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Morphometric Analysis and Length-Weight Relationships of *Arnoldichthys spilopterus* and *Raiamas senegalensis* in a Tropical Man-Made Lake, Northeastern Nigeria

Olanrewaju Adewale Nurudeen, Ebenezer Samuel, Umar Abubakar and Shehu Adam

Department of Fisheries Technology, Federal College of Freshwater Fisheries Technology, P.M.B. 1060, Maiduguri, Nigeria

ABSTRACT

Background and Objective: The knowledge of growth variations, population structure, and condition of endemic fish populations offers valuable information in their conservation and management for sustainable use. This study, thus, investigates the morphometry and length-weight relationships of two indigenous ornamental fish, *Arnoldichthys spilopterus* and *Raiamas senegalensis*, in Lake Alau. **Materials and Methods:** Fifty specimens each of *A. spilopterus* and *R. senegalensis* were caught, weighed, and nine morphometric features were examined. Length-weight relationships and condition factors were calculated for each species following standard methods. Data collected were analyzed using descriptive statistics, linear regression, and correlation analysis. **Results:** The sampled fish had a mean size of 12.66±3.07 cm (33.06±16.81 g) in *A. spilopterus* and 12.65±1.55 cm (17.68±8.62 g) for *R. senegalensis*. Results indicate a significant positive correlation between morphometric characteristics and varying degrees of interdependence with total length in both species. The regression coefficient "b" value of *A. spilopterus* population (2.49) shows negative allometric growth, while *R. senegalensis* (3.33) showed positive allometric growth. The condition factor varied from 0.82±0.09 in *R. senegalensis* to 1.54±0.36 in *A. spilopterus*, indicative that the latter fares better than the former in the Lake. **Conclusion:** The findings suggest that the habitat provides optimal growth conditions for these species, but certain environmental factors might be responsible for the low condition factor in Silver fish.

KEYWORDS

Ornamental fish, morphometric features, length-weight relationship, condition factor, Lake Alau

INTRODUCTION

Small-scale fisheries (SSF), often called artisanal fisheries, have been an age-old activity globally. It accounts for at least 40% of the global catch from capture fisheries, which are relied upon by almost 200 million people for their livelihood[1]. It contributes significantly to local food and nutrition security and livelihoods, particularly in developing countries like Nigeria. In Nigeria, SSF is the dominant source of local fish production, which offers opportunities for sustainable development and food security. It produced

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over 74.09% of Nigeria domestic fish production from mainly coastal, inshore, creeks of the Niger Delta, lagoons, inland rivers and lakes[2]. There are over 300 fish species domiciled in Nigeria's inland waters to the relish of her people, especially the riverine communities[3]. Among these species are fish food and ornamental fish. The ever-increasing human population, along with its attendant industrialization, has brought about direct pressure on these fish fauna through overfishing and pollution[4]. This, however, calls for a proper understanding of the growth and condition of the fisheries for effective management techniques towards sustainable exploitation.

Arnoldichthys spilopterus (Niger Tetra) and *Raiamas senegalensis* (Silver fish) are valued endemic freshwater fish species in the Nigerian freshwater living in shoals naturally found in mid-depth and near surface. Niger Tetra belongs to the family Alestiidae of the order Characiforms, and it is monospecific. This species is a popular indigenous ornamental fish, which is currently classified as endangered by IUCN[5]. Silver fish is, however, a species of freshwater ray-finned fish belonging to the family Danionidae and order Cypriniformes. There is a report of acute reduction in the number of this species due to over-exploitation by indigenous fishers who destroy the habitat and fishery resources[6]. These two species are omnivorous with carnivorous tendencies, and they are typically small with colourful bodies; thus, they are popular indigenous ornamental fish. These fish are not typically considered food fish, but they are widely consumed by Nigerians, especially in Riparian communities. The species are among the major catches of fishermen in Lake Alau, and there is concern over their rate of exploitation, which necessitates this study. Moreso, the biological parameters of these fish species from Lake Alau were rarely studied and reported, particularly for Niger Tetra. Thus, in-depth information on growth patterns and conditions of these fish is fundamental for their sustainable management in Lake Alau, Nigeria.

Fish stock assessment seems indeterminate without sufficient consideration of fish growth and condition of living in their environment. According to Abowei and Davies[7], fish show fluctuation due to numerous factors such as environmental conditions, food composition, competition within food chain, and physical and chemical properties of the aquatic ecosystem. The study of growth patterns in fish has been based mainly on the length-weight relationship to provide information on species status in an environment and characterize patterns of growth. The knowledge of length-weight relationships of fish is essential for successful development, management, production, and ultimate conservation. Kazeem and Olanrewaju[3] further noted that the interplay between environmental factors and fish morphology in freshwater systems is vital for predicting how these species will adapt to changing conditions.

Past reports on the growth patterns and ecology of fish species in Lake Alau mainly focus on food fish[8-10], leaving gaps in small-sized fish species of the ornamental trade. The present study, thus, aims to give useful information on morphometry, length-weight relationship, and condition of Niger Tetra and Silver fish in Lake Alau, due to their important contribution to the aquarium trade.

MATERIALS AND METHODS

Study area: The study was conducted at Lake Alau, Borno State, Nigeria (Fig. 1). It lies in the Northeastern side of Nigeria at Longitude 11°39'84"-11°40'02"N and Latitude 13°39'92"-13°40'12"E with a total surface area of about 56 km^2. The Lake was built in the late 1980s primarily for the provision of potable water but has since sustained a thriving artisanal fisheries activity[11].

Fish collection: Fifty specimens each of *Arnoldichthys spilopterus* and *Raiamas senegalensis* were randomly collected from fishermen's catch upon returning from a fishing trip. This is to ensure that fresh specimens were used in the study. Samples were collected monthly for three months during September to November, 2024 and were identified by the standard key of Ajagbe *et al.*[12].

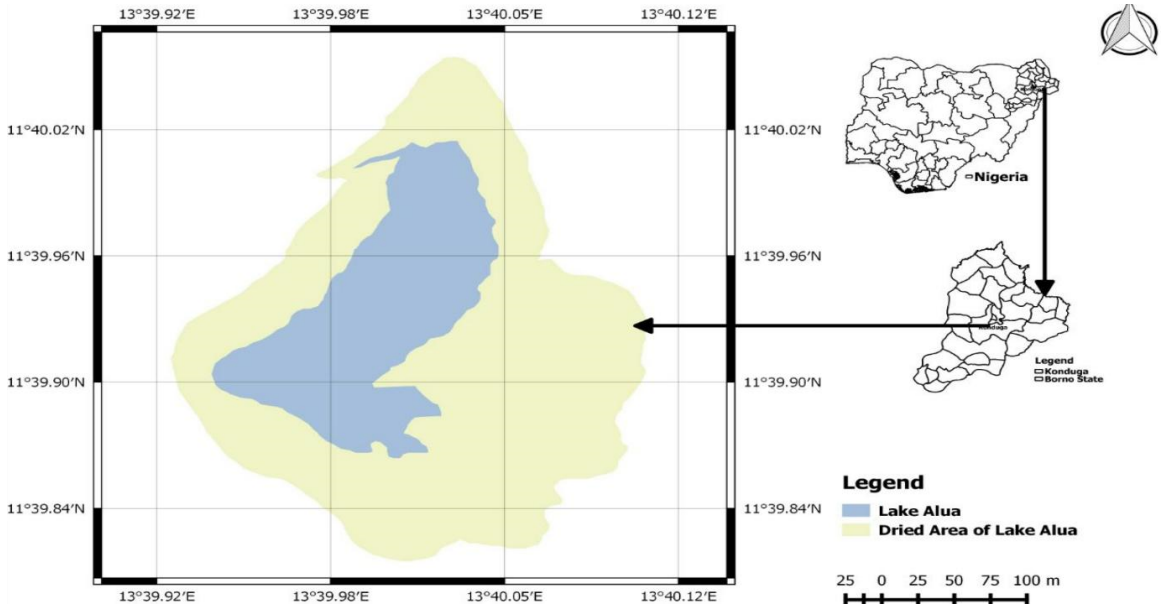

Fig. 1: Map of Lake Alau, Maiduguri, Nigeria

Morphometric measurements: Nine morphometric characters were studied following the standard procedures described by Kazeem and Olanrewaju[3]. Fish were measured and weighed *in situ* to the nearest 0.1 cm and 0.01 g, respectively. A wooden measuring board (30 cm) and digital analytical balance (Camry model EK5350) were used. The biometrics for each specimen were recorded separately on different record sheets for further analysis. Repeated measures of all individuals are taken by multiple observers to avoid measurement error, as suggested by Kazeem and Olanrewaju[3].

Length-weight relationship and condition factor: The length-weight relationship was computed by le Cren[13] equation:

$$W = aL^b$$

where, 'W' is the weight of fish (g), and L is the total length of fish (cm).

The variables 'a and 'b' are the coefficients of functional regression between weight and length. The above curvilinear equation was transformed into a linear relationship using a logarithmic transformation, thus:

$$\log_{10} W = \log_{10} a + b \log_{10} L$$

Fish condition factors (K) were calculated following the equation of Ricker[14]:

$$K = \frac{100W}{L3}$$

Statistical analysis: The Statistical Programming for Social Science (SPSS, version 20.0) software was used to analyze the obtained data. Relationships between various measurements were calculated from linear regression and correlation analysis. Student t-test comparison was performed to determine whether each species is statistically significantly different from the predictions assigned for isometric growth (b = 3). Differences were considered significant at $p<0.05$. These data were subjected to descriptive statistics (mean and standard deviation).

RESULTS

Morphometric variations: The body weight obtained for *Arnoldichthys spilopterus* ranged from 5.00 to 59.00 g with a mean of 33.06±16.81 g, while it varied between 7.00 and 51.00 g (17.68±8.62 g) in *Raiamas senegalensis* (Table 1). The result showed that *A. spilopterus* had significantly ($p<0.05$) higher body weight compared to *R. senegalensis*. The statistical analysis of various morphometric characters is shown in Table 2. The total length (12.66±3.07 cm), standard length (8.77±2.18 cm), and pectoral fin length (1.36±0.32 cm) were slightly higher ($p>0.05$) in *A. spilopterus*, whereas the head length (2.47±0.44 cm) was higher in *R. senegalensis* samples. Also, eye diameter (0.79±0.11 cm), dorsal fin length (1.45±0.36 cm), and pelvic fin length (1.23±0.27 cm) were significantly higher ($p>0.05$) in *A. spilopterus* samples. However, the mean anal fin length (1.82±0.33 cm) and caudal fin length (2.07±0.33 cm) in *R. senegalensis* were markedly higher than in *A. spilopterus* samples.

Regression for various morphometric characteristics: Table 3 indicated that the coefficient of correlation (r) for various characters compared against total length ranged from 0.163-0.816 in *A. spilopterus*, and 0.230-0.854 in *R. senegalensis*. The comparison of eye diameter against head length in *A. spilopterus* and *R. senegalensis* is 0.782 and 0.817, respectively. All the characters compared with total length in *A. spilopterus* were negative coefficient (b) except anal fin length (b = 3.320), while only standard length (b = -0.079) was negative coefficient in *R. senegalensis*. There are high values of regression coefficient (b) for eye diameter in *A. spilopterus* (b = 1.286) and *R. senegalensis* (b = 0.935) when compared with head length.

Condition factor and length-weight relationships: The condition index value ranged from 1.01-2.33 for *Arnoldichthys spilopterus* and 0.68-1.04 for *Raiamas senegalensis* (Table 4). Meanwhile, the mean condition factor calculated for *A. spilopterus* was 1.54±0.36, while *R. senegalensis* had 0.82±0.09. The results showed significant differences between the condition factors of the two fish species studied ($p<0.05$). The regression coefficient "b" values varied between 2.49 (*A. spilopterus*) and 3.33 (*R. senegalensis*). Also, the length-weight linear regression relationships show strong and significant correlations in *A. spilopterus* (0.91) and *R. senegalensis* (0.95).

Table 1: Fish body weight in the study

	Fish species	
Body weight (g)	*Arnoldichthys spilopterus*	*Raiamas senegalensis*
Mean±SD	33.06±16.81[a]	17.68±8.62[b]
Minimum	5.00	7.00
Maximum	59.00	51.00

SD: Standard deviation, means with different superscripts along the same column are significantly ($p>0.05$) different ($p<0.05$)

Table 2: Statistical estimates of various morphometric characteristics

	Arnoldichthys spilopterus		*Raiamas senegalensis*		
Character	Range (cm)	Mean±SD	Range	Mean±SD	Significance values
TL	7.00-18.00	12.66±3.07	10.00-17.00	12.65±1.55	0.98
SL	4.40-12.50	8.77±2.18	7.00-13.00	8.16±1.21	0.16
ED	0.50-0.90	0.79±0.11	0.40-0.70	0.46±0.08	0.00*
HL	1.30-3.20	2.35±0.57	2.00-3.00	2.47±0.44	0.35
DFL	0.70-2.20	1.45±0.36	1.00-2.00	1.16±0.27	0.00*
PeFL	0.70-2.00	1.36±0.32	0.80-1.70	1.28±0.27	0.25
PvFL	0.60-1.70	1.23±0.27	0.60-1.20	0.84±0.15	0.00*
AFL	0.70-1.80	1.27±0.25	1.40-3.00	1.82±0.33	0.00*
CFL	1.00-2.30	1.51±0.43	1.50-3.00	2.07±0.33	0.00*

TL: Total length, SL: Standard length, ED: Eye diameter, HL: Head length, DFL: Dorsal fin length, PeFL: Pectoral fin length, PvFL: Pelvic fin length, AFL: Anal fin length and CFL: Caudal fin length

Table 3: Regression values for various morphometric characteristics as a function of total length (TL) and head length (HL)

	Arnoldichthys spilopterus			*Raiamas senegalensis*		
Character	Intercept (a)	Slope (b)	Correlation (r)	Intercept (a)	Slope (b)	Correlation (r)
TL and SL	3.663	-2.534	0.205	1.166	-0.079	0.230
TL and HL	2.707	-3.927	0.319	0.897	0.527	0.817
TL and DFL	1.758	-3.065	0.271	1.072	0.479	0.854
TL and PeFL	1.780	-4.055	0.341	1.055	0.456	0.853
TL and PvFL	1.681	-4.980	0.403	1.134	0.496	0.745
TL and AFL	0.359	3.320	0.816	0.968	0.516	0.808
TL and CFL	1.610	-1.805	0.163	0.950	0.466	0.554
HL and ED	0.480	1.286	0.782	0.696	0.935	0.817

TL: Total length, SL: Standard length, ED: Eye diameter, HL: Head length, DFL: Dorsal fin length, PeFL: Pectoral fin length, PvFL: Pelvic fin length, AFL: Anal fin length and CFL: Caudal fin length

Table 4: Condition factor and regression coefficient for length-weight relationships of the fish species under study

	Parameter					
Fish species	a	b	MSE (b)	R^2	K range	Mean K
A. spilopterus	-0.87	2.49	0.14	0.91	1.01-2.33	1.54±0.36[a]
R. senegalensis	-2.48	3.33	0.13	0.95	0.68-1.04	0.82±0.09[b]

a: Intercept, b: Regression coefficient, MSE (b): Mean standard error of growth exponent, R^2: Coefficient of determination and K: Condition factor

DISCUSSION

The sustainable exploitation of freshwater fish species of commercial value is inevitable for fisheries to continuously play its role in the social and economic growth of Nigeria[6]. It is particularly interesting in fisheries data to understand whether the stock has the reproductive capacity to sustain the fish population in the future. This study noted that the mean body weight of *Raiamas senegalensis* samples was significantly smaller than *Arnoldichthys spilopterus*. Our results show higher body mass in *A. spilopterus* than 11.18±11.41 g reported by Oribhabor and Archibong[15] in Ntak Inyang stream, Ikpa River, Nigeria. On the other hand, the mean body weight of *R. senegalensis* was significantly less than that reported in earlier studies by Olanrewaju *et al*.[6] and Konan *et al*.[16]. This implies that catching has no influence on the *A. spilopterus* population, unlike *R. senegalensis*, which is considered more as fish food among the people in the study area.

Meanwhile, the statistical analysis of morphometric variables in the present study reveals that *A. spilopterus* was larger in size than *R. senegalensis* in most morphometric variables (TL, SL, PFL, ED, DFL and PvFL). It is an indication that the population of the two species showed different morphological tendencies. A similar result was documented by Chukwuka *et al*.[17] in *Sarotherodon galilaeus* and *Oreochromis niloticus* from Lake Geriyo, Northeastern Nigeria. The findings on morphometric data in the current study revealed that the regression coefficient has a varying degree of interdependence between the total length and other characters for both species. These variations are species-specific and depend on the ontogenetic development of the species, as indicated by Ahirwal *et al*.[18]. Prajapat *et al*.[19], however, remarked that morphometric plasticity in fish populations is driven by local environmental changes, resource use patterns, and habitat characteristics, leading to biological, evolutionary, and ecological shifts in morphological traits.

Allometric relationships are a powerful tool used by taxonomists and ecologists in the analysis of intraspecific and interspecific variation among different populations[20] and to understand fish growth rate and patterns. The estimated b values for *A. spilopterus* (2.49) and *R. senegalensis* (3.33) in this study were consistent with the expected range of 2.5-3.5[21]. The results reveal negative allometric growth in

A. spilopterus, where length increases faster than weight (b<3), resulting in a slender body shape. This result is supported by the findings of Agorua *et al.*[22] on *A. spilopterus* in the Oguta Lake, though with a lesser b value (0.2875). The regression coefficient "b" value (3.161) reported by Konan *et al.*[16] on *R. senegalensis* also coincides with the result for the b value recorded on *R. senegalensis* in this present study. Olanrewaju *et al.*[6], however, reported positive allometric growth for male *R. senegalensis* from Lake Alau with b value of 3.193. In contrast, these authors found negative allometric growth for combined sexes (2.829) and female (2.592) *R. senegalensis*. The differences might be linked to sexual dimorphism, water quality, food availability, period of year, stage of maturity, and sampling procedure as mentioned in the work of Konan *et al.*[16]. Meanwhile, all these attributing factors have strong implications on fish condition factors.

Condition factors (K) are valuable tools for assessing fish populations, monitoring their health, and understanding the impact of environmental changes on fish stocks. The mean K values among species in this study showed good environmental conditions and general wellbeing in *A. spilopterus* (1.54±0.36) when compared to *R. senegalensis* (0.82±0.09). This follows the assertion of Moradinasab *et al.*[23], who implied that a high condition factor indicates favourable environmental conditions, such as habitat and availability of food. Agorua *et al.*[22] and Oribhabor and Archibong[15] also found similar trends in condition factor in *A. spilopterus* from Oguta Lake (2.46±0.71) and Qua Iboe River (1.26±0.28), all from Nigeria. Olanrewaju *et al.*[6], however, reported a higher condition factor (1.97±1.98) for *R. senegalensis* in Lake Alau. According to Okon and Sikoki[24], a high K value is an assumption of high feeding intensity and gradual increase in accumulated fat that also suggests preparation for a new reproductive period. Meanwhile, King[25] attributed the differences to various factors such as availability of food (quality and quantity), seasonal variations, the sex and stage of maturity of the fish, and gonadal conditions/development of the fish.

CONCLUSION

This study reveals that the habitat in Lake Alau supports optimal growth conditions for both *A. spilopterus* (Niger Tetra) and *R. senegalensis* (Silver fish), with significant variations in their growth patterns and physiological condition. The negative allometric growth in Niger Tetra and positive allometric growth in Silver fish reflect distinct species-specific responses. Despite favorable growth conditions, Silver fish exhibit signs of physiological stress, likely influenced by seasonal environmental factors. These findings underscore the importance of monitoring environmental changes to better understand their impacts on these indigenous fish species.

SIGNIFICANCE STATEMENT

Understanding the morphometric characteristics, length-weight relationships, and condition factors of indigenous fish species is vital for sustainable fisheries management. This study assessed the growth and physiological condition of Niger Tetra and Silver fish in Lake Alau, revealing that the lake provides optimal growth conditions, although seasonal changes negatively affect the condition of Silver fish. These findings demonstrate that fishing activities currently have minimal impact on the health and sustainability of these species. The research contributes important baseline data for conservation efforts and fisheries management strategies, supporting the preservation of native biodiversity and promoting ecological resilience in Lake Alau and similar freshwater ecosystems.

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