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Growth Parameters, Mortality Variables and Levels of Exploitation of *Petrocephalus Wesselsi* (Kramer and Van Der Bank, 2000) in Lufupa River, Zambia.

Mauris Chinyama Makeche[1], Gordon Hangoma Mudenda[2] and Geofrey Makwelele[3*]

[1]Institute of Basic and Biomedical Sciences, Levy Mwanawasa Medical University, Lusaka, Zambia.

[2]Department of Biological Sciences, School of Natural Sciences, University of Zambia, Lusaka, Zambia.

[3]Department of Biological Sciences, School of Mathematics and Science Education, Chalimbana University, Chongwe, Zambia.

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ABSTRACT

This study was aimed at documenting the growth parameters, mortality variables and levels of exploitation of *Petrocephalus wesselsi* in Lufupa River. It was the first study which was conducted on *P. wesselsi* in Lufupa River. *P. wesselsi* (n = 913) were collected along the course of Lufupa River, Zambia at Tree tops and at Mushingashi study sites in August, 2017. Fish samples were collected by Gillnetting using Trammel nets, 25 mm nets and 37 mm monofilament nets. The results showed that growth in *P. wesselsi* was sub-optimal (K = 0.179 to 0.289). The sampled fish showed a larger natural mortality (overall M = 0.27) than fishing mortality (overall F = 0.15). Overall data showed below-average levels of exploitation (E = 0.351). The study showed that the major cause of mortality among *P. wesselsi* in Lufupa River were natural causes, and the fish species is under-exploited.

Key words: *Petrocephalus wesselsi*, Lufupa River, growth, mortality, exploitation.

1. Introduction

Petrocephalus wesselsi is an Actinopterygii fish (ray-finned fish) which belongs to order Osteoglossiformes and family Mormyridae (Skelton, 2001). Family Mormyridae is characterized by small fishes (about 10 to 15cm Total length) which are mainly bottom River dwellers. Mormyrids live in groups and are rarely found in Lakes. Genus *Petrocephalus* differ from other members of family Mormyridae by having an orbitosphenoid, a basiphenoid, two nostrils which lay on opposite ends of the head and two single unsegmented and unbranched rays at the origin of the dorsal fin (Skelton, 2001). The major characteristics of fishes in family momyridae is the production and detection of weak electric organ discharges (EOD) which they use for object localization, group cohesion and communication (Kramer, 1996; Lavoue *et al*., 2004). These EODs are species-specific and they are used to morphologically characterize different taxa in genus *Petrocephalus* (Arnegard and Hopkins, 2003; Makeche *et al*., 2022). *P. wesselsi* is characterized by a forked caudal fin, a slender peduncle and a smooth round head. It differs from other mormyrids by lacking sexual polymorphism in the EOD (Skelton, 2001).

Accurate estimations of growth parameters and exploitation levels of fish stocks are very important in having a clue in a fish stock's longevity, Length-at-First Maturity, age at recruitment and growth (Abdul *et al*., 2019; Mudenda *et al*., 2024).

Mortality parameters are essential to the execution of sustainable management practices for improved conservation (Ahmed *et al*., 2020; Saha *et al*., 2021; Mudenda *et al*., 2024). Natural mortality is an important component which is used to estimate exploitation ratios of a fish stock in an aquatic habitat. An exploitation ratio which is less than 0.5 denotes under-exploitation while an exploitation ratio value above 0.5 depicts over-exploitation. A natural aquatic habitat is optimally exploited if its exploitation ratio is 0.5. In a natural water body, if the natural mortality is higher than the fishing mortality, this may denote that the fishery is dominated by small sized-individuals (juveniles) which are very susceptible to adverse environmental conditions (Ahmed *et al*., 2020; Makeche *et al*., 2020). A high fishing mortality relative to natural mortality denotes that a fishery has a mature fish stock which is vulnerable to the fishing gear (Apegyah *et al*., 2008; Ahmed *et al*., 2020).

The majority of studies on various aspects of fish Biology in Zambia have been conducted on large water bodies such as Lake Kariba (Makeche *et al*., 2022, 2023; Nyirenda *et al*., 2024), Kafue Floodplain Fishery (Chikopela *et al*., 2011; Makeche *et al*., 2020), Zambezi River (Mukuka, 2019) and Lake Tanganyika (Katongo, 2005; Bbole *et al*., 2023), while a few have been conducted on small water bodies (Katongo, 2005; Kabundula *et al*., 2023). This study was initiated to fill this gap of little knowledge on fish biology in small aquatic ecosystems and also to provide baseline information for further research to fisheries biologists. This research delivers the first effort to estimate growth parameters, mortality variables and levels of exploitation of *P. wesselsi* in Zambian waters. It will also allow for future comparisons between populations of the same species.

2. Materials and Methods

2.1 Study area and sampling

The Lufupa River has a total length of 38.83 Km and lies at an average elevation of 1, 095 m (openstreetmap.org). The Lufupa River usually floods in summer, during the rainy season, which promotes fish biodiversity. Collection of fish samples was done from the capture fishery at Lufupa River located between latitude -14°31'12'' S and longitude 26°10'37.2'' E in North-Western Province, Zambia (Fig. 1). The sampling points were Tree top (n = 615) (-17°33'20'' S; 26°15'55'' E) and Mushingashi (n = 298) (-17°52'36'' S; 26°32'61'' E). A total of 913 individuals of *P. wesselsi* were collected in August, 2017, using 25 mm and 37 mm monofilament gillnets. Additionally, Trammel nets of five different mesh sizes (16, 17, 18, 20 and 22 mm bar length) for the inner panel of 50 meshes high and one mesh size (100 mm) for the outer panel of 8.5 meshes high were used. For each collected specimen, total length (TL) and Fork length (FL) were recorded to the nearest 0.1 cm using a fish measuring body, 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 Lufupa River

2.2 Data analysis

2.2.1 Growth parameters

The growth coefficient (K) was estimated using the formular: $K = -\frac{1}{\Delta t}$ x ln b (Sparre and Venema, 1998); 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: $L_\infty = \frac{L\max}{0.95}$ (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: $\Phi' = \log_{10}(k) + 2\log_{10}(L_\infty)$, 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 (Lopt) was estimated using the formula (Pauly, 1984): $L_{opt} = L_\infty (3/(3+M/K)$; where M is the natural mortality. 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).

2.2.2 Mortality variables

The total mortality (Z) of *P. wesselsi* 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, L_m is the mean length of the catch samples, L_c 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 *P. wesselsi* 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.

2.23 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

3.2 Growth parameters

The growth coefficient (K) which was determined among the sampled fish ranged from a low of 0.179 to a high of 0.205 (Table 1). Male *P. wesselsi* showed a lower growth coefficient value (0.197) than Female *P. wesselsi* (0.205). The combined data showed a growth coefficient value of 0.179. all the growth coefficient values denoted a below-average growth rate.

The growth performance index was higher in Females (Φ′ = 4.48) than in Males (Φ′ = 3.39). The growth performance index value for combined data was 4.5 (Table 1). A comparison of growth performance indices is shown in Fig. 2.

Length-at-First-sexual Maturity (L_{50}) values ranged from a low of 57.1mm in Females to a high of 62.5mm in Males (Table 1). The combined data showed an L_{50} of 60.4mm. Longevity indices (T_{max}) (in months), ranged from a high of 16.8 months in the combined data to a low of 14.6 months among Female *P. wesselsi*. Male samples showed a longevity value of 15.2 months. The Length at maximum yield (L_{opt}) (Table 1) ranged from 65.5mm among Male samples to 80.4mm among Female samples. The combined data showed a L_{opt} value of 79.1mm. Asymptotic length (L_∞) values ranged from 116.8mm in Males to 118.9 in Females and the combined data.

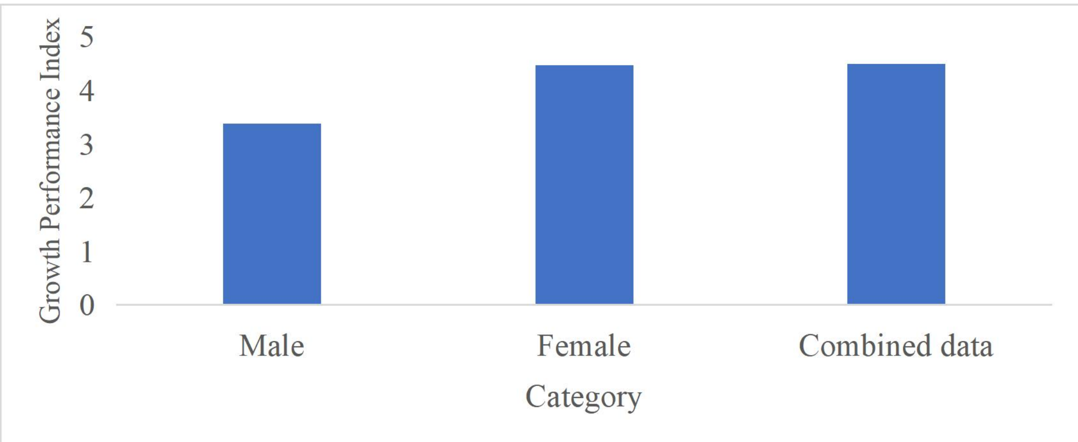

Fig. 2- Histogram comparing Growth performance indices of Males, Females and combined data of *Petrocephalus welsselsi* at Lufupa River.

3.2 Mortality variables

Natural mortality (M) variables ranged from a low of 0.27 in the combined data to a high of 0.295 among Female *P. wesselsi* samples (Table 1). Male *P. wesselsi* samples gave a natural mortality variable of 0.289. All the natural mortality variable were below-average.

Fishing mortality (F) variables ranged from a low of 0.226 among Male *P. wesselsi* to a high of 0.42 when all the sample stock was considered as one stock. Female *P. wesselsi* samples. gave a fishing mortality variable of 0.242 (Table 1). All the fishing mortality variable were below-average.

Total mortality (Z) variable ranged from a low of 0.426 in the combined data to a high of 0.525 among Female *P. wesselsi* samples. Male samples gave a total mortality variable of 0.515 (Table 1). All the total mortality variable were below-optimum (<0.5).

3.3 Levels of Exploitation

The levels of exploitation of *P. wesselsi* in Lufupa River were all sub-optimal (E < 0.5). The combined data gave the smallest level of exploitation (E = 0.351) seconded by Male *P. wesselsi* (E = 0.439). Female samples gave an exploitation ratio of 0.449 (Table 1).

Table 1 - Growth parameters, Mortality variables and Exploitation ratios of *Petrocephalus wesselsi* in Lufupa River.

	N	L_c	L_m	L_{max}	L_∞	L_{50}	T_{max}	L_{opt}	Φ′	K	M_w	F	Z	E
Male	192	69	82	111	116.8	62.3	15.2	65.5	3.39	0.197	0.289	0.226	0.515	0.439
Female	721	72	85	113	118.9	57.1	14.6	80.4	4.48	0.205	0.295	0.242	0.535	0.449
Total	913	69	84	113	118.9	60.4	16.8	79.1	4.50	0.179	0.27	0.146	0.416	0.351

N = sample size, L_c = smallest length in the sample (mm), L_m = sample mean length (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 months), L_{opt} = Length at maximum yield (mm), Φ′ = Growth performance index, K = growth rate, Mw = natural mortality, F = fishing mortality, Z = total mortality and E = Exploitation ratio.

4. Discussion

Existing research results on the population parameters of *P. wesselsi* is still very rare both in Zambia and Worldwide literature. Hence the current research was intended to describe growth parameters, mortality variables and exploitation ratios of *P. wesselsi* using many specimens of various sizes from Lufupa River, North-Western Province, Zambia.

Growth rate expresses how fast fish approaches its L_∞ indicating a direct relationship between the growth coefficient (K) and asymptotic length (L_∞) (Abdul *et al*., 2019). K is related to the longevity of the fish which, in turn, is related to mortality. Zhang and Megrey (2006) generalized that a long-lived fish approaches its limiting size relatively slowly, whereas short-lived fish grow rapidly. 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 (Male = 0.197, Female = 0.205, combined data = 0.179) indicate that *P. wesselsi* is a long-lived species. The results of the current research are in conformity with previous research by Makeche *et al*. (2020) on *Oreochromis niloticus* (K = 0.11) and Nyirenda *et al*. (2024) (K = 0.147 to 0.79) in Zambia but they differ significantly from those obtained by Hotos and Katselis (2011) on *C. planiceps* in Greece (K = 0.8) and Panda *et al*. (2018) among Mullets (K = 0.98) in Lake Chilika, India. Furthermore, Murugan *et al*. (2014) established that Male *Mugil cephalus* grow faster than Female species (Male K = $0.95yr^{-1}$; Female K = $0.82yr^{-1}$). The differences between the results of the current research and those obtained by Hotos and Kaselis (2011), Murugan *et al*. (2014) and Panda *et al*. (2018) can be attributed to differences among the studied species. Since the asymptotic length is a function of the maximum length (Sparre and Venema, 1998), it follows that the L_∞ values obtained are directly related to the maximum length. The L_∞ results of the current study (L_∞ = 119mm) were lower than those obtained by Hotos and Katselis (2011) (L_∞ = 315 mm), Murugan *et al*. (2014) (L_∞ = 546 mm), Panda *et al*. (2018) (L_∞ = 321 mm) and Nyirenda *et al*. (2024) (L_∞ = 350 mm to 458 mm).

The growth performance index (∅) is determined by K and L∞ and an increased K and reduced L∞ values result in a high ∅ value (Yongo and Outa, 2016). Determination of ∅ is one of the best ways to validate other growth parameters because the value of ∅ gives a good indication of the reliability of the estimated growth parameters (Sparre & Venema, 1998; Panda *et al*., 2018). The results of the current research are similar to those obtained by Mudenda *et al*. (2024) among *Cherax qudricarinatus* (∅ ranged between 4.3 to 4.4) and Nyirenda *et al*. (2024) among tilapiines (∅ ranged between 4.36 to 4.98). Yongo and Outa (2016) obtained smaller ∅ (3.14) among tilapiines in Kenya while Panda *et al*. (2018) also obtained smaller values (∅ values ranged between 2.9 to 3.5) among Mullets in Lake Chilika, India.

The size 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). This study showed that the L_{50} for *P. wesselsi* was 60.4 mm in Lufupa River. This study is thus the first effort to document the size at first sexual maturity of *P. wesselsi* in Zambian aquatic ecosystems. Consequently, it provides baseline information for additional research for fisheries biologists. The results of the current research, agree with results found by Nyirenda (2017) in

Zambia which showed that Females attain sexual maturity earlier than Males. The current results are also similar to results from Bangladesh (Saha *et al*., 2021) which showed that *Trichogaster ladius* attains sexual maturity at 60 mm. Abujam (2011), found that Male Spiny eels (L_{50} = 10.1cm) attain sexual maturity earlier than Females (L_{50} = 14-18 cm). Panda *et al.* (2018) found L_{50} values of 153, 149 and 256 mm for *Chelon parsia*, *C. planiceps* and *M. cephalus* in Lake Chilika, India. Differences among L_{50} values obtained by different researches can be attributed to gear selectivity, variation in mesh sizes of gear under operation in the sampling area and sampling period (Panda *et al*., 2018).

Length-at-optimum yield results (L_{opt} = 6.6 cm to 8 cm) of the current research are similar to the results of Saha *et al.* (2021) (L_{opt} = 6 cm) but lower than those of Abdul *et al.* (2019) (L_{opt} = 25.02 cm). The difference among the results of the three studies is attributed to differences in growth coefficients (K) among the studied species.

Longevity results (T_{max}) of the current study (T_{max} = 1.22 years to 1.4 years) are within the range of values found by Nyirenda (2017) from Lake Kariba, Zambia (T_{max} ranged from 1.23 years to 3.01 years). Abdul *et al.* (2019), however, obtained slightly higher values (T_{max} = 3.70 years). In another study, Apegyah *et al.* (2008) recorded a longevity value of 10 years in Bontanga reservoir Ghana. The difference between the present work and other studies is attributed to the different species studied and to differences in the K values among different species in different ecosystems, which have different levels of nutrient availability (Abdul *et al*., 2019).

Natural mortality results of the current study (M = 0.27 per year to 0.30 per year) are larger than natural mortality results obtained by Mudenda *et al.* (2024) among *Cherax quadricarinatus* from the Kafue Floodplain Fishery, Zambia (M = 0.01 to 0.1 per year). The current results are smaller than those obtained by Panda *et al.* (2018) (M = 0.73 $year^{-1}$) among mullets in India, Abdul *et al.* (2019) (M = 1.42 $year^{-1}$) among *Sarotherodon galilaeus* in Nigeria, Makeche *et al.* (2020) (M = 0.49 to 0.68 $year^{-1}$) among Mothbrooding tilapiines from the Kafue Floodplain Fishery, Zambia, and Saha *et al.* (2021) among *Tichogaster ladius* in Bangladesh. Fishing mortality results of the current study are similar to those obtained by Makeche et al. (2020) (F = 0.21 to 1.24 $year^{-1}$) but smaller than results obtained by Panda *et al*. (2018) (F = 1.18 $year^{-1}$) and Abdul *et al.* (2019) (F = 1.22 $year^{-1}$). The below-average levels of exploitation among *P. wesselsi* in Lufupa River are similar to other results obtained by Abdul *et al.* (2019) (E = 0.46). Panda *et al.* (2018) found above-average levels of exploitation among mullets (E = 0.60 to 0.66).

5. Conclusion

P. welsselsi is under-exploited and the major contribution to its mortality are natural causes. The findings of the current research baseline research results for the fishbase online database and a good framework for prospective research on this mormyrid and other related fish species in other riverine ecosystems.

6. Recommendations

Similar studies should be conducted in other aquatic habitats in order to have a basis for comparisons.

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