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RESEARCH ARTICLE

SEXUAL MATURITY STAGES AND CONDITION FACTOR OF *Brycinus imberi* (Peters, 1852) ACCORDING TO SEASON AND BODY SIZE IN SOLOMOUGOU DAM LAKE (COTE D'IVOIRE)

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Abstract

Fulton's condition factor (K) is commonly used to assess fish body condition, but it may vary with reproductive status, season, body size, and sex. This study examined variations in K according to sexual maturity stage, season, and body size in *Brycinus imberi* from artisanal commercial catches in the Solomougou Dam Lake. From March 2024 to February 2025, 835 specimens (474 females and 361 males) were examined. No sampling was conducted in September because of flooding. Variations in K were analysed separately by sex using non-parametric tests and models accounting for monthly variation. In females, K differed among maturity stages (Kruskal-Wallis: $H = 35.11$; $df = 6$; $p < 0.001$; $\epsilon^2 = 0.062$) and was particularly low at the post-spawning stage VI (median = 1.61; $n = 9$). This association remained significant after adjustment for month ($p < 0.001$). In males, the unadjusted differences among maturity stages ($H = 26.26$; $df = 5$; $p < 0.001$) disappeared after adjustment for month ($p = 0.226$). K did not differ significantly between seasons in females ($p = 0.149$) but was higher during the dry season in males ($p = 0.014$). K decreased with standard length in females (Spearman's $\rho = -0.451$; $p < 0.001$), whereas no significant relationship was observed in males ($\rho = 0.018$; $p = 0.739$). Body-condition variations related to sexual maturity, season, and size were sex-specific. These factors should therefore be considered when interpreting K and assessing the reproductive condition of *B. imberi* in commercial catches.

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Introduction:-

The condition factor provides information on a fish's relative mass for a given length and serves as a summary indicator of its body condition (Le Cren, 1951; Froese, 2006). It can vary with food availability, season, size, sex, and reproduction. However, the relative importance of these factors depends on the species, biological stage, and environmental conditions (Dinh et al., 2022; Caballero-Huertas et al., 2022; Le et al., 2024). Gonadal maturation mobilizes resources, while gamete release directly reduces body mass; condition profiles can therefore differ between resting, maturation, emission and post-laying phases. Fulton's condition factor was retained because it is widely used to compare fish condition among reproductive stages and seasons. However, unlike Le Cren's relative condition factor, it assumes isometric growth. This limitation was considered when interpreting the results because the length–weight exponent was lower than 3 in both females ($b = 2.217$) and males ($b = 2.882$).

However, the relationship between condition and reproduction in tropical fish must be interpreted with caution. A K-value calculated from total weight includes gonad mass and does not constitute a direct measure of energy reserves. Furthermore, maturity stages are often seasonal, meaning that differences between stages may partly reflect the influence of the month or environmental conditions. Joint analysis of stages and temporal variation allows for a better distinction between these mechanisms. *Brycinus imberi* (Peters, 1852) is an alestid fish found in the inland waters of Côte d'Ivoire. Despite the species' local importance to fisheries, variations in its condition during maturation remain poorly documented. Studies on related species, particularly *B. nurse*, have shown seasonal reproduction linked to rainfall and flood events (Saliu and Fagade, 2003); however, these observations do not allow us to infer the pattern for *B. imberi* in the Solomougou reservoir. The objective of this study was to determine whether the condition factor varies according to sexual maturity stage, season and size in female and male *B. imberi*, and to examine whether stage-related differences persist after accounting for the monthly sampling structure.

Materials and Methods:-

Study area:-

The study was conducted in the Solomougou dam lake, located approximately 25 km from Korhogo in northern Côte d'Ivoire (Figure 1). The climate is Sudanian, with a dry season from November to April and a rainy season from May to October. Specimens were collected four days a month from commercial artisanal fisheries between March 2024 and February 2025. Fishing gear included gillnets with mesh sizes ranging from 25 to 80 mm. No specimens were collected in September, as flooding prevented fishing.

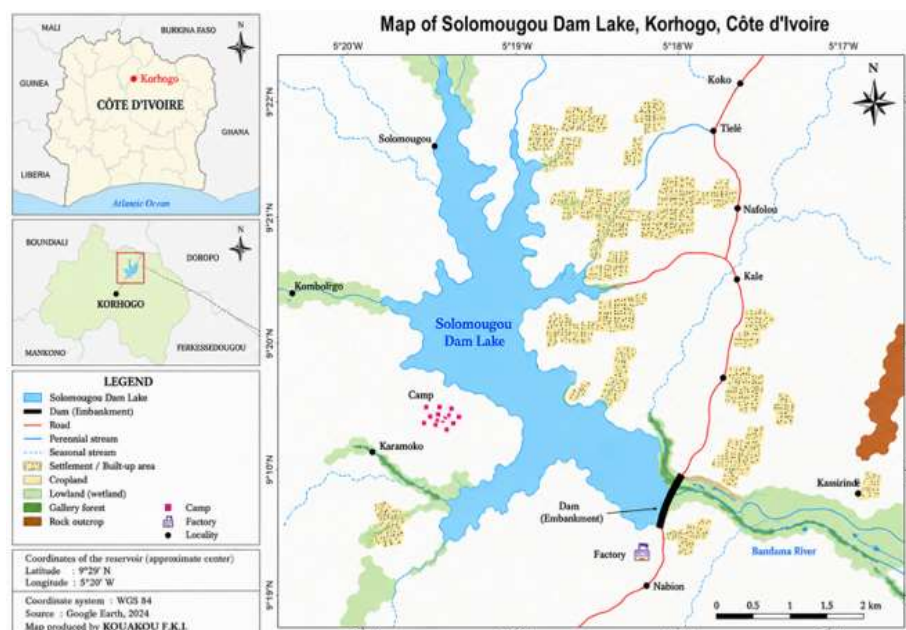


Figure 1. Study site

Sampling Methods:-

Standard length (SL) was measured to the nearest millimeter, and total weight (Wt) was recorded to the nearest 0.01 g. Following dissection, sex and maturity stage were determined macroscopically based on gonad color, consistency, volume, shape, and vascularization, using a scale adapted from Durand and Loubens (1970). Seven stages were

distinguished for females: 0, immature; I, immature and developing; II, beginning of maturation; III, maturing; IV, advanced maturation; V, spawning; VI, post-spawning. Six stages were identified for males: 0, immature; I, developing or resting; II, beginning of maturation; III, pre-emission; IV, emission; V, post-emission. The classification was validated jointly by three observers, without histological validation. Fulton's condition factor was calculated individually using the formula $K = 100 \times Wt/SL^3$, where Wt is total weight in grams and SL is standard length in centimeters. K was treated as a dimensionless index rather than a percentage. Since total weight includes the gonads, K reflects the fish's apparent condition rather than exclusively its somatic reserves.

Statistical analyses:-

Statistical analyses were performed separately for females and males using STATISTICA software (version 7.1, 2006). Condition factor (K) values are presented as mean $\pm$ standard deviation and as the median with the interquartile range. Differences in K between sexual maturity stages and among the five standard length classes $SL < 8$ cm, $8 \leq SL < 10$ cm, $10 \leq SL < 12$ cm, $12 \leq SL < 14$ cm and $SL \geq 14$ cm) were assessed using the Kruskal-Wallis test. When the test result was significant, multiple comparisons were performed using Dunn's post-hoc test, with p -values adjusted using the Holm method. The effect size associated with the Kruskal-Wallis test was estimated using the epsilon-squared coefficient, according to the formula:

$\epsilon^2 = (H - k + 1)/(n - k)$, where H represents the Kruskal-Wallis statistic, k the number of groups compared, and n the total sample size.

The rainy season spanned the months from May to October, and the dry season from November to April. September was excluded due to the absence of sampling. K values were compared between seasons using the Mann-Whitney U test. The monotonic relationship between standard length and K was assessed using Spearman's correlation coefficient. The threshold for statistical significance was set at $p < 0.05$.

Results:-

Variation of K according to stage in females:-

Among the 474 females, the K -factor varied significantly across the seven maturity stages ($H = 35.11$; $df = 6$; $p < 0.001$). The effect size was moderate ($\epsilon^2 = 0.062$). The highest median was observed in immature females (stage 0: 2.08), while the lowest was found in post-spawning females (stage VI: 1.61). Following Holm adjustment, stage VI differed from each of stages 0 through V; stage 0 also differed from stage IV (Table 1). The overall association remained significant when K -values were permuted within each month ($p < 0.001$), indicating that the difference between stages is not solely attributable to their seasonal distribution (Figure 2 A).

Variation of K according to stage in males:-

Among the 361 males, K differed across the six stages in the unadjusted analysis ($H = 26.26$; $df = 5$; $p < 0.001$; $\epsilon^2 = 0.060$). Immature males showed the highest median (2.07), compared to 1.91 at the post-emission stage. Dunn's comparisons indicated differences between stage 0 and stages II and V. However, after month-stratified permutation, the overall association was no longer significant ($p = 0.226$) (Table 1). The variation observed among males across stages thus appears to be largely confounded by monthly variation (Figure 2B).

Table 1. Condition factor K according to sex and stage of sexual maturity of *Brycinus imberi*

Sex	Stage	Description	n	Mean $\pm$ SD	Median	Q1-Q3
Female	0	Immature	48	2.31 $\pm$ 0.78	2.08	1.95-2.28
Female	I	Immature and developing	48	1.99 $\pm$ 0.29	1.99	1.85-2.11
Female	II	Beginning of maturation	32	2.03 $\pm$ 0.32	1.91	1.81-2.15
Female	III	Maturation	89	2.04 $\pm$ 0.37	2.00	1.85-2.15
Female	IV	Advanced Maturation	112	1.89 $\pm$ 0.41	1.92	1.73-2.09
Female	V	spawning	136	1.98 $\pm$ 0.35	2.00	1.85-2.17
Female	VI	Post-spawning	9	1.66 $\pm$ 0.11	1.61	1.61-1.61
Male	0	Immature	140	2.09 $\pm$ 0.20	2.07	1.97-2.22
Male	I	Immature and developing	103	2.00 $\pm$ 0.27	2.03	1.92-2.17
Male	II	Beginning of maturation	42	1.93 $\pm$ 0.25	1.94	1.79-2.09
Male	III	Pre-emission	35	2.00 $\pm$ 0.24	1.99	1.84-2.17
Male	IV	Emission	16	2.01 $\pm$ 0.22	2.07	1.95-2.10
Male	V	Post-emission	25	1.93 $\pm$ 0.21	1.91	1.81-2.08

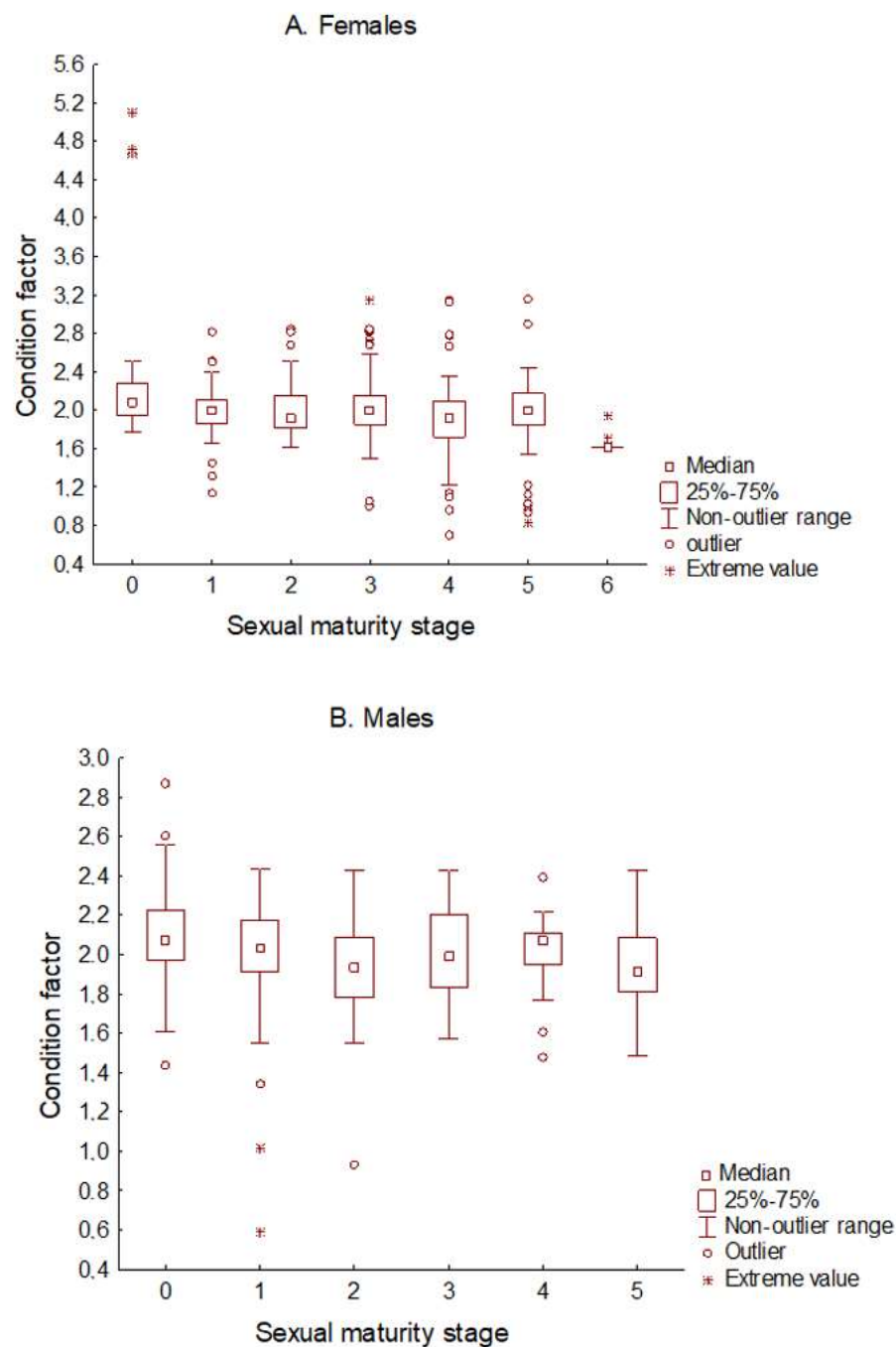


Figure 2. Variation in the condition factor (K) among sexual maturity stages in female (A) and male (B) *Brycinus imberi*. Boxes represent the interquartile range, squares indicate the median, whiskers extend to the non-outlier range, and individual symbols represent outliers.

Temporal structure:-

Reproductively active stages were defined as IV-VI for females and III-V for males. Their proportion was high during several months of the rainy season, whereas active male stages were not observed from November to February. Monthly K profiles did not exactly mirror those of reproductive activity. This dissociation was particularly marked in males and is consistent with the absence of a specific effect of the stage after stratification by month (Figure 3A and 3B).

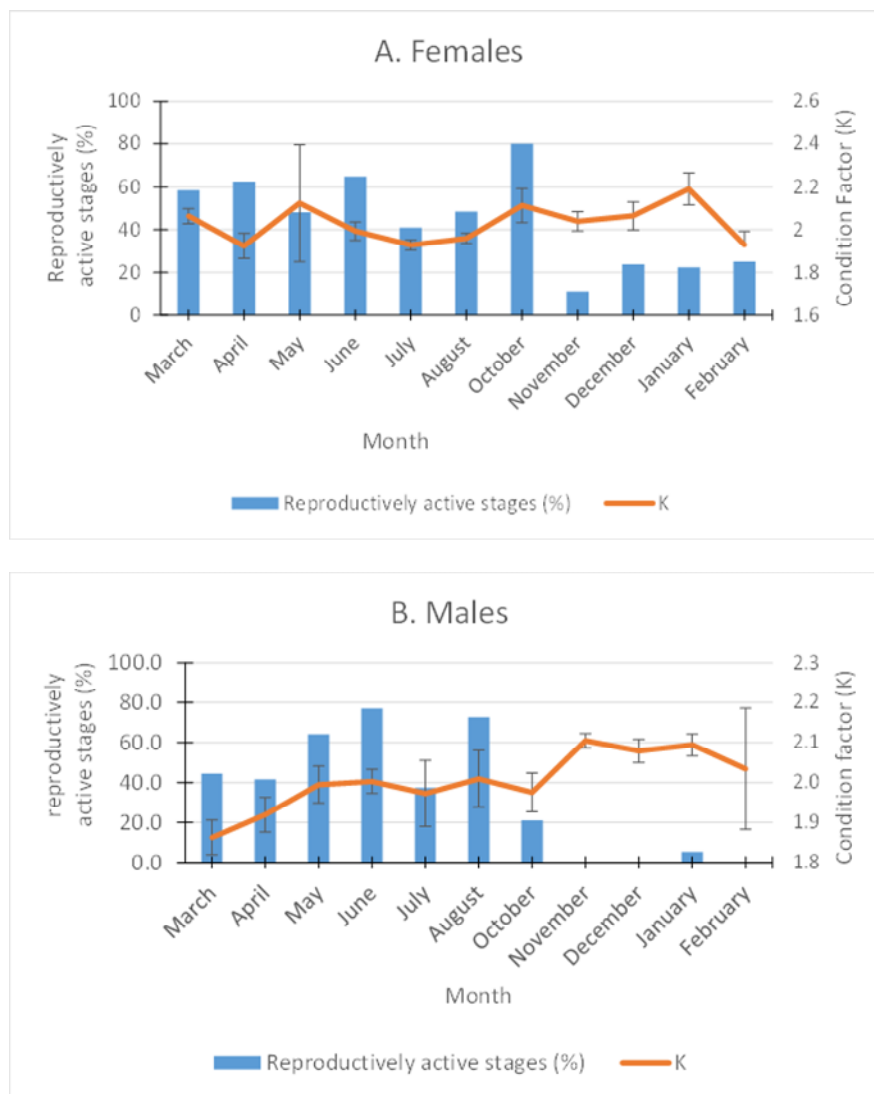


Figure 3. Monthly variation in the mean condition factor and the proportion of reproductively active individuals in *Brycinus imberi*. Error bars represent 95% confidence intervals. No sampling was carried out in September.

Seasonal variation of the condition factor:-

In females, K was comparable between the dry season (median = 2.01; n = 174) and the rainy season (median = 1.99; n = 300; U = 28,177; p = 0.149). In males, K was slightly higher during the dry season (median = 2.06; n = 242) than during the rainy season (median = 1.99; n = 119; U = 16,684; p = 0.014). The effect size of this difference in males was small (rank-biserial correlation = 0.159) (Table 2 ; Figure 4).

Variation of the condition factor according to size:-

In females, K differed significantly among the five standard length classes (H = 84.10; df = 4; p < 0.001). The median decreased from 2.12 in the 8 ≤ SL < 10 cm class to 1.58 in individuals measuring 14 cm or more. Spearman's correlation confirmed a decrease in K with increasing SL ($\rho = -0.451$; p < 0.001). In males, the overall difference between classes was just above the significance threshold (H = 9.35; df = 4; p = 0.053), and no monotonic relationship was observed between SL and K ($\rho = 0.018$; p = 0.739) (Table 2 ; Figure 5A and 5B).

Tableau 2. Condition factor K according to season and standard length classes in *Brycinus imberi*

Sex	Variable	Category	n	Mean $\pm$ SD	Median	Q1-Q3
Female	Season	rainy	300	1.99 $\pm$ 0.49	1.99	1.81-2.10
Female	Season	Dry	174	2.02 $\pm$ 0.32	2.01	1.84-2.18
Female	SL	SL < 8 cm	19	2.56 $\pm$ 1.19	1.95	1.89-2.21
Female	SL	8 $\leq$ SL < 10 cm	130	2.20 $\pm$ 0.33	2.12	1.99-2.34
Female	SL	10 $\leq$ SL < 12 cm	265	1.95 $\pm$ 0.24	1.95	1.81-2.09
Female	SL	12 $\leq$ SL < 14 cm	42	1.72 $\pm$ 0.48	1.86	1.16-2.06
Female	SL	SL $\geq$ 14 cm	18	1.43 $\pm$ 0.49	1.58	0.96-1.78
Male	Season	rainy	119	1.99 $\pm$ 0.24	1.99	1.85-2.11
Male	Season	dry	242	2.04 $\pm$ 0.24	2.06	1.93-2.19
Male	SL	SL < 8 cm	14	2.08 $\pm$ 0.19	2.09	1.90-2.26
Male	SL	8 $\leq$ SL < 10 cm	43	2.07 $\pm$ 0.23	1.99	1.94-2.17
Male	SL	10 $\leq$ SL < 12 cm	166	1.99 $\pm$ 0.23	2.00	1.84-2.13
Male	SL	12 $\leq$ SL < 14 cm	129	2.05 $\pm$ 0.23	2.07	1.94-2.19
Male	SL	SL $\geq$ 14 cm	9	1.91 $\pm$ 0.50	2.02	2.00-2.08

Note: SD, standard deviation; Q1-Q3, first and third quartiles; SL, standard length. The rainy season extended from May to October and the dry season from November to April. No specimens were collected in September.

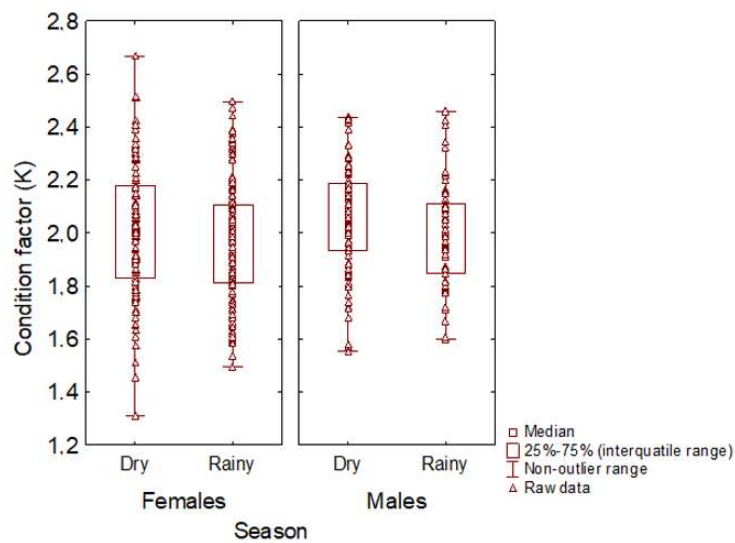


Figure 4. Seasonal variation of condition factor (K) in females and males *Brycinus imberi*. The boxes indicate the median and interquartile range ; the whiskers represent non-outliers.

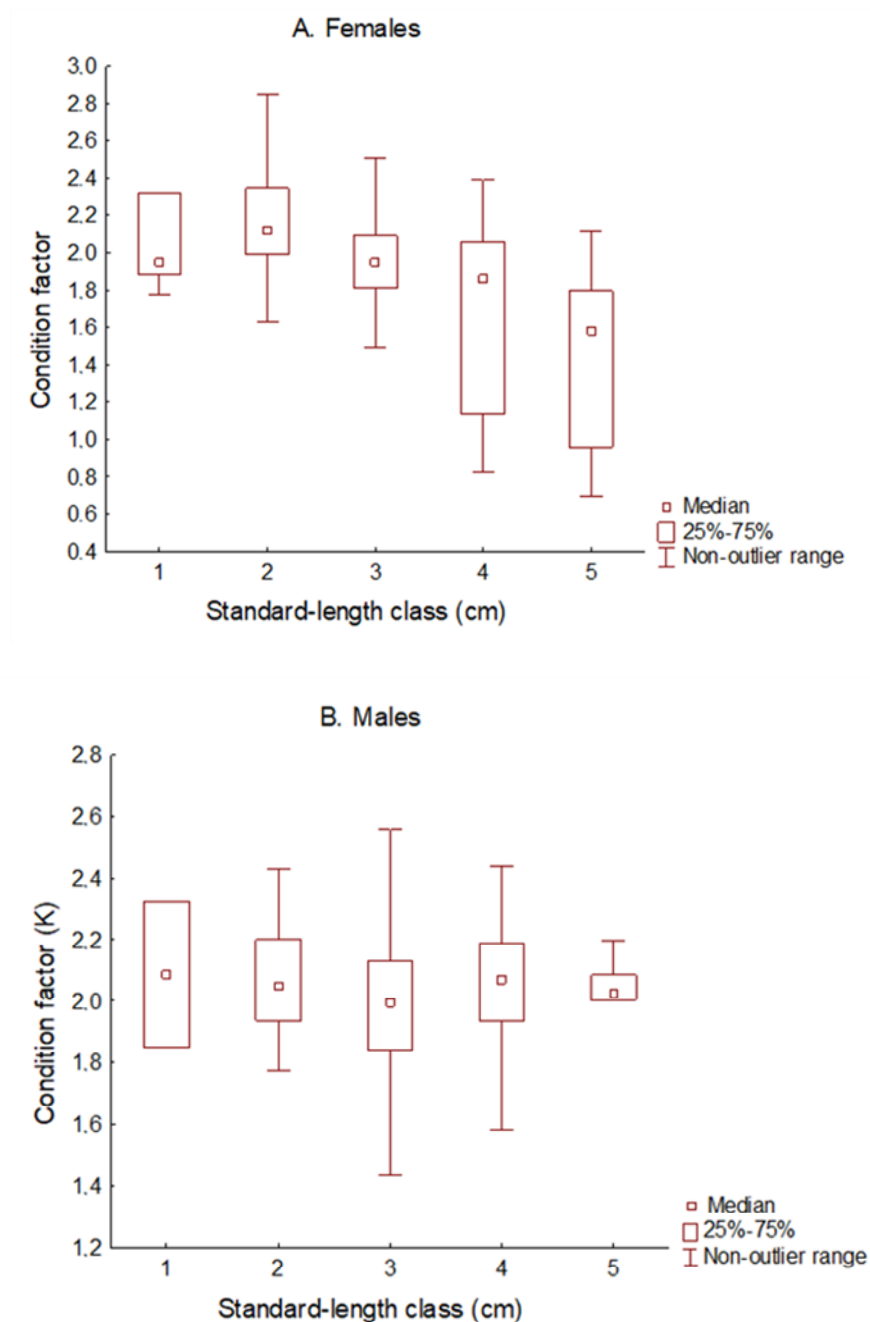


Figure 5. Variation in the condition factor (K) among standard length classes in female (A) and male (B) *Brycinus imberi*. Boxes represent the interquartile range, squares indicate the median, and whiskers extend to the non-outlier range. Class codes correspond to the following intervals: 1 = SL < 8 cm, 2 = 8 ≤ SL < 10 cm, 3 = 10 ≤ SL < 12 cm, 4 = 12 ≤ SL < 14 cm, and 5 = SL ≥ 14 cm.

Discussion:-

Variation in the condition factor according to maturity stage differed markedly between the sexes. In females, the low K-value at stage VI and the persistence of the association after accounting for the month are consistent with a decrease in body weight following oocyte release. A decline in body condition and gonad mass during spawning has also been observed in other teleosts (Anderson et al., 2020). However, this interpretation remains speculative for *B. imberi*, as energy reserves and body composition were not measured.

Female stage 0 exhibited a high and highly variable mean. This dispersion reflects, in particular, a few extreme K values among small individuals and justifies the use of rank-based statistics. The contrast between immature females and those at an advanced stage of maturation may also involve differences in size, recruitment, and season. Nevertheless, the persistence of the association between maturity stage and K after stratification by month indicates that monthly variation is insufficient to explain the differences observed in females.

In males, the differences between stages observed using the Kruskal-Wallis test disappeared after controlling for monthly structure. This result indicates that the crude association between maturity stage and K in males depended largely on the monthly structure of the data. Seasonal analysis confirms this difference between the sexes. The absence of significant variation in females shows that the post-spawning decline, while distinct at stage VI, does not translate into a uniform decrease in K throughout the rainy season. In males, the slightly higher value observed during the dry season is consistent with the absence of reproductively active stages from November to February. However, the small effect size indicates substantial overlap between seasonal distributions, ruling out a simple contrast between fish in good condition and those in poor condition.

The negative relationship between standard length (SL) and K in females warrants particular attention. Fulton's condition factor implicitly assumes isometric growth because length is raised to the third power. The decline in K with increasing SL may therefore partly reflect a mechanical consequence of negative allometric growth, as the length-weight exponent was lower than 3 in females ($b = 2.217$). Changes in body shape and differential allocation to reproduction in larger females may also contribute to this pattern. In males, the exponent was closer to 3 ($b = 2.882$), which is consistent with the absence of a significant monotonic relationship between SL and K. A previous study based on pooled commercial catches from the Solomougou Dam Lake reported an approximately isometric relationship for *B. imberi* ($b = 3.027$) (Kouassi et al., 2020). Differences between the two studies may be related to sex-specific analyses, sampling periods, size distributions and gear selectivity.

In the case of *B. nurse* in the Asa Reservoir, Saliu and Fagade (2003) reported reproduction associated with the rainy season and significant variation in the gonadosomatic index across different stages. These observations underscore the importance of factoring in the season when studying the reproductive parameters of Alestidae. However, differences regarding species, environment, fishing gear, and study periods preclude directly applying these findings to *B. imberi*. Fulton's condition factor should be interpreted as a morphometric index sensitive to gonad mass. When total weight is used, the increase in gonad mass during maturation can raise K, whereas gamete release can contribute to a decrease following spawning (Anderson et al., 2020). Further studies using gutted weight and direct measurements of lipid reserves would help better distinguish the effects of reproduction and size on body condition.

Conclusion:-

The condition factor of *B. imberi* varies with maturity stage, season, and size, but profiles differ by sex. In females, condition is particularly low after spawning and decreases with standard length, with no overall seasonal difference. In males, K is slightly higher during the dry season, while apparent differences between stages are primarily linked to monthly structure, and no monotonic relationship with size is detected. These results provide a basis for studying the physiological costs of reproduction; however, the dependence of K on allometry and the absence of biochemical measurements preclude directly equating this index with energy reserves.

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