REGRESSION ANALYSIS OF THE LENGTH-WEIGHT RELATIONSHIPS FOR 17 COMMON EUROPEAN FISH IN RIVERS IN THE CZECH REPUBLIC

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ABSTRACT

Length-weight relationships (LWRs) are useful for calculating weight based on measurements of length. Here we provide LWRs for 17 species of fish from the rivers Vltava and Elbe in the Czech Republic, Central Europe. The samples were collected by electrofishing from May 2016 to August 2019. There are far fewer LWRs for riverine than lotic fish. All LWRs were significant with r^2 values ranging from 0.99 for the European barbel (*Barbus barbus*) to 0.95 for European bullhead (*Cottus gobio*) and with estimated *b* values ranging from 2.93 in common dace (*Leuciscus leuciscus*) to 3.26 in non-native round goby (*Neogobius melanostomus*). These results increase the data on LWRs for fish in riverine environments and provides a good tool for managing fisheries and future studies.

Keywords: European fish; freshwater fish; length-weight relations; LWR; riverine environment

Introduction

Length-weight relationships provide a quantitative description of the relation between length and weight of individuals in fish populations, which may be used to determine biomass and further indices – e.g., condition based on length distribution data (Ricker et al. 1975; Froese et al. 2011; Verreycken et al. 2011). An obvious advantage of LWR is that just by having length measurements it is possible to estimate weight, thus avoiding further laboratory work and not having to kill the specimens. The relationships provided can also be used to estimate biomass, when only lengths of fishes are available, e.g. in both recreational and commercial fishing. Growth of fish stocks depends on various factors, such as species, sex, age and season (Le Cren 1951; Bagenal and Tesch 1978; Khristenko and Kotovska 2017), but it also differs depending on habitats and nutritional status of fish in different environments. LWR equation is $W = aL^b$, where W is the weight (g), L is the standard length (cm), a is the intercept and b the slope of regression and an allometric coefficient (Le Cren 1951; Froese 2006). Despite the many LWR studies on European freshwater fish, these are mostly for lakes and hence may differ in terms of the parameter b derived from the data for the lotic environment. The aim of this study is to provide LWRs for common European riverine fishes, for which there are far fewer LWRs (Tsionki et al. 2021). LWR were estimated for 17 species of riverine fish species collected in the two largest rivers in the Czech Republic, Vltava and Elbe Rivers.

Material and Methods

Fish were collected by electric fishing powered by a Honda engine and a LENA generator the output voltage of which was 300–600 V (50 Hz) (Bednář, Czech Republic; https://www.r-bednar.cz/). Fish of a range of different sizes were sampled from the entire community by wading upstream along the shoreline for about 100 metres. These surveys were done from May 2016 to August 2019.

In total, 1385 individuals belonging to 17 species were measured and the samples were kept frozen until processed in the laboratory. All fish were identified to species according to Kottelat and Freyhoff (2007) and their length (L; cm; nearest to 0.1 cm), wet weight (W; g; nearest to 0.1 g) measured. The LWRs were calculated using the least square regression method and r^2 (coefficient of determination) used as an indication of the robustness of the relationships (Le Cren 1951; Froese 2006). The coefficient of allometry b (i.e. the slope) describes how the weight of fish (g) scales with body length (cm). The regression equation for the LWRs is $W = aL^b$, the logarithmic form of which is:

$$\log_{10}(W) = \log_{10}(a) + b \log_{10}(L)$$

Curvilinear plots of the length and weight data were generated and used to check for outliers in the dataset (Froese 2006). The significance of the regression analyses was tested using an ANOVA. All statistical analyses were performed in the software R 4.0.5 (R Core Team 2015).

Results

LWRs were calculated for 17 species of fish, see Table 1 for detailed information on sample size, ranges in length (cm) and body weight (g), LWR parameters with 95% CI of a and b, and coefficient of determination (r^2) for each species.

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Table 1 Length-weight relationships for 17 species of fish collected from the Vltava and Elbe Rivers, Czech Republic, from May 2016 to August 2020 (*a* and *b* are parameters of the length-weight relationship; CI confidence interval; *N* sample size; SE standard error (*b*); r^2 coefficient of determination; *L* total length; *W* body weight).

		Length (cm)		Weight (g)		Regression parameters				
Species	**N**	**Min**	**Max**	**Min**	**Max**	**a**	**95% CI**	**b**	**95% CI**	**r^2**
Squalius cephalus	261	4.7	41.2	1.02	1000	0.113	0.1179–0.1274	3.121	3.0864–3.1551	0.992
Rutilus rutilus	292	3	28.1	0.22	264.12	0.106	0.1023–0.1103	3.234	3.1977–3.2706	0.991
Alburnus alburnus	124	2.5	16.7	0.13	47.31	0.101	0.0942–0.1083	3.158	3.0898–3.2264	0.986
Barbus barbus	72	2.4	52.7	0.13	1220	0.101	0.1218–0.1314	3.044	3.0112–3.07664	0.998
Gobio gobio	136	2.7	17	0.16	50.21	0.126	0.1214–0.1298	3.029	2.9924–3.0654	0.995
Leuciscus leuciscus	120	2.4	25.2	0.22	154.74	0.143	0.1344–0.1522	2.930	2.8657–2.9936	0.986
Chondrostoma nasus	63	3.4	45.1	0.32	1160	0.112	0.1019–0.1227	3.143	3.0760–3.2099	0.993
Perca fluviatilis	54	5.3	29	1.58	277.93	0.144	0.1196–0.1738	3.007	2.8252–3.1884	0.955
Leuciscus idus	32	4.4	44	0.65	980	0.111	0.0928–0.1333	3.221	3.0582–3.3845	0.982
Cottus gobio	51	5.1	10.3	1.72	15.88	0.138	0.1150–0.1661	3.119	2.9095–3.3275	0.948
Gymnocephalus cernua	20	0.12	5.2	12.5	22.66	0.123	0.1077–0.1567	3.116	2.9130–3.3186	0.983
Neogobius melanostomus	89	0.12	5.1	1.62	17.68	0.128	0.1165–0.1402	3.255	3.1473–3.3623	0.976
Rhodeus amarus	26	2.3	6.9	0.12	4.28	0.137	0.1249–0.1495	3.108	2.9769–3.2398	0.989
Abramis brama	11	0.14	11.1	11.36	600	0.138	0.0972–0.1957	2.971	2.6976–3.2433	0.985
Blicca bjoerkna	10	9.5	385	10.83	860	0.134	0.1803–0.1340	3.114	2.8734–3.3539	0.993
Barbatula barbatula	10	0.14	5.9	11.3	10.87	0.122	0.0935–0.1591	2.988	2.6991–3.2771	0.986
Pseudorasbora parva	14	0.12	3.8	7.8	4.79	0.120	0.1017–0.1407	3.100	2.9392–3.3883	0.987

Discussion

The LWRs presented in this study are for common European fish within their usual size ranges, except for round goby (*Neogobius melanostomus*), which is a non-native species recently reported in the Czech Republic. The coefficient of allometry (*b*), reported in this study varied from 2.92 to 3.25; the latter being the upper limit for all the species of fish evaluated in this study.

Most of the studies on LWRs have been conducted in the lakes, whereas studies on riverine species are far less common. Our results can be compared to a few of such studies. More specifically, European chub (*Squalius cephalus*), common roach (*Rutilus rutilus*) and European barbel (*Barbus barbus*) in rivers across Europe, for which there are similar *b* coefficients (Prokeš et al. 2006; Verreycken et al. 2011). Although invasive species in Western Europe (Spain, Portugal, and the Middle East), the Common bleak (*Alburnus alburnus)* is only occasionally from lakes (Kleanthidis et al. 1999). The only recent data on this species in a riverine environment comes from the tributaries of the Ebro River in Spain, where the values of $b = 2.84$ and $b = 3.05$ (Leunda et al. 2006) are lower than those recorded in our study. We increased the data on the LWR for gudgeon (*Gobio gobio)*, for which Verrycken et al. (2011) report the value *b* as 3.18, which is higher than our result for this species ($b = 3.03$). We also recorded the LWR for common nase (*Chondrostoma nasus*), for which there is only a single record for $b = 3.04$ from the Skadar Lake (Milosević and Mrdak 2016). Although there are several studies on the LWRs of European perch (*Perca fluviatilis*), most are for lakes and very few for riverine habitats (Rajkova-Petrova 2001). Data on the LWR for European bullhead (*Cottus gobio*) can only be compared with results of a study on this species in the Tiber River, Italy, which reports a *b* value of 3.304 (Bevagna et al. 1990).

Despite being an invasive species in Europe and North America, there is little data on the LWRs of round goby (*Neogobius melanostomus*). MacInnis and Corkum (2000) report the LWR for this species in rivers in the USA, for which $b = 3.0$. Finally, our results for the LWR of silver bream (*Blicca bjoerkna*) can be compared with an older study in the Berounka River, Czech Republic (Hanel 1991), for which $b = 3.27$.

For lakes, the average value for ruffe (*Gymnocephalus cernua)* based on 11 studies 1 is $b = 3.17$ (Ogle and Winfield 2009), which is higher than that recorded in this study ($b = 3.12$). The value recorded for *Abramis brama* in this study is $b = 2.97$, which is lower than that recorded in other studies such as in the Marmara region in Turkey $b = 3.25$ (Tarkan et al. 2006), or in the Danube Delta in Romania, where the average value is $b = 3.20$ (Cernisencu and Staras 1992). Older studies on common bleak *Alburnus alburnus* in 6 lakes in Greece report an average $b = 3.34$ (Kleanthidis et al. 1999), which is higher than the $b = 3.16$ recorded in this study. That is, higher *b* values are reported for lentic environments than for rivers.

Data for European dace (*Leuciscus leuciscus*) $b = 3.19$, Ide (*Leuciscus idus*) $b = 3.26$, ruffe (*Gymnocephalus cernua*) $b = 3.04$, stone loach (*Barbatula barbatula*) $b = 3.14$ and barbel (*Barbus barbus*) $b = 3.10$, are reported by Verreycken et al. (2011) for Flanders (Belgium) and for European chub (*Squalius cephalus*) by Koç et al. (2007).

Comparison of the parameters *b* of the above species studied by Verreycken et al. (2011) indicates that dace (*Leuciscus leuciscus*), stone loach (*Barbatula barbatula*) and barbel (*Barbus barbus*) have low values and ide (*Leuciscus idus*), ruffe (*Gymnocephalus cernua*) and European chub (*Squalius cephalus*; Koç et al. 2007) have high values.

This study aims to provide data for fisheries regulation and management of rivers (Kottelat and Freyhof 2007; Lyach and Čech 2018). The LWRs presented increase the accuracy of fish biomass estimates for rivers and hence can serve as a primary source for fisheries and/or future scientific studies focused on riverine fish communities.

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REFERENCES

Bagenal TB, Tesch FW (1978) Age and growth. In: Bagenal T (ed) Methods for assessment of fish production in fresh waters. 3rd ed. Oxford, London, Edinburgh and Melbourne, pp 101–136.

Bevagna D, Giovinazzo G, Lorenzoni M, Mearelli M, Petesse M (1990) Segnalazioni di *Cottus gobio* (Osteichthyes, Cottidae) in alcuni corsi d'acqua umbri. Riv Idrobiol 29: 113–122.

Cernisencu I, Staras M (1992) Valorificarea durabila a resurselor piscicole – pricipiu de baza in practicarea pescutului in Delta Dunarii. Analele Stiintifice ale Institutului-Delta Dunarii.

Froese R (2006) Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. J Appl Ichthyol 22: 241–253. doi: 10.1111/j.1439-0426.2006.00805.x.

Froese R, Tsikliras AC, Stergiou KI (2011) Editorial note on weight-length relations of fishes. AIeP 41: 261–263. doi: 10.3750 /AIP2011.41.4.01.

Hanel L (1991) Growth of four cyprinid fishes in the river Berounka (Central Bohemia). Zivocisna Vyroba – UVTIZ 36: 929–937.

Khristenko DS, Kotovska GO (2017) Length-weight relationship and condition factors of freshwater bream *Abramis brama* (Linnaeus, 1758) from the Kremenchug Reservoir, Middle Dnieper. Turk J Fish Aquat Sci 17: 71–77.

Kleanthidis PK, Sinis AI, Stergiou KI (1999) Length-weight relationships of freshwater fishes in Greece. Naga, ICLARM Q 22: 37–41.

Koç HT, Erdogan Z, Tinkci M, Treer T (2007) Age, growth, and reproductive characteristics of chub *Leuciscus cephalus* (L., 1758) in the Ikezcetepeler dam lake (Balikesir), Turkey J Appl Ichthyol 23: 19–24.

Kottelat M, Freyhoff J (2007) Handbook of European freshwater fishes. Kottelat, Cornol and Freyhof, Berlin.

Le Cren ED (1951) The length-weight relationship and seasonal cycle in gonad weight and condition in perch (*Perca fluviatilis*). J Anim Ecol 20: 201–219. doi: 10.2307/1540.

Leunda PM, Oscoz J, Miranda R (2006) Length-weight relationships of fishes in tributaries of the Ebro River, Spain. J Appl Ichthyol 22: 299–300.

Lyach R, Čech M (2018). Do recreational fisheries metrics vary on differently size fishing grounds? Fish Manag Ecol 25: 356–365. doi: 10.1111/fme.12301.

MacInnis AJ, Corkum LD (2000) Age and growth of round goby *Neogobius melanostomus* in the upper Detroit River. Trans Am Fish Soc 129: 852–858.

Milosević D, Mrdak D (2016) Length-weight relationship of nine fish species from Skadar Lake (Adriatic catchment area of Montenegro). J Appl Ichthyol 32: 1331–1333.

Ogle DH, Winfield IJ (2009) Ruffe length-weight relationships with a proposed standard weight equation. N Am J Fish Manag 29: 850–858.

Prokeš M, Sovčík P, Peňáz M, Baruš V, Spurný P, Vilizz, L (2006) Growth of barbel, *Barbus barbus*, in the river Jihlava following major habitat alteration and estimated by two methods. Folia Zool 55: 86–96.

R Core Team (2015) R: A language and environment for statistical computing version 3.2.2. Available at: http://www.R-project.org.

Rajkova-Petrova GN (2001) Age and growth rate of Perch (*Perca fluviatilis* L.) in Ovcharitsa Reservoir (Bulgaria). Arch Biol Sci 53: 81–85.

Ricker WE (1975) Computation and interpretation of biological statistics of fish populations. J Fish Res Board Can 191: 1–382.

Tarkan AS, Gaygusuz O, Acipinar H, Gürsoy C, Ozulug M (2006) Length-weight relationship of fishes from the Marmara region (NW–Turkey). J Appl Ichthyol 22: 271–273.

Tsionki I, Petriki O, Leonardos ID, Karachle PK, Stoumboudi MT (2021) Length-weight relationships of 6 fish species caught in a Mediterranean lake (Trichonis – NW Greece). J Appl Ichthyol 37: 631–634. doi: 10.1111/jai.14213.

Verreycken H, Van Thuyne G, Belpaire C (2011) Length-weight relationships of 40 freshwater fish species from two decades of monitoring in Flanders (Belgium). J Appl Ichthyol 27: 1416–1421.