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Length-Weight, Length-Length Relationships and Condition Factor of *Hypophthalmichthys nobilis* Fingerlings from Bahawalnagar, Pakistan

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ABSTRACT

Bighead carp (*Hypophthalmichthys nobilis*) is an economically important aquaculture species valued for its rapid growth and filter-feeding ability. **Objective:** To examine the morphometric parameters specifically the length–weight relationship (LWR), length–length relationships (LLRs), and condition factor of *Hypophthalmichthys nobilis* (bighead carp) fingerlings reared in hatcheries in Bahawalnagar, Pakistan. **Methods:** A total of 35 fingerlings were sampled. Morphometric measurements including total length (TL), standard length (SL), fork length (FL), head length (HL), and body weight (W) were recorded. The LWR was calculated using the formula $W = aTL^b$, and the LLRs were derived through linear regression between different length parameters. The condition factor (K) was determined using the Fulton's formula. **Results:** The mean ± SD values for TL and W were 10.21 ± 0.52 cm and 9.53 ± 1.45 g, respectively. The LWR showed a negative allometric growth pattern with constants a = –1.5671 and b = 2.52, and a strong correlation (r = 0.887). Strong positive correlations were observed in LLRs: TL vs. SL (b = 1.03), TL vs. FL (b = 0.74), and TL vs. HL (b = 0.85). The mean ± SD condition factor was 0.89 ± 0.06, indicating moderately good fish health. **Conclusions:** This study presented updated, population-specific data on morphometric relationships and the condition factor of *Hypophthalmichthys nobilis* fingerlings in Pakistan. These findings provide a valuable baseline for region-specific stock assessments and contribute to informed, sustainable management strategies for bighead carp in hatchery settings.

INTRODUCTION

The sustainability of fisheries science and aquaculture management hinges on the accurate assessment of fundamental biological parameters, including fish growth rates, body composition, and reproductive performance. Simple measures to assess the growth pattern and general fitness in fish populations comprise Length-Weight (LW) relationship and condition factor, respectively, which provide efficient management strategies and stock assessment Naeem *et al.*, in 2010 [1]. Dietary interventions also substantially influence fish growth, feed utilization efficiency, and the overall sustainability of aquaculture systems, highlighting the importance of optimized nutritional formulations in promoting fish health and development Ismat *et al.*, in 2013 [2]. Morphometric analyses play a vital role to understand the fish biology, principally in observing the relations among various body lengths Naeem *et al.*, in 2011; Pervaiz *et al.*, in 2012 [1, 3]. Such morphometric data and their statistical relationships are crucial for fisheries managers and taxonomists in order to determine growth variation in fish and to identify and classify fish species. Furthermore, morphometric studies can uncover distinctions among different populations of same fish species [4, 5]. Assessing morphometric traits and condition factors is essential in evaluating fish health, growth patterns, and aquaculture potential. The condition factor is widely used as an indicator of the physiological status of fish in aquaculture systems [6]. Selective breeding has also been shown to significantly improve

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growth rates and overall quality in farmed fish species, reinforcing the importance of genetic and morphometric assessments [7]. Studies on length–weight and length–length relationships across various fish species, such as those conducted by González-Acosta *et al.*, in 2024 provide comparative benchmarks for evaluating regional fish populations. Additionally, morphometric variability influenced by geographic isolation and environmental conditions has been demonstrated in related species like *Labeo calbasu* stated by Hossain *et al.*, in 2010, underscoring the relevance of localized assessments like the present study [8, 9]. Because, in response to environmental factors, morphometric adaptations are more frequent in fish leading to morphological variation than in other vertebrate groups Loy *et al.*, in 2000 [10]. Length-Weight Relationship (LWR) usually indicated as $W = aTL^{b}$, where W represents weight and TL shows total length, aids to evaluate if a species displays allometric or isometric growth pattern Ding *et al.*, in 2023 [4]. Recent research has applied LWRs to estimate growth patterns in different fish species across different geographical regions, emphasizing their significance in management and ecological contexts Naeem *et al.*, in 2011; Rodriguez *et al.*, in 2023; Yousuf *et al.*, in 2023 [1, 11, 12]. Length-Length Relationships (LLRs) are generally implied in for estimation of population management and dynamics through size conversion (for instance calculated TL to SL), providing accuracy of assessment models for population estimation González-Acosta *et al.*, in 2024 [8]. Condition factor is generally used to evaluate the conformation of the fish and can help producers optimize feed management and the nourishment (energy state) of fish [6]. The length–weight relationship (LWR) and condition factor are widely used tools in fish biology for assessing growth patterns and overall fish health. Studies such as that by Ferdous Jerin *et al.*, in 2023 on threatened riverine catfish in Bangladesh highlight the importance of these parameters in conservation and stock monitoring [13]. Similarly, Khan *et al.*, in 2020 reported region-specific LWR data for *Cyprinus carpio* from the Indus River, underscoring the variability in growth dynamics across ecosystems [14]. According to King in 2013, accurate LWR and condition factor measurements are fundamental to fisheries biology, contributing to effective stock assessment, management strategies, and sustainability planning [15].

The aim of the study was to evaluate the length- weight (LWR), length–length relationships (LLRs), and condition factor of *Hypophthalmichthys nobilis* (bighead carp) fingerlings collected from Bahawalnagar, Pakistan to assess the growth patterns and well-being of carp findings.

METHODS

This study employed a descriptive design to analyze biometric and morphometric parameters (length-weight relationships, length-length relationships, and condition factor) of *Hypophthalmichthys nobilis* fingerlings. Data were collected through standardized measurements without experimental manipulation, following observational protocols for hatery-reared fish. A total of 35 fish fingerlings were procured via convenience sampling from a single hatchery batch at Fish Seed Hatchery, Minchinabad, Bahawalnagar, Pakistan during 2024. Fingerlings were selected based on being healthy, active specimens with no visible deformities or signs of disease (size range: 9.40-11.50 cm TL). To ensure uniformity, fish of similar size and age from the same hatchery batch were used, while excluding any deformed, injured or abnormal specimens. The fingerlings were transported in oxygen-filled plastic bags to the Aquaculture Research Lab, The Islamia University of Bahawalpur, Bahawalnagar Campus, Bahawalnagar, Pakistan . Body Weight (W) was recorded in grams; while various body lengths of *H. nobilis* including Total Length (TL), Standard Length (SL), Fork Length (FL) and Head Length (HL) were measured in centimeter. Condition factor (K) was evaluated following standard formula: $K=W/TL^{3}\times100$. Descriptive analyses such as mean, standard deviation and range; and correlation coefficient was calculated. Relationship of TL (X) with W and various studied morphometric lengths (Y) of *Hypophthalmichthys nobilis* was estimated using the commonly applied power function equation, as described by Le Cren [16] and Froese [5]:

$$W = aL^{b}$$

where W is weight (g), L is total length (cm), a is the intercept, and b is the slope. This was log-transformed to linear form for analysis

Where 'Y' is either W, SL, FL or HL; a is constant (intercept), and b is growth coefficient (or slope). To facilitate linear regression analysis, this equation was log-transformed into the following linear form:

$$\text{Log } Y = \text{Log } a + b \text{ Log } X$$

The value of b provides insight into the growth pattern of the fish. In LWR, if b = 3, growth is considered isometric, meaning weight increases proportionally with TL. When $b \neq 3$, growth is allometric, either positive when $b > 3$ (weight increases faster than length) or negative allometric pattern when $b < 3$ (length increases faster than weight), whereas for LLRs b-value is compared with 1.00. Statistical analysis was done by use of SPSS 26.0, p-value of less than 0.05 was considered statistically significant [5]. Several regional studies support the importance of analyzing length–weight relationships (LWR) and condition factors to assess the growth performance and health status of various fish species.

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RESULTS

The total length of the *Hypophthalmichthys nobilis* fingerlings (n = 35) ranged from 9.40 cm to 11.50 cm, and the corresponding body weight from 7.46 g to 14.15 g. Themean condition factor was observed 0.89±0.06 for the studied samples of *Hypophthalmichthys nobilis* fingerlings. Descriptive statistics for various morphometric measurements, body weight and condition factor of *Hypophthalmichthys nobilis* fingerlings from Bahawalnagar, Pakistan are illustrated as table 1.

Table 1: Descriptive Statistics for Various Body Lengths, Weight and Condition Factor of *Hypophthalmichthys nobilis* Fingerlings

Variables	Range	Mean ± SD
Total Length (TL)	9.40-11.50	10.21 ± 0.52
Standard Length (SL)	7.20-9.10	8.01 ± 0.43
Fork Length (FL)	1.90-2.60	2.22 ± 0.14
Head Length (HL)	2.10-2.70	2.27 ± 0.14
Body Weight (W)	7.46-14.15	9.53 ± 1.45
Condition Factor (K)	0.76-0.99	0.89 ± 0.06

SD= Standard Deviation

The assessed parameters of the length-weight relationship (LWR) were a = -1.5671 and b = 2.52. The coefficient of correlation (r) was 0.887, representing a strong positive relationship between length and weight. The b value suggests a negative allometric growth pattern in the studied Bighead carp population (Table 2).

Table 2: Length-Weight and Length-Length Relationships of *Hypophthalmichthys nobilis* Fingerlings

Equation	a	b	95% CI of a	95% CI of b	r
Log *W*= *a* + *b* Log *TL*	-1.5671	2.52	-2.0348 to -1.0994	2.06-2.98	0.887
Log *SL*= *a* + *b* Log *TL*	-0.1309	1.03	-0.2472 to -0.0145	0.91-1.14	0.953
Log *FL*= *a* + *b* Log *TL*	-0.4020	0.74	-0.7529 to -0.0512	0.39-1.09	0.603
Log *HL*= *a* + *b* Log *TL*	-0.4999	0.85	-0.8074 to -0.1923	0.54-1.15	0.701

a = intercept; b = slope; CI = confidence intervals; r = correlation coefficient

Significant linear relationships were observed between Total Length (TL) and other morphometric measurements of *Hypophthalmichthys nobilis* fingerlings (Table 2). The relationship between TL and SL showed a slope (b) value of 1.03, indicating an isometric relationship. The relationship between TL and Fork Length (FL) yielded a b value of 0.74, while the relationship between TL and Head Length (HL) had a b value of 0.85, both representing negative allometric pattern. All length–length relationships demonstrated strong positive correlations (r=0.603-0.953), suggesting consistent proportional growth among these body dimensions. These findings support the reliability of using alternative length measurements (SL, FL, and HL) for estimating TL in morphometric and stock assessment studies.

DISCUSSION

Ujjania *et al.*, in 2013 investigated *Labeo rohita* in Southern Rajasthan, reporting LWR patterns relevant for aquaculture and resource management [17]. Similarly, Salam *et al.*, in 2005 documented the LWR and condition factor of *Puntius chola* from freshwater bodies in Pakistan, emphasizing environmental influences on fish morphology [18]. Javaid *et al.*, in 2010 explored the relationship between body composition and condition factor in *Oreochromis nilotica*, reinforcing its significance in understanding growth efficiency [19]. Chakravarty *et al.*, in 2012 further extended these findings to marine species, highlighting species-specific variability in LWR, such as in *Trichiurus lepturus* and *Lepturacanthus savala* from the Visakhapatnam coast [20]. Collectively, these studies provide valuable comparative insights that support the present findings on *Hypophthalmichthys nobilis*. The observed length-weight relationship in the present study revealed a strong positive correlation (r = 0.887) between the total length and body weight of carp, indicating that length is a reliable predictor of weight in this species. Compared to earlier studies on carps, the b value reported here falls within normal biological range (2.5–3.5) as described further validating the accuracy of the measurements and analytical approach. The calculated b value (2.52) deviates from the ideal isometric value of 3.0, suggesting negative allometric growth. It indicated that the fish increases in length faster than in weight as it grows [21-23]. A research was conducted to study length-weight relationship (LWR) and length-length relationships (LLRs) of farmed Catla catla, Value of exponent b was found 3.23 in LWR of farmed C. catla indicating positive allometric pattern of growth in C. catla. While, in LLRs, b-value was observed 1.00 or close to 1.00, indicating isometric pattern of growth in SL and FL with an increase in TL for the studied fish species. Such growth patterns are common in juvenile or early growth stages when linear growth is more pronounced. Several factors could influence the allometric nature of growth, including food availability, sex, and environmental conditions of the fish [24, 25]. While the allometric interpretations ($b \neq 3$) in this study are biologically plausible, we acknowledge that the estimated b-values may be sensitive to measurement errors given the modest sample size (n=35). Small variations in length measurements can disproportionately influence slope estimates in power-law relationships [5]. These findings should therefore be interpreted as population-specific estimates for this hatchery cohort, with validation recommended through larger-scale studies. While the sample size (n=35) allowed detection of strong morphometric relationships (e.g., r > 0.88 for LWR), the study's hatchery-specific convenience sampling limits

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generalizability to wild populations or other rearing conditions. These findings provide preliminary biometric baselines for *Hypophthalmichthys nobilis* fingerlings, but larger, multi-location studies are needed to validate broader applicability. The strong positive correlations (P<0.001) among LLRs specify that Standard Length (SL), Fork Length (FL) and Head Length (HL) increase in a proportionate and predictable manner in relation to among Total Length (TL) of *Hypophthalmichthys nobilis*. In a previously reported study on *Ompok bimaculatus*, Ishtiaq *et al.*, in 2021 documented isometric pattern between total (TL) and Standard Length (SL) [23]. The slope value (b=1.02) for the TL–SL relationship in the present study also proposes isometric growth pattern, indicating that total length and standard length of *Hypophthalmichthys nobilis* fingerlings grow at the same rate. This outcome suggests that SL can aid as a reliable substitution for TL in fishery assessments or field studies where measuring TL may be challenging due to specimen preservation methods or fin damage. In contrast, the relationships of TL vs FL and TL vs HL yielded lower *b* values being less than 1.00, representing a negative allometric pattern as also documented by other studies [24, 25]. Another carp *(Cyprinus carpio)* have also reported negative allometric growth pattern for the relationship between TL and HL [16]. The finding suggests that HL (head length) and FL (fork length) of *Hypophthalmichthys nobilis* increase at a lower proportion when compared to TL (total length) of the fish. These differences are not unusual and can result from developmental stages, species-specific body shapes, and/or environmental factors like habitat structure, food availability and water quality. Some authors, including Datta *et al.*, in 2013 reported the condition factor 'K' of the studied fish species above 1.0 indicating robustness or wellbeing of the fish [22]. Whereas the calculated condition factor (K) value for *Hypophthalmichthys nobilis* fingerlings, in this study, remained below than the ideal value of 1.0. This study analyzed the length–weight relationship and condition factor of *Labeo bata* from the Ranikot stream in Sindh, Pakistan, to assess its growth pattern and health status [26].

CONCLUSIONS

This study shown a strong LWR in *Hypophthalmichthys nobilis* fingerlings with negative allometric growth pattern. LLRs also represented strong correlations, representing consistent morphometric proportions. Additionally, condition factor (K) of the studied *Hypophthalmichthys nobilis* population was calculated as 0.89, indicating that the carp fingerlings were in moderately good condition but slightly below the optimal health benchmark. Findings of the present work are useful for fisheries management, stock assessment and growth analysis. Future studies on a larger sample size and the inclusion of habitat or seasonal-based variations may help refine these relationships. Generalizability of the results might also be constrained due to the small size of the sample (n = 35). The results are based on the data collected in one hatchery, and this data cannot show the variability of a wild population. It is suggested that future research that involves big sample size and various locations be conducted to confirm these results.

Authors Contribution

Conceptualization: AI
Methodology: SM, MSA, AS, AN, BA
Formal analysis: SM, MSA, AS, AN, BA
Writing, review and editing: AI, SM, MSA, AS, AN, BA

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

All the authors declare no conflict of interest.

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