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An Evaluation of Biometric Indices of *Brycinus Lateralis* (Boulenger, 1900) of the Kwanda River, Zambia.

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ABSTRACT

This study was aimed at documenting the growth parameters, mortality variables and levels of exploitation 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 high growth coefficient at all study sites (overall K = 0.93 yr $^{-1}$). *B. lateralis* showed longevity values of 1.91 years. Both sexes were over-exploited (Male exploitation ration = 0.927, Female exploitation ratio = 0.693), although the combined data showed that *B. lateralis* was under-exploited (E= 0.293).

Key words: *Brycinus lateralis*, Kwando River, Mortality, Exploitation.

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 Biometric indices 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). Biometric indices 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), size at sexual maturity (L_m) and natural mortality (M) is required (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).

This study was aimed at documenting the growth parameters, mortality variables and levels of exploitation 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.

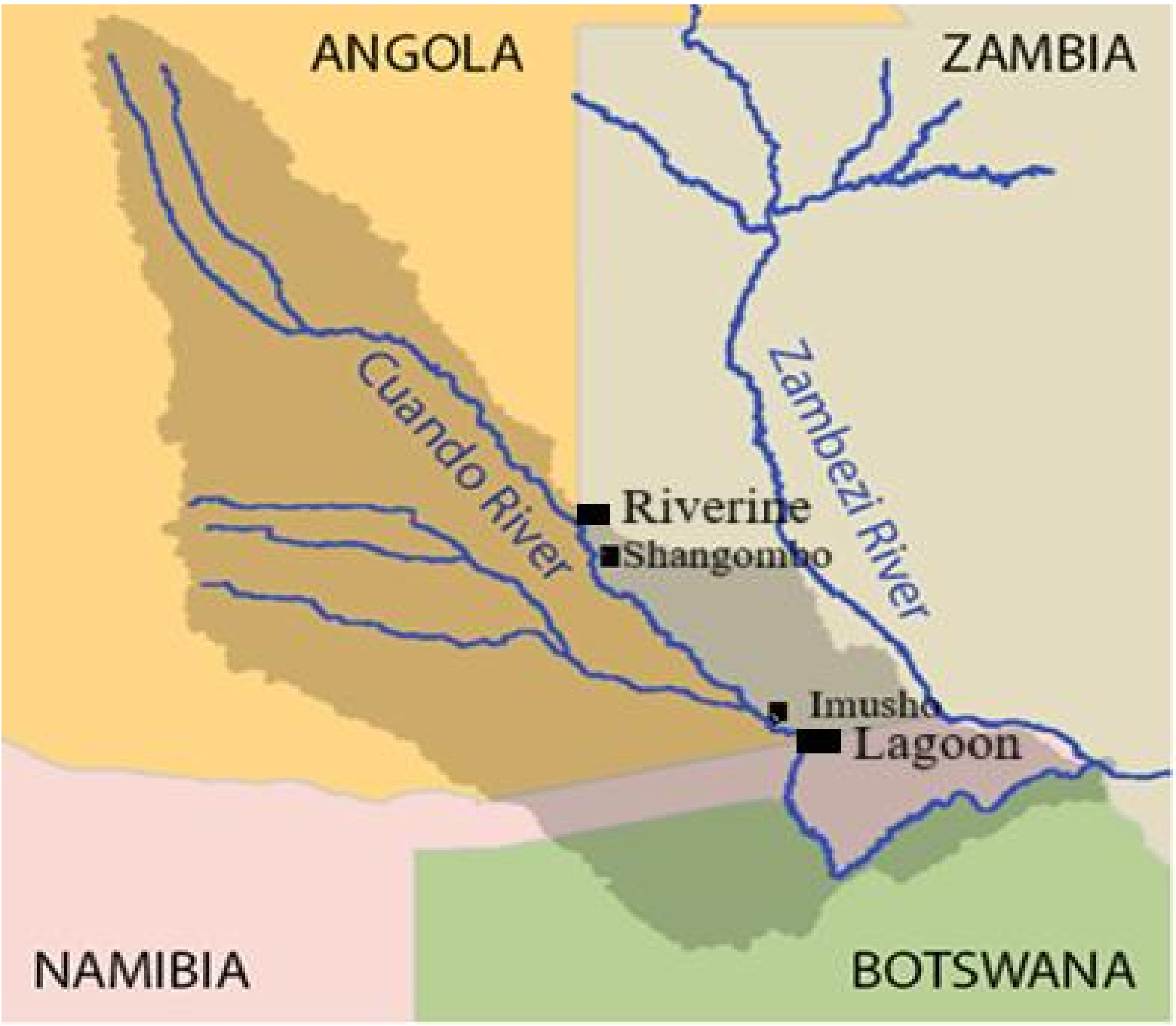

Fig. 1 - Map showing the location of study sites along Kwando River

2.2 Data analysis

2.2.1 Growth parameters

The growth coefficient (K) was estimated using the formular: K = ln (1 + L_m/L_∞)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∞ = L_{max} /0.95 (Sparre and Venema, 1998); where L_{max} is the maximum total length measurement recorded. Growth performance indices (Φ′) were then estimated using the equation by Pauly and Munro (1984) expressed as: Φ′ = log10 (k) + 2 log10 (L_∞), where; K = Von Bertalanffy growth coefficient and L_∞ = Von Bertalanffy asymptotic length. L_{max} is the largest length among the measured total lengths of the fish species. The longevity index (T_{max}) was estimated from the equation of (Pauly, 1984): T_{max} = 3/K; where K = growth coefficient. The Length-at- optimum yield (L_{opt}) was estimated using the formula (Pauly, 1984): L_{opt} = L∞ (3/(3+M/K); where M = natural mortality and K = growth coefficient. The Length-at-first maturity (L_{50}) was computed using the equation: Log L_{50} = 0.8776 Log (L∞)- 0.38 (Froese and Binohlam, 2000). The size at sexual maturity (L_m) of *B. lateralis* was assessed using the formular: log (L_m) = − 0.1189 + 0.9157 × 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) × ln (1 − L_m/ L_∞ (King, 2007).

2.2.2 Mortality variables

The total mortality (Z) of *B. lateralis* was computed using the Beverton-Holt equation method. The Beverton and Holt equation (1957) is based on the mean lengths of a fish species and it is given below:

$$Z = \frac{K(L\infty - Lm)}{Lm - Lc}$$

Where: k is the growth coefficient, L∞ is the asymptotic length, Lm is the mean length of the catch samples, Lc is the smallest length among the measured total lengths of the fish specimens and Z is the total mortality. Total mortality (Z) is made up of two components: the fishing mortality (F) and the natural mortality (M) (Gulland, 1982) and it is expressed as follows: Z = M + F. The natural mortality (M_w) of *B. lateralis* was determined from the equation: M*w* =1.92 year $^{-1}$ *(W) $^{(-0.25)}$ (Peterson and Wroblewski (1984); where, M_w = natural mortality at mass W; and W = a*L^b, a and b are the regression variables of length and weight (total length against body weight). The fishing mortality (F) was calculated using the equation: F = Z-M.

2.2.3 Levels of Exploitation

Using the estimated values of total mortality and natural mortality above, the level of exploitation (E) was then determined from the formula of Gulland (1982) as given below:

$$E = \frac{Z - M}{Z}$$

Where Z is the total mortality coefficient and M is the natural mortality coefficient. Values of exploitation ratios were used to determine whether or not the fish stocks in the Kafue Floodplain fishery are over-exploited. An exploitation value of 0.5 denotes optimal exploitation; an exploitation value above 0.5 denotes over-exploitation while an exploitation value below 0.5 signifies under-exploitation.

3. Results

3.1 Growth parameters

The growth coefficient (K) which was determined among *B. lateralis* ranged from a low of 0.24 to a high of 1.21 (Table 2). Male *B. lateralis* showed a higher growth coefficient value (1.21) than Female *B. lateralis* (0.24). The growth coefficient for combined data was 0.927 (Fig. 2).

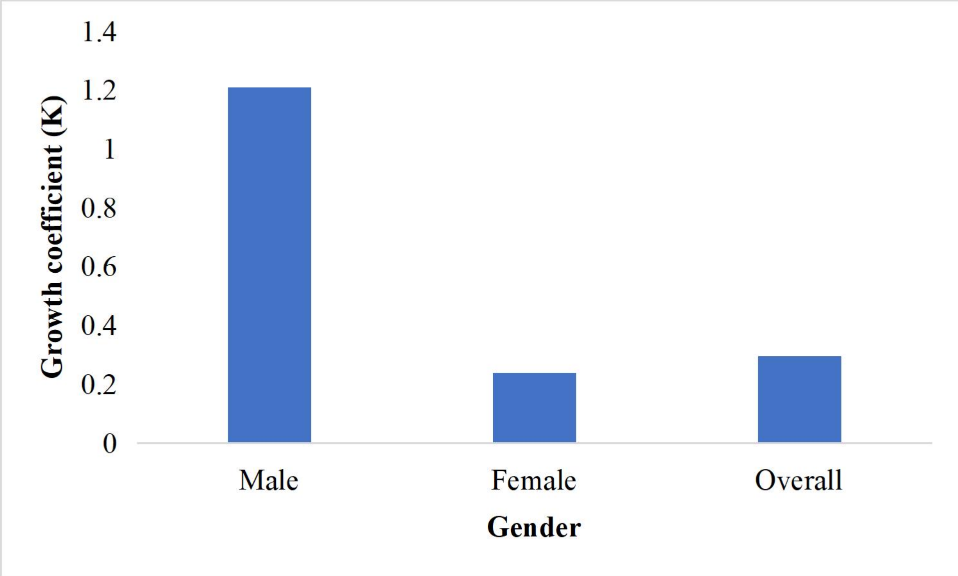

Fig. 2-Histogram of growth coefficients of *B. lateralis* in Kwando river

The growth performance index (Φ′ = 4.91) was larger in Females than in Males (Φ′ = 4.88) in the Kwando river. The growth performance for combined data was 4.93.

Length-at-First-sexual Maturity (L_{50}) values ranged from a low of 164 mm among Males to a high of 170 mm in Females in the Kwando river (Table 2). The L_{50} value for combined data 170 mm. The size at sexual maturity (L_m) values ranged from a low of 93 mm among Males to 96 mm among Females. The L_m value for combined data was 94 mm.

The longevity index (T_{max}) which was determined among *B. lateralis* ranged from a low of 1.85 years among Males to a high of 1.91 years among Females. The T_{max} value for combined data was 1.91 years (Table 2).

The length at maximum yield (L_{opt}) (Table 2) ranged from 154 mm among Females to 184 mm among Males in the Kwando river. The L_{opt} value for combined data was 186 mm.

The maximum attainable length (Asymptotic length, L_∞), (Table 2) ranged from 200 mm among Males to 232 mm among Females in the Kwando river.

3.2 Mortality variables

Fishing mortality (F) values were generally larger than natural mortality (M_w) values (Table 1). Male *B. lateralis* showed an M_w value of 0.43 and an F value of 5.5. Females had an Mw value of 2.44 and an F value of 5.51 (Table 2). The natural mortality (Z) value for combined data was 1.18. Total mortality values for Males, Females and combined data was 5.93, 7.95 and 1.67 (Table 2).

3.3 Levels of exploitation

The exploitation ratio (E) for combined data was below-optimum (0.293). However, Females were less exploited (E = 0.693) than Males (E = 0.927) (Table 2 and Fig. 4.).

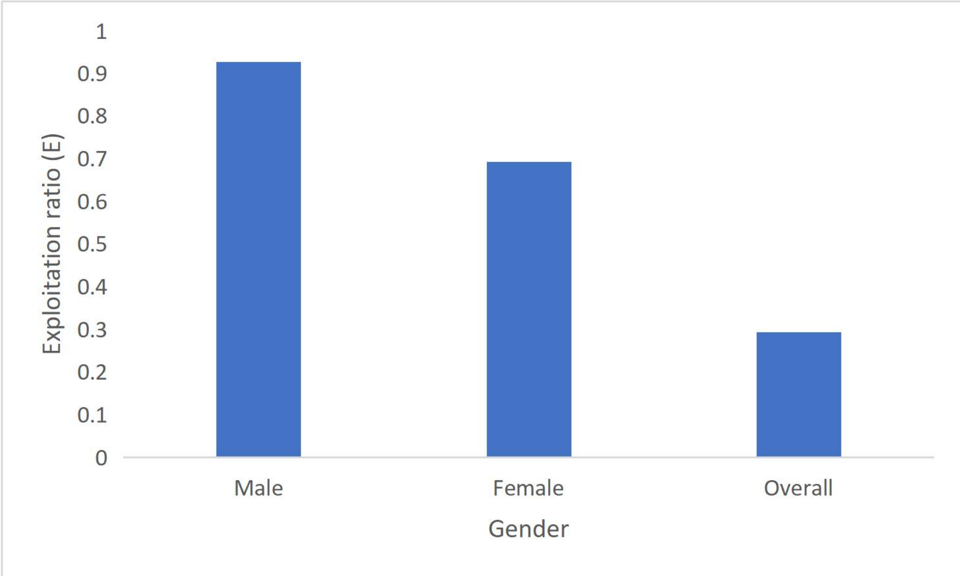

Fig. 4- Histogram of Exploitation ratios of *B. lateralis* in Kwando river

Table 2 - Growth parameters, Mortality variables and Exploitation ratios of *B. lateralis* in Kwando River

	N	L_m	W	L_c	L_{max}	L_∞	L_{50}	T_{max}	L_{opt}	Φ′	K	M_w	F	Z	E
Male	582	93	13	10	190	200	164	1.85	184	4.88	1.21	0.43	5.5	5.93	0.927
Female	662	96	14	70	220	232	170	1.9	154	4.91	0.24	2.44	5.51	7.95	0.693
Total	1244	94	13	10	220	232	170	1.91	186	4.93	0.93	1.18	0.49	1.67	0.293

N = sample size, L_m = sample mean length (mm), W = average weight (g), L_c = smallest length in the sample (mm), L_{max} = Maximum length in the sample (mm), L_∞ = asymptotic length, L_{50} = Length-at-First sexual maturity (mm), T_{max} = longevity index (in years), L_{opt} = Length at maximum yield (mm), Φ′ = Growth performance index, K = growth rate, Mw = natural mortality, F = fishing mortality, Z = total mortality, E = Exploitation ratio.

4. Discussion

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). Zhang and Megrey (2006) generalized that long-lived fish species approach 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 (Kwando river = 0.93 yr^{-1}) indicate that *B. lateralis* is a long-lived species. The results of the current study are within the range of results found on different fish species. Hotos and Katselis (2011) found similar growth coefficients (K = 0.8) among *C. planiceps* in Greece just like Panda *et al*. (2018) found above-average values (K = 0.98) among Mullets in Lake Chilika, India. Mudenda *et al*. (2024a), however, found below-average growth coefficient values (K = 0.179) among *Petrocephalus wesselsi* in Lufupa river. The difference can be attributed to differences among species. 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}).

The growth performance index (Φ′) is a function of both the growth coefficient (K) and asymptotic length (L_∞) (Makeche *et al*., 2024b). The growth performance index is directly proportional to the growth coefficient but inversely proportional to the asymptotic length (Yongo and Outa, 2016). It is very important to determine the growth performance index in order to validate other growth parameters because the value of the growth performance index gives a good indication of the reliability of the estimated growth parameters (Panda *et al*., 2018). The results of the current research (Φ′ = 4.88 for Males, 4.91 for Females and 4.91 for combined sexes) are similar to those obtained by Mudenda *et al*. (2024b) among *Cherax qudricarinatus* (Φ′ = 4.6) and Nyirenda *et al*. (2024) among tilapiines (Φ′ ranged between 4.36 to 4.98). Makwelele (2017) (Φ′ = 2.7 to 2.85), Marufu *et al*. (2018) (Φ′ = 3.96) and Mukuka (2019) (Φ′ = 4.11) all obtained smaller growth performance values among *C. quadricarinatus* from the Kafue Floodplain Fishery, Lake Kariba and Zambezi River. The difference between the current results and those obtained by other researchers can be attributed to the difference in the study areas, the time of sampling and the type of species.

The Length-at-First sexual maturity (L_{50}) is very important for fish stock assessment because it gives an indication of the minimum permissible capture size (Hossain *et al*., 2019; Saha *et al*., 2021). It is affected by at least three factors: demographic structure, resource availability, and size selective predation (Belk, 1995). Different species have different L_{50} values (Nyirenda, 2017). L_{50} results of the current research from the Kwando river (Males = 164 cm and Females = 170 cm), agree with results found by Abujam (2011), who found that Male Spiny eels (L_{50} = 10.1cm) attain sexual maturity earlier than Females (L_{50} = 14-18 cm). Nyirenda (2017), however, found that Females attain sexual maturity earlier than Males.

This study showed that the Length-at-optimum yield (L_{opt}) for *B. lateralis* was 186 mm in the Kwando river. This study is thus the first effort to document the Length-at-optimum of *B. lateralis* in Zambian aquatic ecosystems. Consequently, it provides baseline information for additional research for fisheries biologists. Saha *et al*. (2021) found a smaller Length-at-optimum (L_{opt} = 60 mm) value among *Trichogaster ladius* while Abdul *et al*. (2019) (L_{opt} = 250 mm) found a larger value among *Sarotherodon galilaeus*, implying that L_{opt} values are species-dependent because the Length-at-optimum yield depends on the growth rate of species (Saha *et al*., 2021).

The longevity index results (T_{max}) of the current study (T_{max} = 1.91 years) are smaller than results obtained by Marufu *et al*. (2018) (Tmax = 4.17 years) and Mukuka (2019) (T_{max} = 4.11 years). These differences can be attributed to differences in habitat productivity and the species which were investigated. The current results are similar to those obtained by Nyirenda (2017) (T_{max} ranged from 1.23 years to 3.01 years) among *Oreochromis* fish species in Lake Kariba. These differences are expected because various species have different growth coefficients. Growth coefficients are also determined by nutrient availability (Abdul *et al*., 2019).

The natural mortality (M) results of the current study (M_w = 0.43 to 1.18yr^{-1}) are within the range of values found by Makwelele (2017) (M_w = 0.05 yr^{-1} to 0.8 y^{-1}) and Marufu *et al.* (2019) (M = 0.99 yr^{-1}) among *Cherax quadricarinatus* species from the Kafue Floodplain Fishery and Lake Kariba. The current natural mortality results are however, smaller than natural mortality results obtained by Mukuka (2019) (M_w = 1.45 yr^{-1}). Results of the current study are larger than those obtained by Makeche *et al*. (2024b) (Mw = 0.3) among *Petrocephalus wesselsi* in Lufupa River, Zambia. The fishing mortality (F = 0.49 yr^{-1} for combined data) results of this study are smaller than results obtained by Makwelele (2017) (F = 2.5 to 4.0yr^{-1}), Marufu *et al.* (2018) (F = 1.07 yr^{-1}) and Mukuka (2019) (F = 3.35 yr^{-1}). The exploitation ratios of *B. lateralis* obtained from the Kwando River (E = 0.293 yr^{-1} to 0.927 yr^{-1}) are within the range of results obtained by Marufu *et al.* (2018) (E = 0.52 yr -1) and Mukuka (2019) (E = 0.7yr -1) among *C. quadricarinatus* in Zambia. Makeche *et al*. (2020) also obtained similar exploitation ratios (E = 0.3 to 0.7) among *Oreochromis* fish species of the Kafue Floodplain Fishery.

5. Conclusion

Brycinus lateralis grows very fast in Kwando River, owing to the above-average growth coefficients. The fish species is under-exploited; although the fishing mortality is greater than the natural mortality in both sexes.

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