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Length–weight relations of 12 freshwater fish species (Actinopterygii: Cypriniformes) including two endangered species, *Cobitis choii* (Cobitidae) and *Gobiobotia naktongensis* (Cyprinidae), in the Geum River, South Korea

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Abstract

Length–weight relations (LWRs) of 12 freshwater fish species from the Geum River, South Korea were estimated. The following species representing the family Cobitidae, Xenocyprididae, Acheilognathidae, and Gobionidae were studied: *Cobitis choii* Kim et Son, 1984; *Opsariichthys uncirostris* (Temminck et Schlegel, 1846); *Zacco platypus* (Temminck et Schlegel, 1846); *Tanakia lanceolata* (Temminck et Schlegel, 1846); *Acheilognathus rhombeus* (Temminck et Schlegel, 1846); *Hemibarbus labeo* (Pallas, 1776); *Gobiobotia naktongensis* Mori, 1935; *Hemibarbus longirostris* (Regan, 1908); *Microphysogobio jeoni* Kim et Yang, 1999; *Pseudogobio esocinus* (Temminck et Schlegel, 1846); *Pseudorasbora parva* (Temminck et Schlegel, 1846); *Squalidus japonicus* (Sauvage, 1883). Parameter *b* ranged from 2.820 (*P. parva*) to 3.485 (*C. choii*), and parameter *a* ranged from 0.0015 (*C. choii*) to 0.0145 (*A. rhombeus*). The LWR for *C. choii* and *G. naktongensis*, endangered species in South Korea, was estimated for the first time. Our results could be useful as baseline information for evaluating population status.

Keywords

endangered species, fish stock management, Korean endemic species, LWRs, weight–length relations, WLRs

Introduction

The length–weight relations (LWRs) are derived from regression analysis using a paired dataset of length and weight of specific species that can be used to estimate the weight corresponding to a given length (Le Cren 1951), and parameters *a* and *b* of the LWRs are determined by the body shape and growth patterns of the species (Froese 2006). The LWR provides baseline information for stock management as indicators of stock status, including growth, sexual maturity, and food availability (Le Cren 1951; Al-Zibdah and Odat 2007; Karna et al. 2012). In

addition, because the body shape and growth patterns of fish are related to their habitat status, including food availability and predation pressure (Brönmark and Miner 1992), LWRs are useful not only for fisheries research but also for ecological studies.

LWR estimations from various populations are required to estimate the relative weight index, which is a useful tool for comparing fish conditions across populations or species, unlike the condition factor and relative condition factor, which can only be used to compare conditions within a population (Froese 2006). FishBase currently provides LWR estimations for 6098 fish species, but LWR data are lacking for some species (Froese and Pauly 2021).

Cobitis choii Kim et Son, 1984 and *Gobiobotia naktongensis* Mori, 1935 are endemic Korean species with restricted distribution because they only inhabit streams with wide and clear sand streambeds with moderate water flow (Ko et al. 2012; Kim et al. 2014). *Cobitis choii* and *G. naktongensis* have both been identified as Class I endangered species by the Korean Ministry of Environment (NIBR 2018) because of their restricted distribution and small population size.

In the presently reported study, we provide LWR data for 12 freshwater fish species, including *C. choii* and *G. naktongensis*, which have not been previously reported.

Material and methods

The following species representing the families Cobitidae, Xenocyprididae, Acheilognathidae, and Gobionidae were studied: *Cobitis choii*; *Opsariichthys uncirostris* (Temminck et Schlegel, 1846); *Zacco platypus* (Temminck et Schlegel, 1846); *Tanakia lanceolata* (Temminck et Schlegel, 1846); *Acheilognathus rhombeus* (Temminck et Schlegel, 1846); *Hemibarbus labeo* (Pallas, 1776); *Gobiobotia naktongensis*; *Hemibarbus longirostris* (Regan, 1908); *Microphysogobio jeoni* Kim et Yang, 1999; *Pseudogobio esocinus* (Temminck et Schlegel, 1846); *Pseudorasbora parva* (Temminck et Schlegel, 1846); *Squalidus japonicus* (Sauvage, 1883).

The fishes were collected from the Geum River (36°27′14.89″N, 127°5′37.70″E) using a cast net (mesh 7 mm) and a kick net (mesh 4 mm) from March to October 2021. The total length (L) [cm] and weight (W, wet weight) [g] were measured immediately at the capture site. The fishes were examined after being anesthetized using 0.1 g · L^{-1} ethyl 3-aminobenzoate methanesulfonate salt (Sigma-Aldrich, Munich, Germany). The total length was measured using a digital caliper to the nearest 0.1 cm. The weight of *G. naktongensis* and *C. choii* was determined using a digital balance to the nearest 0.01 g, while other fishes were weighed to the nearest 0.1 g. After the examination and recovery, the fishes were released from the recovery tank (100 × 100 × 80 cm).

The LWR for each species was estimated using the regression equation

$$W = aL^b$$

where a and b are parameters of the equation (Le Cren 1951; Ricker 1973; Froese 2006). Before the regression analysis, outliers were removed by linear regression of the log-transformed equation (Froese 2006). Scientific names for all species and family assignments were based on Eschmeyer's Catalog of Fishes (Fricke et al. 2021).

Results

The LWRs of the 12 species were estimated, and the results are presented in Table 1. A total of 938 individuals were examined, and the sample size, ranges of total length, and weight of each species are presented. The total length ranges for 11 species were wide enough to include juveniles to adults, but *Hemibarbus labeo* only

Table 1. Summary of length-weight relations for 12 freshwater fish species in the Geum River, South Korea.

Species	*N*	Total length [cm]	Weight [g]	Regression parameters					
				a	95% CL of a	*B*	95% CL of *b*	r^2	BE of *b*
Cobitis choii	29	3.5–8.5	0.13–2.66	0.0015	0.0008–0.0029	3.485	3.139–3.831	0.938	3.05 (2.87–3.23)
Opsariichthys uncirostris	126	5.9–23.5	1.0–93.6	0.0035	0.0029–0.0042	3.231	3.154–3.309	0.982	3.08 (3.03–3.13)
Zacco platypus	91	4.8–14.8	0.9–29.0	0.0063	0.0052–0.0075	3.105	3.019–3.190	0.983	3.09 (3.05–3.13)
Tanakia lanceolata	90	5.8–11.2	1.9–16.6	0.0070	0.0051–0.0096	3.214	3.059–3.368	0.950	3.05 (2.92–3.18)
Acheilognathus rhombeus	31	6.9–9.6	4.2–11.7	0.0145	0.0107–0.0196	2.961	2.815–3.108	0.983	3.12 (2.98–3.26)
Hemibarbus labeo	165	6.6–20.0	2.1–53.6	0.0061	0.0051–0.0072	3.044	2.970–3.117	0.976	3.10 (3.05–3.15)
Gobiobotia naktongensis	94	2.4–6.0	0.08–1.30	0.0050	0.0044–0.0056	3.054	2.967–3.142	0.981	3.13 (2.96–3.30)
Hemibarbus longirostris	37	7.5–14.8	3.2–22.4	0.0065	0.0047–0.0092	3.021	2.873–3.169	0.979	3.15 (3.03–3.27)
Microphysogobio jeoni	45	4.7–9.5	0.5–5.4	0.0028	0.0019–0.0042	3.344	3.133–3.556	0.959	3.17 (3.02–3.32)
Pseudogobio esocinus	114	3.3–17.8	0.2–39.7	0.0042	0.0036–0.0050	3.153	3.078–3.228	0.984	3.12 (3.07–3.17)
Pseudorasbora parva	39	2.7–9.3	0.2–6.3	0.0113	0.0098–0.0130	2.820	2.745–2.895	0.993	3.12 (3.07–3.17)
Squalidus japonicus	77	6.1–11.3	1.9–14.9	0.0064	0.0044–0.0093	3.166	2.978–3.354	0.937	3.16 (3.03–3.29)

N = number of specimens studied; BE of *b* = Bayesian estimates of *b* (Froese et al. 2014); Bold font indicates South Korean endangered species; Weight was measured to the nearest 0.01 g; Text in shaded cells marks the species where only juveniles were included in the study.

included juveniles. Parameters *a* and *b* are presented with 95% confidence limits. The coefficient of determination (r^2) for all species was above 0.95, except for those of *C. choii* and *S. japonicus*. Parameter *b* for all species was within the expected range of 2.5–3.5 according to Froese (2006). Parameter *b* of *C. choii* was 3.485, which was the highest among the 12 species, and the other species showed small deviations from 3.0 for *b*. Parameter *a* for *C. choii*, the only species in this study representing the family Cobitidae, was 0.0015, which was the lowest observed, and *a* of *A. rhombeus* was 0.0145, which was the highest.

Discussion

Parameter *b* for *C. choii* was 3.485, which was high compared with that of other species, and such a high value of *b* could be caused by various reasons. One possibility is the narrow size range (Froese 2006). However, in the presently reported study, the total length range of *C. choii* was 3.5–8.5 cm, which was wide enough to cover juveniles through to fully grown adults. The second possibility was the small sample size, which contained a bias for large specimens. For example, large specimens could temporarily become heavier than usual because of the development of eggs or gonads during the spawning season or because large specimens could be in a much better nutritional condition than juveniles. The sample of *C. choii* in this study contained only 29 individuals, which is quite small, and could be the reason for the high value of *b*. The final possibility is that the fish changed their body shape as they grew. Several studies have reported positive allometric growth of *Cobitis* fish (Boroń et al. 2008; Patimar et al. 2011). In particular, *Cobitis keyvani* Mousavi-Sabet, Yerli, Vatandoust, Özeren et Moradkhani, 2012 from the Sefid-rud River of Iran showed a *b* value of 3.411 (Mousavi-Sabet et al. 2016), which is similar to our result. Nevertheless, more detailed investigations are needed to verify this result, and it seems reasonable to refer to our results as a case study from a specific fish population.

The LWR of *G. naktongensis* seemed to be reliable because the data used for the estimation satisfied the majority of the conditions proposed by Froese et al. (2011). The sample included approximately 100 specimens, which was adequate, and the length range was wide enough to cover juveniles to adults. The coefficient of determination (r^2) was higher than 0.950, indicating that the outliers were sufficiently removed. Parameter *b* was slightly higher than 3.0, which is common considering the tendency of the majority of fishes to increase in thickness as they grow (Froese 2006).

Parameter *a* is related to the body shape of fish (Froese 2006). In the presently reported study, the *a* of *C. choii* was the lowest and that of *A. rhombeus* was the highest. *Cobitis choii* was the only species representing the family Cobitidae, which consists of loaches that have an elongated body shape. *Acheilognathus rhombeus* is a representative of the family Acheilognathidae and has a relatively short and deep body shape compared to the other fish examined.

In this study, the LWRs of *C. choii* and *G. naktongensis* were estimated, which are not currently available in FishBase (Froese and Pauly 2021). We expect that the results from this study will be useful as baseline information for evaluating the population status of these species in South Korea.

Author contribution

Conceptualization, JDY; methodology, SHB; software, SHB; validation, SHP, JHK, JHY, and JSM; formal analysis, JHK and DHK; investigation, SHP and JHK; resources, SHK, JHK and DHK; data curation, SHB and DHK; writing—original draft preparation, SHB and JDY; writing—review and editing, JHY; supervision, JDY; project administration, JHY and JSM; funding acquisition, JSM. All authors have read and accepted the final version of the manuscript.

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