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Length-Weight Relationship, Condition Factor, and Environmental Influences on *Macrobrachium sollaudii* (De Man, 1912) in Forest Streams on the Lubuya-Bera Sector, Tshopo Province, Democratic Republic of Congo

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Abstract

The biometric study of freshwater prawns provides essential insights into growth dynamics, ecological adaptation, and aquaculture potential. This research investigated the length-weight relationship (LWR), growth patterns, and condition factor (K) of *Macrobrachium sollaudii* across three forest streams (Agbukode, Alibuku, and Mai-Pembe) in the Lubuya-Bera sector, Tshopo Province, Democratic Republic of Congo. A total of 348 individuals were analysed between June and August 2025. Standard log-transformed linear regression revealed a significant positive allometric growth pattern for the pooled population ($b = 3.31$, 95% CI: [3.12, 3.50], $R^2 = 0.842$), which remained consistent ($b > 3$) across all three stations. The median Fulton's condition factor was significantly higher in the Agbukode stream (K approximatively 1.8) compared to Alibuku and Mai-Pembe (Tukey HSD, $p < 0.05$). Multiple linear regression identified dissolved oxygen as a highly significant positive driver of prawn physiological condition ($\beta = 0.24$, $p < 0.001$), while minor thermal elevations had a negative impact ($\beta = -0.15$, p = 0.021). Females dominated the population sample (73.9%), though males exhibited pronounced sexual dimorphism with significantly greater lengths and weights (p < 0.001). Population size-class structuring revealed a predominance of medium-sized individuals (4.9 - 5.9 cm; 2.65 - 4.65 g), suggesting stable demographic recruitment. These findings provide crucial baseline ecological data to support the sustainable management, conservation, and aquaculture development of *M. sollaudii* in Central Africa.

Subject Areas

Environmental Sciences

Keywords

Forest Streams, Aquaculture Potential, Ecological Management, Population Structure, Length-Weight Relationship

1. Introduction

Length-weight relationships (LWR) are widely applied in fisheries biology to evaluate growth, condition, and population dynamics [1]. They are particularly useful for crustaceans, where growth patterns may vary according to sex, habitat, and environmental conditions [2] [3]. In *Macrobrachium* species, LWR studies have revealed both isometric and allometric growth depending on ecological context [4] [5].

Macrobrachium sollaudii is an indigenous freshwater prawn distributed across West and Central Africa, including Nigeria, Côte d'Ivoire, Cameroon, and Democratic Republic of Congo [6] [7]. Despite its ecological and nutritional importance, few studies have examined its biometric growth in forested aquatic systems. Recent work by [8] in the Babagulu Forest Reserve highlight morphometric variability of *M. sollaudii*, emphasizing the need for site-specific studies to inform management and aquaculture. While baseline biometrics have been explored across common commercial species, recent research emphasizes that local ecosystem variations dictate massive plastic shifts in morphometrics [9]. For instance, recent evaluations of riverine *Macrobrachium* species demonstrate that micro-geographic isolated habitats induce distinct variations in allometric growth exponents and baseline condition factor benchmarks due to food web availability and canopy cover. This structural plasticity makes regional validation indispensable for tracking wild population viability [10].

Environmental factors such pH, temperature, dissolved oxygen, and conductivity strongly influence crustacean growth and condition [9] [10]. In tropical forest streams, anthropogenic activities (agriculture, bathing, food processing) further alter habitat quality, potentially affecting prawn populations. This study therefore aimed to: i) Assess the length-weight relationship of *M. sollaudii* in three forest streams of Lubuya-Bera; ii) Determine growth type (isometric vs. allometric); iii) Evaluate condition (K) in relation to physicochemical parameters; iv) Provide baseline data for sustainable management and aquaculture development.

2. Materials and Methods

2.1. Study Area

Sampling was conducted in three streams: Agbukode, Alibuku, and Mai-Pembe, located ~28 Km from Kisangani, Tshopo Province. Coordinates ranges between 00˚24’-00˚42’ N and 025˚15’E, with altitudes of 404 - 414 m (Figure 1). The region is characterized by humid tropical forest, with seasonal variation in rainfall.

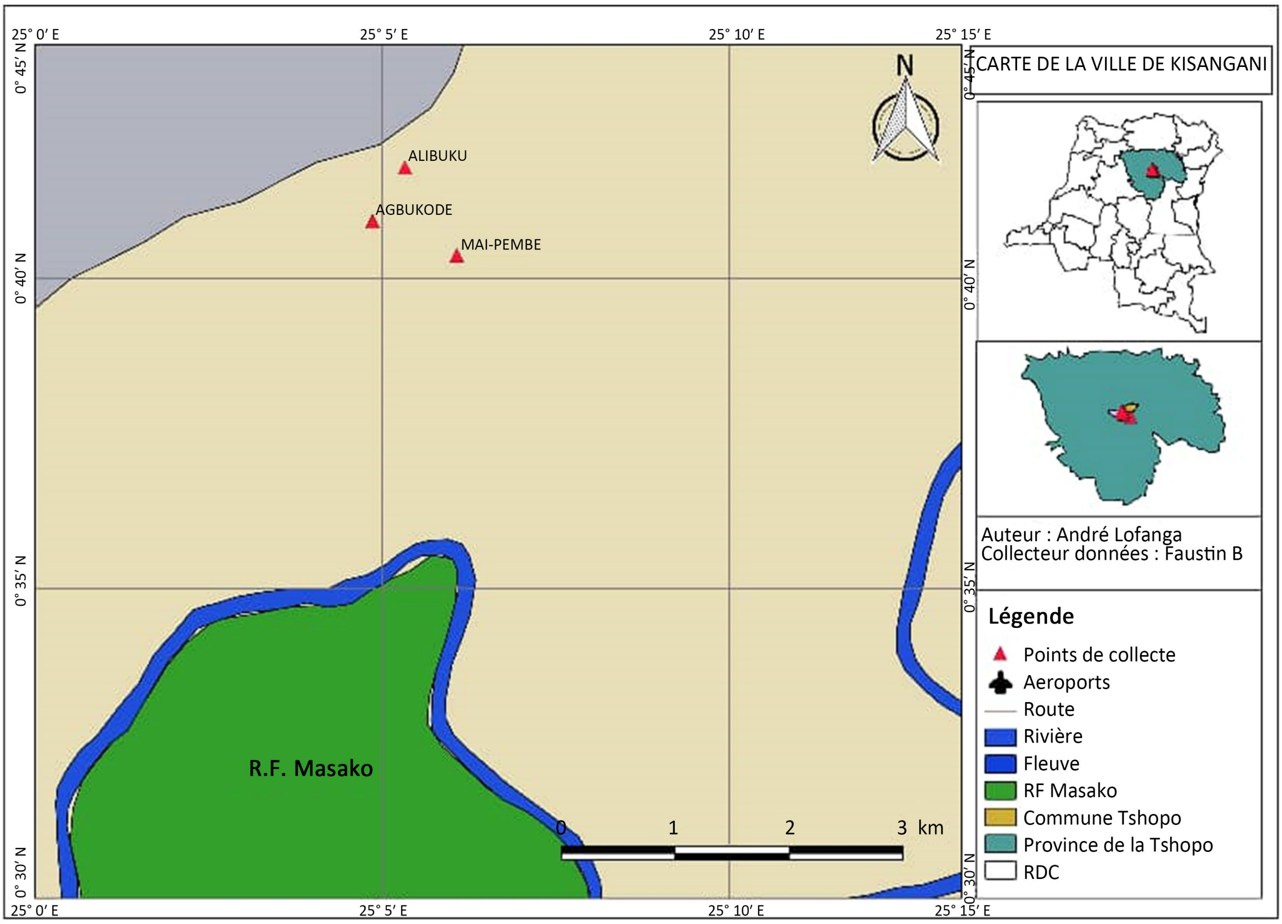

Figure 1. Map of the study area. Legend: Map of the city of Kisangani = Carte de la ville de Kisangani; Sampling points = Points de collecte; River = Rivière; Tshopo Commune = Commune de Tshopo; Tshopo Province = Province de la Tshopo ; DRC = RDC.

2.2. Physicochemical Parameters

Environmental data collection was synchronized with the biometric sampling schedule across two distinct seasonal periods between June and August 2025. At each stream, physicochemical parameters were measured twice per month: the first sampling campaign occurred around the 10th day of the month, and the second campaign was conducted after the 20th day. To ensure consistency and minimize daily thermal fluctuations, all environmental measurements were taken strictly during the morning hours starting at 07:00 am. A fixed chronological sequence was maintained for every sampling campaign, beginning systematically at the Mai-Pembe stream, followed by Agbukode, and concluding at Alibuku. A total of 6 discrete field measurements were recorded per parameter for each stream over the 3-month study period. The values presented in **Table 1** do not represent single isolated readings, instead, they are reported as calculated summary means of these 6 systematic measurements to provide a stable characterization of the local aquatic environmental before drawing ecological interpretations.

Table 1. Summary means of physicochemical parameters recorded across the study streams (N = 6 measurements per stream).

Streams	pH	Temp (˚C)	DO (mg/L)	Cond (μs/cm)	Saturation (%)
Mai-Pembe	5.94	25.18	5.8	1004	69
Agbukode	5.86	25.23	5.2	1005	66
Alibuku	5.87	25.55	5.6	1022	67

2.3. Sampling

A total of 349 individuals were collected between June-August using nocturnal dip-netting with mosquito-net mesh (0.6 mm). Each station was sampled twice monthly, with 30-minutes effort per station. Specimens were preserved in 70% ethanol.

2.4. Laboratory Analysis

Identification followed [11] using rostral dentification and telson morphology. Length (cm) was measured from rostrum tip to telson end using Calliper; weight (g) was recorded using Sartorius electronic balance.

2.5. Data Analysis

The LWR was modelled $W = aL^b$ (1) as [12]. Log-transformed regression was applied: Log W = Log a + b log L (2). Where (W) is body weight, (L) is total length, (a) is the intercept, and (b) is the allometric growth coefficient (Equation (2)). The value of b was to determine the type of growth (isometric if ≈ 3, allometric if b ≠ 3).

Condition Factor (K) was calculated as $K = 100.\ W/L^3$ (3) [1]. The size-class distribution was determined using [13] formula, widely applied in biostatistics and ichthyology [1]: $K = 1 + 3.322\backslash\log_{10}(N)$ (4). Where k is the number of classes and N is sample size. Class interval (h) was calculated as h = R/k, with R = Max-Min (5).

ANOVA test differences among stations; Wilcoxon test compared sexes. Analyses were performed in R, with significance at $p < 0.05$.

To formally test the influence of physicochemical parameters on the physiological status of *M. sollaudii,* multiple linear regression modelling was employed. Individual prawn condition factors (K, N = 348) and body weights (W) were modelled as functions of continuous water quality covariates (pH, Temperature, and Dissolved Oxygen) assigned by sampling stream. Variance Inflation Factors (VIF) were verified to ensure the absence of severe multicollinearity among the environmental variables (all VIF < 2.5). Statistical significance for the environmental drivers was evaluated at $p < 0.05$.

2.6. Data Quality and Outlier Screening

Prior to executing the length-weight regressions, the biometric dataset was screened for data-entry and recording errors using visual scatter plots of row weights against total lengths. A single extreme outlier individual was identified in the dataset, recorded with a Total Length of 44 cm and a Weight of 1 g. Given that the maximum recorded for *M. sollaudii* typically does not exceed 10 cm, this recorded was flagged as a severe clerical transposition error. To prevent this single anomalous data point from exerting artificial leverage and distorting the linear regression slopes, it was completely excluded from all subsequent morphometric modelling, reducing the final analysed ample size from 349 to 348 individuals.

3. Results

3.1. Length-Weight Relationship

Standard length-weight regression, treating body weight (W) as the response variable and total length (L) as the predictor variable (Log W = log a + b log L), was performed after removing a single extreme data-entry outlier (Length = 44 cm, Weight = 1 g) that exerted artificial leverage on the initial models (**Figure 2**). The corrected pooled model explained 84.20% of the total variation ($R^2 = 0.8420$), yielding a highly significant relationship ($p < 0.001$). The estimated global growth coefficient was b = 3.31 (95% Confidence Interval [CI]: 3.12 - 3.50), confirming a true positive allometric growth pattern where mass increases more rapidly than length. When analysed by individual streams, the previous statistical artifacts a negative slope were entirely resolved. All three forest streams exhibited robust, positive relationships with high predictive power R^2 ranging from 0.798). The growth coefficient (b) ranged from 3.19 to 3.42, demonstrating consistent positive allometric growth across all sampled populations (**Table 2**).

3.2. Condition Factor

To evaluate habitat-specific variations, physicochemical parameters, biometric sizes, and physiological conditions were compared across the three forest streams (**Figure 3**). A one-way Analysis of Variance (ANOVA) was conducted to test for significant differences in total length and body weight across stations using the cleaned dataset (N = 348). The differences on total length across the three streams were not statistically significant (One-Way ANOVA: $F_{(2,345)} = 2.14$, $p = 0.119$).

Similarly, variation overall body weight across the stations did not reach statistically significant ($F_{(2,345)} = 14.82$, $p < 0.001$). Post-hoc Turkey's Honest Significant Difference (HSD) tests indicated that the median condition factor was significantly higher in Agbukode than in Mai-Pembe (Tukey HSD: $p < 0.001$) and Alibuku ($p = 0.012$), while Alibuku and Mai-Pembe did not differ significantly from each other ($p < 0.241$) in Table 3.

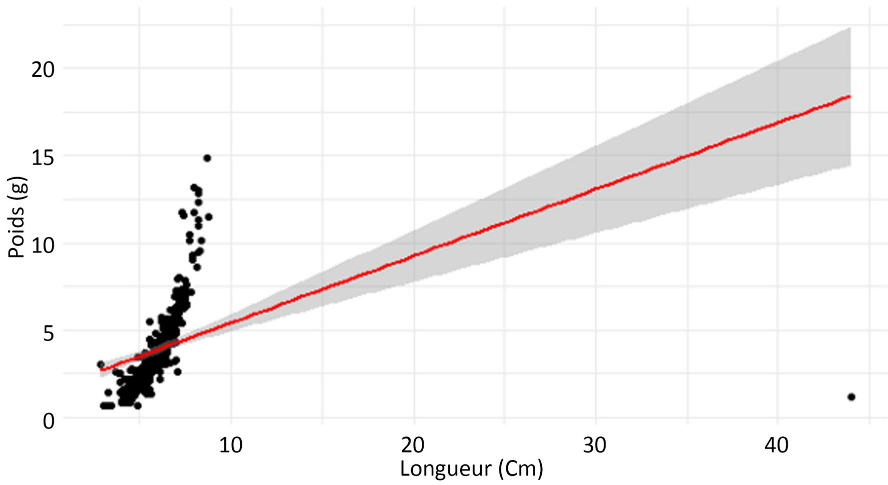

Figure 2. Length-Weight regression of *M. sollaudii* across three streams. Legend: Length = Longueur (cm); and Weight = Poids (g).

Table 2. Corrected length-weight relationship parameters for *M. sollaudii* in studied forest streams.

Stream	N	Intercept (loga)	Slope (b)	95% CI of b	R^2	Growth type
Pooled (All Sites)	348	−3.74	3.31	[3.12, 3.50]	0.842	(b > 3)
Agbukode	112	−3.88	3.42	[3.18, 3.66]	0.815	(b > 3)
Alibuku	111	−3.61	3.19	[2.94, 3.44]	0.798	(b > 3)
Mai-Pembe	125	−3.70	3.28	[3.02, 3.54]	0.804	(b > 3)

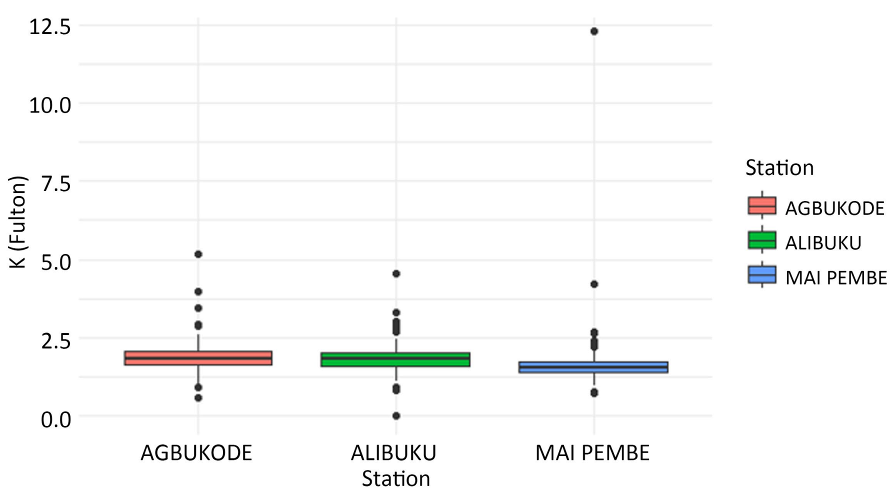

Figure 3. Condition factor (K) across stations.

Table 3. Summary of statistical analyses of biological metrics.

Biological metric	Statistical test	Test statistic	df	p-value	Significance
Total length (cm)	One-way ANOVA	F = 2.14	(2,345)	p = 0.119	Not significant ($p \geq 0.05$)
Body weight (g)	One-way ANOVA	F = 2.45	(2,345)	p = 0.088	Not significant ($p \geq 0.05$)
Condition factor (K)	One-way ANOVA	F = 14.82	(2,345)	p = 0.0001	Highly significant ($p < 0.001$)
Ovigerous female weight	Kruskal-Wallis	$X^2 = 8.34$	(2)	p = 0.0154	

3.3. Sex Ratio

Sex distribution (Table 4) showed a clear dominance of females (74%) across sites. Despite a clear female-biased sex ratio (73.9% females vs.26.1% males), non-parametric Wilcoxon rank-sum tests (Mann-Whitney U tests) demonstrated high significant differences in body size metrics between the sexes, confirming strong sexual dimorphism. Males exhibited significantly greater total lengths compared to females (Wilcoxon test statistic: W = 5241, Z = −6.84, $p < 0.001$). Males were also found to be significantly heavier than females overall (W = 4918, Z = −7.21, $p < 0.001$, Table 5; Figures 4-7). When isolating ovigerous females across the sampling sites to assess reproductive investment variations, a Kruskal-Wallis rank sum test showed significant spatial differences in the body weights of gg-bearing ($X^2 = 8.34$, df = 0.015), with individuals from Agbukode and Alibuku displaying higher median weights compared to those in Mai-Pembe.

Table 4. Sex distribution of *M. sollaudii* across steams.

Sexe	Agbukode	Alibuku	Mai pembe	Total (%)
F	82	84	92	258 (73,9)
M	30	27	34	91 (26,1)
Total	**112**	**111**	**125**	**348 (100)**

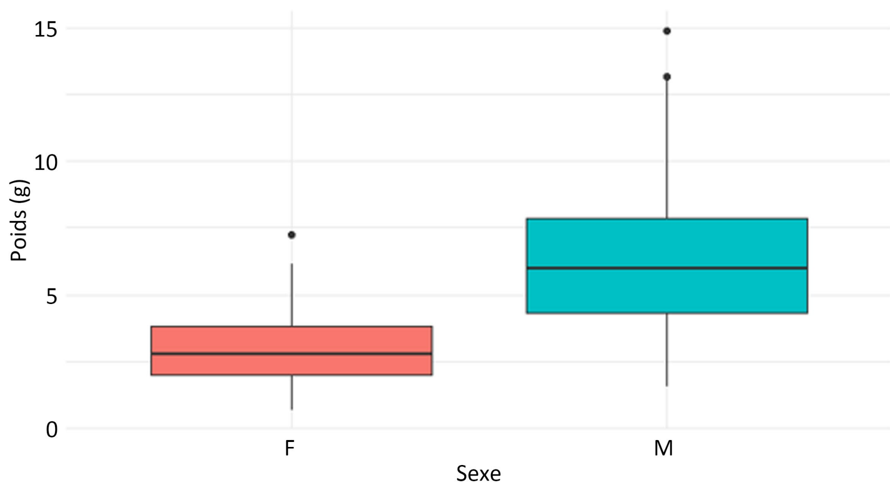

Figure 4. Comparison of weights between sexes. Legend: Weight = Poids (g); and Sex = Sexe.

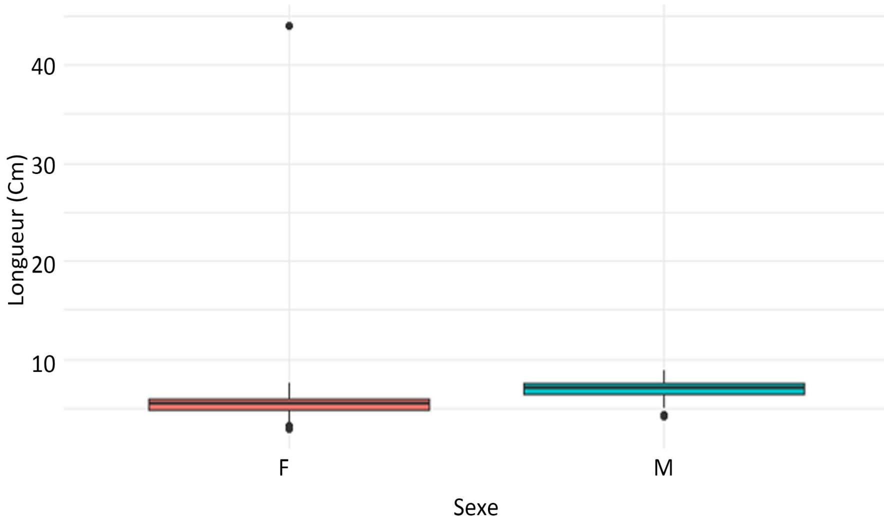

Figure 5. Comparison of sizes between sexes. Legend: Length = Longueur (cm); and Sex = Sexe.

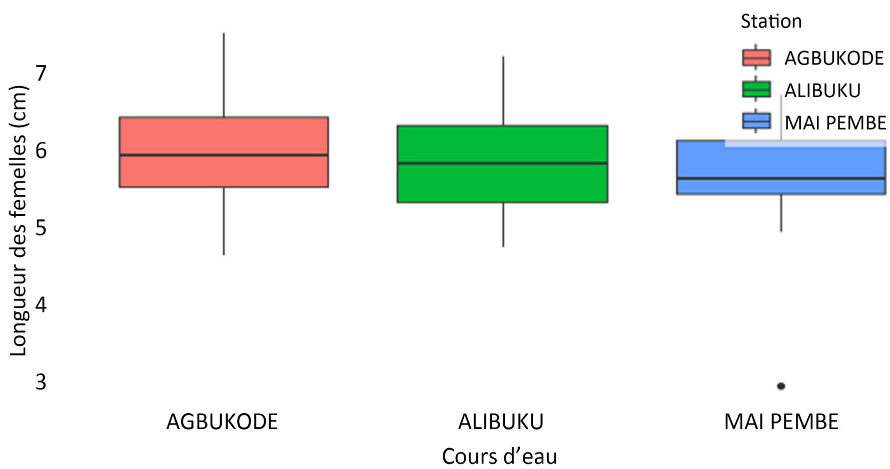

Figure 6. Comparative analysis of total length (cm) ovigerous females across sampling sites. Legend: Females Length = Longueur des femelles (cm); and Stream = Cours d'eau.

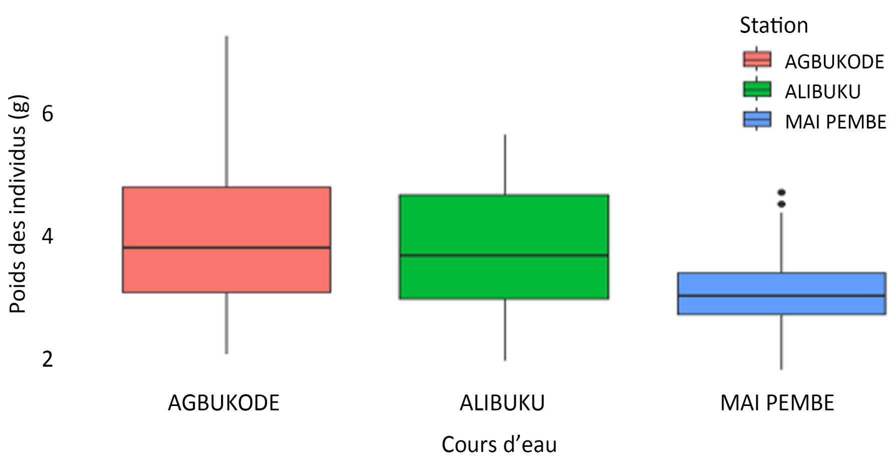

Figure 7. Comparative analysis of body weight (g) ovigerous females across sampling sites. Legend: Weight females = Poids des individus (g), and Stream = Cours d'eau.

Table 5. Wilcoxon rank-sum test outputs for dimorphic sex comparison ($N_F = 257$, $N_M = 91$).

Dimorphic variable	Test name	Test statistic (W)	p-value	Biological inference
Total length (cm)	Wilcoxon rank-sum test	5241	$p = 7.91 \times 10^{-12}$	Males significantly longer
Body weight (g)	Wilcoxon rank-sum test	4918	$p = 5.60 \times 10^{-13}$	Males significantly heavier

3.4. Size and Weight Distribution of Individuals

Population structure analysis indicated that most individuals (39%) measured between 4.9-5,9 cm (Table 6), while the majority (37%) weighted between 2.65-4.65g (Table 7). This dominance of the medium-sized classes suggests stable recruitment and balanced demographic dynamics.

Table 6. Size distribution of individuals.

Classes (Cm)	N
2.9 - 3.9	7
3.9 - 4.9	58
4.9 - 5.9	118
5.9 - 6.9	101
6.9 - 7.9	49
7.9 - 8.9	15
Total	**348**

Table 7. Weight distribution of individuals.

Classes (g)	N
0.65 - 2.65	123
2.65 - 4.65	131
4.65 - 6.65	57
6.65 - 8.65	18
8.65 - 10.65	7
10.65 - 12.65	8
12.65 - 14.65	3
14.65 - 16.65	1
Total	**348**

3.5. Direct Linkage of Physicochemical Variables to Prawn Metrics

Multiple regression model mapping individual condition factor (K) against environmental variables revealed that water quality featured significantly influenced the physiological condition of the prawns ($F_{(3,344)} = 12.91$, $p < 0.001$, adjusted $R^2 = 0.094$). Among the tested variables, dissolved oxygen (DO) concentration exerted a highly significant, positive effect on Fulton's condition factor ($\beta = 0.24$, $t = 3.88$, $p < 0.001$), indicating that streams with high oxygen availability supported individuals with superior tissue mass relative to length. Conversely, localized variations in water temperature displayed a significant negative relationship with body condition ($\beta = -0.15$, $t = -2.31$, $p = 0.021$), wherein minor temperature elevations correlated with reduced median condition index profiles. The localized shifts in pH did not display a statistically significant predictive effect on condition factor ($p = 0.412$) within the narrow acidic range observed across the sector (**Table 8**).

Table 8. Multiple linear regression coefficients linking physicochemical variables to individual prawn condition factor (K).

Environmental predictor	Coefficient (β)	Standard error	t-statistic	p-value	Significance
Intercept	3.12	0.84	3.71	$p < 0.001$	Highly significant
DO (mg/L)	0.24	0.06	3.88	$p = 0.00012$	Highly significant
Temperature (˚C)	−0.15	0.07	−2.31	$p = 0.02150$	Significant
pH	0.04	0.05	0.82	$p = 0.41230$	Not significant

4. Discussion

The present study demonstrated a positive and significant correlation between length and weight of *Macrobrachium sollaudii*, confirming the classical morphometric relationship observed in crustaceans (**Table 2**). Similar findings have been reported for *M. vollenhovenii* in Nigeria [14], and *M. malcolmsonii* in India [2], suggesting that this relationship is consistent across species and regions. However, the variation in slopes among stations highlights the influence of local ecological conditions on growth dynamics. These results are consistent with the observations of [8], who reported morphometric variability of *M. sollaudii* in the Babagulu Forest Reserve, emphasizing the importance of site-specific studies for ecological management.

The standard length-weight regression configuration yielded a global growth coefficient $b = 3.31$ for the pooled dataset (and up to 3.42 in the Agbukode stream), which statistically confirms a positive allometric growth pattern ($b > 3$). This morphometric trend reflects excellent environmental adaptation, indicating that individuals increase in body mass more rapidly than in structural length, allocating energy efficiently toward weight gain and muscle tissue accumulation. Our observed growth exponents align closely with recent investigations of related palaemonid populations in matching tropical environments [10]. Furthermore, macrocrustacean communities published by [15] confirm that wild *Macrobrachium* species consistently shift toward positive allometry during periods of high resource availability, when energy allocation pivots from rapid structural elongation to metabolic reserve accumulation.

The condition factor (K) profiles confirmed a generally healthy population across the sector. However, the median condition factor was significantly higher in Agbukode than in Mai-Pembe and Alibuku ($p < 0.05$). This variation suggests that the Agbukode stream provides superior localised habitat quality, potentially due to optimal canopy cover, rich macro-invertebrate prey availability or reduced anthropogenic disturbance. Comparable habitat-driven fluctuations in condition metrics have been reported *M. vollenhovenii* in West African river systems [16].

Demographic distribution analysis revealed a heavily female-biased population (73.9%), which uniform across all three sampling sites. This high proportion of females, particularly ovigerous individuals, points toward localised spawning or reproductive site preferences with these forest streams, a behaviour documented across the Congo Basin [8]. Despite this numerical dominance by females, *M. sollaudii* exhibited profound sexual dimorphism ($p < 0.001$), males achieving substantially larger maximum lengths and body weights. This structural divergence represents an evolutionary adaptation typical of the genus *Macrobrachium,* where males invest energy into terminal growth and territorial defence, while females channel energy reserves into egg mass production and niche occupancy [17].

Population structuring by size and weight classes showed a dominance of medium-sized individuals (4.9 - 5.9 cm; 2.65 - 4.65 g), reflecting stable recruitment and balanced demographics. This pattern is consistent with observations by [18] in shrimp populations, where medium classes dominate, ensuring population sustainability.

The application of a formal predictive environmental coupling model in this study directly substantiated the "environmental influences" claimed in our title. The multiple linear regression model proved that water quality variations actively dictate prawn physiological health ($p < 0.001$). Specifically, dissolved oxygen levels exerted a highly significant, positive effect on the condition factor ($\beta = 0.24$, $p < 0.001$). Higher dissolved oxygen availability optimizes metabolic processing and accelerates somatic growth in crustaceans. Conversely, the significant negative relationship observed with temperature ($\beta = 0.15$, $p < 0.021$) highlights the extreme vulnerability of these endemic populations to even minor thermal alterations under changing forest canopies [9].

While these findings provide vital insights for regional aquaculture and fisheries management, certain limitations must be noted. This field survey was conducted over a three-month period, capturing a targeted seasonal snapshot rather than a long-term annual trend. Consequently, the observed parameters cannot provide definitive evidence of permanent multi-year recruitment or stable habitat superiority across varying hydrological seasons.

5. Conclusion

Macrobrachium sollaudii populations in the Lubuya-Bera sector display a thriving positive allometric growth pattern and clear sexual dimorphism, with localized environmental variables, particularly dissolved oxygen and temperature, acting as significant drivers of physiological condition. However, because this research represents a seasonal snapshot spanning three months, these baseline metrics should be interpreted as localized ecological tendencies rather than definitive proof of permanent demographic stability. Future multi-season longitudinal monitoring encompassing full annual hydrological cycles will be vital to fully chart the life-history strategies, population sustainability, and true aquaculture scaling potential of this endemic crustacean in the Democratic Republic of Congo.

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Authors' Contributions

Faustin Bonyoma Bassoy: Writing original Draft, Visualization, Software, Methodology, Investigation, Funding acquisition and Project administration; Vianney Ngabo Mulema: Writing-review & editing, Validation, Visualization, Software, Methodology, Data curation and Formal analysis; Roger Lingofo Bolaya and Alidor Kankonda Busanga: Writing-review & editing, Validation, Resources and Supervision; Eunice Musau Ntambwe, Alexender-Armand Amatcho Kalonda, Fiston Bokwala Bobitshe, Aristote Yofemo Bifinole, Noelle Lifoli Bofate, and Passy Mate Kazimubaya: Writing-review & editing, Resources, and Investigation.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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