EVALUATION OF LENGTH–WEIGHT RELATIONS FOR 15 FISH SPECIES (ACTINOPTERYGII) FROM THE SEOMJIN RIVER BASIN IN SOUTH KOREA

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Abstract. This study demonstrates the estimation of length–weight relations (LWR) for freshwater fishes from the Seomjin River basin in South Korea. The LWR estimation is based on the 15 species representing Cyprinidae: *Rhodeus uyekii* (Mori, 1935), *Rhodeus notatus* Nichols, 1929, *Tanakia koreensis* (Kim et Kim, 1990), *Acheilognathus rhombeus* (Temminck et Schlegel, 1846), *Pseudorasbora parva* (Temminck et Schlegel, 1846), *Coreoleuciscus aeruginos* Song et Bang, 2015, *Sarcocheilichthys nigripinnis* (Günther, 1873), *Squalidus gracilis majimae* (Jordan et Hubbs, 1925), *Squalidus chankaensis tsuchigae* (Jordan et Hubbs, 1925), *Hemibarbus longirostris* (Regan, 1908), and *Opsariichthys uncirostris* (Temminck et Schlegel, 1846); Cobitidae: *Cobitis longicorpus* Kim, Choi et Nalbant, 1976 and *Cobitis tetralineata* (Kim, Park et Nalbant, 1999); Bagridae: *Tachysurus ussuriensis* (Dybowski, 1872); and Amblycipidae: *Liobagrus somjinensis* Park et Kim, 2011. Our study provides new information of LWRs for eight species. The LWRs for those species have not been reported yet in FishBase. We also update the existing LWRs for the seven remaining species, because our records are out of their ranges in FishBase.

Keywords: length–weight relations, freshwater fish, Seomjin River, FishBase

INTRODUCTION

Length–weight relation (LWR) offers important ecological information for fish species associated with body shape and nutritional condition (Froese et al. 2011). For this reason, understanding LWR in fisheries science plays a pivotal role in assessing fish-stock conditions and detecting morphological regimes in the context of fisheries management (Le Cren 1951, Rosa et al. 2006). Our study focuses on reporting LWRs for 15 fish species from the Seomjin River basin in South Korea. For the past century, there has been contentious confusion in light of the correct interpretation of LWR (Froese 2006). Nevertheless, the apparently simple relations associated with body shape and length may offer new insights into fisheries management and conservation. With this ecological importance in mind, this paper aims to provide LWR data for poorly known fish species based on the FishBase data (Froese and Pauly 2019), thereby contributing to expanding insights to ecological assessment in relation to fish's allometric states.

MATERIAL AND METHODS

Seomjin River, one of the four major rivers in South Korea, is located in the south-western area of the Korean Peninsula (Fig. 1). The length of the river is 212.3 km, and its catchment area is approximately 4896 km^2. Unlike the other three major rivers of South Korea, the Seomjin River does not have a barrage in the estuary, which implies that the movement and migration of fish species are unrestricted. In the frames of the presently reported study, three surveys were conducted at 13 sites including a main channel and tributaries in July 2018, October 2018, April 2019, July 2019, and October 2019. Fishes were collected using scoop-nets (mesh 5 mm), casting nets (mesh 7 mm), and fixed shore nets (mesh 15 mm). Identification and classification were based on the methods proposed by Kim and Park (2002) and Nelson (2006). Fishes were immediately measured for their total length (TL, cm) and body weight (W, g), on site, up to the nearest 0.1 cm and 0.01 g. Once measured, fish were immediately moved to the recovery tank (100 × 100 × 80 cm) for resuscitation and subsequent

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release. The LWRs of each species were estimated based on the following equation for fish allometry

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

where log *a* is the regression intercept and *b* is the regression slope coefficient (Ricker 1973, Anderson and Gutreuter 1983, Jobling 2008). Given the cubic law of LWRs, *a* is stipulated as a proportionality coefficient and *b* is interpreted as an allometric one (Froese 2006).

RESULTS

A total of 290 individuals comprising 4 families and 15 species were estimated: Cyprinidae: *Rhodeus uyekii* (Mori, 1935), *Rhodeus notatus* Nichols, 1929, *Tanakia koreensis* (Kim et Kim, 1990), *Acheilognathus rhombeus* (Temminck et Schlegel, 1846), *Pseudorasbora parva* (Temminck et Schlegel, 1846), *Coreoleuciscus aeruginos* Song et Bang, 2015, *Sarcocheilichthys nigripinnis* (Günther, 1873), *Squalidus gracilis majimae* (Jordan et Hubbs, 1925), *Squalidus chankaensis tsuchigae* (Jordan et Hubbs, 1925), *Hemibarbus longirostris* (Regan, 1908), and *Opsariichthys uncirostris* (Temminck et Schlegel, 1846); Cobitidae: *Cobitis longicorpus* Kim, Choi et Nalbant, 1976 and *Cobitis tetralineata* (Kim, Park et Nalbant, 1999); Bagridae: *Tachysurus ussuriensis* (Dybowski, 1872), and Amblycipidae: *Liobagrus somjinensis* Park et Kim, 2011. The descriptive statistics and the estimated LWR parameters are summarized in Table 1. All results were statistically significant ($P < 0.001$). The values of parameter *b* for the 15 species ranged from 2.75 to 3.76, while the parameter *a* ranged from 0.0020 to 0.0180. In particular, eight new LWRs for *Rhodeus uyekii*, *Rhodeus notatus*, *Tanakia koreensis*, *Acheilognathus rhombeus*, *Coreoleuciscus aeruginos*, *Squalidus chankaensis tsuchigae*, *Cobitis tetralineata*, and *Liobagrus somjinensis* were found in comparison with the database from FishBase (Froese and Pauly 2019) as of 13 August 2019 (Table 1).

In addition, we also updated the LWRs of the seven remaining species for *Pseudorasbora parva*, *Sarcocheilichthys nigripinnis*, *Squalidus gracilis majimae*, *Hemibarbus longirostris*, and *Opsariichthys uncirostris*, *Cobitis longicorpus*, and *Liobagrus somjinensis*. Their LWR parameters of *a* and *b* were out of the range of values reported in FishBase (Froese and Pauly 2019): *Pseudorasbora parva* (*a*: 0.004–0.013, *b*: 2.90–3.37), *Sarcocheilichthys nigripinnis* (*a*: 0.006–0.007, *b*: 3.15–3.20), *Squalidus gracilis majimae* (*a*: 0.006–0.012, *b*: 2.90–3.37), *Hemibarbus longirostris* (*a*: 0.003–0.004, *b*: 3.24–3.33), and *Opsariichthys uncirostris* (*a*: 0.004–0.006, *b*: 3.02–3.19), *Cobitis longicorpus* (*a*: 0.006, *b*: 3.00), and *Tachysurus ussuriensis* (*a*: 0.018–0.026, *b*: 2.66–2.71). In our estimation, the LWRs were well fitted, having statistical significance ($r^2 > 0.94$, $P < 0.001$ in Table 1).

DISCUSSION

Our study reports the first estimation of LWRs for eight freshwater fish species: six Cyprinidae, one Cobitidae, and one Amblycipidae (Table 1). The majority of them showed positive allometric growth (i.e., $b > 3$), which implies that their nutritious level was in a good state (Froese 2006). Among them, *Tanakia koreensis* and *Liobagrus somjinensis* presented isometric growth (i.e., $b \approx 3$).

In contrast, the remaining seven fish species showed a wider range of allometric growth ($2.75 < b < 3.46$). The LWRs of these species are already listed on FishBase (Froese and Pauly 2019), but our measurements of both *a* and *b* for the seven species are out of the ranges. In order to verify our LWR estimates, we examined the proportionality of fish based on the form factor, $a_{3.0}$ (Table 1). As a result, the seven LWRs were in the plausible range of body shapes (eel-like, elongated, and fusiform) (referring to fig. 10 and

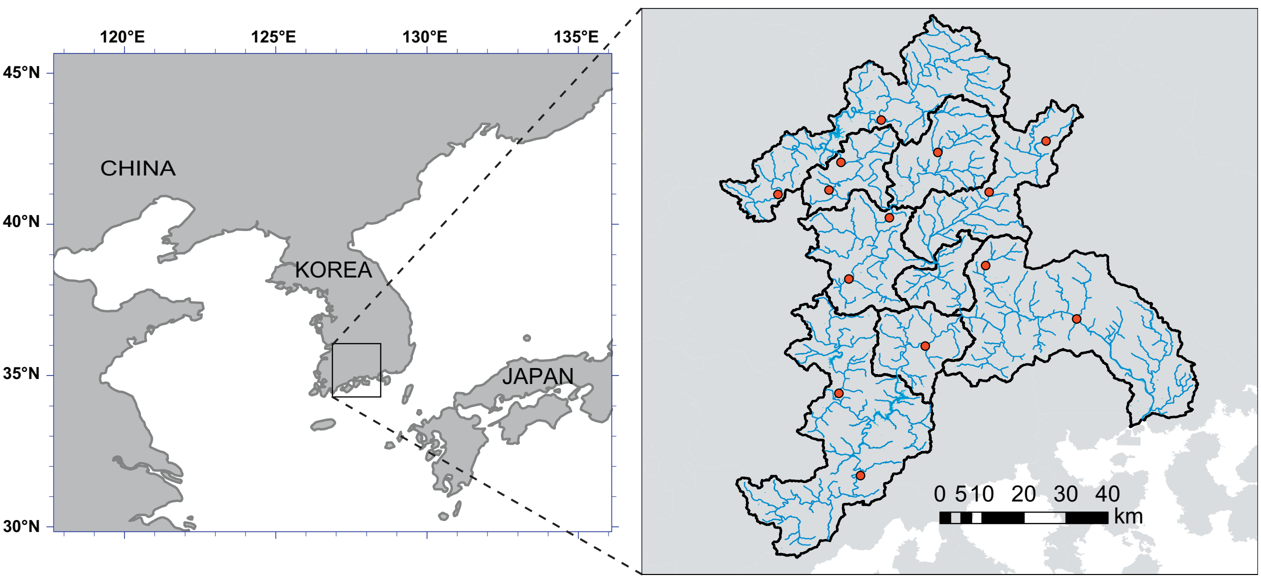

Fig. 1. Map of the Seomjin River basin in South Korea; the red circles mark the location of 13 study sites

Table 1

Estimated parameters of length–weight relations and statistical summary for 15 fish species from the Seomjin River, South Korea

Species	S_{FB}	N	TL range [cm]	W range [g]	a	$a_{3.0}$	95% CL of a	b	95% CL of b	r^2
Cyprinidae										
Rhodeus uyekii	NA	26	3.3–6.2	0.36–2.86	0.0070	0.0112	0.0040–0.0123	3.31	2.93–3.67	0.93
Rhodeus notatus	NA	10	3.6–4.9	0.32–1.24	0.0038	0.0112	0.0020–0.0075	3.76	3.32–4.22	0.97
Tanakia koreensis[1]	NA	31	2.7–8.9	0.27–9.55	0.0139	0.0128	0.0101–0.0176	3.02	2.84–3.18	0.97
Acheilognathus rhombeus	NA	16	6.8–12.7	3.47–22.68	0.0056	0.0112	0.0015–0.0205	3.31	2.73–3.89	0.90
Pseudorasbora parva	16	18	4.7–9.1	0.66–5.62	0.0111	0.0075	0.0053–0.0232	2.77	2.39–3.17	0.92
Coreoleuciscus aeruginos	NA	12	7.5–13.2	3.10–20.15	0.0035	0.0081	0.0006–0.0184	3.36	2.64–4.07	0.90
Sarcocheilichthys nigripinnis	4	32	6.1–15.1	2.65–33.5	0.0183	0.0111	0.0126–0.0265	2.75	2.57–2.94	0.97
Squalidus gracilis majimae	7	29	4.5–9.8	0.81–8.15	0.0051	0.0085	0.0032–0.0083	3.24	3.01–3.52	0.97
Squalidus chankaensis tsuchigae	NA	50	5.7–14.7	1.48–32.27	0.0036	0.0084	0.0023–0.0058	3.37	3.16–3.58	0.96
Hemibarbus longirostris	2	11	6.9–18.8	2.45–53.00	0.0068	0.0074	0.0039–0.0120	3.03	2.81–3.26	0.99
Opsariichthys uncirostris	4	11	10.2–33.2	6.47–403.00	0.0020	0.0073	0.0011–0.0035	3.46	3.25–3.66	0.99
Cobitidae										
Cobitis longicorpus	1	12	7.2–12.7	1.54–10.39	0.0037	0.0049	0.0013–0.0106	3.13	2.65–3.61	0.94
Cobitis tetralineata	NA	14	5.7–12.4	1.03–11.38	0.0040	0.0058	0.0022–0.0072	3.17	2.90–3.44	0.98
Bagridae										
Tachysurus ussuriensis[2]	2	8	12.5–23.2	16.34–95.27	0.0140	0.0072	0.0043–0.0503	2.75	2.35–3.17	0.97
Amblycipidae										
Liobagrus somjinensis	NA	10	7.1–12.1	3.82–17.24	0.0104	0.0092	0.0018–0.0607	2.94	2.16–3.71	0.89

S_{FB} = sample size of LWRs in FishBase (Froese and Pauly 2019); N = number of individuals; a and b = LWR parameters; $a_{3.0}$ = form factor (Froese 2006), CL = confidence limits; r^2 = determination coefficient, NA = not available, Synonyms: [1]*Acanthorhodeus koreensis*, and [2]*Leiocassis ussuriensis* in Korea and China.

table 1 by Froese 2006). All these LWRs showed a high level of goodness-of-fit (r^2 > 0.94). Notably, we found from FishBase (Froese and Pauly 2019) that taxonomically different species in *Squalidus* spp. were grouped as *S. gracilis*. Thus, the relation between log *a* and *b* for *S. gracilis* was quite weak in FishBase. In particular, two species (*S. gracilis* and *S. chankaensis tsuchigae*) were recently observed in Korea (Kim et al. 2017, Chae et al. 2019). Their morphological difference (e.g., lateral lines) is discernable (Fig. 2). Given that the existing LWR records of *S. gracilis* came from South Korea, it is possible that the current LWR information of *S. gracilis* could be mixed with that of *S. chankaensis tsuchigae* in FishBase. Therefore, our study put emphasis on a rigorous assessment on the LWR of *Squalidus gracilis* reported in FishBase.

It should be emphasized that we have found out that the relation between log *a* and *b* for *Squalidus gracilis* was quite weak in FishBase (Froese and Pauly 2019). With this concern in mind, we noticed that two subspecies of our study (*S. gracilis magimae* and *S. chankaensis tsuchigae*) were stipulated as one species, *Squalidus gracilis* (Temminck et Schlegel, 1846) (see Froese and Pauly 2019, Fricke et al. 2020). Given that these two species have been reported taxonomically disparate in Korea (Kim et al. 2017, Chae et al. 2019), it is reasonable to estimate their LWRs separately (Table 1). Their morphological difference (e.g., lateral lines) is discernable (Fig. 2). *Squalidus gracilis magimae* has 33–35 scales on the rectilinear-shaped lateral line, while *S. chankaensis tsuchigae* has 37–40 scales on the hoof-shaped lateral line (Kim and Lee 1984). Since the existing LWR records of *S. gracilis* came from South Korea, it is possible that the current LWR information of *S. gracilis* could be mixed with that of *S. chankaensis* in FishBase. Therefore, our study put emphasis on a rigorous assessment on the LWR of *Squalidus gracilis* reported in FishBase (Froese and Pauly 2019).

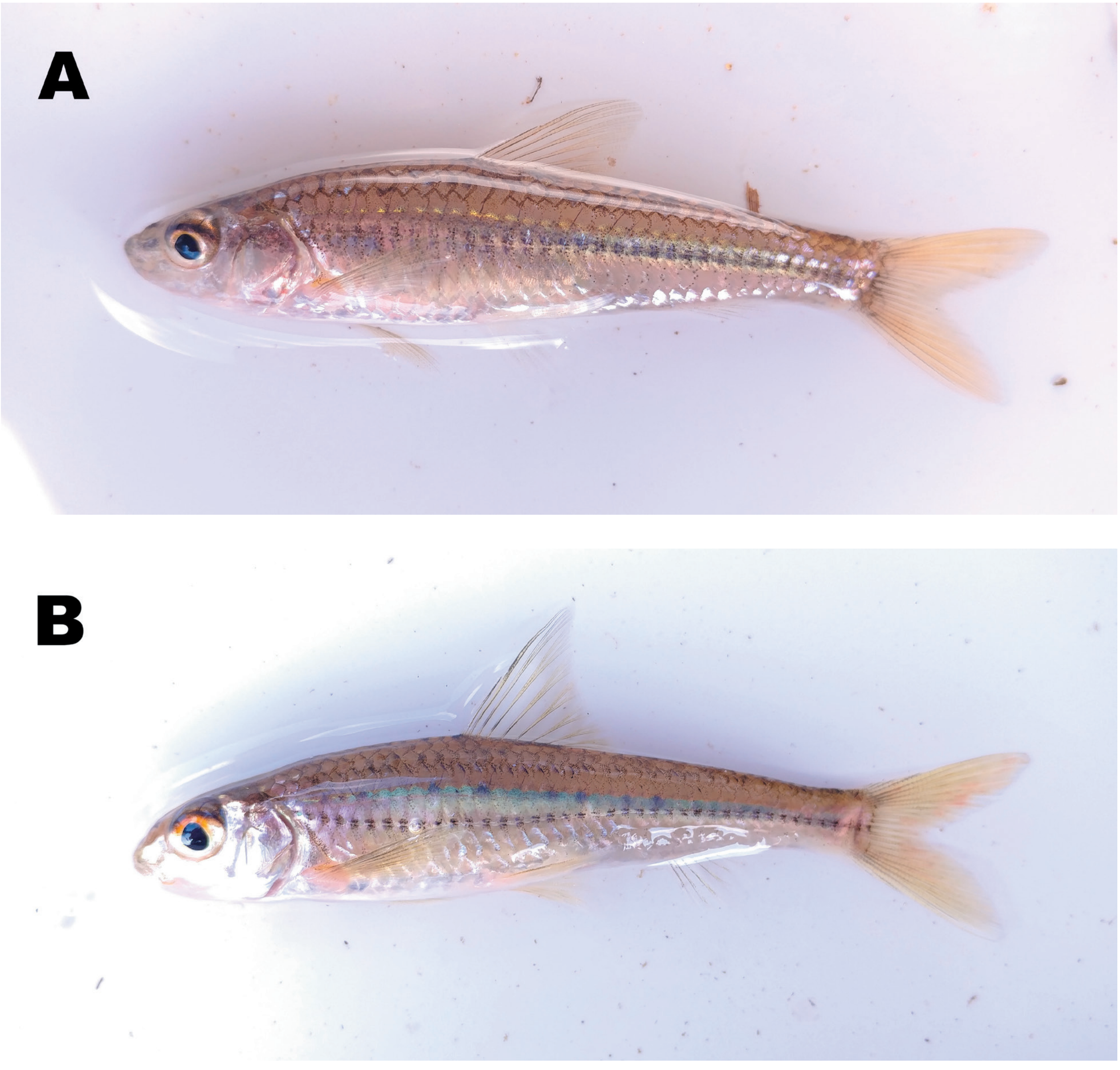

Fig. 2. Phenotypic diversity of *Squalidus gracilis majimae* (**A**), and *Squalidus chankaensis tsuchigae* (**B**) from the Seomjin River, South Korea

Similar to *Squalidus gracilis*, the LWRs of *Tachysurus ussuriensis* could be thoroughly estimated in a legitimate taxonomical classification. Specifically, in FishBase, *Tachysurus ussuriensis* contains *Pseudobagrus ussuriensis* and *Leiocassis ussuriensis* in synonym. Since *Pseudobagrus* and *Leiocassis* are generally different groups of freshwater fish (Chae et al. 2019), it would be more reasonable if their LWRs are separated in FishBase. The small number of sample size (N = 2 in FishBase as of 13 August 2019) prioritizes further surveys to garner additional LWRs for *Pelteobagrus ussuriensis*. Summing up, our study is valuable in view of newly providing the LWRs of freshwater fish. At the same time, we also highlight that updating the LWRs is essential in compliance with adequate taxonomical classification in FishBase (Froese and Pauly 2019).

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