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Biological Characteristics of the Redbelly Tilapia, *Coptodon zillii* (Gervais 1848), Population in a Small Urban Lake: Case of the Kôkô Dam Lake (Korhogo, Côte d'Ivoire)

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ABSTRACT

This study aimed to characterize the *Coptodon zillii* population in a small urban lake subject to strong anthropogenic pressure. Sampling was conducted from August 2023 to June 2024 to assess fish size, size at first maturity, sex ratio, fecundity, length–weight relationship, and condition factor. Statistical analyses included the Chi-square test, Student's *t*-test, and Pearson's correlation. The population in Lake Kôkô was dominated by small individuals exhibiting early sexual maturity. The sex ratio was strongly male-biased (1 female: 3.4 males). Mean fecundity was low, with an average of 541 ± 433 eggs per spawning period per female. The length–weight relationship indicated positive allometric growth, while the condition factor suggested that individuals were overweight. Overall, these findings indicate a low reproductive potential for *C. zillii* in Lake Kôkô, raising concerns about a possible long-term decline of the stock in this environment. This study provides essential baseline information for the rational management of fishery resources in the small reservoirs of northern Côte d'Ivoire, contributing to strategies for sustainable development.

INTRODUCTION

The age-old technique of retaining surface water is becoming increasingly popular in regions affected by persistent drought **(Marzouk, 1989; Oweis *et al.*, 2001)**. Hill dams or small dams in Europe and Africa, Jessour dams in Tunisia, Açudes dams in Brazil, Presones dams in Mexico, and tanks in Asia serve a wide range of purposes **(Cecchi & Wongbé, 2007)**. In Côte d'Ivoire, small dams have been constructed mainly in the northern regions, where the climate is more arid, for three primary purposes: agriculture, pastoralism, and drinking water supply.

Despite these initial objectives, small dams in northern Côte d'Ivoire have quickly become centers of intense artisanal fishing activity **(Da Costa *et al.*, 1998)**. For example, the Kôkô Dam—originally built to supply drinking water to the town of Korhogo—has become the hub of artisanal fishing in the area **(Koudou *et al.*, 2020)**. In addition to fishing pressure, Lake Kôkô faces significant stress from rapid urbanization. Once located on the outskirts of Korhogo, the reservoir is now in the town's center. This anthropogenic pressure increases the risk of pollution through the occupation of the banks by informal settlements, the discharge of wastewater, the presence of dumps along the shore, and the silting of the lake bed **(Silué, 2020)**.

One of the main species landed at the Kôkô Dam Lake is the redbelly tilapia (*Coptodon zillii*), a potamodromous fish native to the brackish and freshwater systems of West Africa **(El-Sayed & Moharram, 2007)**. *C. zillii* belongs to the family Cichlidae, one of the most diverse families of freshwater fishes, with around 202 valid genera **(Nelson *et al.*, 2016)**. Africa is home to more than 1,600 species of Cichlidae, and *C. zillii* is widely distributed in West Africa, from Senegal to the River Benue in Nigeria **(Paugy *et al.*, 2003)**. In Côte d'Ivoire, this species occurs in almost all rivers **(Adou *et al.*, 2017; Kouassi *et al.*, 2020; Kouadio *et al.*, 2024)**. Highly valued by local populations, *C. zillii* commands a strong commercial price in local markets. According to **Nobah *et al.* (2008)**, this species shows high resilience in aquaculture, with survival rates of 100% in floating cages. Its feeding ecology and reproductive strategies are well documented **(Negassa & Prabu, 2008; Bavali *et al.*, 2022)**.

A species' reproductive strategy refers to the set of characteristics necessary to ensure successful reproduction **(Neves *et al.*, 2020)**. When environmental conditions change, certain traits may shift to maintain reproductive success. These variations—deviations from the pre-established strategy in response to environmental fluctuations—are known as reproductive tactics **(Neves *et al.*, 2020)**. Based on the hypothesis that reproductive tactics depend on environmental changes, which are often linked to human activities **(Neves *et al.*, 2020)**, the present study aimed to identify the biological parameters determining the tactics and reproductive success of *C. zillii* in Lake Kôkô.

The parameters examined include individual size, size at first maturity, sex ratio, fecundity, length–weight relationship, and condition factor. These metrics are of critical importance in fisheries science, as they are key tools for characterizing population structure, assessing reproductive potential, and estimating stock size **(Aydın & Ozdemir, 2021; Agumassie *et al.*, 2023)**. Specifically, this work seeks to describe the biological parameters of *C. zillii* to identify those most affected by anthropogenic pressures in Lake Kôkô.

MATERIALS AND METHODS

Study area and sample collection

Coptodon zillii specimens were collected from Kôkô Dam Lake. The Kôkô Dam Lake is a small reservoir of approximately 62 ha located in the city of Korhogo between 9°27'40" and 9°28'20" N and between 5°38'30" and 5°39'30" W in northern Côte d'Ivoire (Fig. 1). Located in an urban area, the Kôkô Dam is subject to intense anthropogenic pressure from urbanization, fishing and market gardening. Northern Côte d'Ivoire has a tropical Sudano-Guinean climate with two seasons: a dry season from November to March and a rainy season from April to October.

Coptodon zillii specimens were collected monthly from August 2023 to June 2024. However, it was not possible to conduct the campaign in May due to dam rehabilitation works. Fishing gear consisted of gill nets (8- 25mm stretched mesh size). All fish sampled were identified according to **Paugy *et al.* (2003)**. Standard length (SL) and body weight were measured for each fish in cm and g, respectively. Gonads were checked macroscopically to determine sex and maturity stages classified as in the study of **Fontana (1969)**. Gonads at an advanced stage vitellogenesis (stage IV at least) were fixed in 5% formalin for subsequent estimation of absolute fecundity.

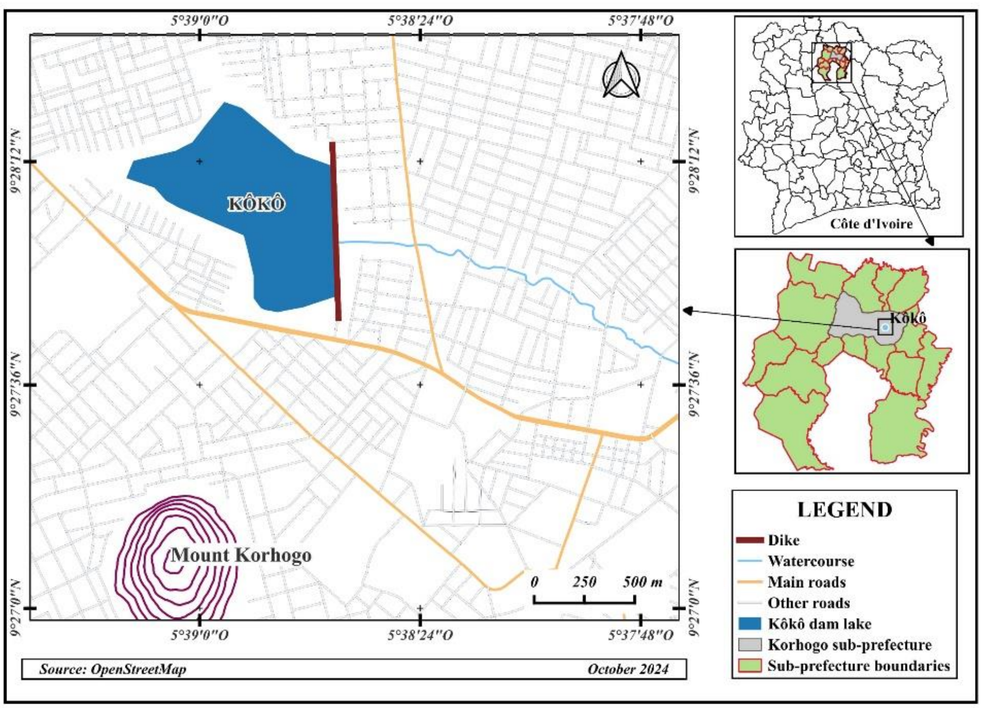

Fig. 1. Location of the Kôkô Dam Lake and its surroundings in the city of Korhogo (Northern Côte d'Ivoire)

Biological parameters determination

- **Size class**

To study the size structure of the population, Sturge's rule **(Sturges, 1926)** was used to determine the different size classes. According to this rule, the number of size classes is given by the following relationship:

$$Nc = 1 + (3.3\log_{10}N) \text{ and } Ic = (SL_{max}-SL_{min})/Nc$$

Where: Nc, number of size classes; N, the total number of individuals examined; Ic, class interval; SL_{max} and SL_{min}, maximum and minimum standard length observed, respectively.

- **First maturity size**

Size at first sexual maturity (SL_{50}) was estimated by fitting the percentage of mature individuals of all months to the logistic function of a non-linear regression according to **Ghorbel *et al.* (1996)**.

$$P = \frac{1}{1 + e^{-(\alpha+\beta SL)}}$$

$$SL_{50} = (-\alpha)/\beta$$

Where: P is the proportion of mature fish at size L, L_{50} is the length at which 50% of individuals were mature, and **α** and **β** are two constants.

- **Sex-ratio**

The sex ratio is the proportion of the two sexes to each other. The sex ratio was determined by the monthly distribution of males and females throughout the study period.

- **Fecundity estimation**

Fecundity is the number of mature eggs in the female before the next spawning. The sexual maturity scale used was that of **Legendre and Ecoutin (1989)**. According to this scale, female tilapia gonads develop in six stages. For the estimation of fecundity, only ovarian development stage IV, which is characteristic of females which are going to reproduce, was used. Fecundity was estimated by the sub-sampling method **(Le Bec, 1983)** of the number of oocytes belonging to the median sector (largest diameter) of the gonads **(Duponchelle *et al.*, 1998)**. The oocytes in this part are clearly separated from the rest of the oocytes and are visible to the naked eye. They correspond approximately to the oocytes that will be ovulated **(Duponchelle *et al.*, 1998)**. This part of the gonad has the advantage of minimising the effect of gonadal heterogeneity on fecundity. It was obtained using the following formula:

$$F = (n \times Wg)/Ws$$

Where F, fecundity; n, number of oocytes in the subsample obtained by manual counting; Ws, weight of subsample; Wg, weight of gonads.

❖ **Size-weight relationship**

The length-weight relationship was estimated by sex using to the standard allometric equation:

$$We = a \times SL^b$$

Where: W_e, eviscerated weight; a, constant; SL, standard length; b, allometry coefficient.

❖ **Condition factor**

The condition factor (K) was estimated for each sex using the following formula:

$$K = We/SL^3 \times 100$$

Where: W_e, eviscerated weight; a, constant; SL, standard length

Statistical analysis

The sex ratio of the fish was examined using the Chi-square test (χ^2), and values were tested at the 95% confidence level. Pearson's correlation coefficient was used to assess the influence of fish size on fecundity. To test whether the calculated b value was significantly different from the theoretical value of 3, the Student *t*-test was used according to **Sokal and Rohlf (1987)** equation:

$$t_s = (b - 3)/sd$$

Where: t_s is the t-test value, and Sd is the standard deviation of the allometric coefficient b. If t_s is greater than or equal to the theoretical value of t_s given by the Student table, this means that $b \neq 3$. The allometry is either negative ($b < 3$) or positive ($b > 3$). If t_s is less than the theoretical value of t_s given by the Student's table then $b = 3$ and growth is said to be isometric.

RESULTS

Size structure of the population and size at first maturity

Fig. (2) shows the standard-length frequency distribution of *Coptodon zillii* specimens caught in Kôkô Dam Lake. Size ranged from 5 to 16.5cm, with a mean of 8.02 ± 1.67cm. The standard-length frequency distribution showed a unimodal distribution. The sizes between 7.8 and 9.1cm predominated in the Kôkô Dam Lake. This size class comprises 38.37% of the sampled individuals. The second largest class consisted of SL between 6.4 and 7.7cm, and individuals in this class represented 31.05% of the population. Individuals with 12cm or larger (SL ≥ 12 cm) are very rare in Kôkô Dam Lake, representing only 2.27% of the sample.

The size at first sexual maturity of *C. zillii* males and females is shown in Fig. (3). The size of mature males ranged from 5.5 to 16.5cm with a mean of 8.79 ± 1.9cm. The size at first maturity was estimated to be 8.82cm (Fig. 3A). For females, the smallest mature individual at standard-length was 6cm, and the largest observed was 9cm, with a mean of 7.63 ± 0.8cm. The size at first maturity of the females was estimated to be

7.02cm in standard length (Fig. 3B). The Yates corrected Chi-squared test indicates that the sizes at first sexual maturity of the two sexes are not significantly different ($P > 0.05$).

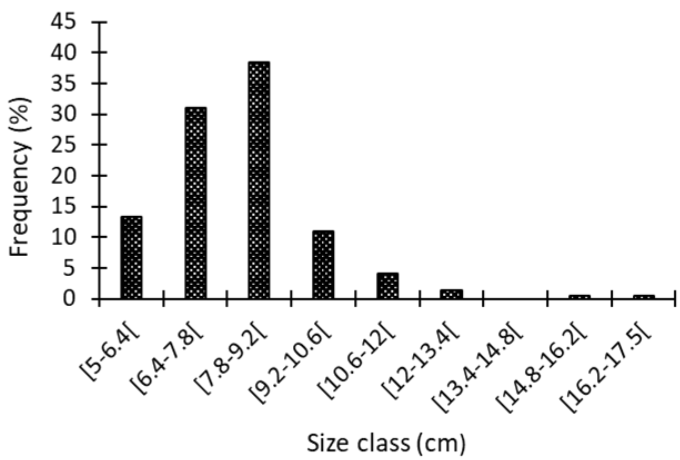

Fig. 2. Size frequency distribution of *Coptodon zillii* specimens caught from August 2023 to June 2024 in Kôkô Dam Lake

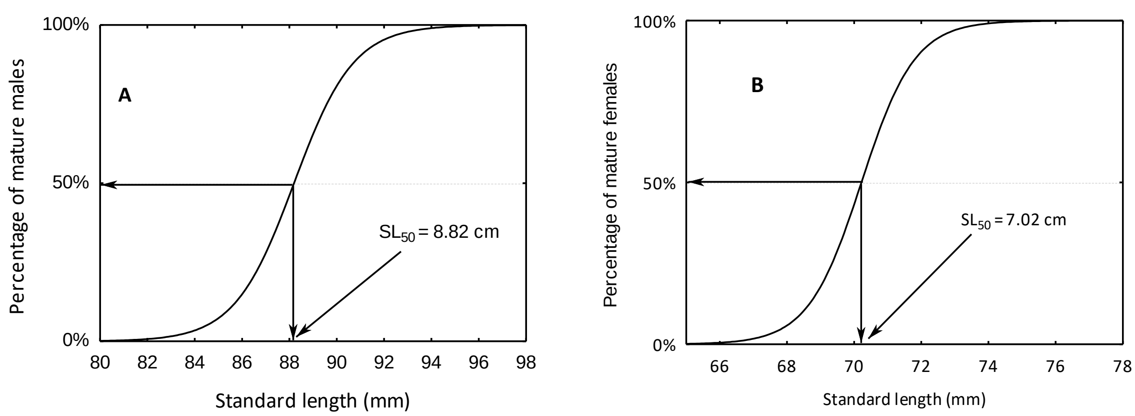

Fig. 3. Size at first maturity of male (A) and female (B) *Coptodon zillii* specimens caught from the Kôkô Dam Lake

Sex-ratio and fecundity

Out the 219 *Coptodon zillii* specimens dissected during the study, the sex of 189 could be identified. 146 of the 189 (77.25%) were males and 43 (22.75%) were females. The sex ratio of the overall captures was 1:3.4 (female: male), which is significantly different from the 1:1 ratio ($\chi^2 = 37.58$; $P < 0.05$) (Table 1). Males predominated in all sampling months. The highest proportion of females was recorded in February with 41.38%.

The fecundity of 16 females was estimated. Absolute fecundity ranged from 88 oocytes (in a fish of standard length 8.2cm) to 1488 oocytes (in a fish of standard length 8.3cm). The mean absolute fecundity observed in Lake Kôkô was 541 ± 433 oocytes. There was no significant correlation between absolute fecundity and standard length (Person Correlation Test, $P > 0.05$) when absolute fecundity was analyzed as a function of fish size (Fig. 4). The coefficient of determination ($R^2 = 0.052$) between absolute fecundity and fish size is very low. Relative fecundity ranged from 4 to 88 with an average of 38 ± 25 oocytes per gram of body weight.

Table. 1. Number of males and females in monthly samples of *Coptodon zillii* in Kôkô Dam Lake

Month	N		Sex-ratio (F:M)	Chi-square (χ^2)	*P*
	Male	Female			
Aug. 2023	12	6	1:2.00	0.76	0.383
Sep. 2023	14	3	1:4.67	3.71	0.054
Oct. 2023	29	2	1:14.5	15.27	**0.000**
Nov. 2023	14	6	1:2.33	1.43	0.231
Dec. 2023	15	7	1:2.14	1.30	0.254
Jan. 2024	19	5	1:3.80	4.51	**0.034**
Feb. 2024	17	12	1:1.42	0.28	0.595
Mar. 2024	15	2	1:7.50	5.55	**0.019**
Apr. 2024	6	0	1:0.00	2.53	0.112
Jun. 2024	5	0	1:0.00	1.84	0.175
Total	146	43	1:3.40	37.58	**0.000**

N: number of individuals, F: female, M: male

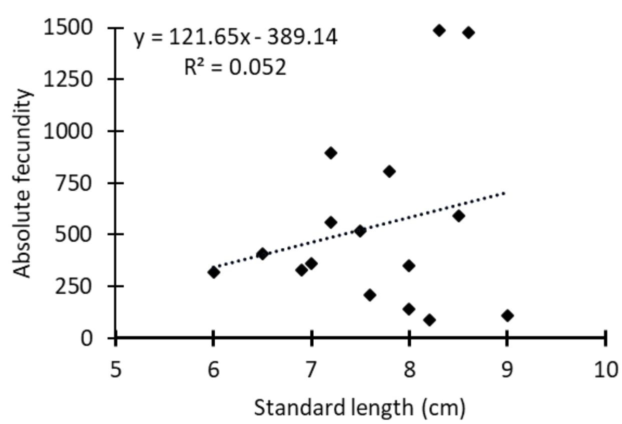

Fig. 4. Fecundity and fish standard length relationship of *Coptodon Zillii* caught from the Kôkô Dam Lake

Length-weight relationship and condition factor

Using standard length as a predictor, it was possible to accurately predict the weight of *C. zillii* individuals in the Kôkô Dam Lake. The generated model for combined sex was TW= $0.026SL^{3.134}$; R2= 0.973, n= 189) (Fig. 5). The calculated value of ts (3.155) is greater than the theoretical value of *ts* (1.96) given by the Student's t-table. This means that the coefficient of allometry (b= 3.134) is greater than the theoretical value (3). These results revealed that *C. zillii* exhibited a positive allometric growth pattern.

Fig. (6) illustrates the variation in the monthly mean condition factor recorded in *C. zillii* in Lake Kôkô. The lowest value of the condition factor was observed in August while the highest value was observed in March. The average value of the factor observed over all the sampling months is 4.04 ± 0.29. The monthly mean condition factor increases from 3.6 in August to 4.62 in March. However, the observed monthly variation of the condition factor is not significant. The value of this parameter is significantly greater than 1 (Student's t-test, $P< 0.00$).

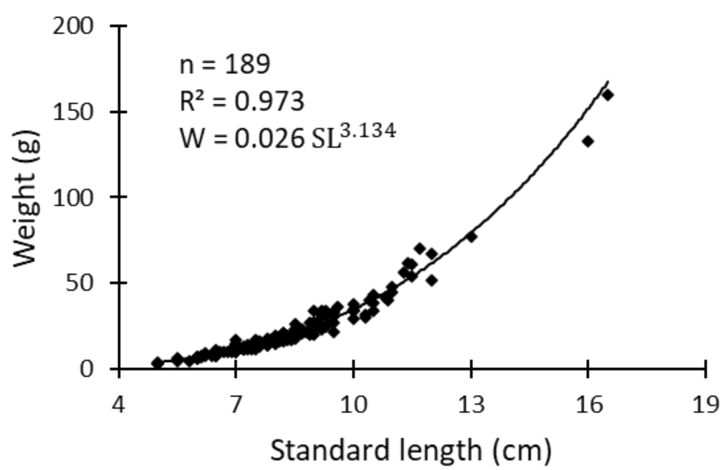

Fig. 5. Weight-length relationship for *C. zillii* in Kôkô Dam Lake from August 2023 to June 2024

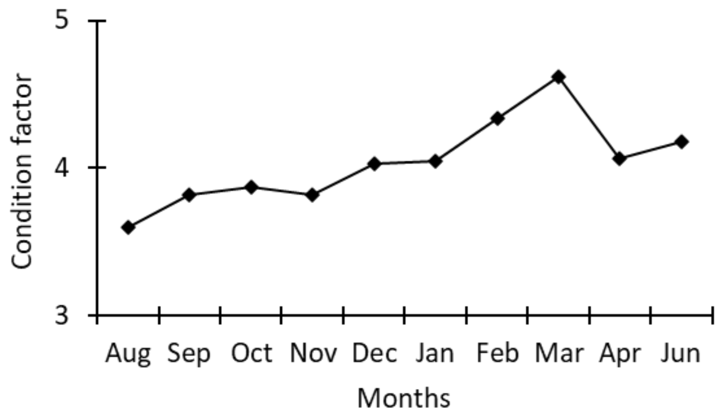

Fig. 6. Condition factor (K) in *Coptodon zillii* of the Kôkô Dam Lake from August 2023 to June 2024

DISCUSSION

The maximum size recorded for *Coptodon zillii* in Lake Kôkô was 16.5cm standard length (SL), with a mean size of 8.02 ± 1.67cm. These values are smaller than those reported in other studies. For instance, in Lake Naivasha (Kenya), **Yongo *et al.* (2022)** documented a mean size of 14.5 ± 2.1cm. On the other hand, in the Samandeni Reservoir (Burkina Faso), **Minoungou *et al.* (2020)** observed a maximum size of 23.60cm and a mean of 15.25cm. In Côte d'Ivoire, larger specimens have also been reported: **Kamelan *et al.* (2021)** recorded a maximum of 32.9cm (mean 12.74cm) in Lake Ayamé 1, and **Kien *et al.* (2022)** reported individuals up to 26.5cm SL in the Bandama River.

Differences in maximum size between populations of the same species are influenced by factors such as food availability, anthropogenic and fishing pressure, fishing gear type, predation on smaller fish, and water quality **(Agumassie *et al.*, 2023)**. In Lake Kôkô, the smaller mean and maximum sizes observed are alarming and indicative of overfishing. This conclusion is supported by **Koudou *et al.* (2020)**, who counted 73 artisanal fishers exploiting this small reservoir.

SL_{50}, the size at which 50% of individuals are sexually mature **(Albaret, 1982)**, is a critical management parameter. Sustainable fishing requires capturing fish after they reach SL_{50} **(Agumassie *et al.*, 2023)**, with recommended capture sizes exceeding first maturity **(Tefera *et al.*, 2019)**. In Lake Kôkô, most specimens were smaller than or equal to SL_{50}, suggesting that a large proportion were harvested before reproducing at least once.

Females reached sexual maturity earlier than males, consistent with findings for *C. zillii* in the Oued Righ wetland (Algeria) **(Zouakh *et al.*, 2016)** and lakes Taabo and Kossou (Côte d'Ivoire) **(Kouakou *et al.*, 2022)**. This finding was recorded for another Cichlid, *Thysochromis ansorgii*, in swamp forests **(Konan *et al.*, 2013)**. Smaller female maturity size reflects the better growth performance of males. **Bolivar *et al.* (1993)**

demonstrated that in tilapia, late-maturing individuals exhibit higher growth rates than early-maturing ones. In Lake Kôkô, SL_{50} was 8cm for males and 7cm for females, both smaller than values commonly reported in the literature. Such reductions are linked to environmental stressors—especially overfishing—which drive early maturation **(Duponchelle & Panfili, 1998)**. Early maturation reallocates energy from somatic growth to reproduction, enabling survival under high exploitation pressure **(Neves *et al.*, 2020)**.

The sex ratio provides insight into reproductive potential and population dynamics **(Vicentini & Araújo, 2003; Santana *et al.*, 2019)**. While a 1:1 ratio is typical, factors such as differential mortality, breeding migrations, size and age at maturity, and habitat segregation can alter it **(Fousseni *et al.*, 2017; Aydın & Ozdemir, 2022)**. In Lake Kôkô, the sex ratio significantly deviated from parity, with a strong male bias. Similar trends have been observed in *C. zillii* populations in the Garmat Ali River (Iraq) **(Mohamed & Al-Wan, 2020)**, the Shadegan wetland (Iran) **(Bavali *et al.*, 2022)**, and Lake Sélingué (Mali) **(Sanogo *et al.*, 2022)**. In this case, the male predominance likely reflects their faster growth rate, as identified by maturity size, which reduces predation risk but increases vulnerability to fishing.

Fecundity in Lake Kôkô ranged from 88 to 1,488 eggs per spawning period, considerably lower than values reported elsewhere: 1,750–4,340 eggs in Ivorian rivers **(Albaret, 1982)**, 4,849–80,993 eggs in the Shadegan wetland **(Bavali *et al.*, 2022)**, and 1,472–6,116 eggs in the Ono Lagoon and 1,676–4,210 eggs in the Kodjoboué Lagoon **(N'Goran *et al.*, 2022)**. **(Geletu *et al.*, 2024)** reported 1,000–6,000 eggs per female. Fecundity is strongly influenced by food availability **(Oso *et al.*, 2011)**. When food is found with reduced rations, a lower reproductive output is recorded **(Springate *et al.*, 1985)**. The low fecundity observed here likely reflects intense fishing pressure and the reduced size of mature individuals. The lack of significant variation in fecundity with size suggests the sampled individuals belong to a single recruitment cohort.

Length–weight relationship analysis indicated that *C. zillii* in Lake Kôkô exhibits positive allometric growth—gaining weight faster than length. Similar results have been reported from the Samandeni Reservoir **(Minoungou *et al.*, 2020)**, Lake Ayamé 1 **(Kamelan *et al.*, 2021)**, and the Bandama River **(Kien *et al.*, 2022)**. The allometric coefficient (*b*) can be influenced by water quality, food supply **(Henderson, 2005)**, sex, growth stage, feeding status, gonad development **(Hossain *et al.*, 2006)**, and hydrology **(N'Dri *et al.*, 2020)**. In Lake Kôkô, however, fishing pressure likely plays a greater role, favoring smaller individuals.

The mean condition factor (*K*) was 4.04, well above the threshold of 1, indicating good physiological condition **(Alhassan *et al.*, 2015)**. Similar high condition values for *C. zillii* have been reported in the Samandeni Reservoir **(Minoungou *et al.*, 2020)**, Lake Ayamé 1 **(Kamelan *et al.*, 2021)**, and the Bandama River **(Kien *et al.*, 2022)**. The high condition factor reflects *C. zillii*'s adaptability to diverse environments. Like other

Cichlids, it is tolerant to environmental variation and has a broad diet including plant material, larvae, zooplankton, small crustaceans, and mollusks **(Negassa & Prabu, 2008)**.

CONCLUSION

The analysis of the biological traits of *Coptodon zillii* in Lake Kôkô revealed strong anthropogenic pressure on the population. This pressure has led to a reduction in individual size, size at first sexual maturity, and fecundity. The population is dominated by small individuals (SL < 10 cm) and shows a pronounced male bias, with a sex ratio of 1 female to 3.44 males. These characteristics indicate a short-term decline in the reproductive potential of *C. zillii* and suggest a possible long-term collapse of the stock in this environment. Despite these pressures, *C. zillii* exhibits a high condition factor, reflecting its tolerance to environmental variability. This study contributes to the rational management of aquatic resources, providing essential data to support strategies for sustainable fisheries development in small reservoirs of northern Côte d'Ivoire.

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