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Variability and Linear Regression of Morphometric Characters of Squeaker-Catfishes (*Synodontis levequei* Paugy, 1987) Specimens Endemic to Republic of Guinea Freshwaters

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Abstract

Synodontis levequei is a species of upside-down catfish endemic to Guinea, where it occurs in the Konkouré River basin. The present research focuses on examining the variability and correlation among 10 morphometric characters of *S. levequei* through 82 specimens collected from fishermen working on the Konkouré River. The specimens were collected between November 2024 and January 2025, corresponding to the favourable period for artisanal fishing in Republic of Guinea. Statistical analyses of linear regression relationships showed that there was a positive linear relationship between various morphometric measurements and total length (TL). Mostly strong correlations (correlation coefficients $r \geq 0.70$; $p < 0.05$) between total length (TL) and most morphometric characters, except the Maxillary Barbel Length (MBL). All morphological characters of *Synodontis levequei* examined in this study showed a coefficient of variation lower than 10%. Hence, according to our present results, there is a direct relationship between the total length of fish (independent variable) and all morphometric characters (dependent variables), where there is a gradual increase in morphometric measurements with an increase in body length. As a result of the applied Correlation matrix

among the morphological characters of *Synodontis levequei*, a very strong, positive relation between all morphological characters examined in this study was proved, except the correlation between Pelvic Fin Length (PVFL) and Inter Orbital Distance (IOD). A negative and significant association was observed between these two variables. Thus, our present study could be valuable for further exploration into the species' ecological adaptations, contributing to our comprehension of its biological characteristics and management of this species endemic to Republic of Guinea. Other studies, particularly on genetic aspects and investigations of the influences of environmental subtleties, are desirable to overlay the mode of saving this species, which is already vulnerable.

Keywords

Synodontis levequei, Linear Regression, Morphometrics, Endemic, Republic of Guinea

1. Introduction

The Republic of Guinea, a country located in southwest West Africa, is characterized by an abundant hydrographic network with more than 1165 rivers distributed in 23 river basins, including 9 national and 14 international. The many rivers and watercourses that flow through the region irrigate all the neighbouring countries, making Guinea the "water tower" of West Africa [1]. However, the explorations carried out on all the basins of the Republic of Guinea remain fragmented and old. Despite the work of [2] and [3], the fish fauna of Guinea's coastal basins is still imperfectly known. There is a glaring lack of recent data and knowledge about the fish populations. African fish fauna has long been one of the least studied in the world and is not well known in the scientific world. However, this one presents a very great ichthyological diversity [4] and provides a diversified, flexible and resilient livelihood portfolio for some 22 million sub-Saharan fisher-farmers, with half of those living in extreme poverty [5].

In order to contribute to the knowledge of the diversity, biology and ecology of species in the basins of West Africa in general and Guinea in particular, this study has been initiated whose main objective is to examine once again since its description in 1967 by Paugy, the morphological variation of *Synodontis levequei* from the Konkouré River basin and describe the relationship between the variables. Their study is highly significant for proper conservation and effective management of fish populations as well as for the scientific community for further research. Indeed, a good knowledge of fish species, through the study of their morphometric characters, meristic, trophic ecology, reproduction and characterization of factors that influence their distribution, is a prerequisite for any measure to conserve fish [6]-[8]. Morphometric study plays a vital role in fish development pattern, habitat conditions, overall health, early life, feeding, fish fatness, development stage, gonad middle age, sexual category, size range, physical condition, and common fish form and maintenance [9]-[13] and can be used for artisanal fishery management and

fish resources preservation [14]. For Basuonie *et al.* [15], morphological characteristics are of fundamental importance in fishery biology, where it is the major source of information for taxonomic and evolutionary studies. Taxonomic identification is the initial step in the study of a species. Linear regression is a technique to quantify the relationship, visualised in a graph, between two variables. The interpretability of linear regression is one of its greatest strengths. The model's equation offers clear coefficients that illustrate the influence of each independent variable on the dependent variable, enhancing our understanding of the underlying relationships. Its simplicity is a significant advantage; linear regression is transparent, easy to implement, and serves as a foundational concept for more advanced algorithms.

Moreover, *Synodontis levequei* Siluriformes, of the Mochokidae family, is a species of upside-down catfish endemic to Guinea, where it occurs in the Konkouré River basin [16]. This species is harvested for human consumption. The main threats to this species are the construction of hydroelectric dams on the upper Konkouré River, deforestation, and farming practices, which are likely causing declines in its overall habitat quality [17]. According to literature and recent data of the International Union for Conservation of Nature and Natural Resources [18] (available at: http://www.iucnredlist.org/), this species is assessed as Vulnerable and research is needed into its population dynamics, distribution, threats and ecology, alongside monitoring of population trends.

2. Materials and Methods

2.1. Study Area

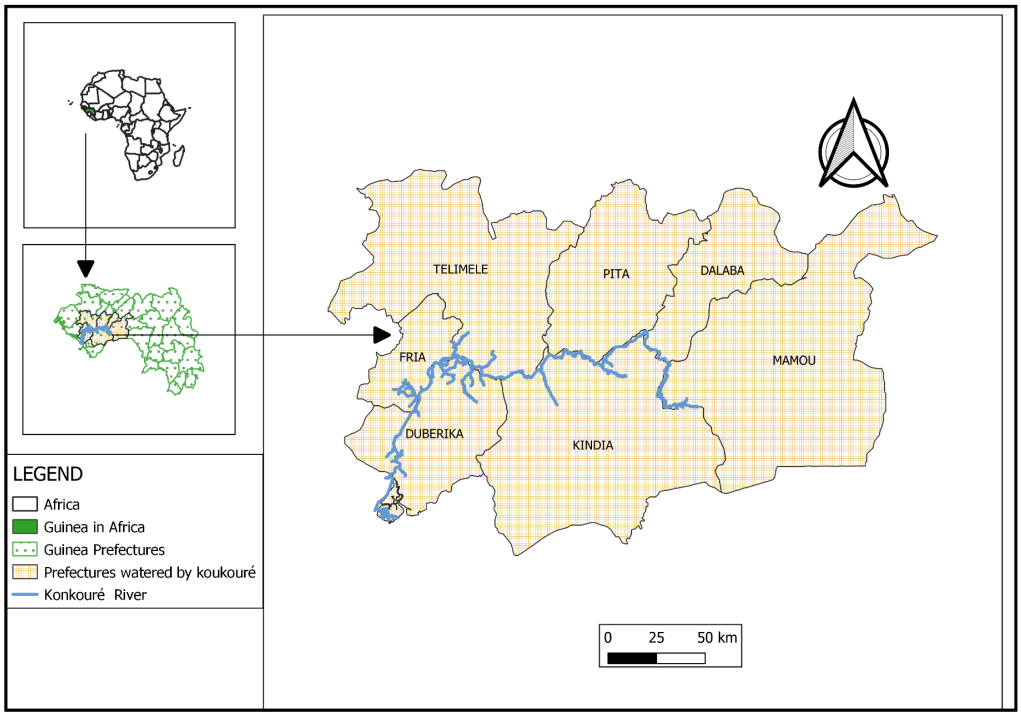


Figure 1. Localisation of the study area.

Fish samples were gathered from Konkouré River, located at 9˚49'50.02" N latitude, and 13˚47'44.99" W longitude in the west-central part of Guinea, West Africa (see Figure 1). Konkouré River, rising in the Fouta Djallon plateau in the Mamou region of west central Guinea, flows in a westerly direction to the Atlantic just north of Sangareya Bay. The river's 188-mi (303 km) course is characterised by many rapids and waterfalls.

2.2. Sampling and Identification of Specimens

Synodontis levequei has become very rare in catches according to fishermen. A total of 82 individuals of the species were collected from fishermen of the Konkouré River in the natural region of Middle Guinea.

The species was certified using the most recent identification key of Mochokidae [16]. The samples were collected between November 2024 and January 2025, corresponding to the favourable period for artisanal fishing in Republic of Guinea in general and Middle Guinea in particular. Indeed, due to the high rainfall in Lower Guinea (June to mid-November), only industrial fishing remains active, and yields are often low. During this period, fishermen are busy with agricultural work and repairing their boats and nets. The best fishing season is the dry season (late November-May).

2.3. Morphometric Measurements

The sampled fish, caught by artisanal fishers using different types of gear and techniques, were examined in place. Immediately after they were caught, the total weight of each specimen was recorded on an electronic balance to the nearest gram. Ten morphometric characters were analyzed with standard procedures as previously followed by [19]-[23]. All these morphological variables were represented and described along with their acronyms in Table 1.

Table 1. Acronyms and description of all Morphometric characters of *Synodontis levequei* examined in this investigation.

Morphometrics	Acronyms	Description
Total Length	TL	The distance b/n anterior tip of snout and tip of the tail (tip of caudal fin)
Head Length	HL	The distance from anterior tip of snout to posterior edge of bony operculum
Pre Dorsal length	PRD	The length from anterior tip of snout to anterior dorsal fin base
Pre Anal length	PRAN	The distance b/n anterior tip of snout to first insertion of anal fin base.
Snout Length	SNL	The distance b/n anterior tip of snout to anterior bony margin of the orbit.
Maxillary Barbel Length	MBL	The distance b/n insertion of barbel and the posterior end

Continued

Eye Diameter	ED	The horizontal distance b/n anterior and posterior bony orbits.
Inter Orbital Distance	IOD	Distance b/n dorsal side of both eyes
Pelvic Fin Length	PVFL	The distance b/n first insertion of pelvic fin and tip of longest ray.
Body Depth	BD	The vertical body depth at origin of dorsal fin base.

The morphometric characteristics were measured from the left side of the fish using a Mitutoyo® brand watch caliper to the nearest millimeter (Figure 2).

Figure 2. Measuring instrument.

All samples are put in bottles containing 10% formaldehyde and transported to the laboratory to prevent spoilage before analysis for possible investigations.

2.4. Statistical Analyses

Linear regression was applied to determine the relationships between total body length versus morphometric variable of this study as follow; $Y = aX + b$ with slop intercep whereas, "Y" represents the morphological parameter and "X" represent the total body length of fish measured in millimeters, whereas, "a" was a constant value and "b" was the regression coefficient [24]. The length of the fish is considered as the independent variable on the horizontal axis for the linear regression analysis. Other variables in the dataset are considered as dependent variables on the vertical axis of the graph for the regression analysis. The range, mean, standard deviations, correlation coefficient "r" and t-test at 5% significance ($p < 0.05$) were also calculated as previously followed by Ambily [25]. The data obtained were compared to those previously described by Paugy [3], available in Fishbase (https://www.fishbase.se/summary/Synodontis-levequei.html).

Excel software was used for data organization and requests enabled data extraction for statistical analyses and graphic making up by using Paleontological Statistics (PAST) version 4.02 accessible on the website https://past.en.lo4d.com/windows. The data was logarithmically transformed in order to homogenize variances

and minimize the effect of non-normalized data.

3. Results

3.1. Morphometric Characteristics of *Synodontis levequei*

The morphometric measurements of various body parts recorded and the mean ± SE, standard error of mean, coefficient of variation, minimum and maximum value were presented in Table 2. Significant variations have been observed between the different morphometric characters. This study revealed significant variation in the morphometrical measurements of the Squeaker-Catfishes, particularly Maxillary Barbel Length, which had the highest coefficient of variation (CV) of 9.67. The morphometric measurements disclose that total body length (TL) were found in a range from 59 to 104 mm, Head Length (HL) ranged from 18 to 31 mm, Pre Dorsal length (PRD) was between 34 to 59 mm, Pre Anal length (PRAN) varies from 38 to 66 mm, Snout Length (SNL) ranged from 15 to 20 mm, Maxillary Barbel Length (MBL) ranged from 39 to 66 mm, Eye Diameter (ED) was ranged from 13 to 16 mm, Inter Orbital Distance (IOD) varies from 13 to 20 mm, Pelvic Fin Length (PVFL) ranging from 12 to 23 mm, and Body Depth (BD) varies from 8 to 24 mm, as shown in Table 2 respectively. All morphological characters of *Synodontis levequei* examined in this study showed a coefficient of variation lower than 10%.

Table 2. Mean, standard deviation, standard error of mean, coefficient of variation, minimum and maximum value of morphometric traits of *Synodontis levequei*.

Characters	Min.	Max.	Mean ± S.D.	S.E. of Mean	C.V.
TL	59.24	103.52	81.41 ± 5.16	0.56	6.33
HL	18.25	30.3	24.63 ± 1.26	0.13	5.15
PRD	34.3	58.48	39.33 ± 2.92	0.31	7.44
PRAN	38.23	65.30	50.46 ± 3.56	0.39	7.05
SNL	15.74	19.49	16.66 ± 0.66	0.07	3.96
MBL	39.3	65.91	48.90 ± 4.73	0.51	9.67
ED	13.53	15.68	14.23 ± 0.37	0.04	2.60
IOD	13.9	19.93	14.69 ± 0.72	0.07	4.94
PVFL	12.15	22.75	16.84 ± 1.39	0.15	8.28
BD	8.85	23.87	18.37 ± 1.66	0.18	9.05

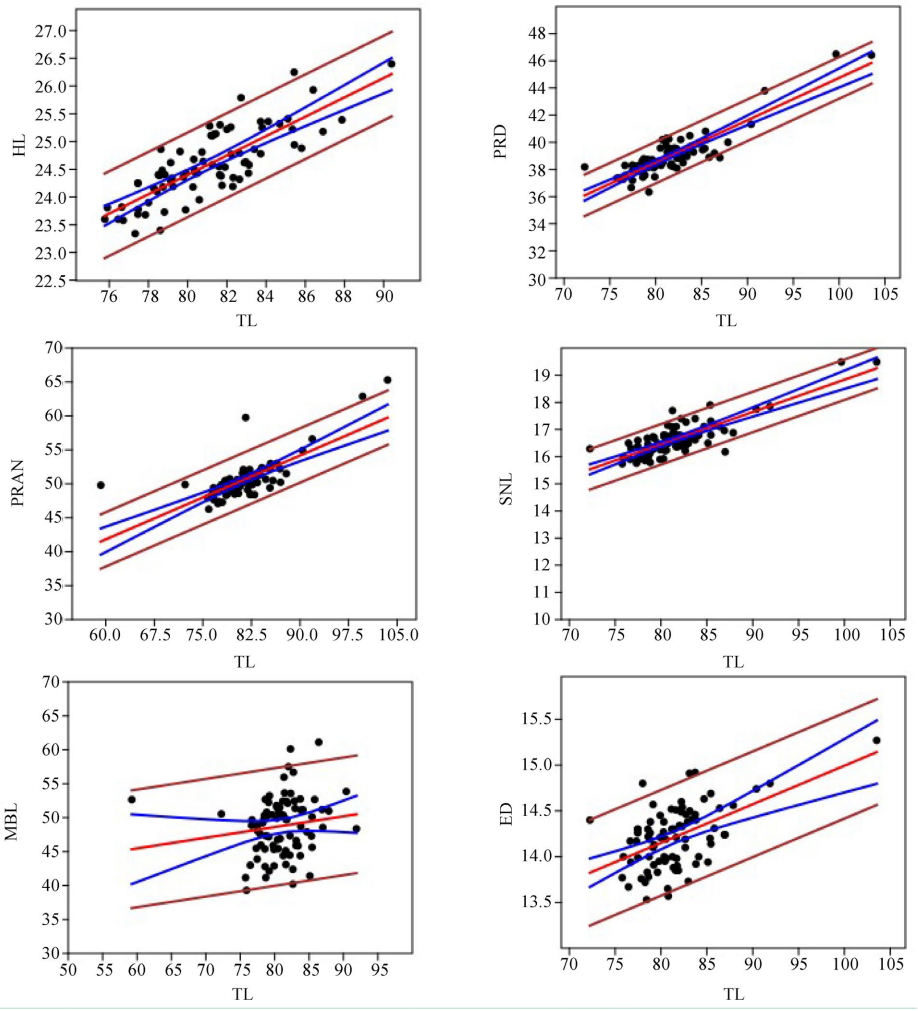
3.2. Linear Regression Relationships between Total Body Length (TL) and Morphological Characters of *Synodontis levequei*

The overall findings of linear regression relationships between total body length (TL) and all morphometric characters of *Synodontis levequei* reveal strong to moderate and significant correlations ($r > 0.70/r = 0.51 - 0.69$; $p < 0.05$) except the Maxillary Barbel Length (MBL) that shows a very weak type of correlation, as obtainable and seen in Table 3 and Figure 3 respectively.

Table 3. Regression coefficients between total body length (TL) and various morphometric characters of *Synodontis levequei*.

Characters		Regression coefficients			t-test at 5% significance ($p < 0.05$)	Correlation type
X	Y	a	b	r	*p*-value	CT
LT	HL	0.17	10.44	0.80	0.00 α	***
LT	PRD	0.31	13.55	0.88	0.00 α	***
LT	PRAN	0.41	17.09	0.73	0.00 α	***
LT	SNL	0.11	6.93	0.82	0.00 α	***
LT	MBL	0.15	36.02	0.14	0.18 ♣	*
LT	ED	0.004	10.78	0.51	0.00 α	**
LT	IOD	0.05	10.4	0.62	0.00 α	***
LT	PVFL	0.14	5.30	0.57	0.00 α	**
LT	BD	0.14	6.54	0.58	0.00 α	**

CT = Correlation type; *** shows the strong correlation (r > 0.70); ** shows moderate correlation (r = 0.51 - 0.69); * represent weak correlation (r < 0.50); ♣ shows insignificant correlation when p > 0.05; α shows significant correlation when p < 0.05; a = intercept of regression line; b = slope of regression line.



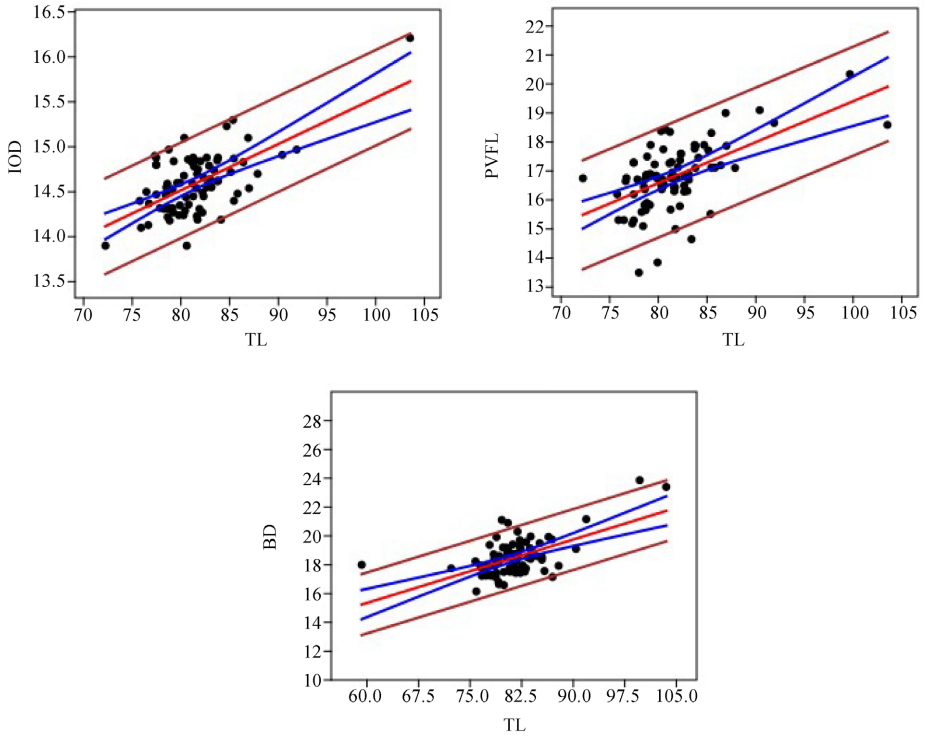


Figure 3. Linear regression association between total body length (TL) and various morphometric characters of *Synodontis levequei*.

3.3. Correlation between All Morphological Characters of *Synodontis levequei*

The square matrix in **Figure 4** shows the correlation between all morphological characters of *Synodontis levequei* examined in this study. Crossed-out boxes indicate insignificant correlation ($p > 0.05$) between the crossed variables and the different colors provide information on the Pearson correlation coefficient r.

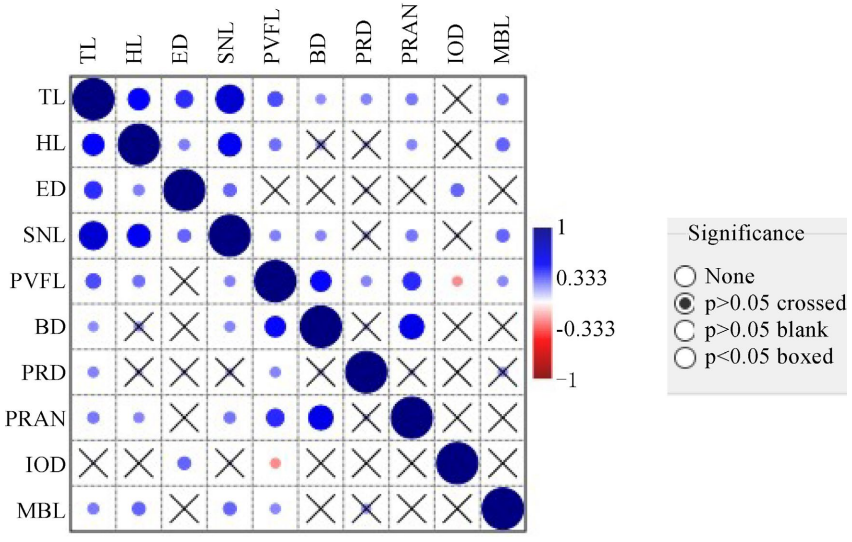


Figure 4. Correlation matrix among the morphological characters of *Synodontis levequei*.

There is a strong to moderate positive correlation between variables HL/ED; HL/SNL; HL/PVFL; HL/PRAN; HL/MBL; ED/SNL; ED/IOD; SNL/PVFL; SNL/BD; SNL/PRAN; SNL/MBL; PVFL/BD; PVFL/PRD; PVFL/PRAN; PVFL/MBL; BD/PRAN with p-values < 0.05, between variables HL/BD; HL/PRD; HL/IOD; ED/PVFL; ED/BD; ED/PRD; ED/PRAN; ED/MBL; SNL/PRD; SNL/IOD; PRD/PRAN; PRD/IOD; PRD/MBL; PRAN/IOD; PRAN/MBL; IOD/MBL with *p*-values > 0.05. On the other hand, the correlation is negative and significant (p < 0.05) between the variables PVFL/IOD.

4. Discussion

Synodontis levequei from the Konkouré River (Guinea) has a short and high body with maxillary barbels longer than the head. These findings are similar to Santos *et al.* [26], who reported that specimens from the Tropical region had comparatively larger body height, mouth length and maxillary length and smaller values for the other characters (e.g., eye diameter, head height, head length and pectoral fin length). Study revealed significant variation in the morphometrical measurements of *Synodontis levequei*, particularly Maxillary Barbel Length, Body and Depth and Pelvic Fin Length, which had the highest coefficients of variation. This high variation indicates a large variability among individuals.

The above-mentioned morphometric characteristics were found to be similar to those previously described by Paugy [3] with some differences in the maximum values, e.g., Total Length can reach 23.8 (Fishbase http://fishbase.mnhn.fr/summary/Synodontis-levequei.html). The scarcity today of large specimens could be due to fishing pressure and the degradation of its habitat (the construction of hydroelectric dams, deforestation and farming practices) as noted by [17], which are likely causing its vulnerability [18]. Therefore, we suggest that the differences observed in the range of morphological variables could be related to different growth rates under the influence of environmental conditions and available food resources. Additionally, differences in TL could also reflect the degree of exploitation to which the different populations were exposed and non-exhaustive sampling [27].

As fish morphometric characters usually refer to the measuring of total body length of fish with various other body parts of its anatomy; therefore, accordance to [28]-[30], a study of linear regression relationships between total body length of fish and several morphometric characters were found to be the best indicator for detecting the growth pattern of fish. In the current study, 5 characters show high values of correlation coefficient with total body length (independent variable), 3 characters show moderate, and 1 shows a low correlation coefficient. Hence, the results of morphometric characters show a positive allometric growth pattern (A+), which reveals the direct relationship between total body length and the growth of various body parts of this species. Similar observations were made by [29] [31]-[33] in morphometric studies of fish. [34] [35] has reported a linear relationship between various body measurements and the total length in other fish

species. The value of the coefficient of correlation showed that the relationship between total length and various body measurements of the fish was highly significant ($p < 0.01$) except the relationship between total length and Maxillary Barbel Length ($p > 0.05$). Thus, various body characters of *S. levequei* are dependent variables on the total length of the fish. The closeness of the observation points to the regression line, which reflects that the model predictions are close to the actual value.

As a result of the applied correlation analysis among the morphological characters of *Synodontis levequei*, a very strong, positive relation between all morphological characters examined in this study was proved, except the correlation between Pelvic Fin Length and Inter Orbital Distance. These findings corroborate the hypothesis described by Devlin *et al.* [36], which suggests that, beyond the simple proportionality of interorbital distance and eye size to head size, the eye development in rapidly growing fish becomes decoupled from their somatic growth, often resulting in negative allometry.

It is not possible for us to compare our results with previous studies, as few studies have been conducted on the species, and so far, no reports are available regarding the morphometric analysis. Further investigation may be conducted to obtain comprehensive information.

5. Conclusions

Despite the limitations of this study, such as the small sample size due to the rarity of the species in catches, we were able to characterize, based on morphometric characters, the species *Synodontis levequei* endemic to the Republic of Guinea. For each specimen, morphometric approaches are discussed. By examining measurements such as body length, head length, Maxillary Barbel Length, etc., we were able to identify significant differences in size and proportions between the morphological characters.

The results obtained provide basic information for stock management and will enable efficient management strategies of populations of *Synodontis levequei* specimens endemic to Republic of Guinea freshwaters stock to ensure that their fisheries are sustainable and also to develop appropriate conservation plans.

Further study, particularly on genetic aspects and investigations of the influences of environmental subtleties, is desirable to overlay the mode of saving this species, which is already vulnerable. From the data collected and those in progress, we will study the parameters across the populations, such as growth, mortality, age, and reproductive biology (size at sexual maturity, spawning time, fecundity) for the development of the fishery management systems of the species.

Data Availability

All raw and analysed data of this work are available from the corresponding author, Gildas Djidohokpin, upon request.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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