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The Reproductive Biology, Condition and Growth Forms of *Brycinus Lateralis* (Boulenger, 1900) of the Kwando River, Zambia.

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ABSTRACT

This study was aimed at knowing the reproductive biology, condition and growth forms of *Brycinus lateralis* in Kwando River. *B. lateralis* (n = 1, 244) were collected using seine nets and gill nets. The results showed that *B. lateralis* reaches its asymptotic length very fast owing to its above-average growth coefficient at all study sites (overall K = 0.93 yr^{-1}). There were more Females (662) than Males (582), giving a sex ratio (Males: Females) of 0.879: 1. Negative allometric growth ($b < 3$) was observed Males and in the combined data while positive allometry ($b > 3$). The sampled fish were in good condition ($K_F > 1$), and Males were in better condition ($K_F = 1.62$) than Females ($K_F = 1.58$).

Key words: *Brycinus lateralis*, Kwando River, growth, Condition factor, sex ratio.

1. Introduction

Brycinus lateralis belongs to family Characidae, order Characiformes (Skelton, 2001). Like other characins, *B. lateralis* (Striped Robber) is characterized by having sharp teeth and a small adipose fin. It is distinguished from other Characids by the presence of a silvery, prominent black caudal dash which is surrounded by a yellow-coloured adipose fin (Skelton, 2001; Marshall, 2010). *B. lateralis* has cycloid scales which are radially striate, with dorsal and anal formulae given as D ii; A III, 15-16 (Skelton, 2001).

B. lateralis shoals in clear, slow-flowing or quiet, well-vegetated waters. It feeds on small fish such as *Limnothrissa miodon* (Kapenta) and aquatic arthropods. *B. lateralis*, like other members of genus *Brycinus*, is used as bait for tigerfish and breams (Skelton, 2001).

B. lateralis is widely distributed in the Zambezi river, Okavango, Cunene, Buzi and Congo river systems (Skelton, 2001; Marshall, 2010). In Zambia, *B.* lateralis is widely distributed in both lontic and lentic ecosystems including Lakes Banweulu, Kariba, Mweru-Wantipa and in major rivers such as Luangwa, Luapula and Zambezi (Skelton, 2001).

Evaluation of population parameters of a fish species from a specific water body is very important because such indices reflect the condition of fish, the ecosystem and the adaptability of the fish to the aquatic habitat (Nadia *et al*., 2023; Makeche *et al*., 2024a, 2024b). Population parameters include growth forms (Makeche *et al*., 2023), the number of offspring, size and sex ratio of the population, breeding seasonality (Makwelele, 2017), age, natural mortality and exploitation ratios (Islam *et al*., 2021; Mudenda *et al*., 2024a, 2024b). Biometric evaluation is done through the estimation of length-weight relationships (Saha *et al*., 2021). In Ichthyology, length-weight relationships are vital in projecting length distributions for proper fisheries management (Gerritsen and McGrath, 2007). Knowledge of growth parameters such as the Von Bertalanffy growth coefficient (K), asymptotic length ($L\infty$), age at zero length (t_0), maximum reported age (Tmax) and size at sexual maturity (L_m) (Saha *et al*., 2021; Makeche *et al*., 2023). The form factor ($a_{3.0}$) is a measure of the body shape of each fish in a stock (Hossain *et al*., 2019; Saha *et al*., 2021). The size at sexual maturity (L_m) is an important management parameter for determining if enough juveniles in a collected stock are mature or ready to reproduce (Saha *et al*., 2021). Besides, morphometric relationships such as length-weight relationships, various condition factors such as the relative condition factor (K_R), and Fulton's condition factor (K_F) are essential biometric parameters that are used to determine the state of fish stock and fish health in an aquatic ecosystem (Makeche *et al*., 2020).

Both condition factor and form factor are fundamental tools that can be used to differentiate organisms that belong to the same species (Chaklader *et al*., 2016; Hasan *et al*., 2020). A condition factor can be used as an indicator of the health and sustainability of a fish stock. Condition factor variables decrease with increase in length (Osho and Usman, 2019). In aquaculture farming, the condition factor can be used to provide information on the variation requirements of major dietary components such as protein and energy requirements of farmed fish (Keri *et al*., 2011). Condition factors of fish are affected by such factors as sex, seasons, environmental conditions, stress and availability of food. Ngodhe and Owuor (2019) observed stress as a result of the reduction in the breeding and nursery grounds of *O. niloticus* in Lake Victoria, Kenya.

This study was aimed at knowing the reproductive biology, growth forms and condition factors of *Brycinus lateralis* in Kwando River.

2. Materials and Methods

2.1. Study area and sampling

The Kwando River is a multi-national river which emanates from Mount Tembo (13°00'08"S, 19°07'16"E) in Angola and has its mouth in the Caprivi Region (18°30'08"S, 23°36'58"E) of Botswana. It has a total length of 731Km and a basin size of 96, 778km^2 (https://en.m.wikipedia.org/wiki/Cuando_River). Fish samples were collected from Riverine (-13°17'30"S, 20°29'13"E), Shangombo (-13°21'34"S, 20°31'15"E), Imusho (-15°57'00"S, 24°04'00"E) and Lagoon (-15°72'23"S, 24°30'15"E) (Fig. 1).

A total of 1,244 individuals of *B. lateralis* (582 Males and 662 Females) were collected from January, 2009 to April, 2020, using a fleet of gill nets with mesh sizes ranging from 1" to 6.5" (Table 1) in order to collect both small and large fish. During low water periods, fish were sampled using seine nets because gill nets are selective.

Table 1: Mesh sizes of nets used in sampling fish

Unit	**Mesh sizes**											
mm	25	37	50	63	76	89	102	114	127	140	152	165
Inches	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5

For each collected specimen, total length (TL) and Fork length (FL) were recorded to the nearest 0.1 cm using a fish measuring board, while body weight (BW) was measured using a digital balance to a 0.01 g precision. Each specimen was sexed and the gonad maturation stage was noted.

The mormyrid fish specimens were dissected using a mounted scalpel by making a longitudinal slit from the cloaca to the region below the pelvic fins; respective sexes were then determined on the basis of morphological appearance (by macroscopic examination) of the gonads. Classifications of the fish gonad maturity stages followed Nikolsky (1963) (Table 2). Stages of maturity of gonads were determined by macroscopic observations in both females and males.

Table 2: Gonad maturity stages, codes and description

Gonad maturity stage	Gonad code	Description
Immature	I (I)	Young individuals not yet engaged in sexual activity; gonads are small and may present with difficulty in distinguishing the sexes
Inactive	Q (II)	Sexual products still undeveloped; gonads still small sized; Oocytes not distinct
Active	A (III)	Oocytes distinguishable; gonads rapidly attain greater weight and size; testes assume a pale rose colour from transparent appearance
Ripe	R (IV)	Sexual products ripe; gonads have attained maximum weight
Ripe-running	K (V)	Oocytes and milt released easily from genital aperture by application of gentle pressure over the belly
Spent	S (VI)	Sexual products have been discharged: genitalia appears inflamed, flaccid with residual oocytes, and sperm

Fig. 1 - Map showing the location of study sites along Kwando River

2.2 Data analysis

Gonad maturity stages

The number of specimens having a particular type of gonad was documented and calculated as a percentage of the total fish samples collected.

Sex ratio

The sex ratio of *B. lateralis* of the Kwando river was determined by dividing the number of Males by the number of Females as earlier determined by Theocharis *et al*. (2023).

Growth parameters

The growth coefficient (K) was estimated using the formular: $K = \ln (1 + L_m/L_\infty)T_{max}$ (Beverton, 1992); where b is a constant obtained by regression analysis of L(t) values of the sample size and Δt is change in time. The asymptotic length (L_∞) was estimated from the formular: $L\infty = L_{max} /0.95$ (Sparre and Venema, 1998); where L_{max} is the maximum total length measurement recorded. The size at sexual maturity (L_m) of *B. lateralis* was assessed using the formular: $\log (L_m) = - 0.1189 + 0.9157 \times \log (L_{max})$ (Binohlan and Froese, 2009); where the L_m = size at sexual maturity and L_{max} = maximum observed length. In addition, the age at maturity (tm) was evaluated through the equation of $tm (50\%) = (- 1/1) \times \ln (1 - L_m/ L_\infty$ (King, 2007).

The age at zero length was studied with the calculation of $\log (- t_0) = - 0.3922–0.2752 \log L\infty - 1.038 \log K$ (Pauly, 1980). The asymptotic weight ($W\infty$) was calculated through $W\infty = a \times L\infty^b$ (Pauly, 1984). The total lengths at various ages (Lt) of *B. lateralis* were calculated from the Von Bertalanffy growth equation: $Lt = L_\infty [1-\exp(-K(t-t_0))]$.

Growth forms

Length-weight relationships were estimated from the allometric formula: $W = aL^b$ which was then log-transformed as: $\log W = \log a + b \log L$. Where W is weight (g), L is the total length (mm), a is a constant and b is the growth form (Froese, 2006). If b = 3 the fish grows isometrically, then small fish in the sample under consideration have the same form and condition as large fish. If b > 3, the fish shows positive allometric growth, then large fish have increased in height or width more than in length, either as a result of a notable ontogenetic change in body shape with size (which is rare) or most large fish in the sample were thicker than small fish (which is common). Conversely, if b < 3 the fish shows negative allometric growth, then large fish have changed their body shape to become more elongated or small fish are in better nutritional condition at the time of sampling (Froese, 2006).

Form factor ($a_{3.0}$)

B. lateralis form factor ($a_{3.0}$) was calculated using Froese's formula: $a_{3.0} = 10^{\log. a\text{-}s\,(b-3)}$ (Froese, 2006), where a and b are Length-Weight regression variables (regression of fin length against body weight), and s is the slope of log a vs. b. A mean slope S = − 1.358 was used as recommended by Froese (2006), because there was no detail on Length-Weight regression for this species.

Condition factors

The condition factor reveals the well-being of fish (Makeche *et al*., 2024b). The allometric condition factor (K_A) was calculated using the equation: $K_A = W/L^b$ (Tech, 1968), where W is the body weight (g), L is the fork length in cm, and b is the Length-Weight regression parameter. The Fulton's condition factor (K_F) was calculated using the formular: $K_F = 100\ (W/L^3)$ (where W is the body weight in g and L is the fork length in cm). A scaling factor of 100 was used to get the K_F close to the unit (Froese, 2006). The relative condition factor (K_R) was evaluated through the following formula: $K_R = W/(a \times L^b)$ (Le Cren, 1951), where W is the body weight (g), L is the fork length (cm), and a and b are the Length-Weight regression parameters. The following equation was used to compute the relative weight of *B. lateralis* (W_R): $W_R = (W/W_s) \times 100$ (Froese, 2006); where W is the weight of a single species and W_s is the expected normal weight as intended by $W_s = a \times L^b$, the values of a and b were calculated from the regression of fork length against body weight.

3 Results

The gonad maturity stages of *B. lateralis* are shown in Fig. 2.

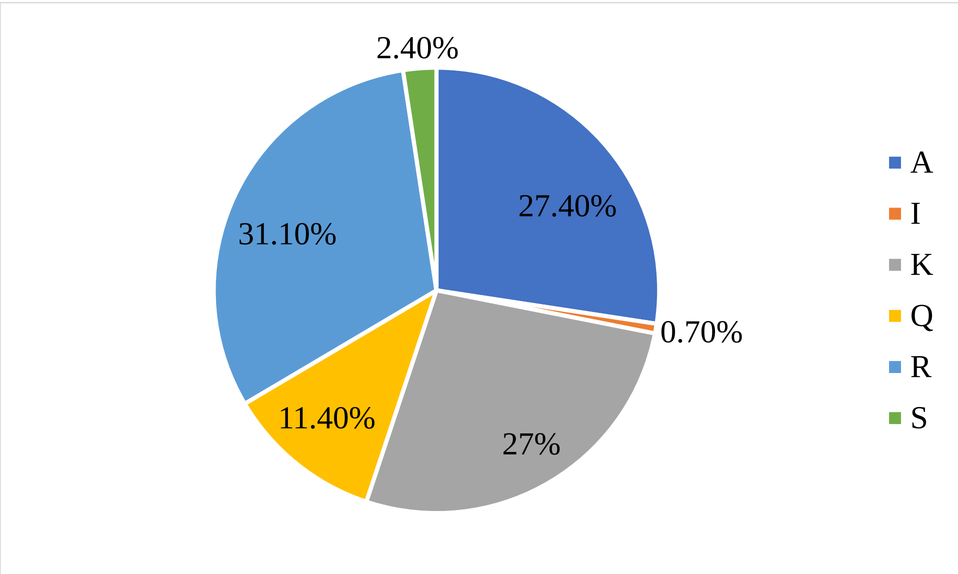

Fig-2: Gonad maturity stages of *B. lateralis* of Kwando river

Figure 2 shows that most sampled fish had ripe gonads (31.1%). A small proportion (0.7%) of sampled fish had immature gonad, while 2.4% of the sampled fish were in the post-reproduction phase (spent).

The age-at- maturity (Tm) ranged from a low of 0.6 yr^{-1} in the among Males to a high of 0.9 yr^{-1} among Female *B. lateralis*. The results showed that Males attained sexual maturity earlier than Females. The Tm value for the total population was 0.5 yr^{-1} (Table 3).

Table 3: Growth parameters and Condition factors of *B. lateralis* in Kwando River

	N	W	a	b	K	$a_{3.0}$	K_A	K_R	K_F	W_r	W_s	W_∞	L_m	T_o
Male	582	13	1.2	1.28	1.21	0.844	0.749	3.27	1.62	64	20.4	56	0.6	0.836
Female	662	14	2.86	4.56	0.24	0.384	0.000464	4.47	1.58	77	18.3	67	0.9	0.125
Combined	1244	13	1.95	2.76	0.927	0.168	0.0268	2.39	1.57	64	20.2	56	0.5	0.733

N = sample size, a and b are length-weight regression coefficients, W = average weight (g), K = growth rate, $a_{3.0}$ = form factor, K_A = allometric condition factor, K_R = relative condition factor, K_F = Fulton's condition factor, Wr = relative weight, W_s = anticipated standard weight, L_m = age at maturity in year and W_∞ = Asymptotic weight (g). T_o = Age at zero length in cm.

The sex ratio of the sampled *B. lateralis* was 0.879: 1 (582 Males and 662 Females). The growth rate was sub-optimal among Female *B. lateralis* (K = 0.24). The growth rate (K) ranged from a low of 0.24 among Female specimens to a high of 1.21 among Male *B. lateralis* (Fig. 3).

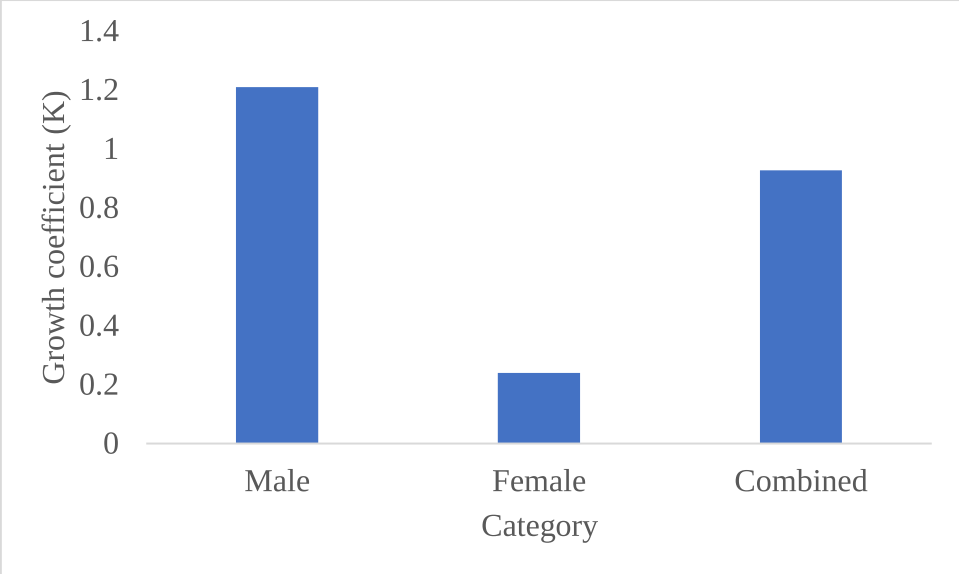

Fig-3: Histogram of growth coefficients of *B. lateralis* of Kwando River

The Von Bertalanffy growth values are given in Table 4. The values show that Males reached asymptoncy earlier (3 years) than Females (6 years). The Von Bertalanffy growth curves of *B. lateralis* at various ages are shown in Fig. 4

Table 4: Von Bertalanffy growth values

	Lt					
Age (Years)	1	2	3	4	5	6
Male	1.5	14.2	19.3	19.8	19.9	20
Female	4.39	8.4	11.6	14	16	17.5
Combined	11.4	16	20.4	22.1	22.8	23

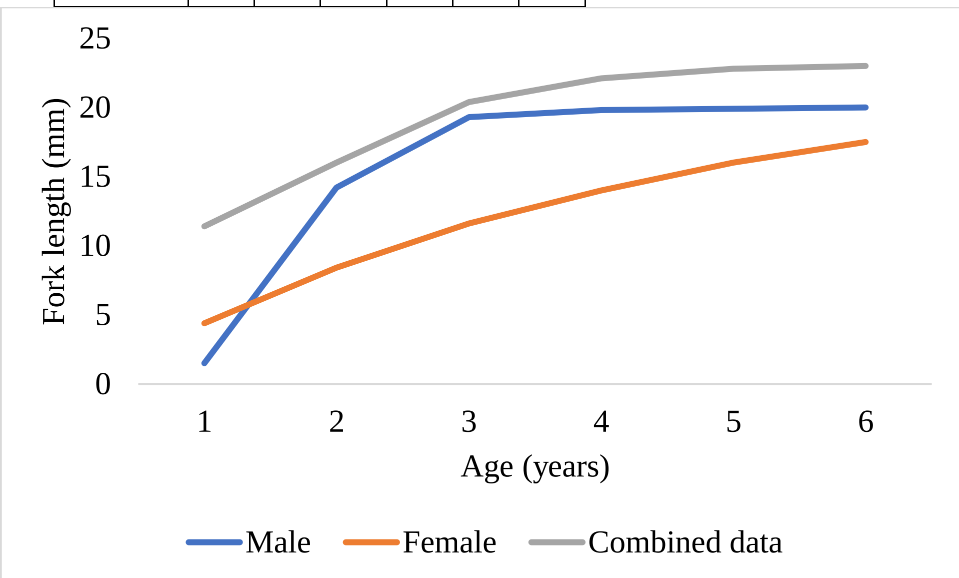

Fig-4: Von Bertalanffy growth curves of *B. lateralis* of Kwando River

The growth form value (b-value) for combined data was 0.96. Since the determined growth form of the sampled *B. lateralis* specimens in the Kwando river was less than 3, this depicts negative allometry. The growth form and the logarithmic equation which shows the length-weight relationship among *B. lateralis* in Kwando river is shown in Fig. 4.

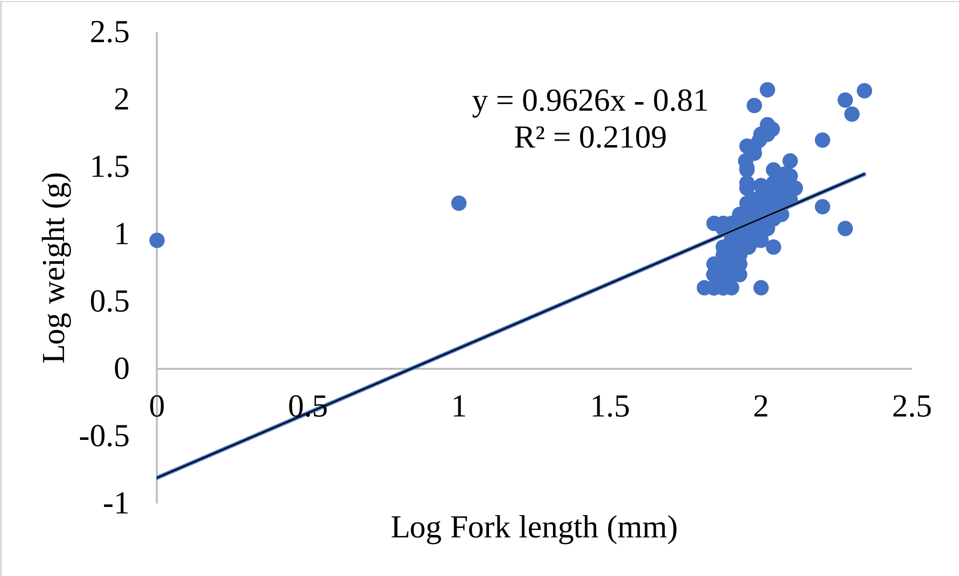

Fig. 4-Length-weight relationship of *B. lateralis* in Kwando river.

The logarithmic length-weight relationships of Male and Female B. lateralis were represented by the mathematical models: Y = 1.20x – 1.28 (r^2 = 0.209) and Y = 2.86x – 4.56 (r^2 = 0.663).

The form factor value for combined data was 0.168 (Table 3), signifying that *B. lateralis* is not short and deep-bodied; but elongate. Males had a larger value ($a_{3.0}$ = 0.844) than Females ($a_{3.0}$ = 0.384).

All the sampled fish species were in good condition (K_F > 1.0) (Table 3). Males were in better condition (K_F = 1.62) than Females (K_F = 1.58). The estimated Condition factor for combined sexes was 1.57 (Table 3).

4 Discussion

The sex ratio and gonad maturity of fish is affected by several factors such as genetic factors, high fishing mortality, sampling time, fish age, habitat variation, food availability, temperature and salinity (Rajendiran *et al*., 2021). Generally, when the fish population consists of small organisms (less than 30 cm in total length), the sex ratio favours males (Yildiz *et al*., 2011). Results of the current study do not tally with the assumption by Yildiz *et al*. (2011) who postulated that populations which are dominated by young organisms mainly consist of Males. This could be attributed to the sampling time and type of fish species studied. Since Female *B. lateralis* fish are the ones which construct nets (Skelton, 2001), they are more mobile than their Male counterparts, hence they have a higher probability of capture and abundance in the catch sample. The high presence of gonads in the developmental stages (Inactive, Active and Ripe) shows that the sampled fish species were young. The results of this study agree with earlier results by Nyirenda (2017) who found that among fish species, reproduction mainly occurs during the rainy season due to abundance of food resources. Before the onset of the rainy season, most aquatic habitats in Zambia are inhabited by young fish with gonads which are predominantly in the growth phase (Nyirenda, 2017). Theocharis *et al*. (2023) also observed that gonads are usually ready for reproduction between November and March, because spawning is affected by environmental temperature, food availability and Condition factor (Beik, 1995: Lappalainen *et al*., 2016)

The above-average Condition factors (K > 1.0) obtained in the current study are similar to previous results found in other studies among various fish species in Zambia (Nyirenda, 2017, Makeche *et al*., 2023; Mudenda *et al*., 2024a). The results of the present study show that *B. lateralis* is in good condition in Kwando River.

Growth coefficients (K) are very useful in knowing how fast fish approaches its asymptotic length (L_∞) because there is a strong correlation between the growth coefficient (K) and asymptotic length (L_∞) (Abdul *et al*., 2019; Mukuka, 2019). Zhang and Megrey (2006) generalized that long-lived fish species approaches their limiting sizes earlier than short-lived fish species. Spare *et al*. (1989) stated that K values greater than or equal to 1 are for short-lived species. Henceforth, the K values of this research (Combined K value = 0.927 yr^{-1}) indicate that *B. lateralis* is a long-lived species. The results of the current research are in conformity with previous research by Marufu *et al*. (2018) (K = 0.72 yr^{-1}) and Mukuka (2019) (K = 0.65 yr^{-1}) from the Zambezi River. Furthermore, Murugan *et al*. (2014) established that Male *Mugil cephalus* grow faster than Female species (Male K = 0.95yr -1; Female K = 0.82yr -1). This study has also shown that Males (K = 1.21 yr^{-1} grow faster than Females (K = 0.24 yr^{-1}).

Weight values of the current study (W_r = 64g to 77g) are within the range of values found by Saha *et al*. (2021) for *Trichogaster ladius* in Bangladesh (Wr = 59-199). Since weight parameters (relative weight, anticipated standard weight and asymptotic weight) are affected by growth coefficients, they are species-specific (Abdel *et al*., 2019).

Studies of crucial biological characteristics such as some aspects of reproduction, fish condition and population parameters are essential for stock management. Results of this study indicated that management measures need to be enforced to prevent fishers from harvesting juvenile fish, thereby protecting the fish stock from possible depletion.

5. Conclusion

Brycinus lateralis is a fast-grower owing to the above-average growth coefficients obtained. Generally, *B. lateralis* exhibits negative allometric growth; but it is in good condition in Kwando River.

References

Abdul, W. O., Omoniyi, I. T., Bahir, A. O., Makinde, A. A., Adekoya, E. O., Owoade, T. and Oriyomi, J. T. 2019. Length Base Structure and Growth Parameters of *Sarotherodon galilaeus* (Pices: Cichlidae) in Tropical Coastal Estuary, Nigeria. *The Pacific Journal of Science and Technology,* **20 (1): 289-297.**

Beik, M. C. 1995. Variation in Growth and Age at Maturity in Bluegill Sunfish: Genetic or Environmental Effects? *Journal of Fish Biology,* **47 (2): 237-247.**

Beverton, R. J. H. 1992. Patterns of Reproductive strategy in some marine teleost fishes. *Journal of Fish Biology*, **41:137-160**.

Binohlan, C. and Froese, R. 2009. Empirical equations for estimating maximum length from length at first maturity. *Journal of Applied Ichthyology*, 25, 611-613.

Chaklader, M., Siddik, M., Hanif, M., Nahar, A. 2016. Size structure of finescale razorbelly minnow, *Salmostoma phulo* (Cyprinidae) inhabiting a coastal river of Bangladesh. *Iranian Journal of Fisheries Sciences,* **15 (4): 1348-1361.**

Gerritsen, H. D. and McGrath, D. 2007. Precision estimates and suggested sample sizes for Length-frequency data. *Fish Bulletin*, **105: 116-120**.

Hossain, M. A., Hossain, M. Y., Hossen, M. A., Rahman, M. A., Islam, M. A., Khatun, D., Nawer, F. and Ohtomi, J. 2019. Temporal variations of sex ratio and growth patterns of critically endangered catsfish *Clupisoma garua* from the Ganges River of north-western Bangladesh. *Indian Journal of Geography and Marine Sciences,* **48 (5): 647-653.**

Hossain, M. Y., Hossen, M. A., Ahmed, Z. F., Hossain, M. A., Pramanik, M. N. U., Nawer, F., Paul, A. K., Khatun, D., Haque, N., Islam, M. A. 2020. Length-weight relationships of 12 indigenous fish species in the Gajner Beel floodplain (NW Bangladesh), *Journal of Applied Ichthyology,* **33 (4): 842–845.**

https://en.m.wikipedia.org/wiki/Cuando_River

Islam, M. A., Hossain, M. Y., Rahman, M. A., Rahman, O, Sarmin, M. S., Khatun, D., Hasan, M. R., Nima, A., Mawa, Z., Rahman, M. Tanjin, A. S. and Parvin, M. F. 2021. Some biological aspects of Asian stinging catfish, *Heteropneustes fossilis* (Bloch, 1794) (Teleostei: Siluriformes) in a wetland ecosystem. *Iranian Journal of Ichthyology*, **8 (1): 52–61.**

Keri, A. I., Aziz, B. A., Abol-Munaf, A. B. 2011. Condition Factor as an Indicator of Growth and Feeding Intensity of Nile Tilapia Fingerlings (*Oreochromis niloticus*) Fed on Different Levels of Maltose. *American-Eurasian Journal of Agriculture and Environmental Science*, **11 (4): 559-563.**

King, M. 2007. Fisheries Biology Assessment and Management. 2nd Edition. Blackwell Science Publications, Oxford. **pp. 1-382.**

Lappalainen, A., Saks, L., Sustar, M., Heikinheimo, O., Jurgens, K., Kokkonen, E., Kurkilahti, M., Verliin, A. and Vetemma, M. 2016. Length at maturity as a potential indicator of fishing pressure effects on coastal pikeperch (*Sander lucioperca*) stocks in the northern Baltic Sea. *Fisheries Research,* **174: 47-57.**

Le Cren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, **20 (2): 201-219.**

Makeche, M. C., Mudenda, H. G. and Katongo, C. 2020. Growth and Mortality of Mouthbrooding Tilapiines of the Kafue Floodplain Fishery, Zambia. *American Scientific Research Journal for Engineering, Technology, and Sciences,* **64, 109-118.**

Makeche, M. C., Nhiwatiwa, T., Chitondo, L., Kanyati, M., Katongo, C., Kaminsa, C., Kaona, M., Ndebe, J., Mulavu, M., Khumalo, C.S., Simulundu, E., Changula, K., Chitanga, S., Mubemba, B., Muleya, W. and Makwelele, G. 2023. Comparative study of growth rates, condition factors and natural mortality of *Oreochromis niloticus* fish from culture fisheries and capture fisheries at Lake Kariba, Zambia. *International Journal of Fisheries and Aquaculture,* **15 (2): 21-35**.

Makeche, M. C., Mudenda, H. G and Makwelele, G. 2024a. Reproduction Frequency, Sex Ratio, Growth Rates, Growth Performance indices, Condition Factors and Natural Mortality of Red Claw Crayfish (*Cherax quadricarinatus*, Von Martens, 1868) in Lake Kariba, Zambia. *International Journal of Research Publication and Reviews,* **5 (7): 748-760.**

Makeche, M. C., Mudenda, H. G and Makwelele, G. 2024b. Growth Parameters, Mortality Variables and Levels of Exploitation of *Petrocephalus Wesselsi* (Kramer and Van Der Bank, 2000) in Lufupa River, Zambia. *International Journal of Research Publication and Reviews,* **5 (9): 177-183.**

Makwelele, G. 2017. Growth, mortality and reproductive biology of the introduced Crayfish, Cherax quadricarinatus (Von Martens, 1868) in Kafue Flats Floodplains. (MS.c. Dissertation). University of Zambia, Lusaka, Zambia.

Marufu, L., Barson, M., Chifamba, P., Tiki, M. and Nhiwatiwa, T. 2018. The population Dynamics of a Recently Introduced Crayfish, *Cherax quadricarinatus* (von Martens, 1868), in the Sanyati Basin of Lake Kariba, Zimbabwe. *African Zoology,* 53 (1): 17–22.

Marshall, B. E. 2010. The Fishes of Zimbabwe and their Biology. South African Institute of Aquatic Biodiversity. Grahamstone, South Africa, **pp. 7-269**.

Mudenda, H. G. and Makwelele, G. Makeche, M. C. 2024a. Aspects of Reproductive Biology and Population Biology of *Petrocephalus wesselsi* (Kramer and van der Bank, 2000) in Lufupa River, Zambia. *International Journal of Research Publication and Reviews*, **5 (7): 741-747**.

Mudenda, H. G. and Makwelele, G. Makeche, M. C. 2024b. Growth Parameter indices, Mortality Variables and Levels of Exploitation of Red Claw Crayfish (*Cherax quadricarinatus*, Von Martens, 1868) in the Kafue Floodplain Fishery and Lake Kariba, Zambia. *International Journal of Research Publication and Reviews*, **5 (9): 166-176.**

Mukuka, K. N. 2019. Establishment and Population Dynamics of the Alien Invasive Red Claw Crayfish (*Cherax quadricarinatus* Von Martens, 1868) on the Upper Zambezi River, Zambia. (M.Sc. dissertation). University of Bremen, Bremen, Germany.

Murugan, S., Ashiq, U. R., Rahman, M., Khan, A. S. and Lyla, P. S. 2014. Growth and population dynamics of Flathead Grey Mullet, *Mugil cephalus* (Linnaeus, 1758) from Parangipettai water (Southeast Coast of India). *Thalassa,* **30 (2): 47–56.**

Nadia, M. Z., Saha, N., Roy, P., Iqbal, A. M., Sarmin, S. M. and Hossain, Y. M. 2023. Evaluating biometric indices for Indian Gagata, *Gagata cenia* (Hamilton, 1822) through multi-model inferences. *Heliyon*, **9: e12739**.

Ngodhe, O. S. and Owuor, O. J. B. 2019. Assessment of Length-Weight Relationship and Condition Factor of Nile Tilapia (*Oreochromis niloticus*) in Cage and Open Waters in Winam Gulf of Lake Victoria, Kenya. *International Journal of Environmental Sciences and Natural Resources,* **22 (3):97-101.**

Nikolsky, D.V. 1963. The Ecology of fishes, Academic, London.

Nyirenda, M. S. 2017. Abundance, growth and reproductive biology of *Oreochromis niloticus* (Linneaus, 1758) compared with tilapiines indigenous to the Middle Zambezi (MSc. Dissertation). University of Zambia, Lusaka, Zambia.

Osho, E. F. and Usman, A. R. 2019. Length-weight relationship, condition factor and fecundity of African Snakehead *Parachanna obscura* from the Anambra River, South-East Nigeria. *Croatian Journal of Fisheries,* **77(2): 99-105.**

Pauly, D. 1980. On the interrelationship between natural mortality, growth parameters and the mean environmental temperature in 175 fish stocks, *ICES Journal of Marine Sciences*, **39 (2): 175–192.**

Pauly, D. 1984. Fish population dynamics in Tropical Waters: A Manual for use with Programmable Calculators. *ICLARM Contribution*, **143-325.**

Rajendiran, P., Jaafar, F., Kar, S., Sudhakumari, B. and Parhar, I. 2021. Sex determination and Differentiation in Teleost: Roles of Genetics, *Environment, and Brain. Biology (Basel),* **10 (10): 973.**

Saha, N., Roy, P., Nadia, M. Z., Ahamed, F. and Hossain, Y. M. 2021. Growth, Condition, Maturity and Mortality of the Dwarf Gourami, *Trichogaster ladius* (Hamilton, 1822) in a Wetland Ecosystem (Beel Dakatia), Southwestern Bangladesh. *Egyptian Journal of Aquatic Biology and Fisheries,* **25 (3): 505-524.**

Skelton, P. H. 2001. A Complete Guide to the Freshwater Fishes of Southern Africa. Random House Struik Publishers Ltd, Cape Town.

Sparre, P., Ursin, E. and Venoma, S. C. 1989. Introduction to Tropical Fish Stock Assessment Part I Manual. *FAO Fish Technical paper,* **337pp.**

Sparre, P. and Venema, S.C. 1998. Introduction to Tropical Fish Stock Assessment, Part: 1 Manual, FAO Fisheries Technical Paper 306/1, Rev 2, Rome, Italy.

Tech, F. W. 1968. Age and growth, in W. E. Ricker (Ed), Methods for Assessment of Fish production in Freshwaters, Blackwell Scientific Publications, Oxford, **pp. 93-123**.

Theocharis, A., Vlachou, M., Conides, A. and Klaoudatos, D. 2023. Population biology of European hake (*Merluccius merluccius*, Linnaeus, 1758) in Greece. *Academia Biology*, **11-15.**

Yildiz, T., Kesiktas, M., Yemisken, E., Sonmez, B. and Erylmaz, L. 2011. Modelling the trajectories of growth and reproduction in European hake (*Merluccius merluccius*, L. 1758) from the Sea of Marmara, Turkey. *Iranian Journal of Fish Science,* **21 (2): 445-462.**

Zhang, C-I. K. and Megrey, B. A. 2006. A revised Alver-son and Carney model for estimating the instantaneous rate of natural mortality. *Transactions in American Fisheries Society*, **135 (3): 620-633.**