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ESTIMATION OF GROWTH, MORTALITY, AND EXPLOITATION STATUS OF NURSE TETRA (*Brycinus nurse*) AND TRUE BIG SCALE TETRA (*Brycinus macrolepidotus*) (FAMILY: ALESTIDAE) FROM THE NEW CALABAR RIVER, NIGERIA

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ABSTRACT

This study aimed to determine the growth patterns, mortality, and exploitation status of two species of Alestidae in the New Calabar River, Nigeria. For this purpose, fish samples were collected monthly from three landing sites from the local fishermen using gill nets (mesh sizes: 15-25mm), beach seine (mesh sizes: 2.3-10mm), and cast nets (mesh sizes: 15 -25mm). The length-weight relationship revealed exponent "b" value for *Brycinus nurse was* 3.54 and 3.21 for *Brycinus macrolepidotus* while the condition factors were 1.08 and 1.02 for *Brycinus nurse and Brycinus macrolepidotus* respectively. The growth parameters of *Brycinus nurse* asymptotic length (L_∞) and growth coefficient (K) were 24.46 cm and 0.52 $yr^{-1,}$ respectively, while those for *Brycinus macrolepidotus* L_∞ was 28.88 cm and K was 0.22 yr^{-1}. The reproductive load (L_{50}/L_∞) ratio was found to be 0.59 and 0.61 for *B. nurse* and *B. macrolepidotus,* respectively. Exploitation rate (E) for *B. nurse* was 0.26 and 0.11 for *B. macrolepidotus* while length-at-first capture (L_c) was 14.49 cm for *B. nurse* and 17.64 cm for *B. macrolepidotus*. The natural mortality was greater than the fishing mortality for both species and Logistic regression of the probability of capture routine values recorded for *B. nurse* were higher than that of *B. macrolepidotus*. Maximum exploitation rate (E_{max}) was less than 0.5 for both *B. nurse* (0.41) and *B. macrolepidotus* (0.42). These values were close to the maximum allowable limit; therefore, the species may be unsustainable when fishery intensifies in the future. To ensure sustainable exploitation of the two Alestid species in the area, fishing effort should be regulated.

Keywords: Alestid species; length-weigth relationship; reproductive load; demographic structure; Nigeria

INTRODUCTION

Alestidae has been described as the most speciose of all African characiform families (Paugy & Schaefer, 2007; Arroyave & Stiassny, 2011). About 118 valid species from family Alestidae greatly vary in body and fin sizes, shapes, and occupied ecological niches (Froese & Pauly, 2016). According to Froese & Pauly (2017), about 21 species spread across eight genera (*Alestes, Alestopetersius, Anorldichthys, Brycinus, Hydrocinus, Bryconaethiops, Micralestes,* and *Rhabdalestes*) have been found in Nigerian waters. Off the eight genera, the genus Brycinus is the most prevalent in Nigerian freshwaters with ten species. The genus *Brycinus* is characterized by presence of rudimentary adipose eyelids, and by having two rows of pluricuspid teeth on the upper jaw (Paugy, 2003). The exploitation history of Characidae from Nigerian waters, according to the NBS (2015), revealed that the annual catch of the characid species from 2010 to 2015 ranged between 14, 784 to 23,124 metric tons (mt), where 23,124 mt was the highest landing occurred in 2014 then decreased to 18,356 mt in 2015.

Brycinus macrolepidotus (Valenciennes, 1850) and *Brycinus nurse* (Rüppell, 1832**)** are native to freshwater systems in Africa thriving well in both lacustrine and riverine conditions (Boulenger, 2002), particularly in the Niger Delta, Nigeria. *Brycinus macrolepidotus* is easily identified by red marks on pectoral, ventral, and anal fins, the tip of adipose fins is reddish, the tail fin of *B. nurse* is bright red, other fins are tinged with red, and there is black patch on the tail peduncle (Adesulu & Sydenham, 2007). These species are said to be of commercial importance due to the fact that they are widely consumed locally and have food value (Reed *et al.,* 1967; Saliu & Fagade, 2004). Like other commercially important fish species in Nigerian inland

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waters, this fish family is currently subjected to intense fishing pressure due to lack of proper management policy. Since unregulated exploitation is still on there are urgent needs to monitor and assess the status of the stocks that are being fished.

Fish stock change depends on recruitment, natural mortality, individual growth, and harvesting. The growth parameters and the mortality rate are important tools to assess the exploitation level of the pelagic species (Wang & Liu, 2006). Length and weight data of fish can be used for the estimation of the length and age structures growth and mortality rates of the fish (Kohler *et al*., 1995) and the condition factor that may help determine whether somatic growth is isometric or allometric (Ricker, 1975). Relationship between length and weight is required for setting up yield equation (Beverton & Hold 1957; Ricker 1968).

The biological information on fish is of paramount importance for the development of effective strategies for their management and conservation. Information on population parameters, i.e., growth, reproduction, recruitment, as well as mortality of fish, is vital to the implementation of sustainable management strategies for their better conservation (Hossain *et al*., 2009). The present study was thus undertaken to estimate the key biological information on two most dominant Alestid species caught in the New Calabar River, Nigeria.

MATERIALS AND METHODS

The Niger Delta is crossed by many distributaries. Off these distributaries is the New Calabar River in the Niger River Delta, Nigeria. It is a partially mixed estuary river lies between latitude 4º252 N and longitude 7º162 E (Olopade *et al.,* 2018). It runs through the most densely populated areas in the hinterland and empties into the Atlantic Ocean at the southern tip of Bonny in the south. The river has high water volume during rainy season due to high runoff. The main rainy season is from April to September with the annual rainfall between 2000 and 3000 mm (Abowei & Hart, 2009). Rainfall is generally negligible in December and February.

Three non-overlapping landing sites were selected along the New Calabar River, namely Choba, Aluu, and Ogbogoro (Figure 1) to provide a representative overview of the fisheries in the river. The fish samples were also collected monthly from three landing sites from the local fishermen using gill nets (mesh sizes: 15-25 mm), beach seine (mesh sizes: 2.3-10 mm), and cast nets (mesh sizes: 15 -25 mm). The fish species were identified using fish identification keys (Paugy, 2003; Adesulu & Sydenham, 2007). Total length, standard length, and weight of the fish species were measured in centimeters and grams, respectively.

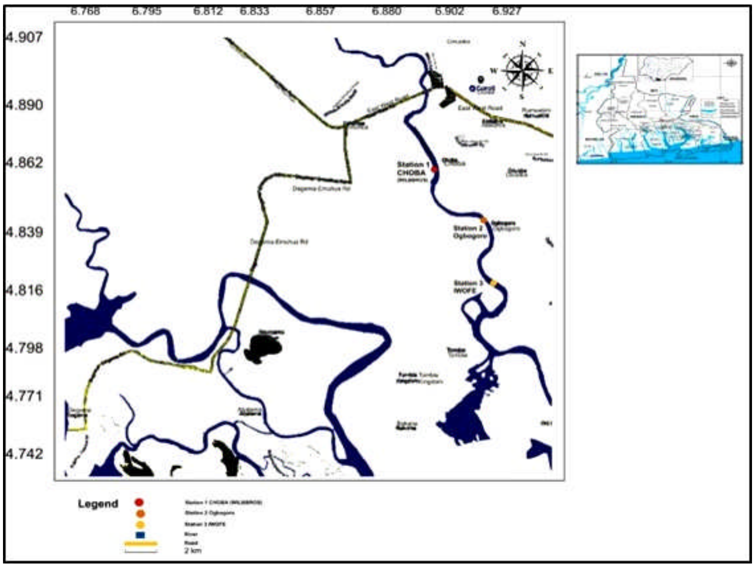

Figure 1. Map Showing New Calabar River, Rivers State Nigeria.

Data Analysis

The length-weight relationship is expressed by the equation $W = aL^b$, where W = Body weight (g), and L = Total length (cm), Ricker (1973) as follows:

$$\text{Log } W = a + b \log L \quad \dots\dots (1)$$

The value of the growth exponent was used to calculate the condition factor using the formula:

$$K = 100\, W / L^b \quad \dots\dots (2)$$

Where;
K = condition factor

W = total body weight (g)
L = Total length (cm) and
b = growth exponent

The length-frequency data for each species were collected monthly from the different sampling sites and subsequently grouped into class intervals for analysis. The data was analyzed using FiSAT II (FAO-ICLARM Stock Assessment Tools) as explained in detail by (Gayanilo *et al.,* 2005).

The von Bertalanffy growth parameters (Pauly, 1980), L_∞ and annual growth coefficient K were computed by ELEFAN I (Electronic Length Frequency Analysis) (Beverton & Holt, 1966). The total mortality rate (Z) was estimated by length-converted catch curve (Pauly, 1984). The natural mortality rate (*M*) was also calculated by using Pauly's empirical formula (Pauly, 1980). The fishing mortality rate (*F*) was calculated by the difference between (*Z*) and (*M*) or

F= Z-M ………………………………………….. (3)

The rate of exploitation (E) was calculated by the quotient between fishing and total mortality (Pauly, 1984):

E = F/Z ………………………………………….. (4)

Relative yield per recruit (*Y'/R*) was estimated using the model of Beverton & Holt (Beverton & Holt, 1966) as modified by Pauly & Soriano (1986) and incorporated in the FiSAT software.

Resource status was evaluated by comparing estimates of the fishing mortality rate with a target (F_{opt}) and limit (F_{limit}) biological reference points (BRP) which were defined as F_{opt} = 0.5M and F_{limit} = 2/3M (Patterson, 1992).

Probability of capture against mid-length a resultant curve was used to compute the length at first capture (Lc50). The length at first maturity (Lm50) was estimated as Lm50 = (2 * L_∞)/ 3 (Hoggarth *et al*., 2006)

RESULTS AND DISCUSSION
Results

A total of 196 individuals Alestid species belong to two species, namely *B. macrolepidotus* and *B. nurse,* were analyzed during this study. Brycinus *nurse* occurred in considerable number (64.3%) more than *B. macrolepidotus* with 35.7% (Table 1).

Table 1. Species composition by number from all types of gears

Species	Beach seine	Cast net	Gillnet	N	Percentage (%)
B. macrolepidotus	29	23	18	70	35.7
B.nurse	53	27	46	126	64.3
Total	82	50	64	196	100

The mean total lengths were estimated to be 15.08±0.37 and 14.58±0.25 cm for *B. macrolepidotus* and *B. nurse,* respectively. The mean weight for *B. macrolepidotus* was estimated as 40.00±3.57 g, whereas it was 39.44±2.73 g for *B. nurse* (Table 2). The length-weight relationship results revealed exponent of (b) values of 3.2103 and 3.5405 for *B. macrolepidotus* and *B. nurse,* respectively (Table 2, Fig. 2 and 3). Also the correlation value (r) for the two species were estimated as 0.8868 and 0.8853, respectively. The mean value for condition factor (K) recorded for *B. macrolepidotus was* 1.02± 0.03, and *B. nurse* had the value of 1.08± 0.02 (Table 3).

Table 2. Total length, standard length and Mean weight of Alestid species from New Calabar River landed by all type of fishing gears

Species	**TL (cm)**		**SL(cm)**		**WEIGHT (g)**		**GIRTH (cm)**	
	Mean±SE	Range	Mean± SE	Range	Mean± SE	Range	Mean± SE	Range
B. macrolepidotus	5.08±0.37	11.50 - 27.00	11.88±0.30	8.70 - 22.30	40.00±3.57	10.00 - 160.00	8.80±0.25	6.00 - 15.30
Brycinus nurse	14.58±0.25	7.30 - 23.00	11.49±0.20	5.50 - 18.60	39.44±2.73	5.00 - 210.00	8.80±0.19	2.50 - 16.50

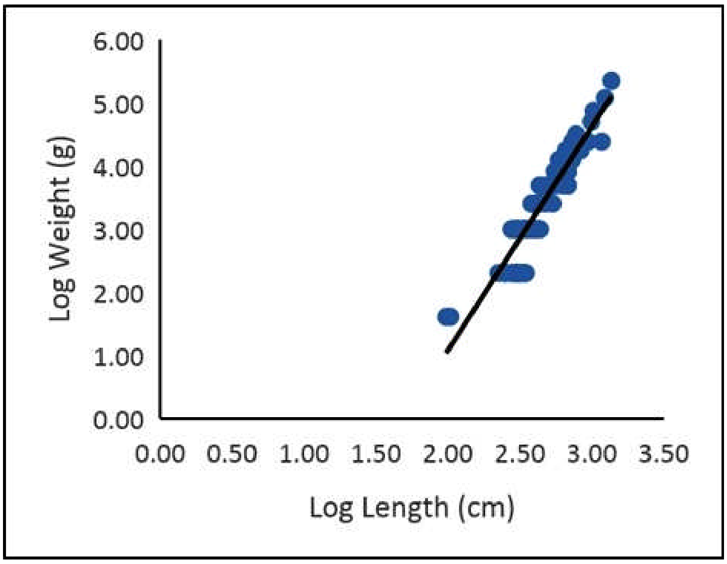

Figure 2. Length-weight relationship of *B. macrolepidotus* in the New Calabar River.

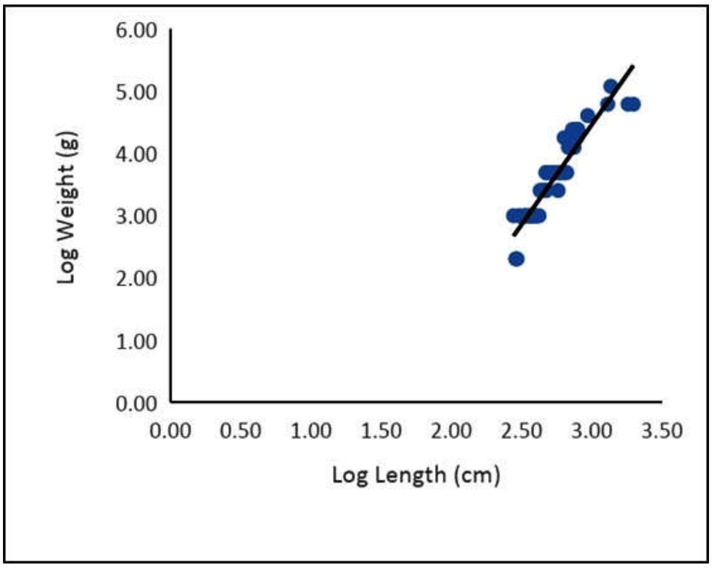

Figure 3. Length-weight relationship of *B. nurse* in the New Calabar River.

Table 3. Condition factors and growth patterns of two Alestid species in the New Calabar River

Species	**K**		**a**	**b**	**r^2**
	Mean	Range			
B. macrolepidotus	1.02±0.03	0.61 - 1.56	-5.1712	3.2103	0.8868
B. nurse	1.08±0.02	0.49 - 1.73	-5.9999	3.5405	0.8853

The growth parameters estimated for *B. nurse* using the length frequency data in ELEFAN I program revealed the best fit for L_∞ = 24.46 cm and k = 0.52 per year while for *B. macrolepidotus*, the best fit were for L_∞ =28.88 cm and k = 0.22 per year (Table 4). The total mortality (Z) of *B. nurse* estimated by the length converted catch curve was 1.88 for *B. nurse* while it was 0.77 for *B. macrolepidotus*. The natural mortality (M / year) as per Pauly's empirical formula was found to be 1.05 for *B. nurse* while it was 0.69 for *B. macrolepidotus*. The estimated fishing mortality (Z-M=F) stood at 0.83 and 0.77 while the exploitation ratio (E) was found to be 0.26 and 0.11 for *B. nurse* and *B. macrolepidotus,* respectively (Table 4).

The logistic regression of the probability of capture routine values recorded for *B. nurse* was lower than that of *B. macrolepidotus* (Table 5, Fig 4 and 5). The estimated L_{50} was 14.49 cm for B. nurse and 17.64 cm for *B. macrolepidotus*. The L_{25} was calculated as

12.88 cm and 15.13 cm while L_{75} was found to be 16.10 cm and 20.16 cm for both species, respectively. In this study, the reproductive load (L_{50}/L_{∞}) ratio was found to be 0.59 and 0.61 for *B. nurse* and *B. macrolepidotus,* respectively.

Table 4. Population parameters of *B. nurse* and *B. macrolepidotus*

Von Bertalanffy's Growth parameters	***B. nurse***	***B. macrolepidotus***
Asymptotic length (L_{∞})	24.46	28.88
Growth coefficient (k)	0.52	0.22
t_0 (yr)	0.04	0.07
Total mortality (Z)	0.83	0.77
Fishing mortality (F)	0.22	0.08
Natural mortality (M)	1.05	0.69
Exploitation rate (E)	0.26	0.11

Table 5. Length at capture of *B. nurse* and *B. macrolepidotus*

Length at capture	*B. nurse*	*B. macrolepidotus*
L_{25}	12.88 cm	15.13 cm
L_{50}	14.49 cm	17.64 cm
L_{75}	16.10 cm	20.16 cm

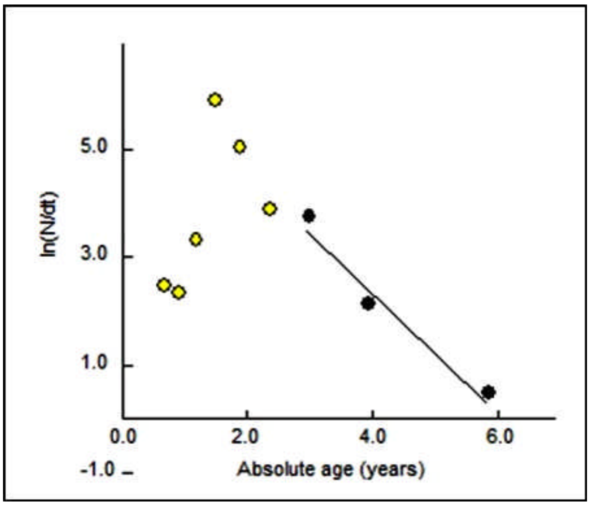

Figure 4. Length converted catch curves of *B.nurse.*

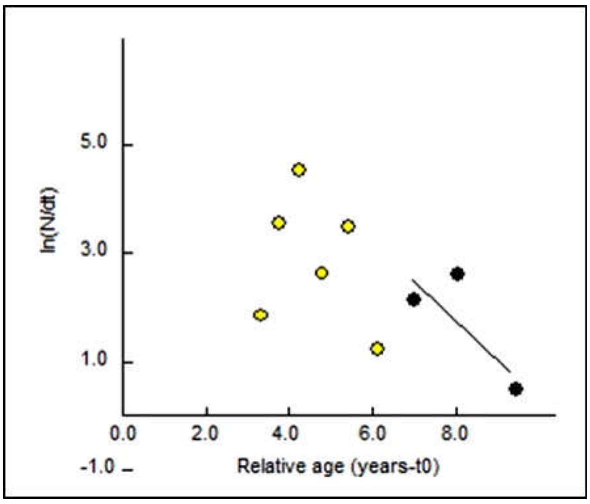

Figure 5. Length converted catch curves of *B. macrolepidotus.*

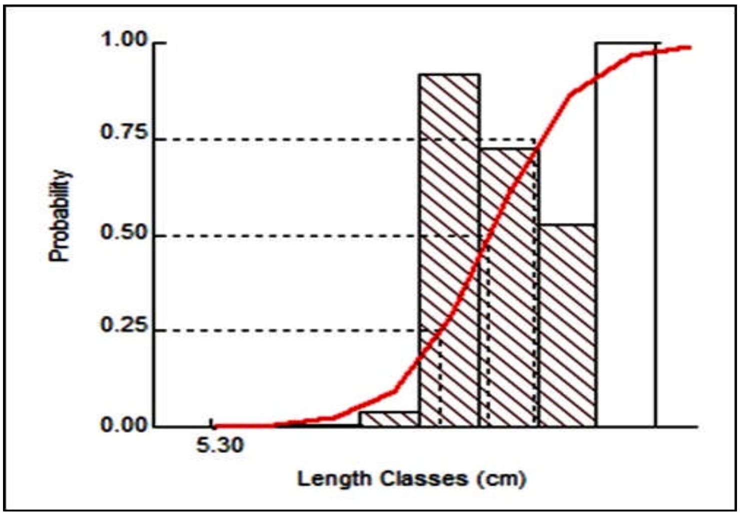

Figure 6. Length at first capture (L_{50}) for *B. nurse.*

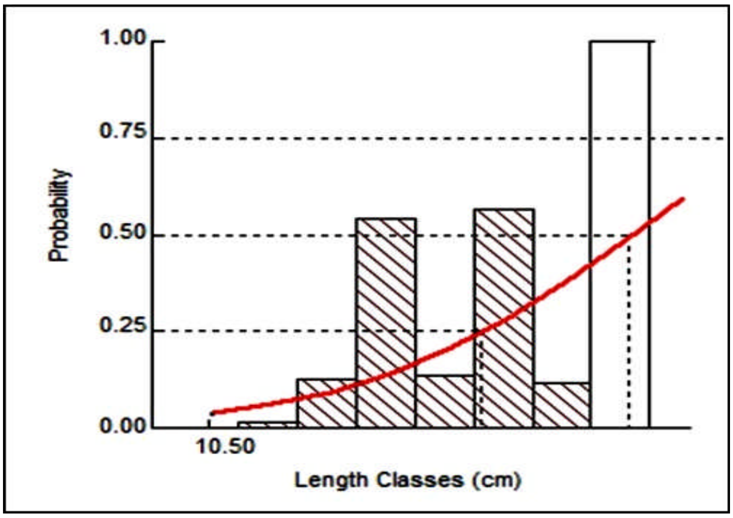

Figure 7. Length at first capture (L_{50}) for *B. macrolepidotus.*

The Beverton-Holt relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were estimated using selective Ogive procedure of FiSAT. The analysis indicated that the exploitation rate, which maximises yield per recruit, produced values of E_{max} = 0.41, 0.42; E_{10} = 0.36, 0.36 and E_{50} = 0.28, 0.29 for *B.nurse* and *B. macrolepidotus,* respectively (Figs 7 & 8).

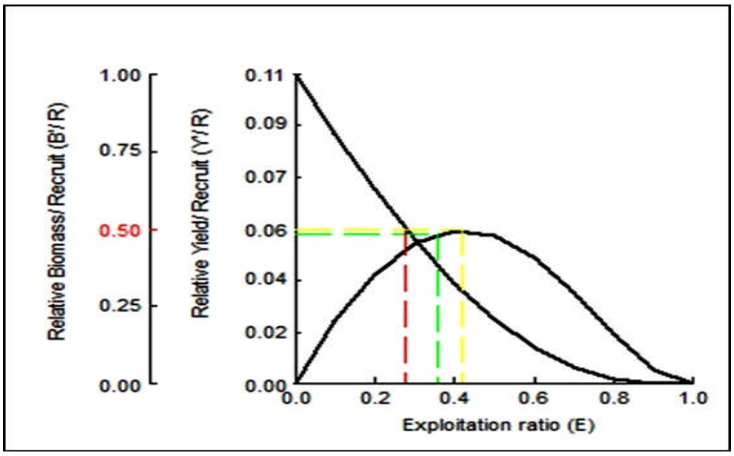

Figure 8. Stock status of *B. nurse* using Beverten and Holt's relative Y/R analysis.

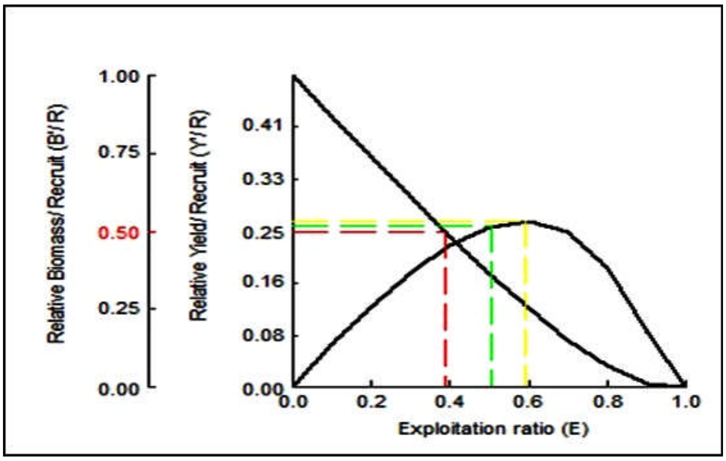

Figure 9. Stock status of *B. macrolepidotus* using Beverten and Holt's relative Y/R analysis.

Discussion

The calculated 'b' values of the LWRs, which were 3.2103 for *B. macrolepidotus* and 3.5405 for *B. nurse,* indicate positive allometric growth. The values fall within the acceptable range of 2.5 and 3.5, which is typical for tropical fish stocks (Carlander, 1969; Froese, 2006). Gopakumar *et al.* (1991) opined that higher b values imply a relatively productive environment. Positive allometric growth implies that the fish grows faster in weight than in length. A similar observation was also reported in *B. nurse* (3.0737) from the White Volta River in Ghana (Abobi & Ekau, 2013). Echi & Ezenwaji (2016) reported contrasting findings for *B. macrolepidotus* from the Anambra River, Nigeria with the males and females showed negative allometric growth (2.309 and 2.734, respectively); in the same vein, the other Alestid species reported in the study, such as *Alestes baremoze, B. leuciscus,* and *Hydrocynus vitttatus,* showed negative allometric growth for their respective male and female. The slight difference in the exponent 'b' values recorded could be associated with several factors, such as temperature, salinity, adequate food, seasonal changes, environmental conditions, sampling procedure, and sexual dimorphism.

The condition factor "K" of a fish can be defined as a measurement of the general health condition of the fish as calculated by the ratio of body weight to body length. This factor implies that whatever is able to affect the weight of fish will definitely affect the K values. Adesulu & Sydenham (2007) reported that condition factor in fish is mainly affected by the amount of food in stomach and stage of egg development that will affect the weight of the body and then the weight of fish is a function of condition factor in fish. The "K" values of the two Alestid species in this study indicate that the population is in moderate growth condition as "K" values are slightly greater than 1. This factor implies that the fishes thrive well in the habitat (Komolafe & Arawomo, 2011). The condition factor for *B. longipinnis* was reported to range 1.94-2.80 in Ikomi & Sikoki (2003).

The asymptotic length (L_∞) is the largest theoretical mean length that a fish could attain in its natural habitat, assuming the fish grows throughout its life (Abobi & Ekau, 2013); while the growth curvature (K) is the rate at which it grows towards this final size (Etim *et al.,*1999). In the present study, *B. nurse* had an asymptotic length (L_∞) of 24.46 cm, growth curvature (k) of 0.52 per year, and t_0 (per year) of 0.04 while *B. macrolepidotus* had L_∞ of 28.88 cm, k of 0.22 per year, and t_0 (per year) of 0.07 (Table 4). These results indicate that both species are fast-growing.

The total mortality (Z), natural mortality (M / year), fishing mortality (F), and exploitation rate (E) of *B. nurse* were found to be 1.88, 1.05, 0.83 and 0.26, respectively; while for *B. macrolepidotus* it was 0.77, 0.69, 0.08 and 0.11, respectively. Values of Z, M, and F were higher for *B. nurse* than for *B. macrolepidotus;* however, since natural mortality (M) exceeded fishing mortality (F) for both species, the stock is not over-exploited. The exploitation rate (E) of *B. nurse was* 0.26. Based on the assumption that a stock is optimally exploited when F=M or E=0.5 (Gulland, 1971). The results of the present study indicate that the current exploitation rate is close to the maximum level of 0.5. The low value of E in the two species in this finding suggests that levels of exploitation may be increased in order to reduce waste of stock through natural mortality; however, caution must be taken to avoid what can be called a skewed exploitation situation (Chukwu & Deekae, 2010). Ahmad *et al.* (2018) reported lower values of Z (1.31), M (1.0), F (0.31), and E (0.24) for *B. nurse* from the Challawa Gorge dam, Kano. Higher values of the fore mentioned parameters were observed for *B. nurse* by Kwarfo-

Apegyah *et al.* (2009) and Uneke & Nwani (2013), respectively; Z = 2.54 and 3.34; M=1.3 and 1.80; F=1.24 and 1.54; and E=0.49 and 0.46. However, the relatively lower values of E in these studies indicate that the stocks were also not over-exploited.

The result of this study showed the estimated length at first capture (L_c) of both *Brycinus* species to be 14.49 and 17.64 cm for *B. nurse and B. macrolepidotus,* respectively. The L_c value recorded in this study falls within the range of the total length 7.30 to 23.00 cm for *B. nurse* and 11.50-27.00 cm for *B. macrolepidotus*. A lower value of L_c (7.58) was recorded for *B. nurse* by Ahmad *et al.* (2018). Uneke and Nwani (2013) found the L_c for *B. nurse* in Cross River to be 8.83 while Kwarfo-Apegyah (2008) found the L_c for *B. nurse* in Bontanga Reservoir (Northern Region of Ghana) to be 10.94.

The predicted E_{max} of the Selective Ogive procedure for *B. nurse* and *B. macrolepidotus* (0.41 and 0.42, respectively) were higher than their respective current exploitation rates E (0.28 and 0.29) showing that both *Brycinus* species were not over-exploited. Uneke & Nwani (2013) and Kwarfo-Apegyah *et al*. (2009) reported the E of *B. nurse* to be 0.46 and 0.49, respectively; both values are higher than the value of E estimated for the two Alestid species in this study. Values of E_{max}, E_{50}, and E for *B.nurse* in the Challawa Gorge dam, Kano, were reported by Ahmad *et al.* (2018) as 0.65, 0.2, and 0.24, respectively.

CONCLUSIONS

The present study provides some important baseline information on the growth and population of two commercially important fish species from the family Alestidae that will help in the development of efficient management strategies. The length-at-first capture (L_c) of *B. macrolepidotus* estimated in this study showed that this species was caught at very small sizes concerning the use of small mesh size nets, such as 2.3 mm and 15 mm. Natural mortality was greater than the fishing mortality for both *B. nurse* and *B. macrolepidotus* while exploitation rate (E) was less than 0.5 for both species. Even though the difference between biological reference point and fishing mortality is small, it would be better for the well-being of fishery to introduce some fishery regulation measures.

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