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Short communication

Length–weight relationships of freshwater fishes of Croatia

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Introduction

Length–weight relationships (LWRs) are needed in fishery management and conservation. Here we report length-weight relationship parameters for 41 fish species from Croatian freshwaters, including 10 species for which no estimates were available in FishBase 8/2007. This paper tries to apply the recommendations given by Froese (2006), including the form factor issue.

Table 1
Values of geometre mean *a* and mean *b* with 95% confidence limits (CL) for 41 Croatian fish species (exlcuding LWRs with $r^2 < 0.800$ and outliers) with the respective form factors ($a_{3.0}$) for species with five or more LWRs (all TL in cm and *W* in g)

Species	TL range (cm)	Mean *a*	95% CL	Mean *b*	95% CL	$a_{3.0}$	No. of LWRs	r^2 range
Abramis brama	7.20–46.10	0.0098	−0.0235–0.0431	3.052	2.6466–3.4574	0.0113	8	0.814–0.999
Abramis sapa	23.35–32.30	0.0037	−0.0037–0.0111	3.262	2.6582–3.8660	–	1	0.982
Alburnoides bipunctatus	4.50–12.50	0.0062	0.0039–0.0085	3.192	3.0035–3.3805	0.0091	8	0.880–1.000
Alburnus alburnus	2.80–19.90	0.0092	0.0016–0.0168	2.932	2.7379–3.1261	0.0077	11	0.815–1.000
Ameiurus nebulosus	7.20–21.80	0.0045	0.0005–0.0085	3.397	3.0213–3.7727	0.0126	6	0.928–0.999
Aulopyge huegelii	6.53–16.61	0.0042	0.0033–0.0051	3.322	3.1285–3.3163	–	1	0.999
Barbatula barbatula	4.75–12.50	0.0076	−0.0014–0.0166	3.188	2.7376–3.6384	–	3	0.975–0.995
Barbus barbus	8.00–55.50	0.0067	−0.0041–0.0175	3.089	2.7025–3.4755	0.0093	6	0.847–0.997
Barbus meridionalis	2.00–15.66	0.0080	−0.0138–0.0298	3.061	2.4284–3.6936	–	3	0.994–0.997
Carassius carassius	5.10–29.20	0.0209	0.0097–0.0321	2.976	2.8016–3.1504	–	4	0.980–0.998
Carassius gibelio	6.20–36.00	0.0077	0.0041–0.0113	3.285	3.0682–3.5018	0.0189	6	0.918–1.000
Chondrostoma nasus	11.70–46.43	0.0063	−0.0087–0.0213	3.150	2.7325–3.5675	–	4	0.990–1.000
Cobitis elongata	4.90–13.30	0.0039	0.0021–0.0057	3.1984	2.9830–3.4138	–	1	0.880
Cobitis elongatoides	5.20–14.60	0.0061	0.0022–0.0100	3.0413	2.7069–3.3757	–	1	
Cottus gobio gobio	3.88–11.00	0.0097	0.0085–0.0109	3.128	2.9673–3.2887	–	4	0.811–0.989
Ctenopharyngodon idella	54.00–71.00	0.0480	−0.1882–0.2842	2.603	1.4118–3.7940	–	1	0.821
Cyprinus carpio	15.20–73.50	0.0238	0.0154–0.0322	2.895	2.7735–3.0165	–	4	0.870–1.000
Esox lucius	8.50–51.20	0.0063	0.0000–0.0126	2.996	2.8386–3.1534	0.0063	10	0.928–1.000
Gobio gobio	3.20–18.20	0.0151	−0.0113–0.0415	2.835	2.5022–3.1678	0.0101	10	0.930–1.000
Gymnocephalus cernuus	9.50–15.00	0.0145	−0.0027–0.0317	2.970	2.5196–3.4204	–	3	0.820–0.938
Lepomis gibbosus	3.70–14.90	0.0121	−0.0003–0.0245	3.214	2.9110–3.5170	0.0187	7	0.922–0.999
Leuciscus idus	3.60–25.40	0.0092	0.0068–0.0117	3.048	2.9732–3.1228	–	2	0.997–1.000
Leuciscus illyricus	4.52–40.50	0.0158	−0.0055–0.0371	2.900	2.7505–3.0495	0.0221	11	0.980–1.000
Leuciscus souffia	3.00–15.00	0.0893	−0.0706–0.2942	2.139	1.2923–2.9857	–	1	0.924
Leuciscus svallize	7.07–19.98	0.0353	−0.0120–0.0826	2.520	2.0065–3.0327	–	1	0.979
Leuciscus ukliva	3.00–13.00	0.0086	−0.0210–0.0382	3.114	2.5027–3.7253	0.0112	6	0.800–0.999
Oncorhynchus mykiss	20.35–43.28	0.0168	0.0078–0.0258	2.903	2.8023–3.0037	–	1	0.999
Perca fluviatilis	2.70–28.80	0.0076	0.0035–0.0117	3.213	3.0416–3.3844	0.0126	12	0.930–1.000
Phoxinus phoxinus	4.40–15.50	0.0119	−0.0004–0.0242	3.023	2.5760–3.4700	–	3	0.910–0.994
Rhodeus sericeus	4.10–5.50	0.0108	−0.0258–0.0474	3.060	1.5382–4.5818	–	2	0.852–0.966
Rutilus pigus	14.25–40.00	0.0065	−0.0154–0.0284	3.119	2.5871–3.6509	–	3	0.973–0.997
Rutilus rubilio	7.70–25.50	0.0439	−0.0017–0.0895	2.596	2.2010–2.9910	–	2	0.987–0.997
Rutilus rutilus	3.40–33.35	0.0058	0.0026–0.0090	3.242	3.1037–3.3803	0.0103	17	0.868–1.000
Salmo obtusirostris	9.50–34.50	0.0789	0.0052–0.1526	2.463	2.1654–2.7606	–	3	0.941–0.988
Salmo trutta	4.50–48.40	0.0136	0.0071–0.0201	2.912	2.8201–3.0039	0.0105	22	0.948–1.000
Scardinius erythrophthalmus	4.00–24.80	0.0090	−0.0292–0.0472	3.410	3.2516–3.5684	–	3	0.977–0.995
Silurus glanis	13.90–140.70	0.0053	−0.0053–0.0159	3.034	2.7145–3.3535	–	4	0.945–0.999
Squalius cephalus	3.30–43.00	0.0079	0.0045–0.0113	3.125	3.0048–3.2452	0.0114	21	0.922–1.000
Thymallus thymallus	21.50–34.50	0.0078	−0.0457–0.0613	2.992	1.4818–4.5026	–	1	0.888
Tinca tinca	6.60–48.00	0.0097	0.0007–0.0187	3.187	2.7744–3.5996	–	4	0.987–1.000
Vimba vimba	13.75–25.60	0.0024	−0.0017–0.0065	3.467	2.9029–4.0311	–	2	0.995–0999

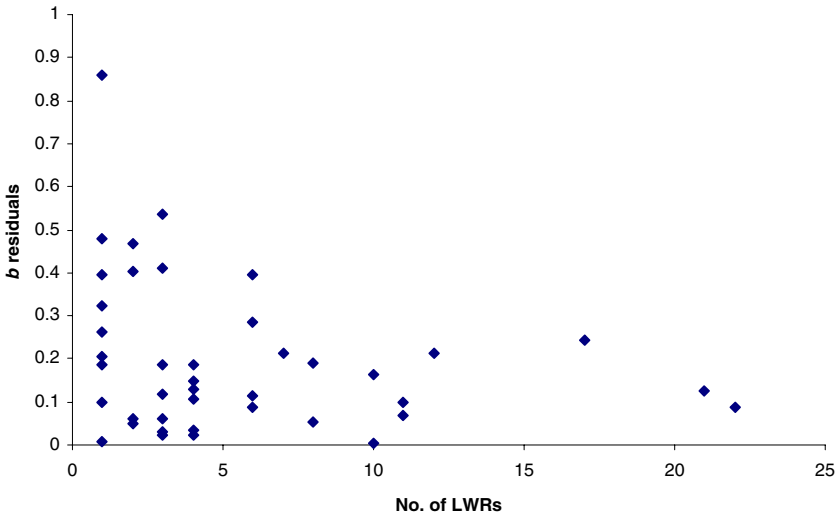

Fig. 1. Absolute residuals of mean b per species from $b = 3.0$, plotted over respective number of weight–length estimates contributing to mean b, for 41 species

Materials and methods

We gathered 269 length–weight relationships (all with total lengths in cm and weight in g) from freshwaters belonging to all regions of Croatia (Habeković et al., 1993; Habeković, 1994a,b; Habeković and Pažur, 1998; Treer et al., 2000, 2003a,b, 2005, 2006, 2008; Jakovlić and Treer, 2001; Šprem et al., 2001, 2005; Bakota et al., 2003; Piria et al., 2006; Prpa et al., 2007). Following Froese (2006), all LWRs that had r^2 lower than 0.800 were discarded, as well as the outliers in log a vs b regressions for species with five or more LWRs. From the remaining 223 equations mean log a and b were calculated. Residuals of parameter b were calculated for each species and then plotted against the number of LWRs per species. For the species with five or more equations the form factor ($a_{3.0}$) was calculated according to Froese (2006):

$$a_{3.0} = 10^{log\,a - S(b-3)},$$

where a and b are coefficients of LWRs and S is the regression slope of log a vs b.

Scientific names for each species were checked with the FishBase (Froese and Pauly, 2007).

Results and discussion

The values of a and b with their respective 95% confidence limits and the form factors for each species are presented in Table 1. Values of parameter b vary from 2.139 for *Leuciscus souffia* to 3.467 for *Vimba vimba*. In both cases this may result from only one or two LWRs being available, respectively. More data are needed to confirm these extreme values. On the other hand, the reason for the second smallest coefficient b for the *Salmo obtusirostris* of 2.463 is apparent. Samplings were performed at the end of March and at the beginning of April, during the period when these fish had just finished the spawning season, which is likely the reason for the low b value result. Similar results ($b = 2.432$) were found e.g. by Leunda et al. (2006) for *Phoxinus phoxinus* sampled at the end of the spawning season and Koç et al. (2007) for the significant variations of condition factor of *Squalius cephalus* during the year.

With more LWRs obtained from differing parts of the year it can be expected that mean b for *Salmo obtusirostris* and for other species with the limited number of equations will come much closer to 3. This is evident in Fig. 1, where the residuals

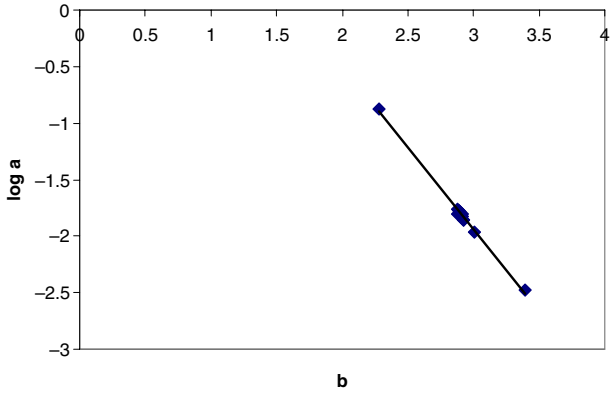

Fig. 2. Plot of log a vs b for 11 weight–length relationships of endemic *Leuciscus illyricus* (log $a = 2.41–1.45b$; $r^2 = 0.997$; $P < 0.05$)

of mean b from 3 are steadily becoming lower as the number of available LWRs grows (Froese, 2006). Different sampling seasons caused wide ranges of parameter b between LWR studies, e. g. for *Barbus barbus*, *Gobio gobio* and the endemic *Leuciscus illyricus*. However, these studies did not divert from the regression line of log a vs b, so they were not outliers (Fig. 2).

The mean value of b for all species together was 3.034 (SD = 0.266), which did not differ significantly from 3 (t-test, $P > 0.05$), similar to Torcu-Koç et al. (2006), who found mean b for the Turkish freshwater fish species not differing from 3 ($b = 2.91$), and Froese (2006) who found that median b for 1773 species was 3.025. The freshwaters in Croatia are mainly rivers (stagnant waters are rare and usually small), where most of the investigations were performed. This may explain why the form factor for most species (Table 1) belonged to the elongated body shape (Froese, 2006).

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