fish species in the LVB and how they cope with the fluctuations environmental conditions as a result of human disturbances.

MATERIAL AND METHODS

The study was conducted in four rivers of the Lake Victoria: Awach, Mara, Sondu Miriu and Nyando. Samples were collected from different rivers sites based on the spatial coverage of LVB and anthropogenic influences in the rivers (Figure 1). The four rivers (Awach, Mara, Nyando and Sondu-Miru) selected for this study differ in terms of the degree to which they have been influenced by land use change and other human anthropogenic activities in their catchments (Achieng *et al.,* 2021). The Mara River has the least catchment area under agricultural use and has the highest population of *L. victorianus*, but suffers from flow variations caused by forest loss in the headwaters, semi-arid conditions in the middle and lower basin and excessive water withdrawals. The Nyando and Awach rivers suffer from intensive farming and wastewater discharges from agro-industrial activities. The Sond-Miriu River has large-scale tea plantations where large quantities of fertilizers are used and many tea factories pose water quality challenges. The river also drains intensive small-scale farmlands which have increased turbidity in the river caused by erosion (Masese & McClain, 2012).

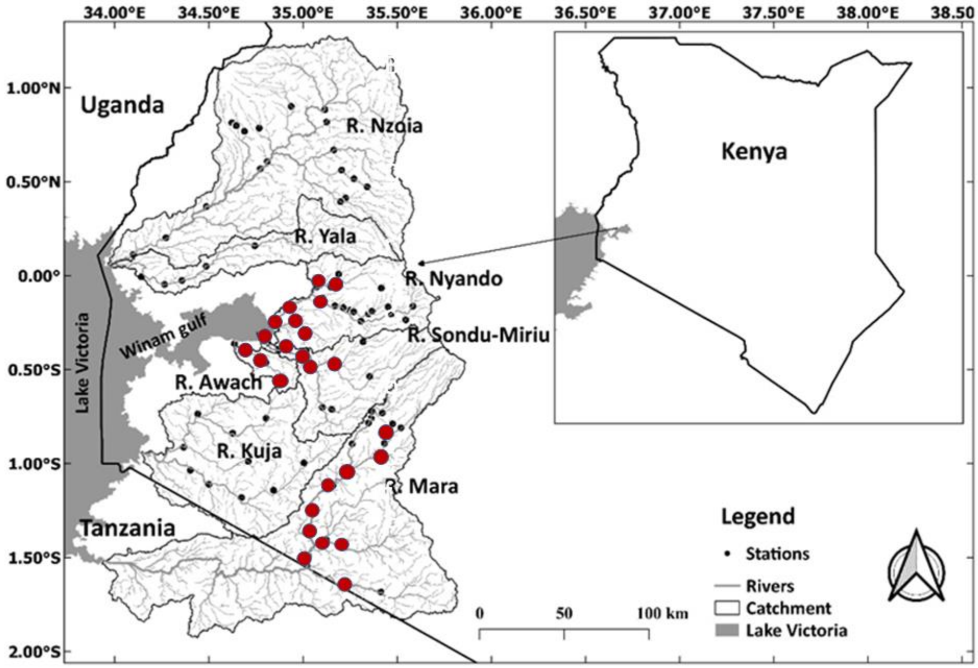

Figure 1: The Sampling Sites in the Kenyan Rivers of the LVB.

Fish were collected using an electrofisher (Honda GX240 8HP; 400V and 10A). During fishing, the power of the electrofisher was adjusted based on the water conductivity on the sampling sites (varied between 34-572µScm^{-1}). Sampling was carried out during daytime hours and fish were collected using a 17mm mesh-size hand net (Achieng *et al*, 2020). For this study, 421 fish samples were collected during different dates in the dry and wet seasons from January 2010 to February 2020.

After capture, total length (TL) of individuals were immediately measured using a pair of calipers calibrated in millimeters (mm) and weight using a portable weighing scale model CY 220. Total weight used to calculate the condition factor was used to estimate the length-weight relationship to avoid seasonal changes in body weight due to feeding (Ondhoro et al., 2016).

Individual relative condition factor was calculated using the following formula: $\mathbf{K_n = W_i / aL^b_i}$ (Le Cren, 1951) where K_n is the relative condition factor, W_i is the fish body weight (g), L_i is the fish total length (cm), and ***a*** and ***b*** are species-specific constants. The specific constants were calculated from the relationship between length-and weight ($W = aL^b$) obtained by pooling data from each river (Ondhoro *et al*., 2016).

Statistical Analysis

The data on LWR were subjected to one-way analysis of variance (ANOVA) to test the differences in mean relative condition factor among rivers. Before ANOVA, data was tested for normality using the Shapiro-Wilk test and log (x) transformation was performed where normality assumptions were violated. Linear correlation analysis was used to assess the level of interdependence between the relative condition factor (K_n) and the fish total length (TL). All statistical tests were performed using MINITAB and Microsoft Excel (Windows version 10) at the significance level of p= 0.05.

RESULTS

The Spatial Variation in the Condition Factor of *L. victorianus*

The mean condition factor, length and weight for *L. victorianus* is shown in Table 1. There was no significant variation in mean relative condition (K_n) of *L. victorianus* (ANOVA F= 0.54, df=3, p=0.65) in the rivers. The mean condition factor recorded for this study ranged between 1.019±0.144 in the Mara River to 1.056±0.258 in River Sondu-Miriu. The mean condition factor value *K* is slightly above 1.00, showing that the condition of the fish was good, long and thin. The length (ANOVA F=64.20, df=3, p<0.001) and weight (ANOVA F= 25.56, df=3, p< 0.001) were significantly different in Mara River.

Table 1: Mean Length, Weight and Condition Factor (K) of *Labeo victorianus* from Rivers Awach, Mara, Nyando and Sondu Miriu of the LVB, Kenya

	Length(cm)		Weight(g)		K_n
Rivers	min-max	mean±sd	min-max	mean±sd	mean±sd
Awach	4.9-24	10.27±5.32	1.5-146	20.28±32.14	1.023±0.251
Mara	8.5-37.4	20.39±6.62	110.56±106.74	1.019±0.144	
Nyando	8-31	13.4±7.26	51.25±88.83	1.051±0.3612	
Sondu-Miriu	5.5-24	12.81±4.76	30.83±40.82	1.056±0.258	

There were only minor differences in the mean condition factor between males and females in all the rivers, except in river Nyando (Table 2). The condition factor was slightly above unity for both males and females in all the rivers.

Table 2: Mean Condition Factor of Female and Male Samples of *Labeo* v*ictorianus* from Rivers Nyando, Mara, Awach and Sondu-Miriu of the LVB, Kenya

	Condition factor Kn	
	Females	Males
Rivers	mean±sd	mean±sd
Awach	1.011±0.071	1.00±0.004
Mara	1.009±0.14	1.02±0.16
Nyando	1.01±0.148	1.01±0.148
Sondu-Miriu	1.06±0.314	1.07±0.312

The Length-Weight Relationship of *Labeo victorianus* Fish Samples from Rivers of LVB, Kenya

The weight of fish samples from River Mara was significantly higher than those from river Awach, and Sondu-Miriu (F=25.93*;* df=3, *p<0.001).* The weight of individuals did not vary in River Nyando, except for one individual that weighed nearly 250 g from the rest of the individuals weighing 50 g and below. The length of the fish in River Mara was significantly higher than those from other rivers (F=64.20; df=3, *p<0.001*). The *b* value of the length-weight relationship of the *L. victorianus* was above 3.0 (the ideal fish shape), showing positive allometric growth in rivers Mara and Sondu-Miriu. The value of exponent *b* of the LWR was slightly <3, showing tendency towards negative allometric growth in Awach and Nyando rivers (Figure 2).

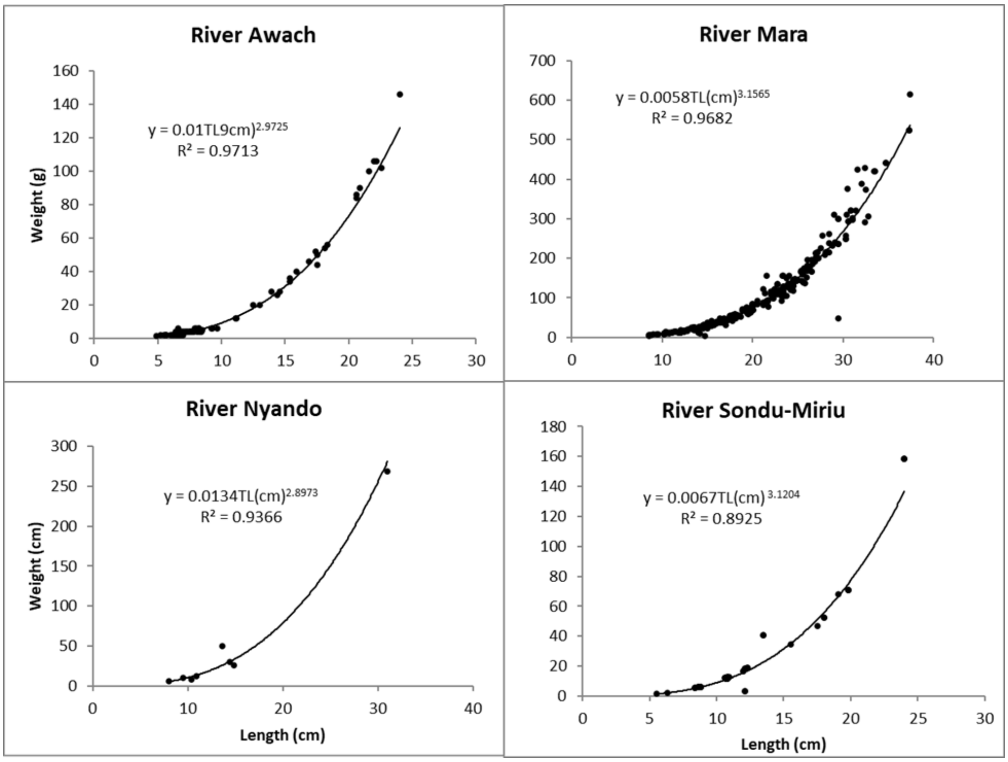

Figure 2: Relationship between the Weight (g) and the Total Length (cm) for *Labeo victorianus* Fish Samples from Rivers Nyando, Mara, Awach and Sondu-Miriu derived from Pooling Data from all the Sampled Rivers.

The Relationship between the Condition Factor (K_n) and Total Length of *Labeo victorianus* Fish Samples from Rivers of LVB, Kenya

The relationship between the condition factor (K_n) and the fish total length in the sampled rivers is shown in Figure 3. In all the rivers, the relative condition factor showed significant variation with the total length (*p<0.0001* and VIF <1). The minimum (r^2=0.88) and maximum (r^2=0.95) value of correlation were obtained in Sondu Miriu and Awach Rivers, respectively (Figure 3).

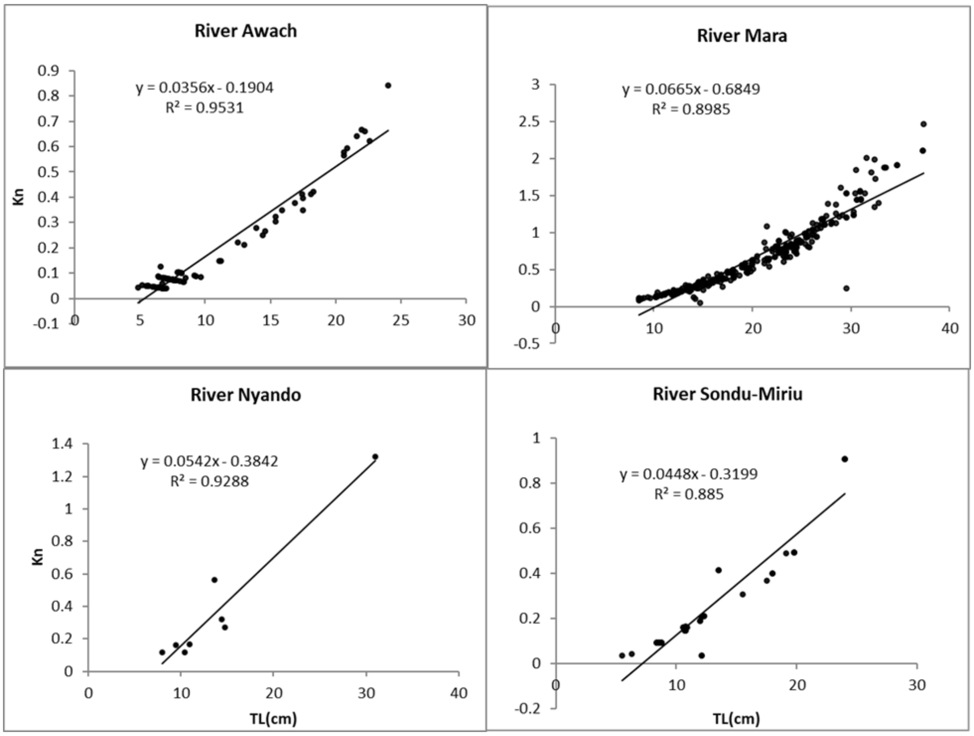

Figure 3: The Relationship between the Condition Factor (K_n) and Total Length of *Labeo victorianus* Fish Samples from Rivers of the LVB, Kenya.

DISCUSSION

There was considerable variation in sizes (smallest to the largest) and maturity stages observed among *L. victorianus* in the rivers. The stable relative condition factor observed for this study might be due to favorable conditions in the riverine habitats as reported by Masese & McClain (2012). The result of this study showed a positive allometric growth, b-value of the LWR were >3.0, for the species in the Sondu-Miriu and Mara rivers which is the ideal fish shape according to LeCren's concept, compared to those from Nyando and Awach rivers that had a with negative allometric growth (b<3). This might be related to environmental conditions in Nyando and Awach rivers which have been found to negatively influence fish diversity and ecosystem health (Achieng *et al.*, 2021). Anthropogenic activities of waste disposal and sedimentation influence aquatic organisms by reducing the quality of the water and food availability (Masese & McClain, 2012). For instance, agricultural practices, overgrazing by livestock have negatively influenced the catchment areas of streams and rivers and their flow regimes around the world (Mayo *et al.,* 2018; Achieng *et al.*, 2020).

Interestingly, the Mara River was found to face more environmental problems. This was due to nutrients loads from animal manure and fertilizers used in agriculture containing phosphorus and nitrogen responsible for eutrophication and anoxic waters (Weigelhofer *et al.*, 2018) which are carried into the river resulting in decline in fish biodiversity in rivers (Mayo *et al.*, 2018). Positive allometric growth in *L. victorianus* was also reported by Kembenya *et al.* (2017) in the Migori River Basin of the Lake Victoria. The condition factor often decreases at the beginning of the reproduction process due to high metabolic rate then becomes normal and increases afterwards. During that period, the fish does not feed and utilizes the accumulated visceral fat during the spawning (Lizama *et al.*, 2002).

The spatial changes in the condition factor of fishes in the LVB rivers is related to changes in environmental conditions driven by diverse human activities (Masese & McClain, 2012; Achieng *et al.*, 2020; Masese *et al.*, 2020). Although the Mara River is the most hydrologically variable and experiences the highest input of organic matter and nutrients by livestock and hippopotamus resident in the river, the river has the largest population of *L. victorianus*, which, surprisingly, is in better condition than populations in Nyando and Awach rivers. This means that the disturbances are within the evolutionally range of acceptable conditions to the species, e.g., droughts and organic matter loading. The river has the lowest land area under agriculture, which could be an issue posing problems to species in the other rivers studied. Also, no fishing occurs in the Mara as in the rest of the rivers because of the protected areas in Maasai mara National Game Reserve**.** The Mara River basin differ from the rest of the river basins by having the least land area under farming in the headwater, with few urban areas and large-scale farms in the middle reaches (Achieng *et al.*, 2021).

Moreover, a large proportion of the middle and lower reaches are under protection as part of group ranches (conservancies) around the Masai Mara National Reserve. This offers protection to the fishes from overfishing and pollution from human settlements and farmlands. Despite the hydrological instability in the Mara River, the fishes have adapted their life history, behavior and morphology to the seasonal flow regime (Lytle & Poff, 2004) as they take advantage of the fluctuating food resources.

Despite differences in length and weight among the populations of *L. victorianus*, the relative condition did not differ considerably among the rivers (Table 1) as hypothesized. This is intriguing and indicates that the fish could beresponding more specifically to changes in environmental conditions at the small scales, e.g., river reaches, and not at the catchment scale. It also confirms that the population of *L. victorianus* in the rivers is the same migratory population from Lake Victoria, although the number of migrating individuals has declined over the years (Masese *et al.*, 2020). Positive allometric growth in *L. victorianus* was also reported by Kembenya *et al.* (2017) in the Migori River Basin of the Lake Victoria. The condition factor often decreases at the beginning of the reproduction process due to high metabolic rate then becomes normal and increases afterwards. During that period, the fish does not feed and utilizes the accumulated visceral fat during the spawning (Lizama *et al.*, 2002).

This study shows that *L. victorianus* has experienced the negative effects of human disturbance in most rivers in the LVB. Thus, there is a need for management efforts to maintain water quality and habitat condition in the rivers. The fishes are largely omnivorous and need high dissolved oxygen concentrations found in riverine ecosystems. This will also support diverse macroinvertebrates, including shredders which play an important role for breaking down particulate organic matter and macrophytes for other invertebrates and fishes. Similar results emphasizing the rapid growth of fish in riverine ecosystems were reported by Singh & Serajuddin (2017), for *Channa punctatus* from Gomti, Ganga and Ken rivers in India, *Labeo bata, L. rohita, Oreochromis mossambicus* (Hossen et al., 2018; Sheriff and Altaff, 2018) and *Labeo boga* in Bangladesh (Pervin & Mortuza, 2008).

CONCLUSION

The condition factor and the length and weight relationship of *Labeo victorianus* in the LVB gives an insight on how the fish species is adapting to the changing environment. Although the condition factor did not vary a lot, the variation in length-weight relationship were subjected to different pressure indicating the degree of environmental degradation to which the fish species was subjected to in the rivers of the LVB. Future research should focus on how spatial differences in environmental conditions at the reach-scale and seasonality influence the condition of the species.

Fishing of *L. victorianus* in the rivers should be moderated in the future to protect this species from overexploitation. Research should also focus on culture of the species as a restoration strategy to restock depopulated areas.

Conflict of Interest

The authors declare no conflicts of interest

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