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Length-weight relationship, condition factor and reproductive characteristics of *Synodontis rebeli* from the lower Sanaga River, Cameroon

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This study investigated the length–weight relationship (LWR), condition factor (K), and reproductive characteristics of *Synodontis rebeli* from the lower Sanaga River, Cameroon. A total of 257 specimens were collected bimonthly between January 2024 and March 2025. The LWR, K, and gonadosomatic index (GSI) were determined, while linear regression, Chi-square, Kruskal–Wallis, and Mann–Whitney tests were used for statistical analyses. The specimens exhibited negative allometric growth (b = 2.82), indicating that body weight increased at a slower rate than the cube of body length. A strong positive correlation was observed between standard length (SL) and body weight (r = 0.93). The inverse relationship between the K and the GSI suggests that energy reserves are progressively allocated from somatic growth to gonadal development during the reproductive period. Peak reproductive activity occurred in March and from September to November, corresponding to the onset of the short and long rainy seasons, respectively. These findings provide valuable baseline biological information for stock assessment, the development of seasonal fishing regulations, and the sustainable management and conservation of *S. rebeli* in the lower Sanaga River.

Key words: Allometric growth, reproductive biology, gonadosomatic index, spawning season, freshwater catfish, fisheries management.

INTRODUCTION

Fisheries make a significant contribution to food and nutritional security in Cameroon, where fish represents the main source of animal protein for the population. According to FAO (2022), annual per capita fish consumption is approximately 19 kg, accounting for 42.3% of total animal protein intake and about 9.5% of the overall dietary protein consumed in the country. Inland fisheries contribute approximately 50,000 tonnes annually and are distributed across three major fishing zones: the forest, central, and northern zones. The central zone, which is dominated by the Sanaga River basin, produces an estimated 5,500–6,400 tonnes per year, representing

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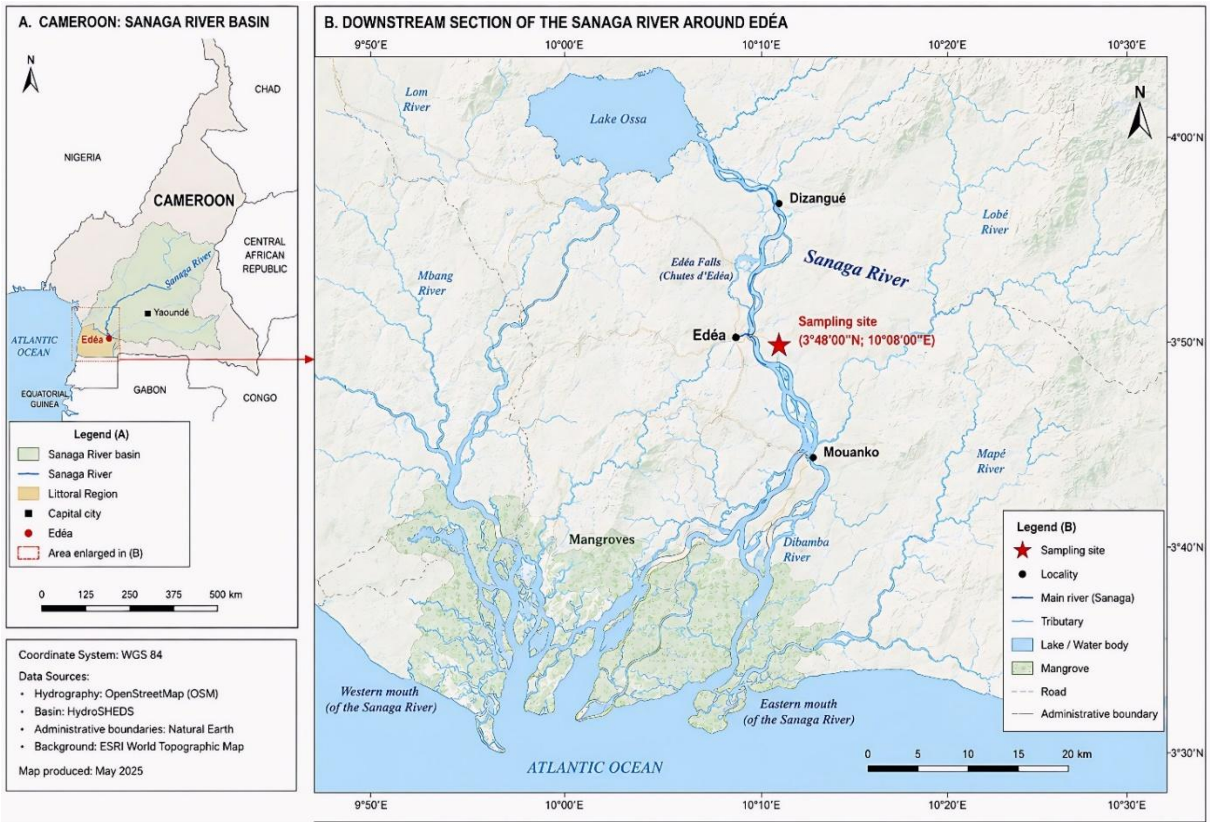

Figure 1. Location of the sampling stations in the Lower Sanaga River, Cameroon, where *S. rebeli* specimens were collected between January 2024 and March 2025.

nearly 20% of the country's inland fish production (FAO, 2022). In the lower Sanaga River, *Synodontis rebeli* (Holly, 1926) is widely consumed by local communities and has considerable potential for aquaculture development (Mbondo et al., 2019).

Declining fish abundance, reduced body size, and changes in species composition in inland fisheries have largely been attributed to overfishing and environmental degradation (Allan et al., 2005). Although several fish species, including *Oreochromis niloticus* (Linnaeus, 1758), *Clarias gariepinus* (Burchell, 1822), and *Cyprinus carpio* (Linnaeus, 1758) are successfully farmed in Cameroon, many indigenous species, including *Synodontis* species, remain dependent on capture fisheries and have received little attention for aquaculture development. Improving knowledge of the population biology of these native species is therefore essential to support their sustainable exploitation and conservation. Despite its commercial importance, information on the growth pattern, reproductive biology and population dynamics of *S. rebeli* remains scarce. Fish morphometric analyses have long played a fundamental role in fisheries science (Froese and Pauly, 2024). Among these, the length–weight relationship (LWR) is one of the most widely used tools for describing growth patterns, estimating fish biomass from length data, and providing essential parameters for stock assessment and fisheries management (Akombo et al., 2014). Jamabo et al. (2009) also emphasized that LWR parameters are indispensable in fisheries biology because they are incorporated into numerous population dynamics and stock assessment models. Likewise, the condition factor (K), which reflects the physiological condition or "well-being" of fish, provides valuable information on environmental quality, feeding intensity, reproductive status, and habitat suitability (Andrade et al., 2020). Given the limited biological information currently available for *S. rebeli*, this study aimed to investigate its LWR, K, and reproductive characteristics in the lower Sanaga River, Cameroon. The findings are expected to provide baseline information for the sustainable management, conservation, and potential aquaculture development of this economically important species.

MATERIALS AND METHODS

The study was conducted in the lower Sanaga River at Edéa (3°48′00″ N, 10°08′00″ E), Littoral Region, Cameroon (Figure 1), between January 2024 and March 2025. The lower Sanaga River extends approximately 67 km from the Edéa Falls to its mouth in the Atlantic Ocean. Downstream of the falls, where the main channel rejoins a secondary channel, the river is approximately 600 m wide. It gradually widens toward the estuary and is characterized by numerous islands and sandbanks during the low-water season. The floodplain is bordered by lowlands covered with dense forests, swamps, and several lakes, the largest of which is Lake Ossa in the Dizangué area. Further downstream, the freshwater forest gradually transitions into mangrove ecosystems intersected by tidal creeks and channels. Near Mouanko, the Sanaga River discharges into the Atlantic Ocean through two main distributaries separated by an island approximately 12 km long and 2 km wide (Wirrmann, 1992).

The Edéa area is characterized by an oceanic variant of the Guinean equatorial climate, with a three-month dry season extending from December to February, during which monthly rainfall is generally below 50 mm, and a seven-month rainy season. Mean monthly air temperature remains relatively stable throughout the year, averaging 26.5°C. Atmospheric humidity is consistently high, with a mean annual water vapour pressure of 28.4 mb, varying mainly with temperature (Wirrmann, 1992). The diversity of aquatic habitats, stable hydrological conditions, and high biological productivity make the lower Sanaga River an important ecosystem supporting artisanal fisheries and a rich diversity of freshwater fish species, including *S. rebeli*. Fish sampling was carried out at the Edéa artisanal landing site.

Fish sampling was conducted bimonthly from January 2024 to March 2025, resulting in eight sampling campaigns (January, March, May, July, September, and November 2024, and January and March 2025). During each campaign, freshly caught fish were purchased immediately after landing from artisanal fishers operating at the Edéa landing site. Fish were captured using gillnets. A total of 257 specimens of *S. rebeli* were collected, with approximately 30–35 individuals examined during each sampling campaign to ensure comparable sampling effort throughout the study period. All available *S. rebeli* individuals landed during each sampling campaign were included irrespective of sex or body size, to obtain a representative sample of the population. Immediately after collection, specimens were fixed in 10% buffered formalin and transported to the laboratory for identification and biological analyses. Fish identification was carried out using the taxonomic key of Stiassny et al. (2007), based on external morphological characteristics and diagnostic meristic features of *Synodontis* spp.. For each specimen, standard length (SL) = horizontal distance from front tip of snout to base (articulation) of caudal fin (Stiassny et al., 2007) was measured to the nearest 0.01 cm using a digital carbon-fibre caliper (B-G Carbon Fiber Digital Caliper, BG5153). Gutted body weight and gonad weight were measured to the nearest 0.01 g using a digital electronic balance. Gutted body weight was used instead of total body weight to minimize variability associated with stomach contents and seasonal changes in gonad mass, thereby providing a more reliable estimate of somatic growth for the length–weight relationship analysis (Froese, 2006). Each specimen was sexed as male, female, or undetermined following macroscopic examination of the gonads. The LWR was described using the equation:

$$W = aLb$$

where W = Gutted Body weight (g) and SL = Standard length (cm). Parameters “a” and “b” were estimated by a linear regression equation based on the natural logarithm: Log (W) = Log (a) + b Log (SL). Additionally, 95% confidence intervals (CI) of b, the coefficient of determination r^2, t, and P values were estimated. The K was calculated for each fish, irrespective of sex, using gutted body weight and SL according to the equation proposed by Froese (2006):

$$K = (Wx100) / L3$$

where W = Gutted weight of fish in g; SL = Standard length of fish in cm. Mean K values were subsequently computed separately for males and females during each bimonthly sampling campaign to evaluate temporal variations in body condition throughout the study period. Gonadosomatic index (GSI) was calculated using the following equation (Unlu and Balci, 1993):

$$GSI= W /W\text{-}GW \times 100$$

where GW = gonad weight, W = Body weight. Annual variation in this index in a fish population provides information on their spawning periods: a fall in its value indicates the spawning season (Lizama and Ambrosio, 2002).

The Chi-square (χ^2) test was used to compare the observed sex ratio with the expected 1:1 ratio and to determine whether deviations from equality were statistically significant. The Kruskal–Wallis test was used to compare the mean K and GSI among the eight bimonthly sampling campaigns. When significant differences were detected, pairwise comparisons were performed using the Mann–Whitney U test. Linear regression permitted the investigation of the relationship between body weight and SL. All statistical analyses were performed using PAST (Paleontological Statistics) version 6.0 (Hammer et al., 2025). All values of $P < 0.05$ were considered significant.

RESULTS AND DISCUSSION

A minimum of 30 specimens were collected during each sampling campaign to ensure sufficient sample size for reliable statistical analyses. The distribution of *S. rebeli* specimens among the eight sampling campaigns is presented in Table 1. Of the 257 specimens examined, sex was successfully determined for 232 individuals, comprising 119 males and 113 females. The remaining 25 specimens could not be sexed because their gonads were immature or insufficiently developed. The overall male-to-female sex ratio was 1.05:1. Comparison of sex ratios among the eight sampling campaigns using the Chi-square test showed no significant temporal variation (χ^2 = 8.89, df = 7, $P > 0.05$), indicating that the proportions of males and females remained relatively stable throughout the study period.

The SL of *S. rebeli* specimens varied by fishing campaigns, as presented in Figure 2. The box plot shows that the median SL was significantly lower in May and November, in contrast to January 2024 and 2025, when larger individuals were caught. The Kruskal-Wallis test for equal medians showed significant differences in fish length between campaign captures (K = 35.85; P = 7.74^{E-6}).

About 257 individuals weighed 12 to 280.8 g, while standard lengths ranged from 8.85 to 22.06 cm. The correlation coefficient (r) and allometry coefficient (b) are 0.93 and 2.82, respectively, as presented in Figure 3. The length–weight relationship showed a strong positive correlation between SL and body weight (r = 0.93). The estimated allometric coefficient (b = 2.82) was significantly lower than the theoretical isometric value of 3.0, indicating negative allometric growth in *S.s rebeli*, suggesting that the growth of the species studied is therefore negative allometry. The corresponding regression equation is Log PE = -1.40 + 2.82 LogLS; t: 40.502, p = 4.5385^{E-113}.

The condition coefficient K has, on average, varied

Table 1. Distribution of *S.s rebeli* during the fishing campaign.

Sex	Fishing campaign								Total
	Jan-24	**Mar-24**	**May-24**	**Jul-24**	**Sept-24**	**Nov-24**	**Jan-25**	**Mar-25**	
Male **(%)**	11 (4.3)	17 (6.6)	14 (5.5)	19 (7.4)	16 (6.2)	16 (6.2)	9 (3.5)	17 (6.6)	119 (46.3)
Female (%**)**	20 (7.8)	11 (4.3)	16 (6.2)	10 (3.9)	16 (6.2)	10 (3.9)	18 (7)	12(4.6)	113 (43.9)
In.*(%)	1 (0.4)	2 (0.8)	1 (0.4)	4 (1.5)	3 (1.2)	7 (2.7)	3 (1.2)	4 (1.5)	25 (9.73)
Sub-total	32 (12.5)	30 (11.7)	31 (12)	33 (12.8)	35 (13.6)	33 (12.8)	30(11.7)	33 (12.8)	257 (100)
Sex-ratio (M/F)	0.55	1.54	0.87	1.9	1	1.6	0.5	1.41	1.05

in*= undetermined sex.

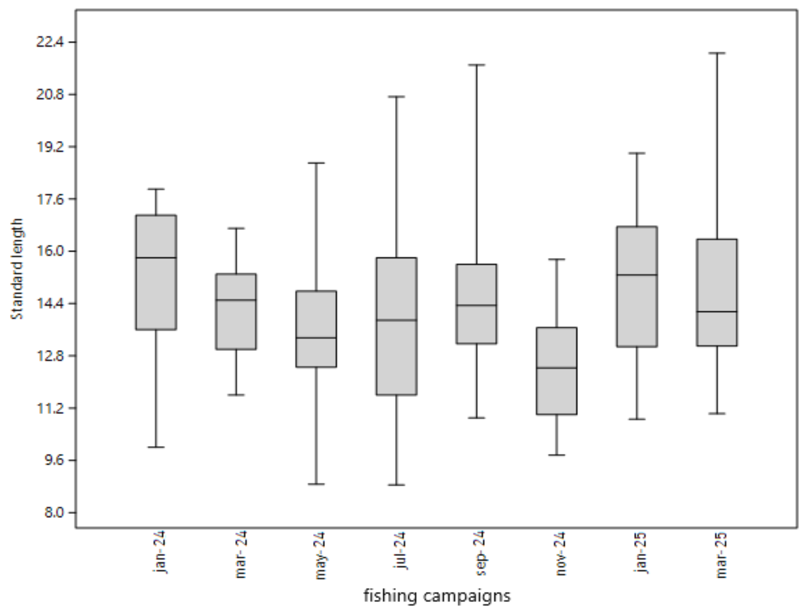

Figure 2. Variation in the SL of *S. rebeli* across the eight bimonthly sampling campaigns.

between 1.4 (January, 2024) and 3.2 (July and September, 2024) (Table 2). Differences in this parameter between fishing periods were significant (K = 33.15; P = 2.48E-5).

As for the gonado-somatic index of *S. rebeli* females, the above table showed two peaks in the dry season, occurring in January 2024 (GSI=0.55) and 2025 (GSI=0.34). The differences observed for this parameter were significant (K = 38.27; P = 2.69E-6). The regression line established between these two parameters (Figure 4) shows that the condition coefficient decreases while the GSI increases, indicating an inverse relationship between body condition and gonadal development in female *S. rebeli*.

The present study showed that *S. rebeli* exhibited a negative allometric growth pattern (b < 3), indicating that body length increased proportionally faster than body weight. The estimated values of b (2.82) and r^2 (0.93) are comparable to those reported by Tah et al. (2012) for *Synodontis bastiani* from Lake Buyo (b = 2.89, r^2 = 0.92) and by Koné et al. (2022) for the same species in the Bandama River (b = 2.71, r^2 = 0.93). Similar growth coefficients have also been reported for *Synodontis punctifer*, with values of b = 2.68 (Tah et al., 2012) and b = 2.89 (Koffi et al., 2018). These findings suggest that negative allometric growth is a common characteristic among several African *Synodontis* spp..

The allometric coefficient (b) reflects the relationship between fish length and body mass and may vary according to environmental and biological factors. Variations in water temperature, food availability, reproductive status, habitat conditions, as well as intrinsic factors such as sex and age, together with sampling season, fishing gear, and geographic location, have all been reported to influence length–weight relationships (Medina-Reyha, 2001; Prasad, 2001; Ama-Abasi, 2007;

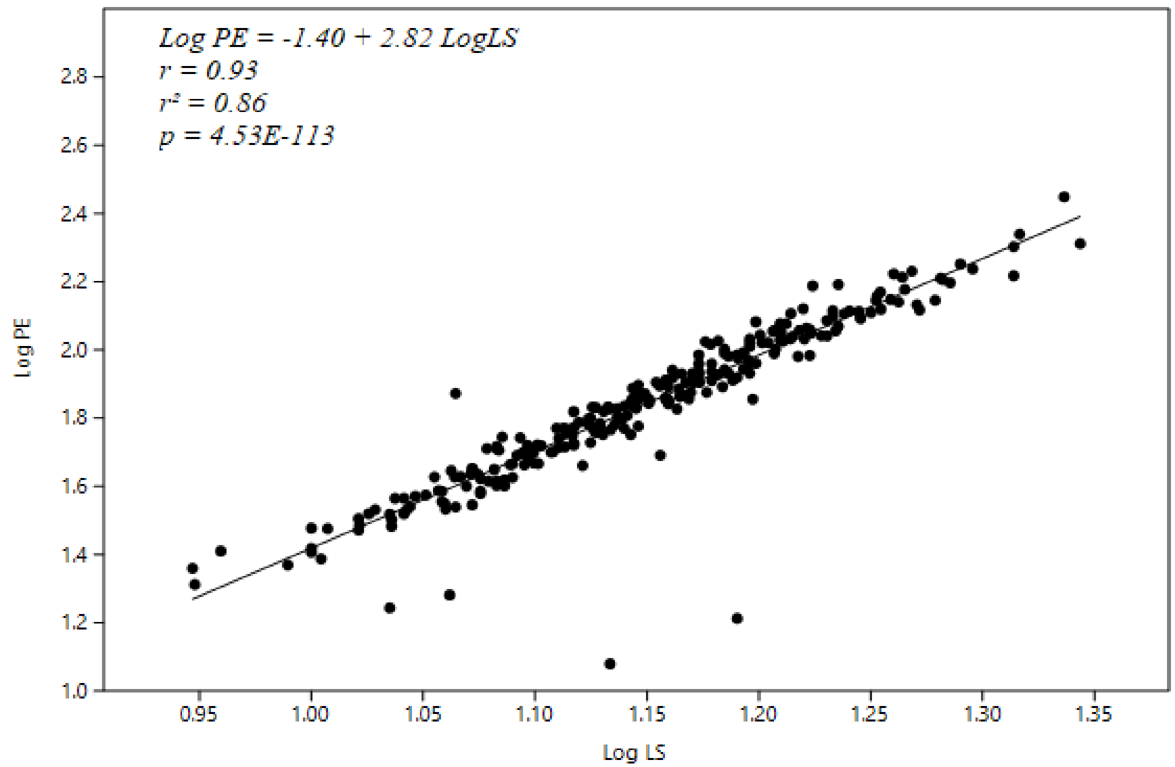

Figure 3. LWR of *S. rebeli* from the lower Sanaga River.

Table 2. Variation of K and GSI values during the fishing campaign.

Parameter	**Fishing campaign**							**Statistics**	
	Jan-24	**Mar-24**	**May-24**	**Jul-24**	**Sept-24**	**Nov-24**	**Jan-25**	**Mar-25**	Statistics
K (Mean ± SD)	1.9 ± 0.2 (n = 32)	2.9 ± 0.2 (n = 30)	2.9 ± 0.3 (n = 31)	3.2 ±0.3 (n = 33)	3.2 ± 0.3 (n = 35)	2.6 ± 0.2 (n = 33)	1.4 ±0.2 (n = 30)	2.9 ± 0.2 (n = 33)	33.15; 2.48^{E}-5
Female ISG (Mean ± SD)	0.5 ± 0.1 (n = 20)	0.2± 0.02 (n = 11)	0.29 ± 0.03 (n = 15)	0.25 ± 0.02 (n = 9)	0.19 ± 0.01 (n = 15)	0.27 ± 0.02 (n = 7)	0.34 ± 0.01 (n = 17)	0.22 ± 0.04 (n = 12)	38.27 2.69^{E}-6

n = number of fish examined.

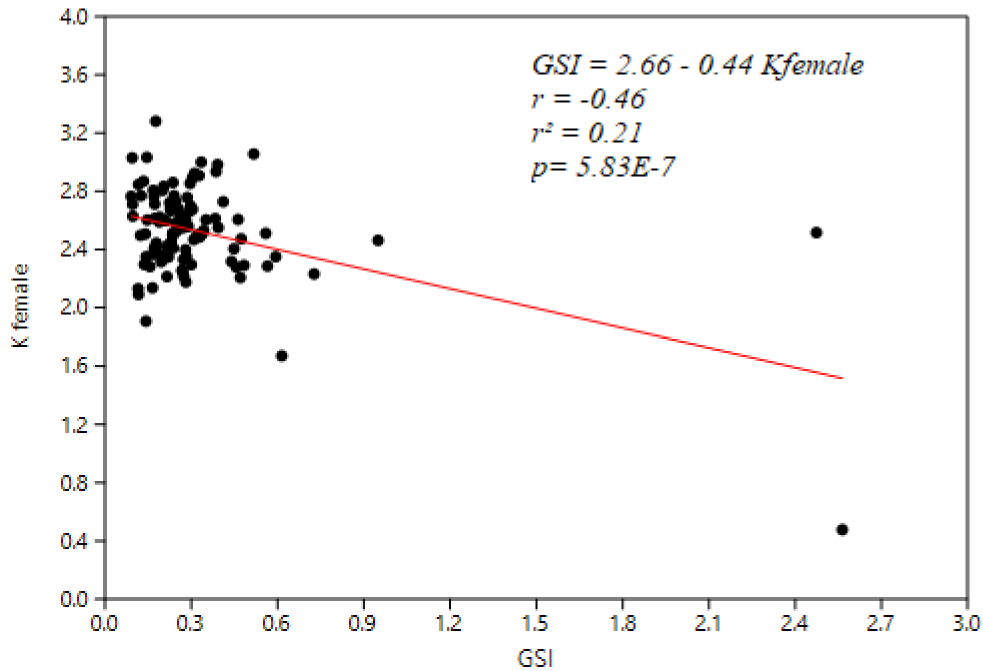

Figure 4. Regression line of the coefficient condition of female specimen (K female) as a function of GSI.

Yem et al., 2007; Adeyemi et al., 2009; Oliva-Paterna et al., 2009; Adaka et al., 2015). Furthermore, the high coefficient of determination (r^2 = 0.93) indicates that SL explained most of the variation in body weight, confirming a strong length–weight relationship in *S. rebeli*.

The K remained above 2 throughout most of the study period, except during January 2024 and January 2025, indicating that the fish were generally in good physiological condition (Abowei, 2010). However, the lowest K values coincided with periods of high GSI values in females, suggesting an inverse relationship between somatic condition and reproductive investment. Similar observations have been reported in several teleost species, where energy reserves are progressively reallocated from somatic tissues to gonadal development during sexual maturation (Lowerre-Barbieri et al., 2023). Lizama and Ambrosio (2002) proposed that the decline in K during the reproductive period reflects the increased energetic demands associated with gonadal maturation rather than a deterioration in fish health. This pattern is consistent with the progressive mobilization of energy reserves from somatic tissues to gonadal development during the reproductive cycle, resulting in a decline in the K as spawning progresses (Lowerre-Barbieri et al., 2023; Bhat et al., 2025).

Similarly, the increase in K before the spawning season is generally associated with gonadal development and energy storage, whereas its decline during or immediately after spawning reflects the energetic cost of reproduction (Kobayashi et al., 2026). The marked decreases in GSI observed in March 2024 and 2025, and again between September and November 2024, indicate that spawning most likely occurred during these periods.

Comparable reproductive patterns have been reported for several African *Synodontis* spp., whose breeding activity generally coincides with the rainy season. Increased rainfall and flood events expand available aquatic habitats, enhance food availability, and provide favourable nursery conditions for eggs and larvae (Albaret, 1982; Halim and Guma'a, 1989; Paugy, 2002; Kouassi et al., 2018). This seasonal reproductive strategy is widely recognized among tropical freshwater fishes, where rainfall constitutes one of the principal environmental cues regulating reproductive timing (Lam and Munro, 1987; Lowe-McConnell, 1987; Boujard, 1992). In the lower Sanaga River, the declines in GSI recorded in March and from September to November coincide with the onset of the short and long rainy seasons, respectively, suggesting that reproduction in *S. rebeli* is closely synchronized with seasonal rainfall patterns.

Conclusion

This paper has provided basic data on weight - length relationships, condition coefficient (K), GSI, and reproduction period of *S. rebeli* that would be beneficial for fishery managers to impose suitable regulations of natural stocks for sustainable fishery management in the Sanaga River. An expensive and continuous study should be carried out to always know the actual population of fish species in this river for proper management and control.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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