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(RESEARCH ARTICLE)

Analysis of biometric relationships and condition factor of *Oreochromis niloticus* in the lacustrine ecosystems of Yamoussoukro (Ivory Coast)

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Abstract

The study focused on the size distribution, length–weight relationship, and condition factor of *Oreochromis niloticus* in several urban and peri-urban lakes of Yamoussoukro. Standard lengths of individuals varied across lakes, ranging from 8.3 to 18.5 cm. Size classes were established according to Sturges' rule, revealing variable counts between 2 and 38 individuals per class. In all lakes, counts differed significantly between size classes (Kruskal–Wallis tests, $p < 0.05$), with the largest size classes generally having the fewest individuals and intermediate classes the most. Analyses of the length–weight relationship showed a strong positive correlation ($0.87 \leq R^2 \leq 0.95$) and no outliers, indicating reliable measurements. Fish growth was isometric in Lake 4 ($b = 3$) and negatively allometric ($b < 3$) in the other lakes. The mean condition factor (K) was above 0.5 in all lakes, with no significant differences between sites, suggesting that the fish were generally in good body condition.

Keywords: *Oreochromis niloticus*; Lacustrine Hydrosystems; Length–Weight Relationship; Condition Factor; Yamoussoukro

1. Introduction

The city of Yamoussoukro, the political and administrative capital of Côte d'Ivoire, is characterized by an extensive network of interconnected artificial and semi-natural lakes, constructed in the 1960s for hydraulic, aesthetic, and fishery purposes (Kouamé *et al*., 2015). These lacustrine ecosystems now play a major ecological role by hosting rich aquatic biodiversity, as well as an important socio-economic role by providing fishery resources for local consumption. Among the exploited species, *Oreochromis niloticus* (Nile tilapia) is one of the most abundant and highly valued due to its commercial importance, nutritional value, and high ecological adaptability (El-Sayed, 2006).

Although the lakes of Yamoussoukro are exploited by local communities, few scientific studies have documented the biological and ecological parameters of the fish populations inhabiting them (N'Douba *et al*., 2010; Kouamélan *et al*., 2017). However, knowledge of biometric relationships and condition factors constitutes a fundamental tool in ichthyology for assessing growth, reproduction, health status, and population dynamics of fish (Froese, 2006). The lack of data on these parameters for local populations of *Oreochromis niloticus* limits the understanding of their ecology and hampers the development of strategies for the sustainable management of this fishery resource.

Length–weight relationships are commonly used in fish biology to estimate body weight from length and to describe the growth pattern of a species (Ricker, 1975). These relationships make it possible to determine whether growth is

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isometric (proportional increase in length and weight) or allometric (differential growth), thereby providing insights into how fish adapt to their environment (Pauly, 1984). The condition factor (K), for its part, is an index that reflects the physiological status of individuals and their level of well-being within a given habitat (Le Cren, 1951; Bagenal and Tesch, 1978).

In *Oreochromis niloticus*, several studies have shown that length–weight relationships and condition factors vary according to environmental characteristics such as water quality, temperature, and food availability, as well as seasonal changes and fishing pressure (Abowei, 2009; Ayoade and Ikulala, 2007 ; Oso *et al*., 2011). For example, studies conducted in Nigeria and Ghana have reported predominantly positive allometric growth, indicating good nutritional status in certain water bodies, whereas less favorable environments tend to induce negative allometric growth (Dan-Kishiya, 2013 ; Lawson, 2011). These variations confirm that biometric monitoring is a reliable indicator of environmental quality and fish growth performance.

However, in Yamoussoukro, no specific study has yet investigated these parameters in *Oreochromis niloticus*, despite the importance of this species for local nutrition and the economy.

The present study is justified by three main aspects. First, it aims to fill the gap in scientific data on the biology and ecology of *Oreochromis niloticus* in the urban and peri-urban lakes of Yamoussoukro. Second, it will provide useful information for the sustainable management and valorization of local fishery resources, in a context of increasing pressure on aquatic ecosystems. Finally, it will contribute to enriching the literature on Ivorian freshwater fish species, which are often less studied than marine species, despite being an essential source of protein for local populations (Koné *et al*., 2019).

The general objective of this study is to assess the health status and growth performance of *Oreochromis niloticus* in the lacustrine ecosystems of Yamoussoukro. Specifically, the study aims first to determine the different size classes of *Oreochromis niloticus*, then to establish the length–weight relationships of *Oreochromis niloticus* populations, and finally to evaluate the condition factor of *Oreochromis niloticus* individuals in the different lakes of Yamoussoukro.

2. Materials and methods

2.1. Presentation of the study environment and selection of sampling lakes

The study was conducted in the lakes of the city of Yamoussoukro, located in central Côte d'Ivoire (Figure 1). The country's political capital since 1983, Yamoussoukro lies between latitudes 6°48’ North and longitudes 5°17’ West. It is the capital of the department and the Lacs region. The city is located approximately 206 km from Abidjan, the economic capital. It has 340,234 inhabitants and covers an area of 3,500 km², making it the sixth most populous city in the country after Abidjan (5,616,633 inhabitants), Bouaké (832,371 inhabitants), Korhogo (440,926 inhabitants), Daloa (421,879 inhabitants), and San-Pédro (390,654 inhabitants) (RGPH, 2021). Climatically, Yamoussoukro is characterized by a transitional humid tropical climate, marked by two main seasons: a dry season from November to February and a rainy season from March to October, with peak rainfall in September (N’guessan *et al*., 2014).

The region’s hydrographic network is dense and branching, dominated by the Bandama River and its tributaries, as well as the N’Zi and Kan Rivers. The Kossou hydroelectric dam serves the Bandama River, while numerous small hydro-agricultural dams have been constructed on the N’Zi and Kan Rivers (Ouattara, 2015).

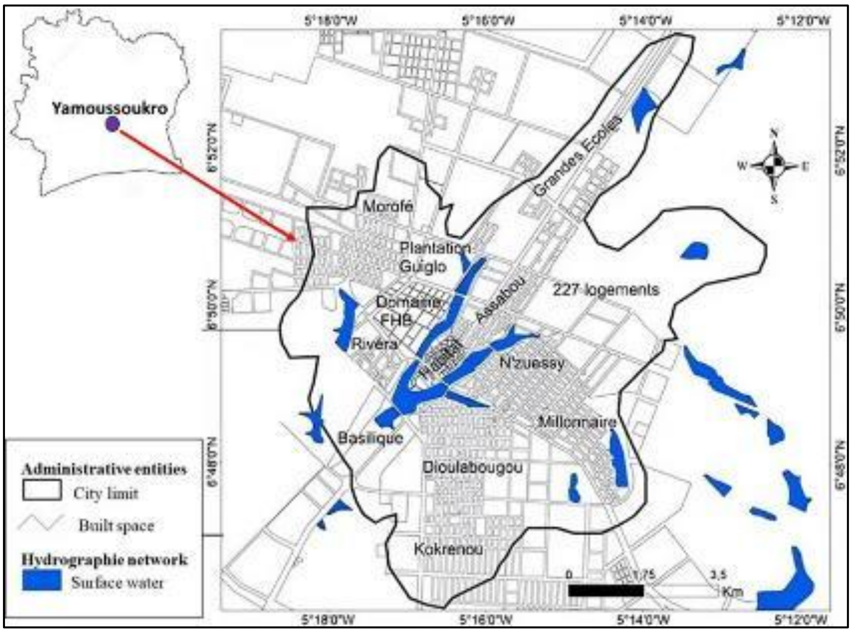

Figure 1 Presentation of the city of Yamoussoukro

The selection of sampling lakes was based on several criteria, including their accessibility, proximity to potential sources of pollution (cattle farming, intensive agriculture, fishing activities, etc.), land use, surrounding human activities, and their degree of human impact. A total of six (6) lakes were selected, three (3) located in the city center and three (3) on the outskirts. The city center lakes include Lake 6 (Petit Bouaké), Lake 5 (Hôpital), and Lake 8 (Agip). The outlying lakes are Lake 10 (Millionnaire), Lake 2, and Lake 4.

The study was conducted over four (4) seasonal campaigns organized monthly between January and April 2023. Two (2) campaigns were carried out during the dry season (January and February) and two (2) during the rainy season (March and April), corresponding to the main climatic seasons of the study area.

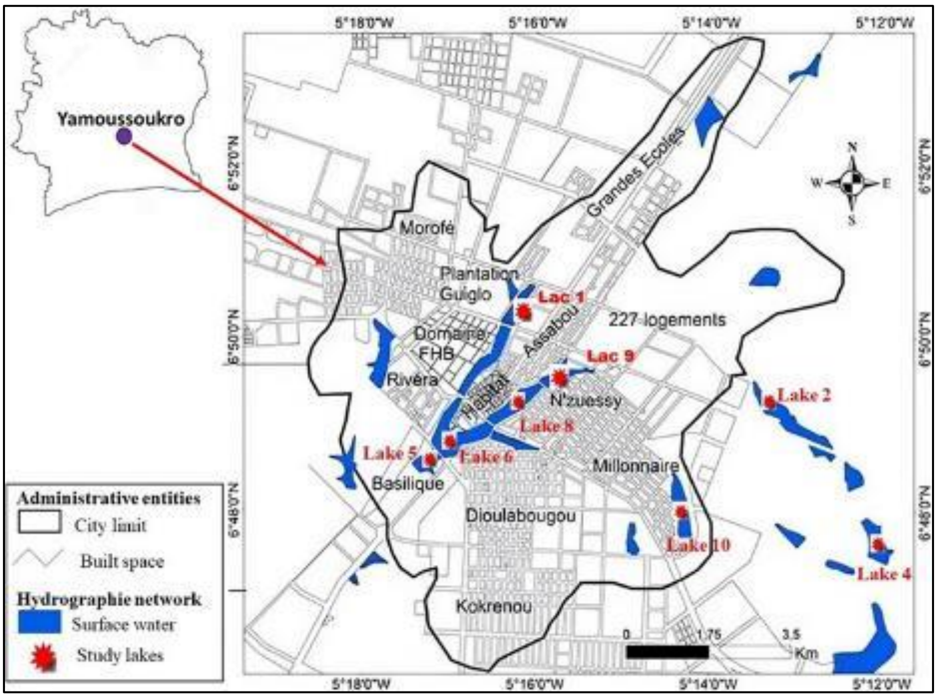

Figure 2 Presentation of the lakes sampled in the city of Yamoussoukro

Table 1 Description of the sampling lakes

	Lakes	Coordinates	Description and human activities
Urban lakes	Lake 5	6°48‘40’’ N 5°16‘10’’ W	Largest lake in the system, receiving water from Lake 6. Presence of washerwomen and vehicles using laundry equipment. Presence of cattle and poultry farms, scrubland, dwellings and market gardeners.
	Lake 6	6°48‘41’’ N 5°17‘9’’ W	Receptacle of the system located below lake 5 and adjacent to livestock parks and presence of market gardeners.
	Lake 8	6°49’ 08’’ N 6°16’ 22’’ W	Concentration on the edges of tourist activities (restaurants, train stations, hotels) from which it receives wastewater, with the presence of market gardeners.
Peri-urban lakes	Lake 2	6°50‘35’’ N 5°14‘44’’ W	Located in uninhabited areas with the presence of market gardeners.
	Lake 4	6°47‘35’’ N 5°12‘9’’ W	Located in uninhabited areas with no market gardeners.
	Lacke 10	6°48‘23’’ N 5°14‘35’’ W	Located in moderately populated areas with market gardeners.

2.2. Sampling methods

Fish samples were collected from experimental fishing. Gillnets were set between 4:00 and 5:00 PM and retrieved the following morning between 6:00 and 7:00 AM. Concurrently, a cast net was used to catch fish. This net was cast manually from a dugout canoe or from the lake banks and then hauled in by pulling on the retrieval line.

Only the Nile smelt (*Oreochromis niloticus*) was selected for this study. A total of 30 specimens of this species were collected per sampling campaign for analysis. Specimen identification at the species level was performed using the taxonomic keys proposed by Paugy *et al*. (2003a, 2003b) and by Froese and Pauly (2012, 2014).

In the laboratory, the individuals were measured with an accuracy of 0.01 mm for standard length and weighed with a precision balance to the hundredth of a gram (0.01 g).

2.3. Data Analysis

The size classes used in the size frequency distribution were determined using Sturge's rule (Scolt, 2009). This rule varies the integer number k of classes or intervals to be created according to the number n of data points (total number of individuals) using the following logarithmic operation:

$$K = 1 + (3{,}3 \times log10(n))$$

The lower bound of the classes is the smallest value, and the upper bound corresponds to the largest value. The class interval is calculated as follows:

$$Class\ Interval = (maximum\ value - minimum\ value) / (Number\ of\ classes)$$

A premise for constructing Sturge's rule is that the number of classes used must be sufficiently large when data is scarce in order to identify any potential concentration of data within a class. This rule is implemented using Excel.

Weight-length relationships in fish are considered models of allometric growth (Palomares *et al*., 1966). Power regression curves of the formula P = aLSb were obtained from weight-length pairs, where P represents the individual's weight (g), LS the standard length (cm), a the initial growth coefficient, and b the slope of the regression line. The parameters of such a model are estimated by linear regression on data that have undergone a logarithmic transformation (LogP = Loga + bLogLS). The parameters a and b for each of the equations in the Length-Weight relationship were estimated by linear regression analyses (Zar, 1999). The weight-length relationship reflects isometric growth (I) when b = 3 and allometric growth when b ≠ 3. However, positive allometric growth (AP) is observed when b > 3, and negative allometric growth (AN) is observed when b < 3 (Shingleton, 2010). The 95% confidence interval for a and b was estimated using Statview software version 1992-98 (SAS Institute INC). The statistical difference between the value of b for each species and the isometric value (b = 3) was obtained using the student's t-test performed according to Sokal and Rohlf (1987): ts = (b - 3) / ESb, where ts is the t-value of the student's t-test, b is the slope of the regression line, and ESb is the standard error of b. All tests were significant at the 5% level ($p < 0.05$). To assess the body condition of the fish in the Mvassa lagoon, the individual value of the condition factor for each specimen was calculated using the formula K = (100P/LSb) (Bagenal and Tesch, 1978), where P represents the weight of the individual (g) and LS the standard length (cm).

3. Results

3.1. Size frequencies of *Oreochromis niloticus*

The size frequency distribution of *Oreochromis niloticus* specimens sampled from the lakes of Yamoussoukro is shown in Figure 3. For urban lake 5, the standard-length ranges from 8.3 to 15.3 cm. A total of seven size classes were formed according to Sturge's rule. These are: 8.3–9.3 cm, 9.3–10.3 cm, 10.3–11.3 cm, 11.3–12.3 cm, 12.3–13.3 cm, 13.3–14.3 cm, and 14.3–15.3 cm. The number of individuals per size class fluctuates between 2 and 34. The smallest number of individuals is recorded in the class]14.3 – 15.3 cm [while the largest number is observed in the class]10.3 – 11.3 cm [. The number of individuals differs significantly between the different size classes (Kruskal-Wallis tests, $p < 0.05$) (Figure 3).

As for urban lake 6, the standard length varies between 8.6 and 17.4 cm. A total of eight size classes were formed according to Sturge's rule. These are the classes :]8.6–9.7 cm [,]9.7–10.8 cm [,]10.8–11.9 cm [,]11.9–13.0 cm [,]13.0–14.1 cm [,]14.1–15.2 cm [,]15.2–16.3 cm [, and]16.3–17.4 cm [. The number of individuals per size class varies between 2 and 34. The class]16.3–17.4 cm [has the fewest individuals, while the largest number is observed in the class]11.9–13.0 cm [. The number of individuals differs significantly between the different size classes (Kruskal-Wallis tests, $p < 0.05$). In relation to urban lake 8, the standard length varies between 8.3 and 14.6 cm. A total of seven size classes were formed according to Sturge's rule. These are the classes :]8.3–9.2 cm [,]9.2–10.1 cm [,]10.1–11.0 cm [,]11.0–11.9 cm [,]11.9–12.8 cm [,]12.8–13.7 cm [, and]13.7–14.6 cm [. The number of individuals per size class varies between 3 and 37. The class]16.3–17.4 cm [has the fewest individuals, while the largest number is observed in the class]11.9–13.0 cm [. The number of individuals differs significantly between the different size classes (Kruskal-Wallis tests, $p < 0.05$). Regarding peri-urban lake 2, the standard length fluctuates between 9.0 and 17.75 cm. A total of seven size classes were formed according to Sturge's rule. These are the classes :]9.0 – 10.25 cm [,]10.25 – 11.5 cm [,]11.5 – 12.75 cm [,]12.75 – 14.0 cm [,]14.0 – 15.25 cm [,]15.25 – 16.5 cm [, and]16.5 – 17.75 cm [. The number of individuals per size class fluctuates between 2 and 38. The smallest number of individuals is recorded in the class]16.5 – 17.75 cm [, while the largest number is observed in the class]11.5 – 12.75 cm [. The number of individuals differs significantly between the different size classes (Kruskal-Wallis tests, $p < 0.05$) (Figure 3). Regarding peri-urban lake 4, the standard length varies between 10.5 and 18.5 cm. A total of eight size classes were formed according to Sturge's rule. These are the classes :]10.5 – 11.5 cm [,]11.5 – 12.5 cm [,]12.5 – 13.5 cm [,]13.5 – 14.5 cm [,]14.5 – 15.5 cm [,]15.5 – 16.5 cm [,]16.2 – 17.3 cm [, and]17.5 – 18.5 cm [. The number of individuals per size class varies between 3 and 30. The class]17.5 – 18.5 cm [has the fewest individuals, while the largest number is observed in the class]12.5 – 13.5 cm [. The number of individuals varies significantly between the different size classes (Kruskal-Wallis tests, $p < 0.05$). Regarding urban lake 5, the standard length varies between 8.3 and 18.3 cm. A total of eight size classes were formed according to Sturge's rule. These are the classes :]8.3 – 9.5 cm [,]9.5 – 10.8 cm [,]10.8 – 12.1 cm [,]12.1 – 13.3 cm [,]13.3 – 14.5 cm [,]14.5 – 15.8 cm [,]15.8 – 17.1 cm [, and]17.1 – 18.3 cm [. The number of individuals per size class fluctuates between 2 and 28. The smallest number of individuals is recorded in the class]17.1 – 18.3 cm [, while the largest number is observed in the class]10.3 – 11.3 cm [. The number of individuals differs significantly between the different size classes (Kruskal-Wallis tests, $p < 0.05$) (Figure 3).

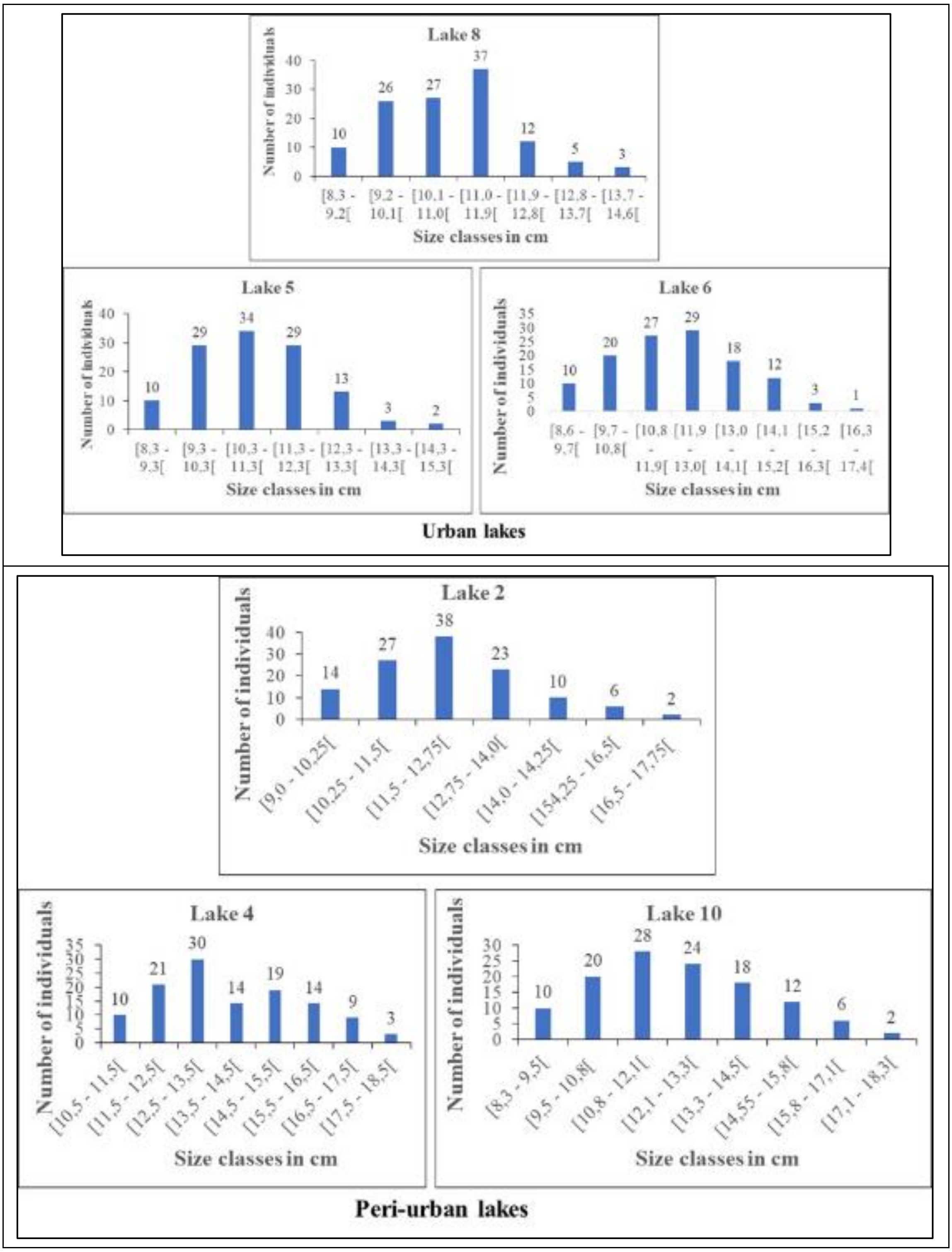

Figure 3 Distribution of size frequencies of *Oreochromis niloticus* specimens sampled in the lakes of Yamoussoukro

3.2. Length-weight relationship

Figure 4 presents the regression curves of the relationship between weight and standard length for *Oreochromis niloticus* individuals sampled from the lakes of Yamoussoukro.

The regression equation between weight and standard length indicates the absence of outliers in the measurements and weighings performed, and reveals a strong positive correlation between these two parameters ($0.87 \leq R^2 \leq 0.95$) across all the surveyed lakes (Figure 4).

Table 3 shows the parameters of the length-weight relationship for *Oreochromis niloticus* specimens sampled from the lakes of Yamoussoukro. *Oreochromis niloticus* individuals in Lake 4 exhibit isometric growth (b = 3), while those in the other lakes (2, 5, 6, 8, and 10) show negative allometric growth (b < 3).

Table 2 Length-weight relationship parameters and growth type of *Oreochromis niloticus* specimens sampled in the lakes of Yamoussoukro

Types of lakes	Lakes	Parameter of the length-weight relationship			Types of growth
		a	b	R^2	
Urban lakes	Lake 5	1,06	2,62	0,88	Negative allometric
	Lake 6	1,33	2,89	0,94	Negative allometric
	Lake 8	0,89	2,24	0,89	Negative allometric
Peri-urban lakes	Lake 2	1,33	2,94	0,87	Negative allometric
	Lake 4	1,46	3	0,93	Isometric
	Lake 10	1,38	2,9	0,95	Negative allometric

a: proportionality constant; b: allometric coefficient; R2: correlation coefficient

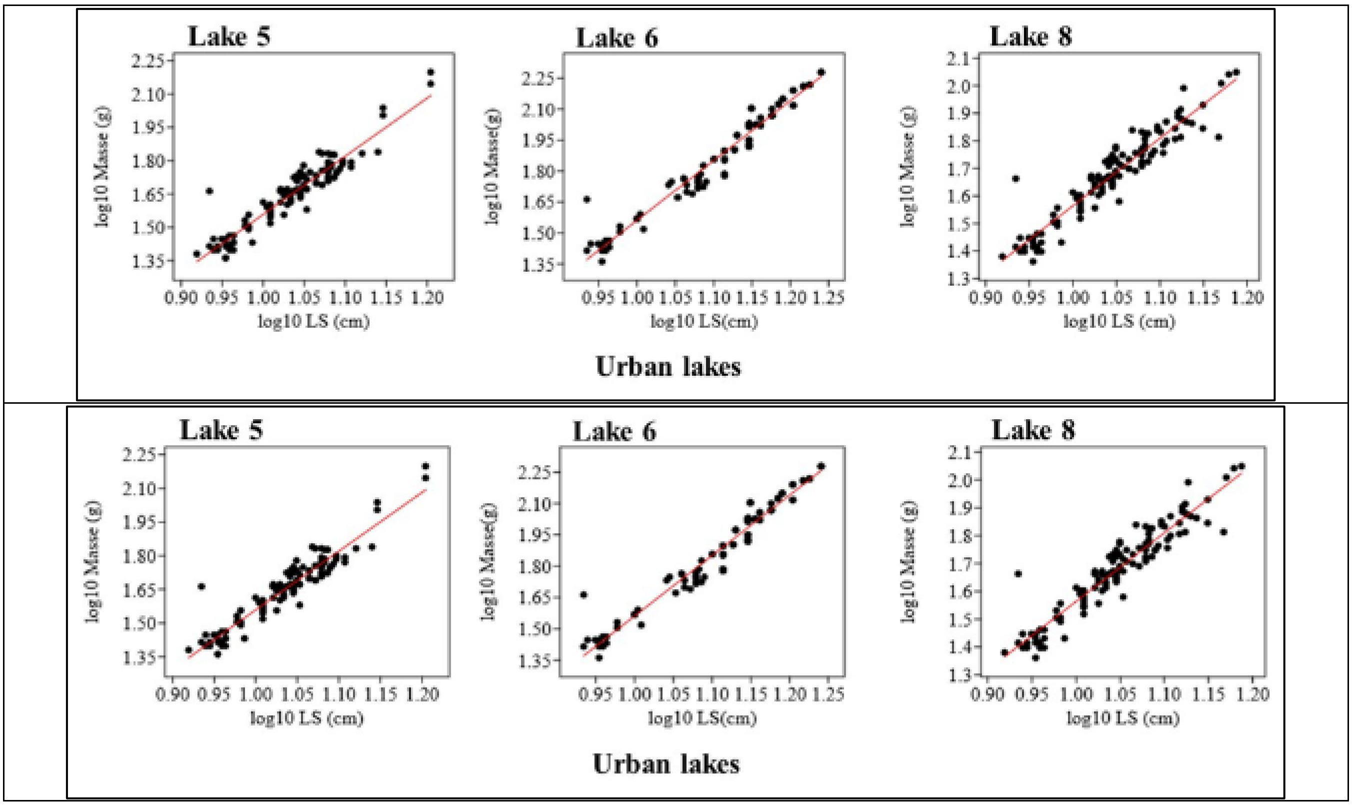

Figure 4 Scatter plot and regression line of weight as a function of standard length of *Oreochromis niloticus* specimens sampled in the lakes of Yamoussoukro

3.3. Facteur de condition

Table 3 presents the condition factor K values for *Oreochromis niloticus* specimens sampled from the lakes of Yamoussoukro.

The mean condition factor values are all greater than 0.5. No significant difference was observed between the mean condition factor values of *Oreochromis niloticus* specimens across all the surveyed lakes (Kruskal-Wallis test, $p < 0.05$) (Table 3).

Table 3 Condition factor K of *Oreochromis niloticus* specimens sampled in the lakes of Yamoussoukro

Types of lakes	Lakes	Condition factor (K)
Urban lakes	Lake 5	3,52
	Lake 6	3,57
	Lake 8	3,5
Peri-urban lakes	Lake 2	3,5
	Lake 4	3,71
	Lake 10	3,73

4. Discussion

The size class distribution of *Oreochromis niloticus* specimens in Urban Lake 5 shows that the standard length ranges from 8.3 to 15.3 cm , with the highest concentration in the]10.3–11.3 cm [class. This predominance of intermediate-sized individuals is similar to observations made by Saeed et al. (2019) in Lake Manzala, Egypt, where medium-sized individuals constituted the majority of catches. This can be explained by high mortality among juveniles and selective fishing that reduces the number of large individuals (Nguyen et al., 2020). In Urban Lake 5, the number of individuals differs significantly between classes, reflecting a non-uniform population structure, as observed by Khalil et al. (2018) in Blue Nile urban lakes, highlighting that anthropogenic pressures and local ecological conditions influence size distribution. For urban lake 6, the standard fish length ranged from 8.6 to 17.4 cm , with the highest concentration in the]11.9–13.0 cm [size class. This distribution, with a low number of individuals in the extreme sizes, is comparable to the findings of Abdel-Tawwab et al. (2015) in Lake Nasser (Egypt), where intermediate sizes were dominant, which could indicate recent recruitment and higher mortality among large individuals. Furthermore, the significant differences between size classes ($p < 0.05$) reflect demographic dynamics and intraspecific competition, as noted by Bhat et al. (2020) in Lake Vembanad, India, where ecological and dietary variations explained the dominance of medium sizes.

In urban lake 8, individual sizes fluctuated between 8.3 and 14.6 cm , with the largest population in the]11.9–13.0 cm [class. The dominance of intermediate sizes corresponds to trends observed by Hassan et al. (2017) in urban Nile lakes in Egypt, where medium sizes were favored by stable ecological conditions and moderate fishing. Furthermore, the significantly different number of individuals between sizes ($p < 0.05$) is similar to the observations of Goma et al. (2019) at Lake Burullus, where spatial variations and habitat availability resulted in a non-homogeneous size distribution. For peri-urban lake 2, the standard length ranges from 9.0 to 17.75 cm , with the]11.5–12.75 cm [size class having the highest concentration of individuals. This predominance of medium sizes is comparable to the studies by Ali et al. (2016) on Lake Qarun (Egypt), suggesting that food availability and refuges for juveniles favor these sizes. The significance of the differences between classes ($p < 0.05$) indicates a clear population structure, similar to what was observed by Ahmed et al. (2018) in peri-urban lakes in the Khartoum region (Sudan), where environmental factors and fishing strongly influence size distribution. The study conducted on *Oreochromis niloticus* in the lakes of Yamoussoukro revealed a strong positive correlation between standard length and individual weight, with a coefficient of determination (R^2) ranging from 0.87 to 0.95. This strong correlation suggests an absence of outliers in the measurements and weighings, indicating a rigorous and reliable methodology. Similar studies have been conducted in other regions. For example, a study on the Nile perch in Lake Naivasha, Kenya, also observed a strong correlation between length and weight, with an R^2 of 0.98, indicating a robust relationship between these two parameters (Otieno *et al*., 2014). Similarly, research in the Samandeni Reservoir in Burkina Faso reported a coefficient of determination of 0.96, reinforcing the idea of a stable and predictable relationship between length and weight in this species (Minoungou *et al*., 2020). Analysis of length-weight relationship parameters showed that *Oreochromis niloticus* individuals in Lake 4 exhibit isometric growth, with a growth coefficient (b) of 3. In contrast, those in the other lakes (2, 5, 6, 8, and 10) show negative allometric growth, with b values less than 3. This variation in growth patterns is also observed in other studies. For example, a study conducted in the Samandeni Reservoir in Burkina Faso reported a growth coefficient of 2.91 for Coptodon zillii, indicating negative allometric growth (Minoungou *et al*., 2020). Similarly, research in Lake Ayamé in Côte d'Ivoire found b values close to 2.8, also suggesting negative allometric growth (Otieno *et al*., 2014).

The mean condition factor of *Oreochromis niloticus* specimens in the lakes of Yamoussoukro is greater than 0.5, indicating that the individuals are healthy and in optimal body condition. Furthermore, no significant differences were observed between the mean condition factor values of specimens from the different lakes, suggesting homogeneity in the health status of the studied populations. Comparative studies have also reported similar values. For example, a study conducted on *Oreochromis niloticus* in the Samandeni Reservoir found a mean condition factor of 2.15, indicating good health (Minoungou *et al*., 2020). Another study in Lake Naivasha in Kenya observed condition factor values ranging from 1.93 to 2.11, also suggesting good health in the tilapia populations (Otieno *et al*., 2014).

5. Conclusion

The study of *Oreochromis niloticus* in the lakes of Yamoussoukro allowed for the characterization of size distribution, the length-weight relationship, and the condition factor of the populations. The size frequency distribution shows a predominance of intermediate classes and a reduced number of individuals in the extreme classes, indicating active recruitment and a population dominated by young and medium-sized individuals.

The length-weight relationship reveals a strong positive correlation ($0.87 \leq R^2 \leq 0.95$). Individuals from Lake 4 exhibit isometric growth ($b = 3$), while those from the other lakes show negative allometric growth ($b < 3$), suggesting possible differences in food availability or local conditions.

The condition factor K values, all greater than 0.5 and without significant differences between the lakes, indicate that the populations are generally in good physiological condition and adapted to environmental conditions.

This study thus highlights a relatively stable population dynamic, with local variations in growth and size distribution, providing reliable bases for the management and conservation of the species

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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