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Length–weight relationships for 11 freshwater fish species (Actinopterygii) from four protected areas, northern Vietnam

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Abstract

The length–weight relationships (LWRs) of 11 fish species from one national park and three nature reserves, in northern Vietnam, totaling 737 individuals between October 2018 and November 2021, are described in this study. The following species, representing 11 genera and seven families, were studied: *Aphyocypris normalis* Nichols et Pope, 1927, *Barbodes semifasciolatus* (Günther, 1868), *Beaufortia pingi* (Fang, 1930), *Carassius auratus* (Linnaeus, 1758), *Glyptothorax honghensis* Li, 1984, *Hemibarbus medius* Yue, 1995, *Macropodus opercularis* (Linnaeus, 1758), *Neolissochilus benasi* (Pellegrin et Chevey, 1936), *Onychostoma gerlachi* (Peters, 1881), *Opsariichthys minutus* Nichols, 1926, *Rhinogobius duospilus* (Herre, 1935). All regressions were highly significant ($P < 0.001$). Positive allometric growth was seen in six species ($b > 3$, $P < 0.01$) and isometric growth in five species ($b = 3$, $P > 0.05$). This is the first report on the LWRs of six fish species, including *Beaufortia pingi*, *Barbodes semifasciolatus*, *Neolissochilus benasi*, *Opsariichthys minutus*, *Glyptothorax honghensis*, and *Rhinogobius duospilus* from four conservation areas. The presently reported study provides foundational data for future stock assessment works and management initiatives in protected areas, as well as facilities comparisons of LWRs from different habitats.

Keywords

conservation, growth pattern, length–weight relationship, new data

Introduction

Management of aquatic resources requires systematic assessments, integrating accurate data and representative parameters (e.g., abundance, size, and age structures) of fish populations at the local scale (Lou et al. 2005), including the length–weight relationships (LWRs). In fish biology, length–weight relationship is an essential fisheries management technique because they allow the mean weight of fish belonging to a length group to be estimated by establishing a mathematical relationship between length and weight (Beyer 1987). Knowledge of LWRs is essential for characterizing fish growth, body condition, size at first maturity, and life-history phenotypes (Le Cren 1951; Froese 2006).

Mountain regions have high levels of biodiversity and a wide variety of natural habitats due to their varied elevation and topography (Sterling et al. 2017). Bac Me, Nam Xuan Lac, Cham Chu Nature Reserves, and Phia Oac–Phia Den National Park have all been established to safeguard and sustain biodiversity in natural resources, uncommon species, and vulnerable species. Research on species diversity (Ta et al. 2023, 2024; Nguyen et al. 2024), records of new species for the region and for science in recent years have been updated and supplemented in protected areas (Duong

et al. 2022; Tran et al. 2023; Dang et al. 2024). Moreover, Dang et al. (2023) presented a study on the extraction and usage of fish resources in these areas, which discovered that fish populations have decreased in certain sites.

Recent taxonomic and ecological work on the fish fauna of northern Vietnam has included an updated checklist summarizing the fauna (Ha et al. 2021), providing a foundation for additional work; however, LWR research on this fauna has been limited to various species of estuarine gobies (e.g., Tran et al. 2021; Ha et al. 2022; Nguyen et al. 2022; Ta et al. 2022). In this study, we present results from the first study of LWRs in primarily freshwater fishes of northern Vietnam, including a total of 11 species, six of which currently have no LWR information publicly available in FishBase (Froese and Pauly 2024). By presenting novel data and results on LWRs of freshwater fishes from protected areas of northern Vietnam, our study provides baseline data for future stock assessment and contributes to a greater understanding of the basic biology and growth patterns of freshwater fishes of conservation concern, which is critical for future conservation and management efforts.

Material and methods

Eight field surveys were conducted to sample freshwater fishes between October 2018 and November 2021 in northern Vietnam (Fig. 1). Fish were collected using hand nets, casting nets, and gillnets. In the field, specimens were first fixed in 10% formalin solution, and in the lab, samples were later preserved in 70% ethanol.

A total of 11 fish species representing 11 genera of 7 families were studied: *Aphyocypris normalis* Nichols et Pope, 1927, *Barbodes semifasciolatus* (Günther, 1868), *Beaufortia pingi* (Fang, 1930), *Carassius auratus* (Linnaeus, 1758), *Glyptothorax honghensis* Li, 1984, *Hemibarbus medius* Yue, 1995, *Macropodus opercularis* (Linnaeus, 1758), *Neolissochilus benasi* (Pellegrin et Chevey, 1936), *Onychostoma gerlachi* (Peters, 1881), *Opsariichthys minutus* Nichols, 1926, *Rhinogobius duospilus* (Herre, 1935).

The total length (TL) and weight (W) of each individual were determined to the nearest 0.01 cm and 0.01 g, respectively. The length–weight relationships

$$W = a\mathrm{TL}^b$$

of 11 species were estimated from the following log-transformed equation

$$\mathrm{Log}(W) = \log(a) + b \times \log(\mathrm{TL})$$

where W is the total weight of an individual [g], TL is the total length [cm], a is the intercept, and b is the

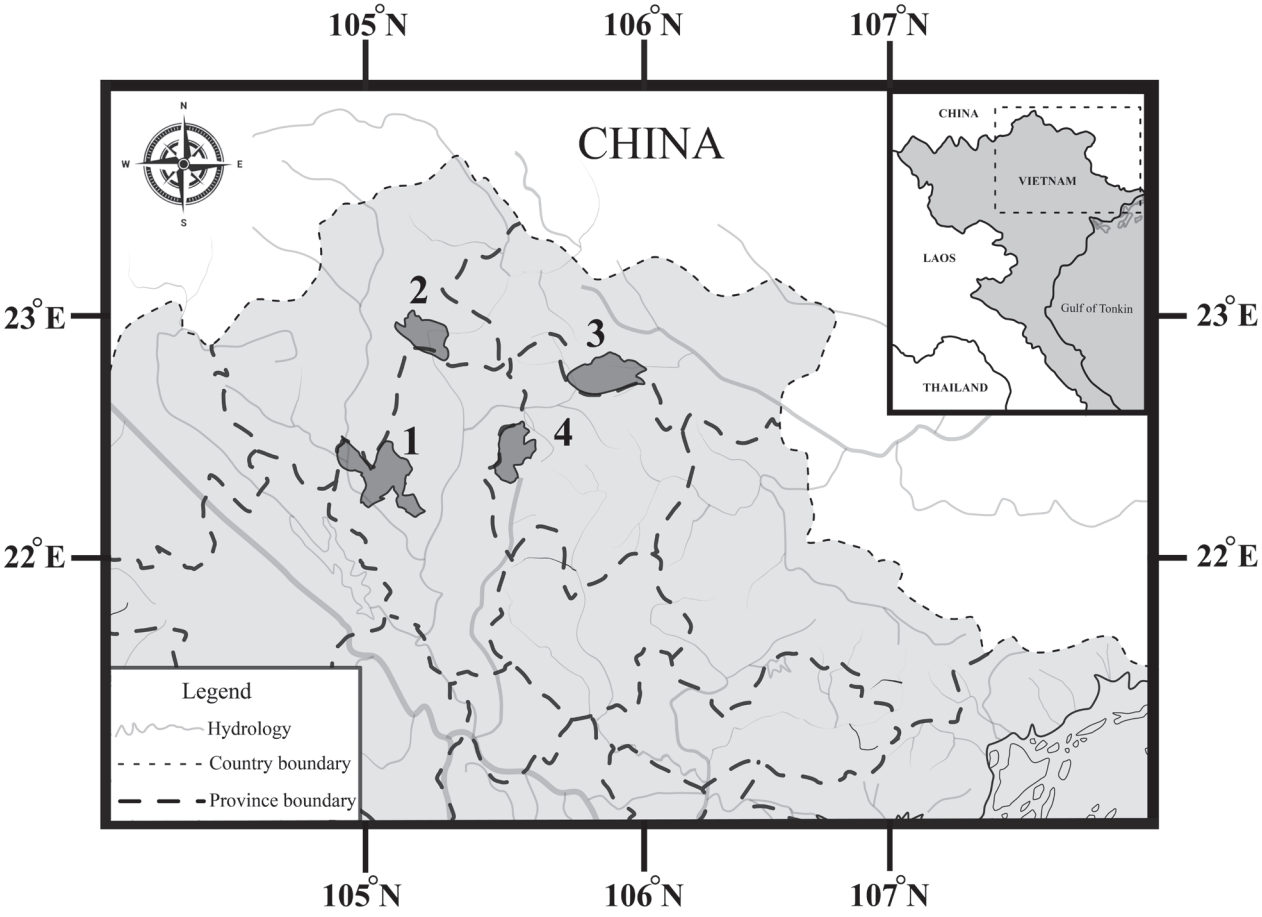

Figure 1. Map of the study area and sampling sites within four protected areas in northern Vietnam. 1. Cham Chu Nature Reserve; 2. Bac Me Nature Reserve; 3. Phia Oac–Phia Den National Park; 4. Nam Xuan Lac Habitat and Species Conservation Area.

slope (Le Cren 1951; Ricker 1973; Froese 2006). In addition, the 95% confidence interval (CI) of the parameters and the statistical significance of the regression relationships (r^2) were calculated statistically. The log-transformed data should be plotted, and obvious outliers should be removed before performing linear regression (Froese et al. 2011). The coefficient *b* was compared with 3 using Student's *t*-tests to evaluate the growth pattern. Here, $b = 3$ is generally taken to represent isometric growth, while $b > 3$ indicates positive allometric growth and $b < 3$ indicates negative allometric growth (Froese 2006). Basic functions in R software version 4.1.0 were used to perform all statistical analyses (R Core Team 2024).

Results

A total of 737 specimens were examined in the presently reported study. The LWRs and related statistics for 11 of the species studied are presented in Table 1. The highest number of specimens was measured for *Rhinogobius duospilus* ($n = 294$), while 2 species (*Hemibarbus medius* and *Carassius auratus*) had much smaller sample sizes (17 and 12, respectively). The estimated values of coefficient (*a* value) from LWRs ranged from 0.004 (*Opsariichthys minutus* and *Aphyocypris normalis*) to 0.012 (*Macropodus opercularis*) while the exponent (*b* value) ranged from 2.954 (*M. opercularis*) to 3.407 (*A. normalis*). The coefficients of determination r^2 were between 0.952 (for *R. duospilus*) and 0.997 (for *Onychostoma gerlachi* and *A. normalis*). The LWRs of each species were highly significant ($P < 0.001$). The *b* values of 11 species were significantly higher than or at least equal to three (Table 1).

Discussion

The *b* values of all species in this study were within the expected range predicted by Froese (2006) and the 95% confidence limits of the Bayesian LWR predicted value at FishBase (Froese et al. 2024), the value of sole *b* usually falls from 2.50 to 3.50 (Froese 2006). Many factors can affect the parameters of LWR of fish such as different fishing methods, storage techniques, and sample-collecting periods. In addition, the value of slope *b* could vary mainly due to several environmental (habitat, season), anthropogenic (length type, size range, number of specimens), and biological factors, gonadal maturation, diet, degree of stomach fullness, and growth stage (Hanif et al. 2018). However, the number of specimens for *Carassius auratus* and *Hemibarbus medius* was insufficient to derive an appropriate LWRs equation.

Comparing our results with published LWRs for the focal taxa shows that the slope *b* of *Hemibarbus gerlachi* (3.096), *Aphyocypris normalis* (3.407), *C. auratus* (3.316) and *H. medius* (3.171) was quite similar (Froese and Pauly 2024). However, *Macropodus opercularis* (2.954) was smaller when compared with the results of Tang et al. (2015). For the range of TL values, *C. auratus* (6.09–12.88 cm) was most similar to the study by Wang et al. (2015); *O. gerlachi* (1.05–17.81 cm) were supplemented with small-sized specimens in our study which conforms with the findings of Que et al. (2014) and He et al. (2023); the range of *A. normalis* was expanded (3.54–10.41 cm); the *b*-values of *H. medius* and *M. opercularis* were similar or narrower than previous research. Concerning the last six fish species (*Beaufortia pingi*, *Barbodes semifasciolatus*, *Neolissochilus benasi*, *Opsariichthys minutus*, *Glyptothorax honghensis*, and *Rhinogobius duospilus*), no previous data on LWRs were available in FishBase (Froese and Pauly 2024) for these species or areas, hence our study provides the first data on LWRs for them.

Table 1. LWR estimates for 11 species reported from four protected areas in northern Vietnam.

Family and species	*n*	TL [cm]	*W* [g]	$W = aTL^b$					*P* (*t*-test)	*b* FishBase
				a	*b*	r^2	95% CI of *a*	95% CI of *b*	*b* compared to 3	
Balitoridae										
Beaufortia pingi	35	1.06–7.44	0.01–4.25	0.006	3.318	0.991	0.005–007	3.206–3.431	<0.001	—
Cyprinidae										
Barbodes semifasciolatus	74	2.12–7.57	0.10–5.56	0.008	3.294	0.982	0.007–0.010	3.190–3.398	<0.001	—
Carassius auratus	12	6.41–12.88	3.12–35.44	0.005	3.337	0.994	0.004–0.016	3.181–3.566	0.002	2.732–3.336[1]
Neolissochilus benasi	51	2.51–17.86	0.12–71.75	0.008	3.060	0.990	0.006–0.009	2.973–3.147	0.171	—
Onychostoma gerlachi	49	1.05–17.81	0.01–49.80	0.006	3.069	0.997	0.006–0.007	3.023–3.115	0.004	3.060[2]; 3.231[3]
Gobiidae										
Rhinogobius duospilus	294	2.32–5.28	0.12–1.58	0.007	3.201	0.952	0.007–0.008	3.118–3.284	0.020	—
Gobionidae										
Hemibarbus medius	17	7.47–12.49	3.33–16.18	0.006	3.171	0.982	0.003–0.010	2.932–3.410	0.148	3.124[4]; 3.220[3]
Osphronemidae										
Macropodus opercularis	46	3.08–8.12	0.33–5.12	0.012	2.954	0.956	0.009–0.017	2.762–3.146	0.632	3.088[5]
Sisoridae										
Glyptothorax honghensis	39	3.13–13.37	0.35–29.59	0.009	3.068	0.982	0.007–0.012	2.930–3.206	0.327	—
Xenocyprididae										
Aphyocypris normalis	26	3.54–10.41	0.33–12.03	0.004	3.407	0.997	0.004–0.005	3.331–3.483	<0.001	3.103[4]
Opsariichthys minutus	91	2.01–16.92	0.05–47.88	0.004	3.3093.	0.985	0.003–0.005	3.224–3.395	<0.001	—

n = sample size, *a* = intercept, *b* = slope, CI = confidence interval, r^2 = coefficient of determination, TL = total length; FishBase references: [1]Froese and Pauly (2024); [2]Que et al. (2014); [3]He et al. (2023); [4]Li et al. (2014); [5]Tang et al. (2015).

In terms of growth type, we found that six species had positive allometric growth ($b > 3$, $P < 0.01$ for all cases), five species had isometric growth ($b = 3$, $P > 0.05$ for all cases), and none had negative allometric growth ($b < 3$). Positive allometric is usually associated with changes in body shape between growth stages, with smaller fish having more elongated or thinner bodies than larger fish. Moreover, smaller individuals have the same body shape and density as larger individuals for isometric growth. In this study, the calculated parameters can be taken as mean values because the data were gathered over a long time and did not indicate any single season. The LWR results give fundamental information for the studied fish and will be valuable for managing and conserving these freshwater fishes.

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