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Aspects of Reproductive Biology and Population Biology of *Petrocephalus wesselsi* (Kramer and van der Bank, 2000) in Lufupa River, Zambia.

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A B S T R A C T

This study was aimed at documenting some aspects of the reproductive biology, growth rates and Condition factors 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. Three distinct gonad maturity stages were identified (active, immature and inactive). The Male to Female ratio (1:4) was different from the expected ratio of 1:1. The size at first capture for the total population was estimated at 69 mm in total length. Longevity was estimated at 16.8 months for the total population (14.6 months for Females and 15.2 months for Males). Overall results showed that growth in P. wesselsi was sub-optimal (K = 0.179). The studied fish were all in good Condition (KF = 1.03).

Keywords: *Petrocephalus wesselsi,* Sex ratio, Condition factor, mortality, Lufupa River.

1. Introduction

Petrocephalus wesselsi is a fin-rayed fish which belongs to order family Mormyridae in the order Osteoglossiformes (Skelton, 2001). Mormyrids are small fishes (about 10 to 15cm total length) and they are mainly found in the hypolimnion of fast-flowing aquatic bodies. Genus *Petrocephalus* differ from other mormyrids 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 production and detection of weak electric organ discharges (EOD), which is used for object localization, group cohesion and communication is the major characteristics of fish in family momyridae (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. *P. wesselsi* differs from other mormyrids by having the same EOD in both sexes (Skelton, 2001).

Proper estimations of growth parameters of fish stocks are very important in having a clue in a fish stock's longevity, Length-at-First Maturity, maximum sustainable yield and growth (Abdul *et al*., 2019; Mudenda *et al*., 2024).

Length-weight studies are also important in estimating the average weight of a fish species at a given length group and in assessing the wellbeing of a fish population (Makeche *et al*., 2023). As a practical index of the condition of fish, length-weight relationships are used to determine the degree of wellbeing of individuals, known as the Condition factor (Dalu *et al*., 2013). The Condition factor is based on the hypothesis that heavier fish of a particular length are in a better physiological condition (Saha *et al*., 2021). Life history and morphological comparisons of fish populations provide a useful index for monitoring feeding intensity, age and growth rates in fish. Length and weight of fish are strongly influenced by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live and for further purposes of new stocking (Dalu *et al*., 2013).

The type of gonads found in a fish is related to the age of the fish. Young fish have small and immature gonads which are sexually inactive. Such fish are usually difficult to distinguish between sexes. As a fish grows, oocytes become distinguishable as gonads rapidly attain greater weight and size and testes assume a pale rose colour. Old fish have sexual products which have already been discharged, the genitalia appears inflamed and flaccid with residual oocytes, and sperm (Nikolsky, 1963).

Since the majority of studies on various aspects of fish Biology in Zambia have been conducted on large water bodies and mainly on breams 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 aimed at generating knowledge in fish biology from a small aquatic habitat and also to provide baseline information for further research to fisheries biologists.

2. Materials and Methods

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.

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 1). Stages of maturity of gonads were determined by macroscopic observations in both females and males.

Table 1- 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 Lufupa River

2.1 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 sampled fish specimens was calculated as a ratio of Males to Females according to Theocharis *et al*. (2023) = Number of Male/Number of Female.

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.

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 and Munro, 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 ($L\infty$)- 0.38 (Froese and Binohlam, 2000).

Condition factors

Based on the expression of Fulton (1904): $K = 100\times (W/L^3)$, where W is body weight (g), and L is Total Length (cm), Fulton's condition factor (K) was estimated. To obtain a Condition factor value close to unit, a scaling factor of 100 was used (Froese, 2006).

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.

Balance between population growth and mortality

The balance between population growth and mortality was assessed from the ratio of the total mortality to the growth coefficient (El Bouzidi *et al*., 2022): P = Z/K

Maximum Sustainable Yield

The Maximum Sustainable Yield (the length class at which the fish population can achieve its maximum sustainable yield, eumetric length), L_e was calculated according to Froese and Binohlam (2000): $L_e = 3L\infty/3+ M/K$

Results

Gonad maturity stages of *P. wesselsi* are shown in Fig. 2.

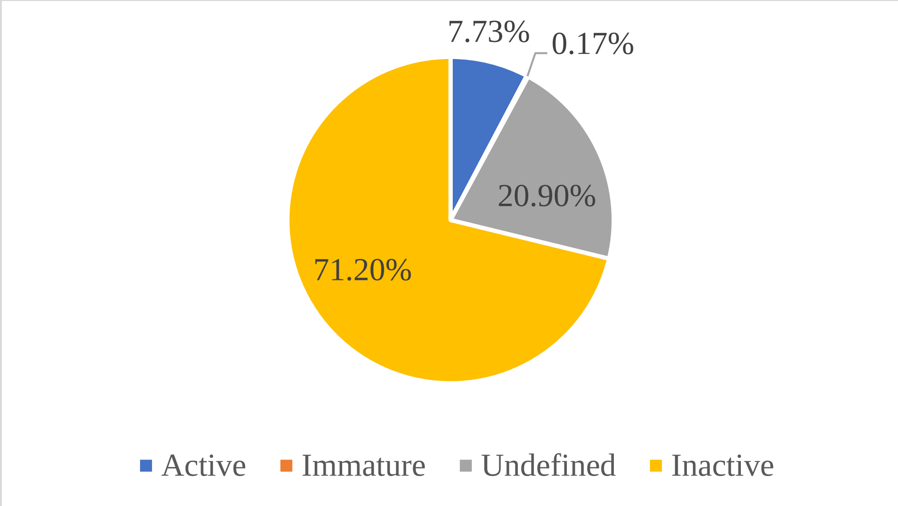

Fig. 2- Gonad maturity stages of *P. wesselsi* in Lufupa River.

Figure 2 shows that most sampled fish had inactive gonads (71.2%). A small proportion (7.73%) of sampled fish had active gonads. 20.9% of gonads could not be classified and there were very few young fish with immature gonads (0.17%).

The size at fisrt sexual maturity (L_{50}) ranged from a low of 57.1 mm among Female *P. wesselsi* to a high of 62.3 mm among Male *P. wesselsi*. The results showed that Females attained sexual maturity earlier than Males. The L_{50} for the total population was 60.4 mm (Table 2).

The sex ratio of the sampled *P. wesselsi* was 1: 4 (192 Males and 721 Females). Growth was sub-optimal among the sampled fish specimens (Figure 2). The growth rate (K) ranged from a high of 0.205 among Female specimens to a low of 0.197 among Male *P. wesselsi* (Fig. 3).

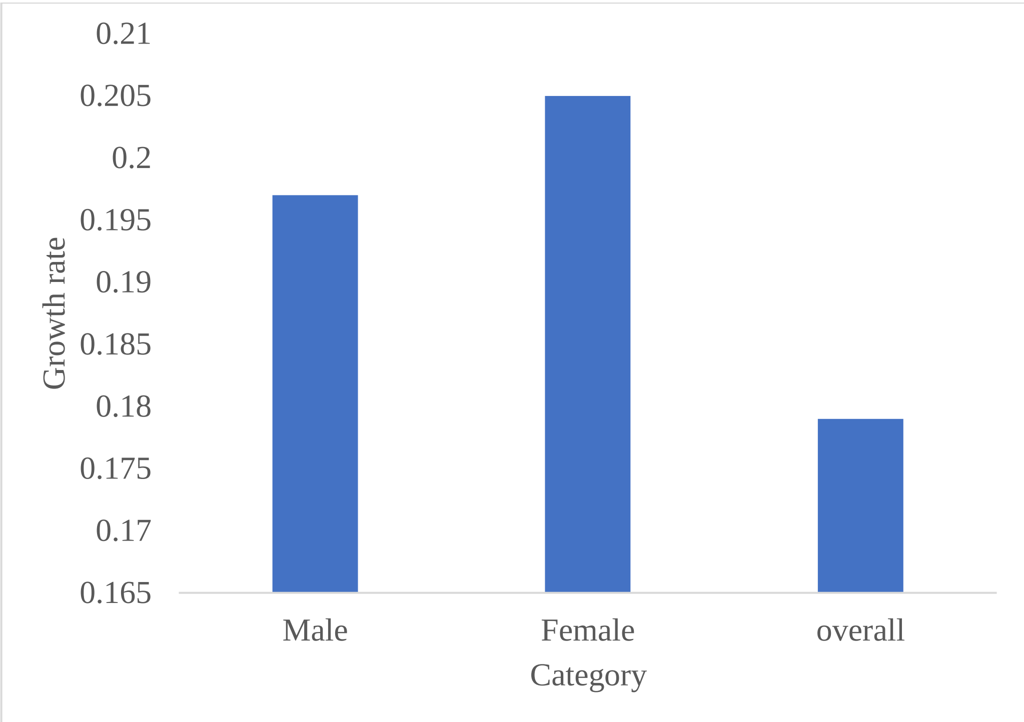

Fig. 3- Histogram of growth rates among *P. wesselsi* in Lufupa River.

Figure 3 shows that Females grew faster than Males. The overall growth rate among the sampled mormyrids was 0.179.

All the sampled fish species were in good condition ($K_F > 1.0$) (Table 2). Females were in better condition ($K_F = 1.02$) than Males ($K_F = 1.01$). The estimated Condition factor for combined sexes was 1.03.

The balance between population growth and mortality was skilled towards total mortality. Total mortality variables were larger than growth rate coefficients in both sexes. The overall balance between population growth and mortality (P) was 2.32 (Table 2).

The results showed that Male *P. wesselsi* could be optimally harvested at or above 65.5mm while Female samples could be optimally harvested at 80.4 mm. The length at maximum yield (L_{opt}) for combined data was 79.1 mm (Table 2).

Table 2- Growth parameters, Condition factors and Mortality variables of *P. wesselsi* in Lufupa River.

	N	L_c	L_m	L_{max}	L_∞	L_{50}	T_{max}	L_{opt}	K_F	K	M_w	F	Z	P	L_e
Male	192	69	82	111	116.8	62.3	15.2	65.5	1.01	0.197	0.289	0.226	0.515	2.61	78.4
Female	721	72	85	113	118.9	57.1	14.6	80.4	1.02	0.205	0.295	0.242	0.535	2.61	80.4
Total	913	69	84	113	118.9	60.4	16.8	79.1	1.03	0.179	0.27	0.146	0.416	2.32	79.1

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), K_F = Fulton's Condition factor, K = Growth rate, M_w = natural mortality, F = fishing mortality, P = balance between population growth and mortality, and L_e = Maximum sustainable yield.

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 *P. wesselsi* 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 (Immature, Inactive and Active) 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 Male length-at-first sexual maturity (L_{50}) results of the present study are comparable to those of Soykan *et al*. (2015) who found that Males attain sexual maturity later than Females. However, Kahraman *et al*. (2017) and Theocharis *et al*. (2023) found that Males attain sexual maturity earlier than Females. Variations L_{50} value are usually caused by phenotypic responses to environmental factors (competition, population distribution, habitat space, nutrient availability), fishing effort, which leads to overexploitation of fish stocks and lower spawning biomass (El Habouz *et al*., 2011; Carbonara *et al*.,2019). The observed difference between Males and Females with Males maturing in larger sizes compared to Females (62.3 mm versus 57.1 mm) could be attributed to the high fishing mortality among Females relative to Males (Table 2).

The absence of similar data on other growth parameters such as asymptotic length (L_∞), Length-at-First sexual maturity ((L_{50})), longevity index (T_{max}) and Length at maximum yield (L_{opt}) among *P. wesselsi* in Zambian aquatic habitats makes this study the first effort in documenting these parameters which will form a basis for future comparisons by fish biologists.

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*., 2024). The results of the present study show that *P. wesselsi* is in good condition in Lufupa River.

This study estimated below-average fishing mortalities ($F < 0.5$) among *P. wesselsi* signifying underfishing (Froese *et al*., 2008; Hossain *et al*., 2019). The calculated balance between population growth and mortality (Z/K ratio) was greater than the equilibrium ($Z/K = 1.0$). The above-average ($P > 1.0$) implies that mortality dominated growth among the sampled fish species. Similar results were also obtained by El Bouzidi *et al*. (2022) ($P = 4.97$) in Morocco and Theocharis *et al*. (2023) ($P = 7.81$) among *Merluccius merluccius* in Greece.

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

This study was aimed at assessing some aspects of the reproductive biology and population biology of *Petrocephalus wesselsi* in Lufupa River, Zambia. It was found that the fish was in good condition and it is underfished.

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