Length-weight, length-length and empirical standard weight equations for *Capoeta baliki*, *Capoeta sieboldii* and *Chondrostoma angorense*, three endemic cyprinid species of northwestern Anatolia

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Abstract

In this study, length and weight data for three endemic fish species of North-western Anatolia (*Capoeta baliki*, *Capoeta sieboldii* and *Chondrostoma angorense*) were collected throughout their distribution ranges and used to estimate length-length, total length (TL) – weight and empirical standard weight (W_s) equations. The obtained W_s equations were: $log_{10}W_s = -6.743 + 4.768 log_{10} TL - 0.437 log_{10} TL^2$ (TL range: 7-28 cm) for *C. baliki*; $log_{10}W_s = -5.966 + 3.833 log_{10}TL - 0.181 log_{10} TL^2$ (TL range: 7-36 cm) for *C. sieboldii*; $log_{10}W_s = -10.017 + 7.402 log_{10}TL - 0.971 log_{10}TL^2$ (TL-range: 7-24 cm) for *C. angorense*. For *C. angorense*, these data represent the first reference on length-weight relationship for this species. In addition, a new maximum length was reported for *C. baliki*.

Keywords: Body condition indices, Endemic species, *Capoeta baliki*, *Capoeta sieboldii*, *Chondrostoma angorense*, Relative weight.

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Introduction

Anatolia is an important biodiversity hotspot for freshwater fish species and represents high level of endemism with nearly 300 native fish species of which more than one third endemic (Fricke et al., 2007). This endemic fauna is dramatically and constantly threatened mainly by pollution, introduction of non-native species, dam constructions, draining and over abstraction of water (Tarkan et al., 2015). These factors have contributed to most of the endemic species in Turkey to be listed in the endangered status in IUCN (Hermoso and Clavero, 2011). Despite their importance, the available information on biology and ecology of endemic species is often very partial and this limits their proper conservation and management (Giannetto et al., 2013).

The genus *Capoeta* is represented by nineteen species, seven of which are endemic to Turkey (Turan, 2008; Bektas et al., 2017). Fourbarbel scraper baliki Turan, Kottelat, Capoeta Ekmekci and Imamoglu, 2006 and Nipple-lip scraper Capoeta sieboldii (Steindachner, 1864) are two Turkish species endemic to Sakarya -Yeşilırmak (Northwestern drainages Anatolia. Turkey) (Freyhof, 2014 a, b) (Fig. 1). Both species are able to inhabit a wide range of water bodies (lakes, reservoirs and large rivers) and they are locally consumed as a low prized food fish. C. baliki and C. sieboldi are assessed as Least Concern according to the IUCN Red List of Threatened **Species** (Freyhof, 2014 a, b) despite they are strongly impacted by the massive presence of hydropower plants within

their distribution range. Currently, there are no data on the population trends of these two species but it is suspected to be slowly declining (Freyhof, 2014 a, b).



Figure 1: Distribution areas for *Capoeta* baliki, *Capoeta* sieboldii and *Chondrostoma* angorense (dark grey area) as reported by Freyhof (2014a,b,c) (modified).

Chondrostoma is another cyprinid around genus comprising thirty freshwater species distributed throughout Europe and Asia (from the Iberian Peninsula to Iran) (Elvira, 1987; Nelva. 1988; Bogutskaya, 1997; and Carmona, 2003). In Doadrio Turkey the Chondrostoma genus occurs with eleven species five being endemic (Elvira, 1997; Geldiay and Balık, 2007; Özcan, 2009). Ankara nase С. angorense Elvira, 1987 is endemic to Sakarya and Kızılırmak River Basins (Northwestern Anatolia) (Freyhof, 2014c) (Fig. 1). The species of Chondrostoma reported from Sakarya River Basin were previously assessed as C. nasus (Linnaeus, 1758). Elvira (1987) described a new subspecies as C. nasus angorensis. There have been many reports of C. nasus from Turkey

(Mermer and Balık 1991; Aslan and Kiziroğlu 2003; Ünver and Ünver 2004), but the information on the biology and ecology of C. angorense is still very scarce. In this regard, Tarkan et al. (2007) noted that several old reports of C. angorense from Turkey might have been wrongly identified as C. nasus. Currently, C. angorense is accepted as a valid species and it is listed as Least Concern according to the IUCN Red List of Threatened Species (Freyhof, 2014c). Although the species is not assessed as threatened, it is principally impacted by hydropower development that it is largely diffused within the distribution area (Freyhof, 2014c). С. angorense is locally consumed as a low prized commercial species and, although specific data on population trends are not available, the species is expected to be slowly declining due to ongoing threats (Freyhof, 2014c).

All these endemic species are extremely affected by hydropower plants, especially those managed with peak floods, which could threaten their survival. Hydro-dam induces numerous changes in the aquatic ecosystems both upstream and downstream and can drastically change the fish community (Franchi et al., 2014). In addition, the basins where the considered species occur have recently been severely polluted and affected by other serious habitat destruction such as water abstraction (Bostancı and Polat, 2009). To date, there are no conservation actions in place for these three species. Although the species are reported as abundant within the distribution area,

monitoring of the populations should be considered to watch over declining populations. Detailed information on biology and ecology of these species are required for a proper management and to propose conservation actions where the information on their condition (well-being) represents a crucial component for this purpose (e.g. Blackwell *et al.*, 2000).

In this context, the estimation of the well-being fish populations of represents a useful tool for the study of fish populations (Anderson and Neumann, 1996; Blackwell et al., 2000; Froese, 2006). Relative weight (W_r) (Wege and Anderson, 1978) is an index of condition proposed to evaluate the well-being of one or more populations of fish compared to "standard" conditions (Gerow et al., 2004). Wr is estimated comparing the measured weight of a specimen (W) with a standard weight (W_s) that represents the weight in the same length of an ideal fish of the same species in good physiological condition (Blackwell et al., 2000). W_s is assessed by a standard weight equation that is a length-weight equation typical of the species. Then, the big advantage of W_r, when compared with the other condition indices proposed in the literature (i.e. Fulton's (1911) condition factor and Le Cren's (1951) condition factor), is that the species-specific W_s equation allows to compare the condition of fish of different lengths and also belonging to different populations (Murphy et al., 1991).

The aim of this research was, thus, to develop length-length, length-weight

and empirical W_s equations for these three endemic species of Northwest Anatolia (*C. baliki*, *C. sieboldii* and *C. angorense*) within their natural distribution ranges.

Materials and methods

Data collection and datasets validation Samples of the three species were collected during different monitoring studies carried out throughout the areas of distribution of the species (Table 1). Specimens were collected by means of electrofishing (SAMUS 725G) and each fish was measured for lengths (total (TL), standard (SL) and fork (FL) length) to the nearest mm and wet weight (W) to the nearest 0.1 g. The total dataset was then validated following the steps summarized by Giannetto et al. (2011). For each species a TL-W regression was computed for the total sample and all specimens that were large outliers were they were probably excluded, as derived from wrong measurements. Then. a log transformed TL-W regression and specific linear conversion models to convert SL and FL to TL were computed by means of the equations:

 $log_{10}W = log_{10} a + b log_{10} TL (mm),$ TL (mm)= a + b SL (mm)and

TL (mm)= a + b FL (mm)

where a is the intercept on the Y-axis of the regression curve and b is the regression coefficient.

Species	GPS coordinates	River Basin	
	N 39 05 50; E 030 39 52	Seydisuyu	
	N 39 21 33; E 030 26 08	Seydisuyu	
	N 39 21 03; E 030 33 24	Seydisuyu	
	N 39 21 25; E 030 35 35	Seydisuyu	
C. Daliki	N 39 24 52; E 031 07 23	Seydisuyu	
	N 39 19 07; E 031 20 12	Seydisuyu	
	N 39 19 15; E 029 59 35	Porsuk	
	N 39 19 36; E 029 54 13	Porsuk	
	N 39 18 09; E 030 34 43	Seydisuyu	
	N 39 19 15; E 029 59 35	Porsuk	
C. sieboldii	N 39 19 36; E 029 54 13	Porsuk	
	N 39 16 24; E 029 13 44	Emet	
	N 39 28 11; E 029 15 17	Emet	
	N 39 21 33; E 030 26 08	Seydisuyu	
C an concerce	N 39 21 03; E 030 33 24	Seydisuyu	
c. angorense	N 39 56 97; E 030 91 40	Seydisuyu	
	N 39 24 52; E 031 07 23	Seydisuyu	

 Table 1: List of the sampling stations for each species.

The validated dataset was separated into statistical populations according to Ogle and Winfield (2009). Data were further

validated by computing a $log_{10}TL - log_{10}W$ regression for each population (Bister *et al.*, 2000): all populations for which equation had R^2 value less than

0.90 or slope (*b* value) outside the range of 2.5-3.5 were removed from the dataset and excluded from further analyses (Froese, 2006). At last, the outliers from the regression between the value of slopes (*b*) and intercepts ($\log_{10} a$) of all populations were removed because they probably represented the populations composed by few fish or samples with a narrow length-range (Froese, 2006).

Selection of the applicable total length range for the W_s equations

The development of a W_s equation requires a previous selection of a suitable applicable length-range (Willis et al., 1991). The minimum applicable length is required due to the high variance in the measurements of the small fishes: juvenile stages have different growth patterns and, in addition, a higher potential error is associated to the measurement of the small specimens in the field (Froese, 2006; Giannetto et al., 2012a). As suggested by Willis et al. (1991), the minimum applicable total length was assessed by the plot between the variance/mean ratio of log₁₀W and TL intervals (1 cm) as the size at which the value of that ratio was smaller than 0.01.

As suggested by Gerow *et al.* (2005), the maximum application length was determined as the maximum size that occurs in at least three fish populations in the dataset being three the smallest number required for the estimation of quartiles. All specimens of the dataset with a length outside the selected applicable range were removed and not further utilized for analyses.

Calculation of Empirical W_s equation The Empirical Percentile (EmP) method proposed by Gerow *et al.* (2005) was used to develop the W_s equation for *C. baliki*, *C. sieboldii* and *C. angorense*. According to this method, for every 1cm length-class the mean empirical W was estimated by the logaritmic TL-W equation of the different populations; then the 75° percentile of these estimated mean empirical W were plot on TL by means of a weighted quadratic model.

Validation of the developed EmP W_s equations

The W_s equations developed for the three species were validated to detect any potential length-related biases. To this aim two different methods were applied: the residuals analysis of the W_s equation (to investigate whether the distribution of residuals exhibits evident patterns) (Ogle and Winfield, 2009; Lorenzoni et al., 2012) and the Empirical Quartiles (EmpQ) method (Gerow et al., 2004) by means of the FSA package version 0.3.2 (Ogle, 2012) of R Software (to determine if the slope of the quadratic regression of the the 75° percentile of mean W standardized by W_s against length intervals of 1-cm had a value of zero) (Ogle and Winfield, 2009; Lorenzoni et al., 2012).

Results

A total of 863 *C. baliki*, 177 *C. sieboldi* and 372 *C. angorense* collected across

the distribution ranges of the species were used in the research. The basic descriptive statistics (TL, FL, SL and W) of the samples used were summarized in Table 2. For *C. baliki* a new maximum total length was recognized as 40.7 cm. The estimated SL-TL, FL-TL and the log-transformed TL-W equations for the three species were summarized in Table 3.

Table 2: Descriptive statistics of total length (TL), fork length (FL), standard length (SL) and weight (W) with minimum (Min), maximum (Max), mean value and standard deviation (Mean±SD) for *Capoeta baliki*. *Capoeta sieboldii* and *Chondrostoma angorense*.

	Capoe	ta baliki	.	Capoe	eta siebol	dii	Chondrostoma angorense			
	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	
TL (cm)	4.2	40.7	15.4 ± 5.2	7.1	43.7	20.9±8.3	6.8	24.7	17.6±3.4	
FL (cm)	3.7	37.3	14.1±4.7	6.3	39.8	18.8 ± 7.5	6.2	22.4	16.3±3.1	
SL (cm)	3.3	34.7	12.6±4.4	5.6	36.2	17.1±6.9	5.5	21.1	14.8 ± 2.9	
W (g)	1	753	50.2 ± 60.9	3.0	842	130.2±147.9	2.4	137	55.5 ± 22.9	

Table 3: Estimated parameters of logarithmic total length-weight (TL-W), total-standard length (SL-TL) and total-fork length (FL-TL) equations for *Capoeta baliki*, *Capoeta sieboldii* and *Chondrostoma angorense*.

	TL-W			SL-TL			FL-TL		
	log ₁₀ a	b	\mathbf{R}^2	a	b	\mathbf{R}^2	a	b	\mathbf{R}^2
C. baliki	-4.875	2.9429	0.974	5.040	1.1755	0.996	1.4368	1.0873	0.996
C. sieboldii	-5.063	3.0173	0.989	3.869	1.189	0.997	-0.121	1.103	0.997
C. angorense	- 5.581	3.241	0.986	0.5090	0.115	0.989	0.148	0.107	0.993

The datasets were separated into statistical populations: 26 for *C. baliki*, 10 for *C. sieboldii* and 16 for *C. angorense*. For all populations of the three species the value of \mathbb{R}^2 was always bigger than 0.95 and the *b* value results within the range of 2.5 - 3.5 therefore no populations were removed from the datasets.

The W_s equations developed for the three species by means of the EmP method were reported below.

For *C. baliki* (TL-range: 7-28 cm): $log_{10}W_s$ =-6.743+4.768 log_{10} TL-0.437 $(log_{10}$ TL)² (R² = 0.999). For *C. sieboldii* (TL-range: 7-36 cm) $log_{10}W_s$ =- 5.966+3.833 log_{10} TL-0.181 $(log_{10}$ TL)² (R² = 0.999). For *C. angorense* (TL-range: 7-24 cm): $\log_{10}W_s = -10.017 + 7.402 \log_{10}TL - 0.$ 971 $(\log_{10}TL)^2 (R^2 = 0.991).$

The residuals values of the proposed W_s equations displayed a random distribution and did not exhibit evident patterns for all the three considered species (Fig. 2a, b and c). Applying the EmpQ method, the value of the slope was not significantly different from zero for both terms of the equations (for C. baliki: pquadratic=0.775, plinear=0.921; for С. sieboldii: p_{quadratic}=0.958, $p_{\text{linear}}=0.982;$ for С. angorense: p_{quadratic}=0.755, p_{linear}=0.879) suggesting the absence of any length related bias for the proposed W_s equations.



Figure 2: Plots showing the distribution of the residuals used to investigate potential length-bias in the standard weight (W_s) equations for a) *Capoeta baliki*, b) *Capoeta sieboldii* and c) *Chondrostoma angorense*. (Residuals= standardized residuals of the regression; Fitted values= values obtained by the model fit).

Discussion

Condition indices have been used in fisheries research since the beginning of the 20^{th} century (Froese, 2006) as an easy tool to assess the well-being of the specimens without sacrificing them. Among the condition indices proposed in literature, W_r was found to be the most trustful being not influenced by changes in fish body shape (Gerow et al., 2004). Thus, variations in W_r values can be primarily due to extant ecological factors (Blackwell et al., 2000). Relative weight is currently widely used in the United States of America as a basic tool for fisheries management. With regard to Turkey, currently the sporadic utilization of this method is due to the lack of specific W_s equations for each species that have to be developed considering a wide dataset representative of the lengthrange of the species and collected throughout its distribution area. Specific W_s equations have been proposed only for a few endemic Turkish freshwater species: Barbus pergamonensis, Capoeta bergamae and

Ladigesocypris irideus (Giannetto et al., 2015), Squalius fellowesii (Giannetto et al., 2012b) and Squalius pursakensis (Sulun et al., 2014).

On the basis of the results of the present study, the use of the proposed EmP equations to determine W_r for the considered species throughout their area of distribution is suggested. Further research is encouraged to extend the use of this methodology to other species with particular attention to those endemic.

For *C. angorense*, the estimated TL-W represents the first reference for the species. To the authors' knowledge, any previous studies on this species have been carried out and this lack of basic knowledge on biology of this species is also remarked on Fishbase (Froese and Pauly, 2016).

For *C. baliki*, the *b* value of the TL-W equation estimated in this study (2.942) was lower than that reported by Gaygusuz *et al.* (2013a) from Sakarya River (3.017). In addition to the proposed equations, a new maximum total length (407 mm) was stated for

this species. This finding underlined the representativeness of the dataset used in the present study and contributed to strengthen the validity of the results. The new maximum total length was considerably higher than that previously reported for the species by Gaygusuz et al. (2013a) from Sakarya River (322 mm). This can be attributed to the low level of fishing pressure other than the negligible effects of the low number of anglers in the distribution range of the species. These new findings remark the current lack of information on the biology of these endemic species and suggest the need for more detailed studies.

With regard to C. sieboldii, the estimated value of the b found in the present study (3.107) was in line with the results of other previous studies reporting local length-weight relationships for some populations of the species (Ekmekci, 1996; Yildirim et al., 2008; Yılmaz et al., 2010). On the other hand, Gül et al. (2005) reported a lower value of b (2.71) for the population of the Delice Branch of Kızılırmak River. As noted by Bagenal and Tesch (1978), the parameters of the length-weight equations in fish can be affected by a number of factors including food availability, feeding rate, spawning period as well as season, sex and habitat. In addition, Froese (2006) remarked that lenght-weight equations could also be affected by the lengthrange and composition of the sample used to calculate. For all these reasons it is suggestible to estimate lengthweight equations by using a large dataset covering a reasonable geographic range of the species and inter-annual variations. Indeed, according to Froese (2006), only in these cases it is possible to discuss isometric versus allometric growth of the species as a whole by using the value of b.

Gaygusuz et al. (2013b) provided relative condition factors of several native and endemic freshwater fish species from western Anatolia living with and without non-native species to reveal the potential impact of nonnative species on native and endemic species and they found out that C. sieboldii had better conditions in the absence of non-native Carassius gibelio. However, relative condition index (Le Cren, 1951) has some restrictions that populations in comparison should be sampled at the same time of the year and preferably under similar environmental conditions (Lorenzoni et al., 2015) whereas relative weight allows reliable comparisons among different locations and specimens of different lengths. Giannetto *et al.* Indeed. (2012c)successfully used mean relative weight of native fish species of Tiber River basin (Italy) with the same purpose and found very similar results (i.e. the condition of some of the endemic species had significantly worse when non-native species were present than when non-native species were absent). Non-native and invasive fish species have commonly been found (especially the one that is considered as most invasive species, C. gibelio in Anatolia) in the natural distribution range of all populations of the species under study

(Tarkan *et al.*, 2012), which is one of the most threatening factors along with habitat destructions for endemic species. Recent observations have confirmed that *C. sieboldii* has not been found despite its high abundance in early 2000s in Porsuk stream (pers. obser. Emiroğlu, Aksu and Başkurt) where *C. gibelio* invasion has taken place (Gaygusuz *et al.*, 2013b).

For all these reasons, as it is the case in the present study, the use of standardized methods as relative weight or specific length equations to study fish populations is strongly recommended being easy and not cruel tools that can assist in comparing populations of the same species inhabiting different habitats or biotopes.

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