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Age, Morphology, Reproduction and Feeding Habits of Two Strains of *Auchenoglanis Occidentalis* (Valenciennes, 1840) from Lakes Bangweulu and Tanganyika, Zambia

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***Abstract*: Due to inadequate published information, this study addressed the knowledge gap in reproductive biology, feeding habits, and morphology of *Auchenoglanis occidentalis* in order to provide basic biological data for domestication in Zambia. One hundred and thirty two (132) fish were sampled from Lakes Bangweulu and Tanganyika in Zambia with males having total length of 390.5±11.0mm and 400.9±23.0mm respectively while females had total length of 380.55±52mm and 390.80±43mm. Total length was a significant ($p<0.05$) predictor of fecundity, gonadosomatic index, maturity and age with mean age of 1 year. The presence of Diptera insect larvae and blood worms (Chironomous midge) in the diets of this species suggests the need for a high protein formulated aquaculture diet. The higher absolute mean fecundity of 8066.3±926.3 than tilapias suggests the need for adequate facilities for incubating eggs. Results of this study show that the fish is a good species for domestication and brood stock from Lakes Tanganyika and Bangweulu are recommended for culture.**

***Keywords*: Auchenoglanis occidentalis, reproduction, morphology, age, feeding habits.**

1. Introduction

Zambia is blessed with abundant natural waters which support aquaculture and fisheries production as well as livelihood and nutrition. The country has close to 15,000,000 hectares of natural waters which supports production of fish from the wild, and rural inhabitants raise income through trade of this fish, (Kakwasha *et al.,* 2021). Published literature has shown that large scale fisheries like Lake Tanganyika, Lake Kariba, Lake Bangweulu and Zambezi River supply 40% of total catch consisting of *Clarias gariepinus* while in aquaculture *Orechromis andersonii* is mostly cultured (Ng'onga *et al*., 2019).

In Zambia, efforts are underway to culture some of the species that are declining in the wild but are preferred by consumers. One such species is *Auchenoglanis occidentalis* (Valenciennes 1840), commonly called Giraffe nosed catfish. *Auchenoglanis occidentalis* is also found in Egypt, Nigeria, Cameroon, Democratic Republic of Congo. In Zambia, it is found in Lake Bangweulu, Luapula River and Lake Tanganyika (Foster and Smith, 2005). *Auchenoglanis occidentalis* is part of Auchenoglanidae family, which comprises 2 species (Abobi *et al.,* 2019). The other species is *Auchenoglanis biscutatus* (Geoffroy Saint-Hilaire, 1809). *Auchenoglanis occidentalis* has a ratio of carbohydrate, lipid and protein contents of 1:3:4; the moisture is 74.6-78.04g/100g net weight, and the mineral content is high in calcium. Its flesh is fair quality, buttery, tasty and has good appearance (Edem and Opeh, 2018).

Despite *A. occidentalis* being one of the aquatic delicacies served in Zambia, there is little published information on this species in the country. Available information is mostly on description and taxonomy. Only Ghana and Nigeria have researched on reproductive biology (Shinkafi and Ipinjolu, 2012) and feeding habits of this species (Abobi *et al.,* 2019; Ikongbeh *et al.,* 2014). Kamilov *et al*., (2021) reported that in order to examine what remains to be studied a gap analysis should be done. The main objective of the present study was to address some information gaps of *Auchenoglanis occidentalis* and provide some of the fundamental biological characteristics, in particular, reproductive biology, age and feeding habits.

2. Materials and Methods

A. Study Area and Sampling of Fish

This investigation was done in Zambia on Lake Bangweulu (Chilomba and Kapoma village fishing camps) and Lake Tanganyika (Chipwa and Kapembwa fishing camps). One hundred and thirty two (132) fish with total length 260 to 660 mm were collected. *Auchenoglanis occidentalis* were identified in having a dorsal fin with 7 branched rays preceded by 2 spines, 3 barbels pairs, an anterior nostril on the upper lip, short snout, elongated body, body color brownish with large rounded brown spots. The adipose fin begins just behind the dorsal fin, while the pectoral fins with 9 branched rays are preceded by a

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strong spine, the pelvic fins are well developed, with 6 rays, 5 of them branched, while the anal fin is medium-sized, with 6 to 8 branched rays. The caudal fin is emarginated, meaning that it has a shallow notch at the tip (Froese and Pauly 2011). Fish specimens were analyzed at Ndola Central Hospital laboratory for growth and reproductive parameters.

B. Morphology and Body Weight

Total length, standard length and head length were measured with a meter rule while weight was measured with a weighing scale. This was done to determine the similarities of morphometric characters between population groups.

C. Analysis of Reproductive and Growth Parameters

Absolute fecundity was calculated following Valentin et al. (2015).

$$\text{Absolute Fecundity} = \frac{\text{No. of eggs in sub sample}}{\text{weight of sub sample}} \times \text{gonad weight}$$

Gonadosomatic index was calculated following Ekokotu and Olele (2014).

$$\text{Gonad somatic index (\%)} = \frac{\text{gonad weight G (g)}}{\text{weight of fish W (g)}} \times 100$$

D. Determination of Maturity Using Histology

Oocytes and testes were embedded in xylene-paraffin, pure paraffin, stained in haematoxylin and eosin and analyzed under a microscope for maturity. Fish having oocytes in the cortical alveoli stage indicated that they had started maturing. Testes had patches of germinative cells in different spermatogenesis stages. (Santos *et al*., 2001).

E. Age determination

The spines were fixed in Epoxy synthetic resin, and then cross-sectioned to 0.7 mm thickness with a low-speed saw and diamond blades. The sections were put on glass slides and observed under microscope. The translucent ring was the annulus equivalent to 1 year, (Rodriguez-marin *et al.,* 2014)

F. Determination of Feeding Habits

Large food items were identified using eye observation and small food items were examined under binocular microscope. Gut contents analysis was classified using keys as described by Abowei *et al.,* (2012).

G. Proximate Analysis of Stomach Content

Moisture analysis of stomach contents was done using hot air oven, while crude protein using (Kjedahl apparatus, N x 6.25), crude lipid (Soxhlet apparatus), ash (muffle furnace), total carbohydrate (Anthrone method), (Barua and Chakraborty, 2011).

H. Data Analysis

Two-way analysis of variance (ANOVA) compared means and established significant differences, Shapiro-Wilk test assessed normality and Fligner-Killeen test assessed homoschedasticity (Zar, 2010). Logistic regression was used for binary response while Poisson regressions was used for count data (Zar, 2010). Akaike information criterion (AIC) for model selection. R version 3.6 for all analysis (R Core Team, 2021). Significant tests at 5% level.

3. Results

A. Absolute Fecundity of the Two Fish

There were no significant differences (P=0.89) between the relative fecundity of the two strains. The main effect of strain on fecundity was not significant (P>0.05). The fecundity of the two fish was the same, (Table 1).

Table 1
Absolute fecundity of two strains

Strain	Absolute fecundity
Bangweulu	7921.2 ± 915.4
Tanganyika	8211.3 ± 937.5
p-value	0.9

B. Relationship of Absolute Fecundity with Weight and Standard Length of the Strains

There was a significant (p<0.001) effect of total length on fecundity. Total length could be used to predict fecundity. As the total length increased, the fecundity also increased. The best fit model was the reduced model with the least AIC of (929.3) which is a model between total length and fecundity (Table 2).

Fig. 1. Maturity of ovary left and maturity of testes right

Figure 1 shows sections of ovaries with different stages of maturity at the same time. The stages are differentiated by the presence of the following; Oogonia (Og), Primary oocyte (Po), Nucleus (nu), Yolk granule (yg), Post ovulatory follicle (pof), cortical alveoli (ca).

Table 2
Relationship between absolute fecundity, weight and total-length

Model Parameters	Full model	Reduced models	Reduced models	Reduced models
	Estimate ± Std error	Estimate ± Std error	Estimate ± Std error	Estimate ± Std error
Intercept	-9227.4 ± 3194.5**	-9280.4 ± 3078.1**	-9280.4 ± 3278.2**	-9280.4 ± 3278.2**
Total length	502.4 ± 86.9***	502.2 ± 85.8***	502.3 ± 84.7***	
Weight	784.3 ± 45.7***	784.3 ± 48.2***		782.9 ± 42.7***
Strain (Tanganyika)	-124.9 ± 1685.2			
AIC	931.2	929.9	929.3	929.3

Significant codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Fish having oocytes in the cortical alveoli stage indicated that they had started maturing.

Apart from that testes with different stages of maturity differentiated by the presence of the Spermatozoa (sz) in the middle of most of the tubules indicated that the fish had started maturing.

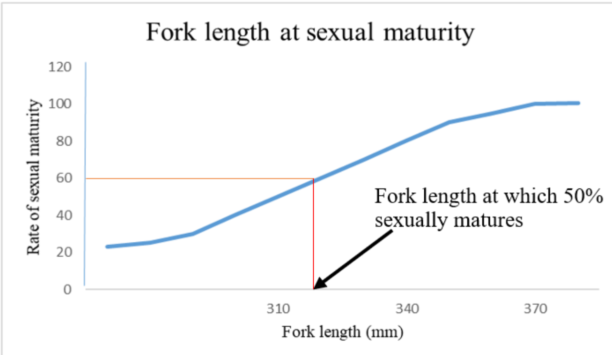

Fig. 2. Fork length at which 50% of fish reaches sexual maturity

C. Proximate Analysis of Stomach Contents of the Two Strains

There were no significant differences (P>0.05) between the proximate analysis of the nutrients in the stomach contents of the two strains (Table 3).

Total length and weight were significant predictors of age of *A. occidentalis*. (Table 4). Head length was not a predictor of age of *A. occidentalis*. Age of fish increases as total-length and weight increases. The best fit model is the reduced model with the least AIC of (-150.1) which is a model between age of fish and the total length and weight.

D. Age of Auchenoglanis Occidentalis

The interactive effect was not significant (P=0.95) between strain and sex on the age of *A. occidentalis* (Table 5). The main effects of strain and sex on age of *A. occidentalis* were also not significant. This shows that the ages of the two strains were similar

Table 5
Age, sex and strain

	Sex	Age (years)
Bangweulu	Females	1.00 ± 0.08
	Males	1.00 ± 0.06
Tanganyika	Females	1.00 ± 0.09
	Males	1.00 ± 0.10
p-value		0.95

4. Discussion

A. Relationship of Absolute Fecundity with Weight and Standard Length of the 2 Strains

In the current investigation the number of eggs was better predicted by weight and total length, there was a linear relationship among number of eggs, weight and standard length, an increase in fecundity was observed as weight and total length increased. This agrees with the findings of Jabed *et al.,* (2021) who observed an increase in the number of eggs with increase in total length and body weight for long whiskered catfish (*Sperata aor*). According to Shinkafi and Ipinjolu, (2012), in Nigeria, the relationship of number of eggs, total length and total weight of *A. occidentalis* was not significant (P>0.05). In the current investigation histological assessment revealed all ovaries and testes had immature and mature eggs and sperms indicating that the fish has asynchronous oocyte growth similar to results reported by Shinkafi and Ipinjolu, (2012) in Nigeria. Grande, (2013) also reported that a cluster of oocytes among the secondary growth stage is detached from neighboring group of oocytes, that progress into a new group.

B. Proximate Analysis of Stomach Contents of the Two Strains

There were no significant differences (P>0.05) in the number of worms eaten between both strains and sex. In the present study the fish consumed worms and insect larvae which show that this fish is carnivorous and it would be best to formulate a feed containing high protein which is required to build the muscle of this big late maturing fish. Barua and Chakraborty, (2011) in Iraq also found that stomach contents on Red bellied pacu fish (*Piaractus brachypomus)* consisted of 78.9±8.2% moisture, 69.1±13.5 crude protein, 13.3±8.3% crude lipid, 10.4±3.8% ash. Deepika *et al.,* (2018) reported that worms contain 30-50% crude protein. A study by Ikongbeh *et al.,* (2014) in Nigeria showed that *A. occidentalis* is mostly omnivorous and an adaptive generalist feeder, with strong insectivorous tendency.

C. Determinants of age of A. Occidentalis

Fork length could be used to predict maturity of *A. occidentalis* like in the current investigation mature eggs and sperms were observed in fish that was 310mm fork length and 1-year-old (12 months). This is similar to observations made by Kamilov *et al.,* (2021) in Uzbekistan were histological analysis

Table 3
Protein, fat, carbohydrate, ash, moisture of the two strains

Strain	Fat %	Protein %	Carbohydrate %	Ash %	Moisture %
Tanganyika	13.3 ± 1.5	55.5 ± 5.7	24.3 ± 4.5	13.6 ± 1.4	68.6 ± 6.7
Bangweulu	12.9 ± 1.4	52.3 ± 5.6	25.8 ± 4.2	13.1 ± 1.8	64.8 ± 6.6
P-Value	0.93	0.61	0.72	0.92	0.56

Table 4
Age and total length and weight relationship

Model Parameters	Full model	Reduced models				
	Estimate ± SE	Estimate ± SE	Estimate ± SE	Estimate ± SE	Estimate ± SE	Estimate ± SE
Intercept	-0.1 ± 0.1	-0.1 ± 0.1	-0.0 ± 0.0	0.0 ± 0.0	-0.0 ± 0.0	0.9 ± 0.0***
Standard length	0.0 ± 0.0***	0.0 ± 0.0***	0.0 ± 0.0***	0.0 ± 0.0***		
Weight	0.1 ± 0.0***	0.1 ± 0.0***	0.1 ± 0.0***		0.2 ± 0.0***	
Head length	-0.0 ± 0.0	-0.0 ± 0.0				0.1 ± 0.0
Strain-Tanganyika	0.0 ± 0.0					
AIC	-289.6	-288.9	-289.7	-150.1	-245.5	-270.7

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 and fork length were used to predict maturity of Gibel carp (*Carassius gibelio)*. In captivity, females Gibel carp matured in 2 years at 1-2 cm fork length and 2-3 cm in the river. Subir and Puchanan, (2018) reported that histological analysis revealed that the ovary contained yolky oocytes and testes contained spermatozoa when sampled in the 12 and 15 month suggesting that *Clarias gariepinus* attains sexual maturity after 1 year of its age and 35 cm total length to facilitate competency of breeding in successive years. This shows that total length and fork length can be used to predict maturity and age of *A. occidentalis*. Tapp, (2003) in Australia used general linear models to investigate age and also found similarities in age of *pangrus auratus* of different regions was similar, which is also similar to the present study.

5. Conclusion

In conclusion there were no significant differences (P>0.05) between the reproductive characteristics and diet. The fish is highly fecund and is asynchronous breeder. The fish sexually matures at 310mm fork length and 1 year of age in the wild.

Brood stock of 310mm fork length from the wild could be selected for reproduction. The presence of eggs at different stages shows that the fish is a multiple spawner within the breeding season and requires breeding facilities to induce spawning throughout the year to be available for extended periods. The significant proportions of blood worms and insect larvae in the diet of wild specimen indicate the need for aquaculture diets that are high in protein content. Further studies should be done to compare strains from rivers, as well as fish in captivity.

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