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Research Article

Non-annual Nothobranchiid (Cyprinodontiformes) Growth Type and Health in Southern Cameroon Rainforest Streams: Perspectives from Condition Indices

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Abstract

Understanding population dynamics involves key variables like growth type and body condition, the latter indicating energy acquisition, foraging behaviour, and prey availability, factors influencing species growth, reproduction, fitness, and survival in their habitat. Therefore, using accurate fish condition indices is essential. This study examined the length-weight relationships of 1010 cyprinodontiform individuals from 12 species of non-annual nothobranchiids in southern Cameroon rainforest streams and their well-being using Fulton (*Kc*), allometric (*Ka*), and relative weight (*Kn*) condition factors. Species differed significantly in length ($F = 56.79$, df = 11, $p < 0.00$) and weight ($F = 46.66$, df = 11, $p < 0.00$). Findings showed allometric growth patterns ($p < 0.001$ and R^2 ranging from 0.808 to 0.965); three species exhibited positive allometric growth ($b > 3$) and tended to be thicker, while the other species had negative allometric growth ($b < 3$) and tended to be thinner. Nothobranchiid growth pattern does not follow the cube law, with mean *Kc* values consistently below 1.0, a range proposed to be that of this fish family and not necessarily indicating a poor fish condition. Mean *Ka* values indicated varying feeding intensities among species, ranging from 0.29 ±0.01 to 7.63 ±0.21, and influenced by *b*-values. Mean *Kn* values were always greater than 1.0 across all nothobranchiids, not differing among them and reflecting good growth conditions. The study provides first insights into the growth patterns and health of the nothobranchiids within their unique ecosystem, highlighting the advantage of using multiple condition factors to describe species' physiological and ecological well-being and offering essential perspectives for sustainable management and biodiversity conservation efforts.

Keywords

Allometric Growth, *Aphyosemion*, Biodiversity Sustainable Management, Condition Factors, Length-weight Relationship, Cameroon

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1. Introduction

Monitoring fish stocks through fisheries is essential for ensuring the health of water bodies for sustainable practices that protect these ecosystems for future generations. Despite attempts to retain a healthy ecosystem and preserve fish biodiversity and biomass, some fisheries continue to collapse globally [1]. Fisheries management considers economic, social, and ecological variables to ensure fish populations meet societal needs without overfishing [2]. The achievement of this goal involves biometric studies that are essential for assessing fish species and estimating their biomass [3]. In such studies, it is crucial to determine the growth characteristics associated with the weight and length of fish [4] alongside the welfare of the species, which is affected by various biotic and abiotic factors, including food availability and the fish size, age, and sexual maturity, among others [5]. The practice involves evaluating relationships between fish length and weight (LWRs) and examining their condition indices. LWRs help determine the weight of fish at a specific length, shed light on morphological traits and growth patterns, and facilitate further research on fish populations and stock evaluations [6-8].

As for condition factors, they are vital instruments applied in as many fields as environmental biology and conservation. Some studies link them to biotope degradation causes such as pollution, overfishing, habitat loss, and climate change; others relate them to life history traits like reproduction, survival, parasite infection, and ecological factors affecting endangered species, aiding in understanding population dynamics [9-11]. The nutritional and physiological state of fish reflects its condition, which offers information about its life history and habitat [12-15]. These factors contribute to effective fish management and ecosystem balance [16, 17]. Indirect morphometric condition indices, assuming that larger fish of a particular length are healthier, are widely used, with total weight being a key indicator [6, 18, 19]. Among these indices are the Fulton's coefficient of condition factor (*Kc*), the relative weight condition factor (*Kn*), and the allometric condition factor (*Ka*) [6, 12, 20], and they are essential for fish health monitoring and fisheries management [16, 21, 22]. Thus, the use of accurate condition factor is important in ecological studies of fish well-being.

Body relationships are well-studied in commercial fisheries for common species but limited for many freshwater fish, particularly non-edible species in less-explored areas [23], with the challenges for modelling aquatic ecosystems, where specimen counts by length class are converted into biomass estimates [24]. An example includes the complex non-seasonal African killifish family Nothobranchiidae, which represents 19% of marketable ornamental freshwater fish endemic to Africa [25]. They inhabit diverse habitats within the southern plateau and coastal plain of Cameroon, hidden in pools and streams of the Lower Guinean rainforest. This region houses over 200 valuable ornamental fish species [26], crucial for research and ecological studies [27-30]. The Nothobranchiidae includes 37 genera and 426 species [31], with only five having described length-weight relationships, including a single species of the genus *Aphyosemion*, i.e., *Aphyosemion splendopleure* (Brüning, 1929) [32, 33]. Knowledge of the biology of these fish, especially regarding their growth and well-being in their natural habitats, is limited because their small size, catching difficulty, and non-eating value deter research interest [34]. Despite the potential for killifish trade development, it remains under-regulated in Africa [25], often dominated by a few traders, risking sustainable fish management and resource availability [26]. The degradation of forest ecosystems and unsustainable activities necessitates a deeper understanding of these species' life histories before implementing management strategies for conservation or domestication.

Therefore, this study aimed to investigate the growth type, well-being, and fitness of non-annual nothobranchiid killifish inhabiting the backwaters, brooks, and streams of the southern rainforest of Cameroon through LWRs and morphometric condition indices estimation. The results obtained contribute to the database update for these fish species to support their management strategies and/or conservation and allow future comparisons of their population dynamics.

2. Materials and Methods

2.1. Fish Sampling and Data Collection

The sampling of Cyprinodontiforms took place in deep-forest first- to second-order springs, brooklets, and streams tributaries of the Nyong and Sanaga Rivers of the Atlantic Basin of the Cameroonian coastal plain and centre-south plateau, within an area extending from 2°43′2″N to 4°02′55″N latitude and 9°51′59″E to 11°58′44″E longitude (Figure 1).

Sampling campaigns, lasting three to six days, were conducted bimonthly from January 2012 to February 2014. Specimens were collected using a rigid rectangular iron frame with a 90 cm by 60 cm hand dip net of 3 mm mesh size (Figure 2). The specimens were euthanized with clove oil and then fixed with 10% formalin before being placed into appropriately labelled vials containing 70% alcohol. In the laboratory, fish identification was based on appropriate keys [35-38]. Each specimen's total length (cm) and weight (mg) were measured using an ichthyometer and electronic balance. Fishing permit number 0020/ASE/MINEPIA/DIRPEC/SDARA approved the fish collection, and the handling of fish was in respect with the Cameroon National Ethical Committee (Reg. Num. FWAIRD 0001954) following the European Union on Animal Care (CEE Council 86/609) international principle guidelines.

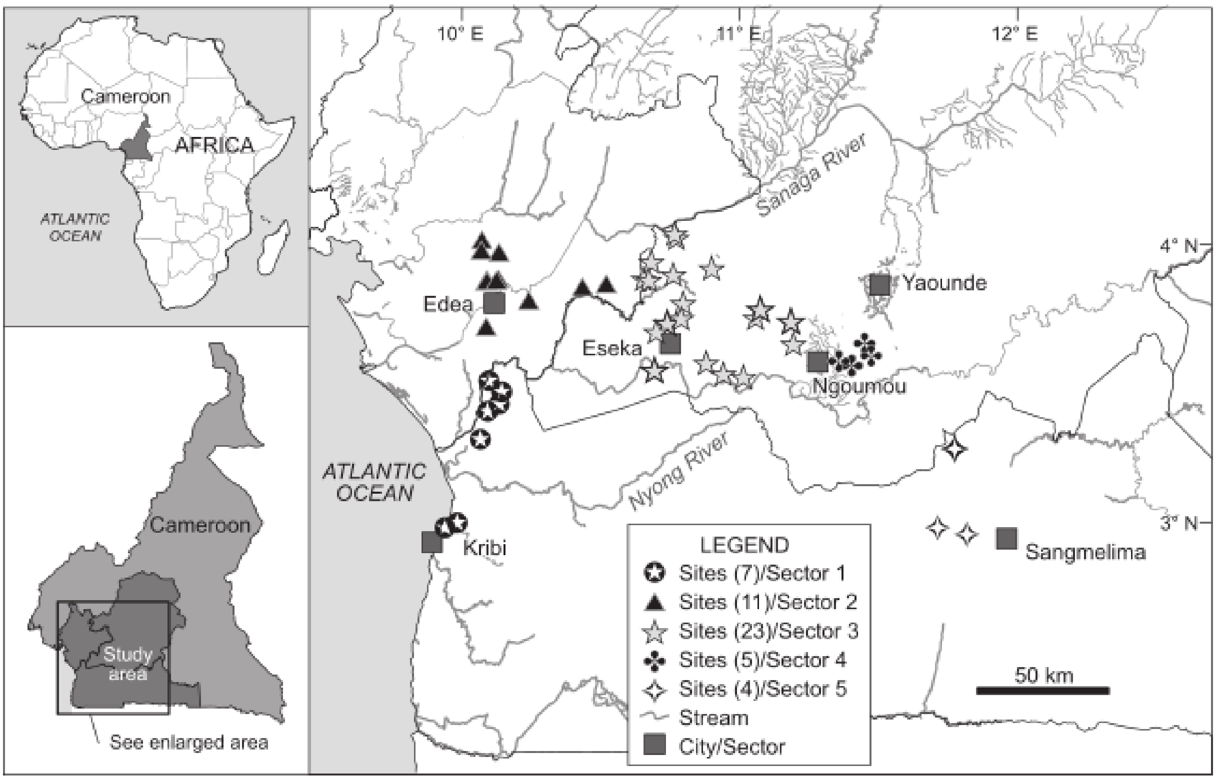

Figure 1. *Map of the nothobranchiids sampling sites.*

Figure 2. *Sampling of the nothobranchiids in the sourthern Cameroon rainforest (Photos by Messu Mandeng).*

2.2. Length-weight Relationships (LWRs)

This study only included nothobranchiid species with a minimum of 15 specimens. The LWRs were estimated using the power equation $W = aL^b$, where W is the fish's total weight, L is the total length, a is the rate of change of weight with length (regression intercept), and b is the weight at unit length (the regression slope or the allometric coefficient), obtained from the examination of the scatter plot diagram [12, 39]. The determination of the a and b coefficients resulted from the logarithmic transformation of the formula as $LogW = Loga + b\,LogL$ [12]. The fish's growth pattern determination followed the statistical comparison of the obtained b-value with the hypothetical isometric value 3, and an allometric growth could be of the negative ($b < 3$) or positive type ($b > 3$) [40].

2.3. Condition Factors

Fulton's coefficient of condition factor (*Kc*) was computed as an approximate value [41] to measure individuals in the form of hypothetical fish using the formula $Kc = 100\,W/L^3$ [20], where W stands for the fish's total weight and L for its total length. To assess deviations from the form of hypothetical fish [42], the allometric condition factor (*Ka*) was estimated using the equation: $Ka = 100W/L^b$, where W is the fish's total weight, L its total length, and b the allometric coefficient of the length-weight relationship [6]. The habitat conditions of the species were assessed by calculating the relative weight condition factor (*Kn*), which is a measure of an organism's deviation from the average weight in a given sample [40, 43], computed as $Kn = Wo/Wc$, where *Wo* is the observed total weight and *Wc* is the predicted total weight of each fish as $Wc = aL^b$. A value of $Kn \geq 1$ denotes good growth conditions for the fish, while a $Kn < 1$ indicates poor growth conditions [12].

2.4. Statistical Analyses

Due to the small sample sizes (< 30 individuals) during some surveys, statistical analyses were conducted by compiling data from the wet and dry seasons. Length-weight relationship and condition factor mean values were considered to be representative of the area of study regardless of the sampling locations or factors also affecting the length-weight relationships such as habitat, stomach fullness, seasonal effect, age, maturity stage, and sex [44, 45]. Therefore, the estimated length-weight relationships and regression coefficients are taken as mean annual values, as proposed by some authors [46-49].

The Microsoft Office Excel and Statistica software helped conduct the analyses. The fish body condition and LWRs were statistically described as mean ± standard error and presented as graphs or tables. ANOVA was used to evaluate differences in mean lengths and condition factors across the samples, highlighting the statistical significance of the regression model with a p-value of less than 0.05. For any significant ANOVA p-value, the *post hoc* Tukey test allowed pinpointing which pairwise comparison of means contributed to the overall significant difference observed in the computation of the F-statistic. The data were normally distributed following an evaluation by the Shapiro-Wilks test [50] with an assumption of the homogeneity of variances via Levene's test [51]. The evaluation of the fitting model and measure of the quality of regression predictions were given by the determination coefficient (R^2), which, when close to 1, indicates a better model. The Student's t-test at a 95% confidence interval (CI) permitted checking on the hypothetical value of isometry ($b = 3$) to establish the growth type of fish species and to check for any difference between the mean condition values.

3. Results

3.1. Species Collected and Morphometrics

This study considered 1010 cyprinodontiform individuals from 12 species, subdivided into six subgenera of two genera. Table 1 summarises the taxonomic affiliation of the species involved. It is a revised table mentioned previously by [52] and inserted here for clarity and follow-up of the analyses. Nothobranchiids were harvested in shallow streams (mean depth = 14 cm; mean width = 1 m) with slowly flowing waters (0.11 m s^{-1}) characterised by acidic pH (5.8), high oxygenation (dissolved O_2 = 17.68 mg l^{-1}), poor mineralization (conductivity = 24.79 µS cm^{-1}), and a mean temperature of 23.61 ℃. There was dense marginal vegetation and a high canopy closure above the watercourse. Stream substrate was mainly made up of litter, sand, mud, and pebbles [52].

Table 1. *Taxonomic affiliation of the nothobranchiid species from the southern Cameroonian rainforest streams related to the study of length-weight relationships and condition factors.*

Genus	Sub-genus	Species
Aphyosemion	*Aphyosemion* Myers, 1924	*Aphyosemion* sp.
	Chromaphyosemion Radda, 1971	*A. loennbergii* (Boulenger, 1903)

Genus	Sub-genus	Species
		A. omega (Sonnenberg, 2007)
		A. riggenbachi (Ahl, 1924)
	Kathetys Huber, 1977	*A. exiguum* (Boulenger, 1911)
	Mesoaphyosemion Radda, 1977	*A. amoenum* Radda et Pürzl, 1976
		A. obscurum (Ahl, 1924)
		A. cameronense (Boulenger, 1903)
		A. raddai Scheel, 1975
	Raddaella Huber, 1978	*A. batesii* (Boulenger, 1911)
	Scheelsemion Huber, 2013	*A. ahli* Myers, 1933
Epiplatys		*Epiplatys infrafasciatus*

Table 2 summarises the length, weight, length-weight regression parameters, and growth type of each of the species collected. The results indicated that the total lengths of specimens ranged from a minimum of 16 cm for *Aphyosemion loennbergii* to a maximum of 88 cm for *Epiplatys infrafasciatus*. The smallest and largest weights measured were those of *Aphyosemion exiguum* (39 mg) and *E. infrafasciatus* (4846 mg). Species differed significantly in length (F = 56.79, df = 11, p < 0.00) and weight (F = 46.66, df = 11, p < 0.00), differences especially brought about by *E. infrafasciatus* and *Aphyosemion batesii*, which presented higher values of both parameters that, however, did not differ between these two species. There were significant differences in length (F = 17.08, df = 2, p < 0.0000) and weight (F = 10.85, df = 2, p < 0.0000) between species of the subgenus *Chromaphyosemion*. The most statistically significant differences were observed in the mean length and mean weight between *A. loennbergii* and *Aphyosemion omega*. Meanwhile, these parameters did not differ between the species of the subgenus *Mesoaphyosemion* (F = 0.639, df = 3, p = 0.6).

Table 2. *Total length, total weight, length-weight parameters, and growth type of 12 nothobranchiid species encountered in the southern Cameroonian rainforest streams.*

Species	n	Total length (mm)		Total weight (mg)		Length-weight parameters					Growth behavior
		Range	Mean TL ± SE	Range	Mean TW ± SE	*a*	*b*	R^2	CI (*b*)	*p* regression	
Aphyosemion sp.	18	19–40	31.39±1.37	80–600	251.11±33.67	0.0214	2.6903	0.8879	2.0–3.15	< 0.001	A-
Aphyosemion loennbergii	266	16–48	30.98±0.37	44–700	260.43±8.4	0.0206	2.7244	0.9125	2.58–2.86	< 0.001	A-
Aphyosemion omega	85	17–39	26.9±0.5	43–657	186.9±10.54	0.0199	2.7525	0.837	2.46–3.03	< 0.001	A-
Aphyosemion riggenbachi	18	19–40	29.11±1.3	73–487	218.72±29.8	0.0124	2.8692	0.8665	1.99–3.45	< 0.001	A-
Aphyosemion exiguum	100	17–36	24.67±0.39	39–500	147.68±8.17	0.0053	3.1603	0.8393	2.89–3.41	< 0.001	A+
Aphyosemion amoenum	71	21–45	32.51±0.8	51–711	277.82±20.45	0.0154	2.7753	0.808	2.49–3.06	< 0.001	A-
Aphyosemion obscurum	46	22–47	33.74±0.83	66–804	317.7±24.17	0.0028	3.2772	0.9302	2.95–3.58	< 0.001	A+
Aphyosemion cameronense	133	19–47	33.6±0.56	43–656	312.27±13.53	0.019	2.7392	0.889	2.53–2.94	< 0.001	A-
Aphyosemion raddai	83	22–50	33.84±0.8	87–800	338.9±21.3	0.0139	2.8357	0.9403	2.68–2.99	< 0.001	A-
Aphyosemion batesii	61	27–70	47.56±1.42	92–1826	742.9±50.38	0.0744	2.3589	0.8687	2.06–2.62	< 0.001	A-

Species	n	Total length (mm)		Total weight (mg)		Length-weight parameters					Growth behavior
		Range	Mean TL ± SE	Range	Mean TW ± SE	*a*	*b*	R^2	CI (*b*)	*p* regression	
Aphyosemion ahli	86	17–45	30.7±0.71	46–713	271.1±17.4	0.0219	2.7182	0.9145	2.53–2.91	< 0.001	A-
Epiplatys infrafasciatus	43	23–88	44.88±1.91	99–4846	837.67±122.74	0.0054	3.0805	0.9655	2.87–3.23	< 0.001	A+

A- (negative allometry); A+ (positive allometry); n = sample size; CI = confidence interval of the *b* value.

3.2. Length-weight Relationships

As shown in Table 2, the *b*-value of the length-weight relationships of the species ranged from 2.3589 to 3.2772. Three species exhibited a positive allometric growth, tending to be thicker. These were *Aphyosemion exiguum*, *Aphyosemion obscurum, and E. infrafasciatus*. The other species demonstrated a negative allometric growth, suggesting that their length growth is privileged over weight input and tended to be thinner. For all the species tested, the correlation between the length and weight relationships was significant ($p < 0.001$), with high determination coefficient R^2 values varying between 0.808 and 0.9655, thereby depicting a good quality of the regression predictions for the studied species (Figure 3).

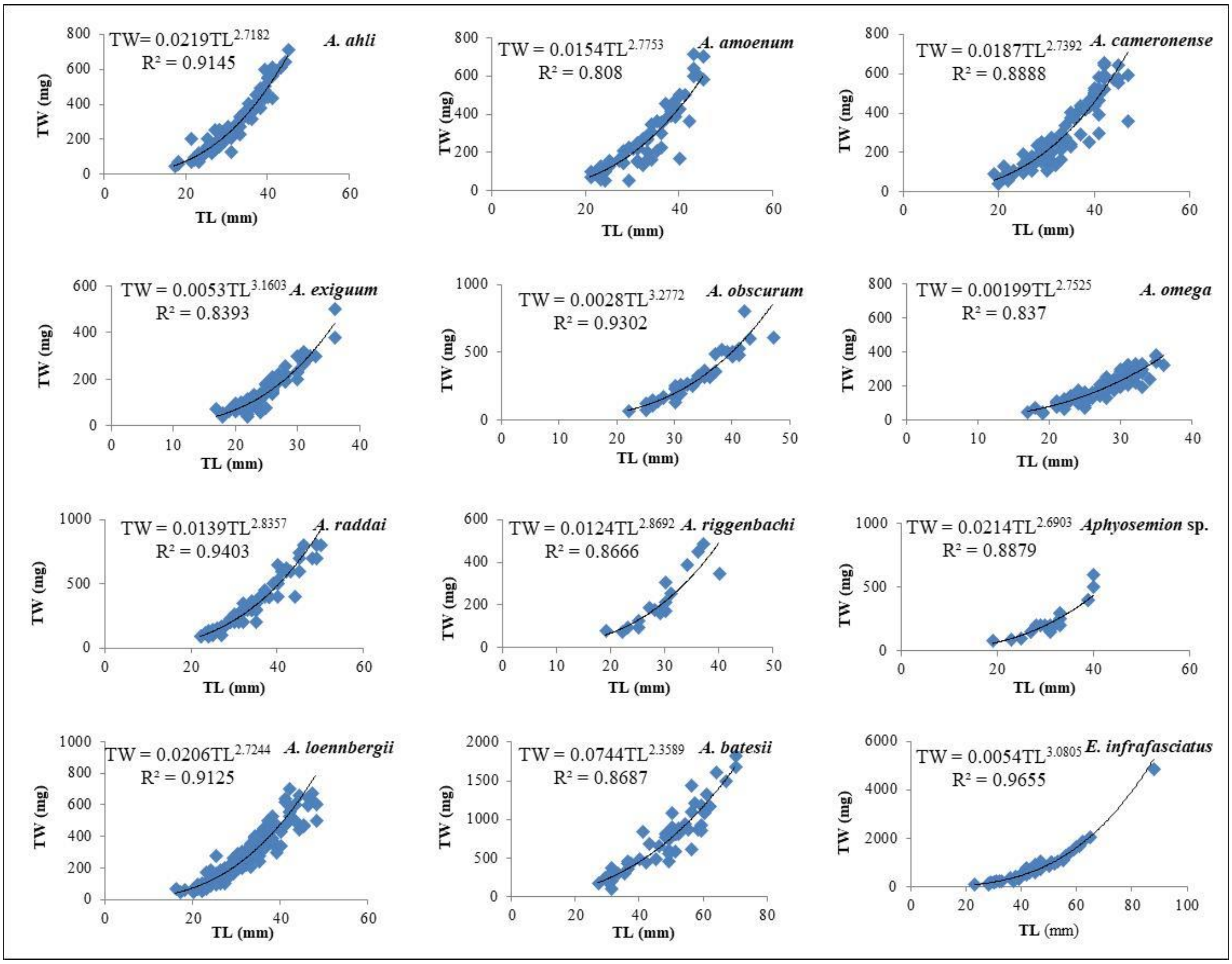

Figure 3. *Length-weight relationship regression curves of the nothobranchiids in the southern Cameroon rainforest. (TW: total weight; TL: total length; R ²: determination coefficient).*

3.3. Condition Factors

Table 3. *Ranges and mean values of the Fulton's condition factor (Kc), allometric condition factor (Ka), and relative condition factor (Kn) of 12 nothobranchiid species in the southern Cameroonian rainforest streams.*

Species	Fulton *Kc*		Allometric *Ka*		Relative weight *Kn*	
	Range	mean *Kc* ±SE	Range	mean *Ka* ±SE	Range	mean *Kn* ±SE
Aphyosemion sp.	0.50–1.20	0.75±0.04	1.46–2.94	2.17±0.10	0.68–1.37	1.02±0.04
Aphyosemion loennbergii	0.45–1.76	0.81±0.01	1.21–4.27	2.09±0.02	0.59–2.07	1.01±0.01
Aphyosemion omega	0.46–1.32	0.90±0.02	1.02–2.88	2.04±0.04	0.51–1.44	1.02±0.02
Aphyosemion riggenbachi	0.54–1.20	0.81±0.04	0.88–1.76	1.26±0.06	0.71–1.42	1.02±0.05
Aphyosemion exiguum	0.37–1.49	0.91±0.02	0.22–0.94	0.54±0.01	0.42–1.78	1.02±0.02
Aphyosemion amoenum	0.21–1.06	0.73±0.02	0.45–2.11	1.59±0.04	0.30–1.37	1.04±0.03
Aphyosemion obscurum	0.44–1.08	0.75±0.02	0.18–0.39	0.29±0.01	0.65–1.38	1.02±0.02
Aphyosemion cameronense	0.35–1.37	0.77±0.01	0.94–3.03	1.90±0.03	0.50–1.62	1.02±0.02
Aphyosemion raddai	0.47–1.07	0.79±0.01	0.84–1.89	1.41±0.02	0.6–1.36	1.01±0.01
Aphyosemion batesii	0.31–1.23	0.66±0.02	2.79–13.12	7.63±0.21	0.38–1.76	1.03±0.03
Aphyosemion ahli	0.44–2.16	0.85±0.02	1.15–5.09	2.22±0.05	0.52–2.33	1.02±0.02
Epiplatys infrafasciatus	0.45–1.03	0.74±0.02	0.34–0.78	0.54±0.01	0.64–1.42	1.01±0.02

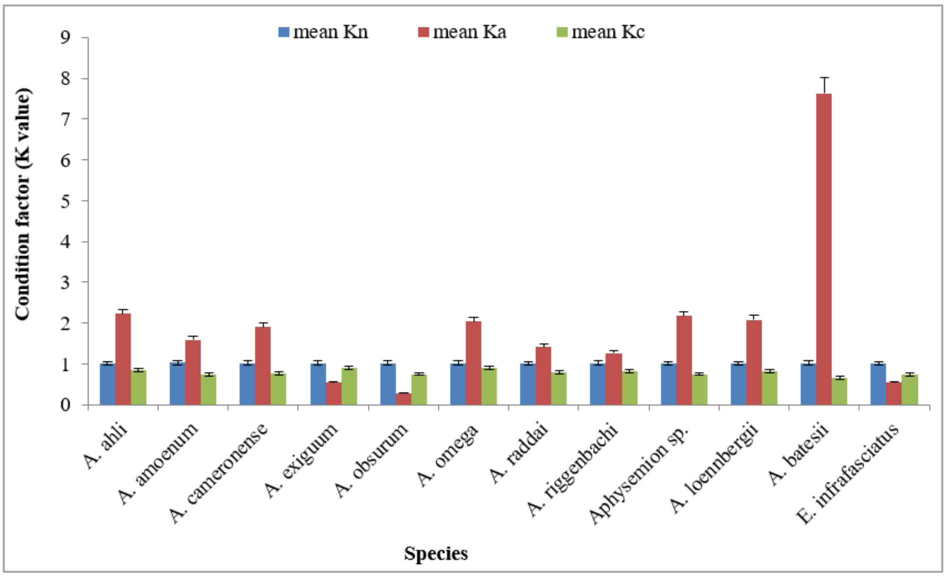

Figure 4. *Relative condition factor (Kn), allometric condition factor (Ka), and Fulton's condition factor (Kc) of 12 nothobranchiid species in the southern Cameroonian rainforest streams.*

Table 3 presents the range and mean value estimates of the Fulton condition factor (*Kc*), the allometric condition factor (*Ka*), and the relative weight condition factor (*Kn*) from this study, and Figure 4 pictures the differences observed. Globally, the estimation of the well-being of the various species of this fish family using the standard condition factor tool, Fulton's condition factor (*Kc*), yielded mean values less than 1, varying between 0.66 ±0.02 for *A. batesii* and 0.91 ±0.02 for *A. exiguum*, and differed significantly among species (F = 15.46; df = 11; $p < 0.0000$). A measure of the feeding rate of the species, evaluated using the allometric condition factor (*Ka*), showed mean values ranging from 0.29 ± 0.01 for *A.*

obscurum to 7.63 ± 0.21 for *A. batesii*. Together with *A. obscurum*, two other species presented values of *Ka* < 1, namely *A. exiguum* and *E. infrafasciatus*. The *Ka* values also differed significantly among species ($F = 866.5$; df = 11; $p < 0.0000$). The assessment of the suitability of the habitat conditions for the fish species by the relative weight condition factor (*Kn*) revealed values always greater than 1 for all the species under study and not differing among them ($F = 0.1117$; df = 11; $p = 0.999$). Therefore, the habitat characteristics provide good growth conditions for these species.

4. Discussion

The purpose of this study was to use length-weight data analysis to ascertain the growth patterns of non-annual killifish in their rainforest habitat. There was a strong correlation between the body length and weight in all species. *A. exiguum*, *A. obscurum*, and *E. infrafasciatus* showed positive allometric growth, while other species exhibited negative allometric growth. Growth types can vary due to factors such as fish body shape (*b*-value) [12, 53, 54], water quality, seasonal changes, fish condition, sex, gonadal development, food availability, and sampling methods [8, 44, 45, 52-58]. The growth pattern of *E. infrafasciatus* differed from two other sympatric *Epiplatys* species in Nigeria's Kainji Lake Basin, where *Epiplatys bifasciatus* (Steindachner, 1881) showed negative allometric growth and *Epiplatys spilargyreius* (Duméril, 1861) displayed isometric growth [59]. Comparisons are hampered by the paucity of research on *Aphyosemion* species, although [32] pointed out that *Aphyosemion splendopleure* in Nigeria also showed negative allometric growth.

Condition indices are metrics to assess animal health and energetic status, informing on life history traits, ecology, and resource management [9, 60, 61]. However, [9] highlighted a lack of consensus on the best morphological metrics for evaluating animal well-being. Following [39], the morphological condition factors *Kc*, *Kn*, and *Ka* were studied to understand nothobranchiid feeding behaviour and well-being in the wild. In this study, Fulton's condition factor (*Kc*) was less than one for all species, as observed for *E. bifasciatus* and *E. spilargyreius* in Nigeria [59], suggesting that nothobranchiids may not grow according to the cube law, indicating weight gain is not proportional to length [14]. According to [41], *Kc* differences among species could arise from body shape and growth type, resulting in each family having its own *Kc* range. We therefore propose *Kc* < 1 as typical for this fish family. Although not evaluated here, *Kc* values can vary among species or populations over time based on nutrition [62]. This index is widely used to investigate fish well-being because of its simplicity [9], even for species with allometric growth patterns [41], but assuming an isometric growth is a fair approximation for many species [63, 64].

The species exhibited significant differences in foraging intensity, indicated by mean values of the allometric condition factor (*Ka*). The *Ka* index assesses fish feeding rates [42, 65, 66]; it is less used than the Fulton factor despite being more relevant for species with allometric growth or for sufficient data to minimize *b*-value computation errors. Both indices interpret higher values as indicative of better fish body condition [6, 41]. There could be physiological or genetic reasons for the observed variations in mean *Ka* values between species [9]. In this study, species with positive allometric growth (*A. exiguum*, *A. obscurum*, and *E. infrafasciatus*) had lower *Ka* than *Kc* values, while those with negative allometric growth had higher *Ka*. These results concur with those of [41], who observed that *Kc* and *Ka* values were comparable for isometric growth but that *Ka* was higher for negative allometric growth and lower for positive allometric growth. The author suggested *Ka* might be more suitable for allometric growth scenarios, particularly when feeding rates and weight variations primarily influence condition factor variations.

All of the fish species under study had relative weight condition factors (*Kn*) greater than 1, suggesting that the stream ecosystems of tropical rainforests are favourable for their growth and survival due to the abundance of food sources [7], high water quality [52, 67], and low levels of predation [68, 69]. The presence of nothobranchiids is determined by local environmental factors like canopy cover (providing terrestrial insects falling into the streams and on which these fish mostly prey) and stream habitat characteristics kept almost constant by the vegetation cover [52]. Because it prevents the assumption of isometric growth and avoids a potential length effect, *Kn* is generally used as a proxy of individual growth if species exhibit an allometric growth pattern [18]. This index indicates an individual's energy reserves (i.e., lipid and protein contents) for reproductive success and survival during food shortage [19, 60, 70]. By measuring variations from the average weight for length, it provides information about fish health and possible regional environmental changes [71, 72]. Deviations from 1 reflect variations in prey abundance and ecological factors affecting life cycles [12, 42]. Computing relative mass is recommended whenever possible, with attention to statistical implications [9].

While *Ka* more accurately captures the effects of the environment on fish well-being simultaneously in space and time, *Kc* appears to be appropriate for comparing species across time or space [41]. When [14] suggests using the numerical condition factor (*Kn*) for assessing length-weight relationships within species, [41] instead found that some species can have *Kc* > 1 and *Kn* < 1, indicating good body condition despite poor growth, possibly due to life history or environmental factors that may lead species to increase their feeding intensity (described by *Ka* > 1). The author then suggested that *Kc* > 1 does not necessarily reflect better fish condition, so studying all three indices together is preferable for understanding species' well-being. In the present study, *A. batesii* had the highest *Ka*, the lowest *Kc*, and a *Kn* similar to its congeners, indicating good feeding in favourable conditions and suggesting that relying solely on *Kc* can misrepresent a fish's well-being, as it assumes isometric growth, which is negatively allometric for this species. Thus, monitoring condition indices can aid in assessing fish population health or food availability and informing fisheries management [71, 72].

5. Conclusions

The study of the growth patterns and well-being of non-annual nothobranchiid species in their natural habitat revealed that these species all displayed allometric growth types that do not follow the cube law, and differed significantly in their foraging intensities. The findings imply that tropical rainforest stream ecosystems offer favourable habitat conditions for these fish species' growth and survival and the factors contributing to their success. Results also emphasise the advantage of using multiple condition factors to describe species' physiological and ecological well-being in their habitats. Fisheries management and fish stock assessment may benefit from these findings.

Abbreviations

Ka	Allometric Condition Factor
Kc	Fulton's Condition Factor
Kn	Relative Weight Condition Factor
LWR	Length-weight Relationship

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Author Contributions

Françoise Danielle Messu-Mandeng: Conceptualization, Field work activities, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resource acquisition, Validation, Visualization, Writing – original draft, Writing – review & editing.

Charles Félix Bilong-Bilong: Conceptualization, Resource acquisition, Supervision, Visualization, Writing – review & editing.

Jean-François Agnèse: Conceptualization, Design, Resource acquisition, Supervision, Visualization, Writing – review & editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

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