

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

**Emirođlu Ö.¹; Giannetto D.^{2*}; Aksu S.³; Bařkurt S.¹; Çiçek A.⁴;
Tarkan A.S.⁵**

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Abstract

In this study, length and weight data for three endemic fish species of North-western Anatolia (*Capoeta baliki*, *C. 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.

1-Eskiřehir Osmangazi University, Faculty of Sciences, Department of Biology, Eskiřehir, Turkey.

2-Muđla Sıtkı Koçman University, Faculty of Sciences, Department of Biology, Muđla, Turkey.

3-Eskiřehir Osmangazi University, Vocational School of Health Services, Eskiřehir, Turkey

4-Anadolu University, Applied Environmental Research Centre, Eskiřehir, Turkey

5-Muđla Sıtkı Koçman University, Faculty of Fisheries, Muđla, Turkey.

*Corresponding author's Email: danielagiannetto@mu.edu.tr

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 *Capoeta baliki* Turan, Kottelat, Ekmekçi and Imamoglu, 2006 and Nipple-lip scraper *Capoeta sieboldii* (Steindachner, 1864) are two Turkish species endemic to Sakarya -Yeşilirmak drainages (Northwestern 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. sieboldii* 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 genus comprising around thirty freshwater species distributed throughout Europe and Asia (from the Iberian Peninsula to Iran) (Elvira, 1987; Nelva, 1988; Bogutskaya, 1997; Doadrio and Carmona, 2003). In Turkey the *Chondrostoma* genus occurs with eleven species five being endemic (Elvira, 1997; Geldiay and Balık, 2007; Özcan, 2009). Ankara nase *C. 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. angorensis* is still very scarce. In this regard, Tarkan *et al.* (2007) noted that several old reports of *C. angorensis* from Turkey might have been wrongly identified as *C. nasus*. Currently, *C. angorensis* 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). *C. angorensis* 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 of fish populations 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). W_r 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. angorensis*) 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 excluded, as they were probably 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:

$$\log_{10}W = \log_{10}a + b \log_{10}TL \text{ (mm)},$$

$$TL \text{ (mm)} = a + b SL \text{ (mm)}$$

and

$$TL \text{ (mm)} = a + b FL \text{ (mm)}$$

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

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

Species	GPS coordinates	River Basin
<i>C. baliki</i>	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
	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
<i>C. sieboldii</i>	N 39 19 15; E 029 59 35	Porsuk
	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
<i>C. angorensis</i>	N 39 21 03; E 030 33 24	Seydisuyu
	N 39 56 97; E 030 91 40	Seydisuyu
	N 39 24 52; E 031 07 23	Seydisuyu

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 $\log_{10}W$ 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. angorensis*. According to this method, for every 1-cm length-class the mean empirical W was estimated by the logarithmic 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 75° percentile of the 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. sieboldii* and 372 *C. angorensis* 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*.

	<i>Capoeta baliki</i>			<i>Capoeta sieboldii</i>			<i>Chondrostoma angorense</i>		
	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	R ²	a	b	R ²	a	b	R ²
<i>C. baliki</i>	-4.875	2.9429	0.974	5.040	1.1755	0.996	1.4368	1.0873	0.996
<i>C. sieboldii</i>	-5.063	3.0173	0.989	3.869	1.189	0.997	-0.121	1.103	0.997
<i>C. angorense</i>	-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 R² 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):

$$\log_{10}W_s = -6.743 + 4.768 \log_{10} TL - 0.437 (\log_{10} TL)^2 (R^2 = 0.999).$$

For *C. sieboldii* (TL-range: 7-36 cm)

$$\log_{10}W_s = -5.966 + 3.833 \log_{10} TL - 0.181 (\log_{10} TL)^2 (R^2 = 0.999).$$

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*: p_{quadratic}=0.775, p_{linear}=0.921; for *C. sieboldii*: p_{quadratic}=0.958, p_{linear}=0.982; for *C. angorense*: p_{quadratic}=0.755, p_{linear}=0.879) suggesting the absence of any length related bias for the proposed W_s equations.

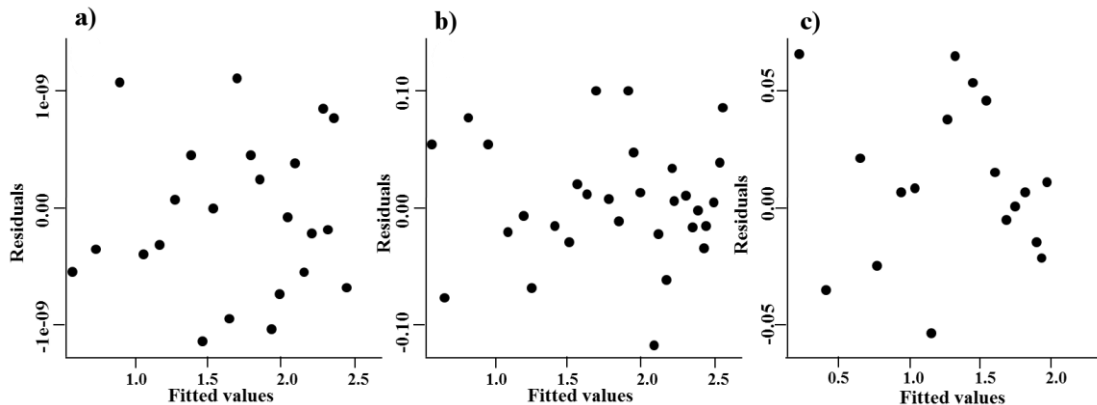


Figure 2: Plots showing the distribution of the residuals used to investigate potential length-bias in the standard weight (W_s) equations for a) *Capoeta baliki*, b) *Capoeta sieboldii* and c) *Chondrostoma angorense*. (Residuals= standardized residuals of the regression; Fitted values= values obtained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

Discussion

Condition indices have been used in fisheries research since the beginning of the 20th 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 length-range 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 length-weight equations could also be affected by the length-range and composition of the sample

used to calculate. For all these reasons it is suggestible to estimate length-weight 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 non-native 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. Indeed, Giannetto *et al.* (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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References

- Anderson, R.O. and Neumann, R.M. 1996.** Length, weight, and associated structural indices. In: Murphy B.R., Willis DR editors. Fisheries techniques, 2nd edition. Bethesda, Maryland: American Fisheries Society. pp. 447–481.
- Aslan, A. and Kiziroğlu, I., 2003.** A study on the ornithofauna of Sakaryabaşı/Eminekin pond and its vicinity. *Turkish Journal of Zoology*, 27, 19–26.
- Bagenal, T.B. and Tesch, F.W., 1978.** Age and growth. In: Bagenal T. (ed.), Methods for assessment of fish production in freshwaters. IBP Handbook No. 3. Blackwell Scientific Publications, Oxford. pp. 101–136.
- Bektas, Y., Turan, D., Aksu, I., Ciftci, Y., Eroglu, O., Kalayci, G. and Belduz, A.O. 2017.** Molecular phylogeny of the genus *Capoeta* (Teleostei: Cyprinidae) in Anatolia, Turkey. *Biochemical Systematics and Ecology*, 70, 80–94.
- Bister, T.J., Willis, D.W., Brown, M.L., Jordan, S.M., Neumann, R.M., Quist, M.C. and Guy, C.S., 2000.** Proposed standard weight (W_s) equations and standard length categories for 18 warm water nongame and riverine fish species. *North American Journal of Fisheries Management*, 20, 570–574.
- Blackwell, B.G., Brown, M.L. and Willis, D.W., 2000.** Relative weight (W_r) status and current use in fisheries assessment and management. *Reviews in Fisheries Science*, 8, 1–44.
- Bogutskaya, N.G., 1997.** *Chondrostoma beysehirensis*, a new cyprinid fish from Beysehir Lake, central Turkey. *Ichthyological Exploration of Freshwater*, 8, 151–158.
- Bostancı, D. and Polat, N., 2009.** Age determination and some population characteristics of chub (*Squalius cephalus* L., 1758) in the Çamlidere Dam Lake (Ankara, Turkey). *Turkish Journal of Science and Technology*, 4, 25–30.

- Doadrio, I. and Carmona, J.A., 2003.** A new species of the genus *Chondrostoma* Agassiz, 1832 (Actinopterygii, Cyprinidae) from the Iberian Peninsula. *Graellsia*, 59, 29–36.
- Ekmekci, F.G., 1996.** Some growth properties of *Capoeta capoeta sieboldi* (Steindachner, 1897) in Sariyar Dam Lake (Ankara). *Turkish Journal of Zoology*, 20, 127–136. (In Turkish).
- Elvira, B., 1987.** Taxonomic revision of the genus *Chondrostoma* Agassiz, 1835 (Pisces, Cyprinidae). *Cybium*, 11, 111–140.
- Elvira, B., 1997.** Taxonomy of the genus *Chondrostoma* (Osteichthyes, Cyprinidae): An updated review. *Folia Zoologica*, 46(1), 1–14.
- Franchi, E., Carosi, A., Ghetti, L., Giannetto, D., Pedicillo, G., Pompei, L. and Lorenzoni, M., 2014.** Changes in the fish community of the upper Tiber River after construction of a hydro-dam. *Journal of Limnology*, 73, 2.
- Freyhof, J., 2014a.** *Chondrostoma angorense*. The IUCN Red List of Threatened Species 2014: e.T19083537A19222928. <http://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T19083537A19222928.en>.
- Freyhof, J., 2014b.** *Capoeta baliki*. The IUCN Red List of Threatened Species 2014: e.T19024691A19222843. <http://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T19024691A19222843.en>.
- Freyhof, J., 2014c.** *Capoeta sieboldii*. The IUCN Red List of Threatened Species 2014: e.T19026443A19222898. <http://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T19026443A19222898.en>.
- Fricke, R., Bilecenoğlu, M. and Sarı, H.M., 2007.** Annotated checklist of fish and lamprey species (Gnathostomata and Petromyzontomorphi) of Turkey, including a Red List of threatened and declining species. *Stuttgarter Beiträge zur Naturkunde A Biologie*, 706, 1-172.
- Froese, R., 2006.** Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. *Journal of Applied Ichthyology*, 22, 241–253.
- Froese, R. and Pauly, D., 2016.** FishBase. World Wide Web electronic publication. www.fishbase.org, version (10/2016).
- Fulton, T.W., 1911.** The sovereignty of the sea: An historical account of the claims of England to the dominion of the British Seas and of the evolution of the territorial waters. Edinburgh: William Blackwood. pp.1–799.
- Gaygusuz, Ö., Aydın, H., Emiroğlu, Ö., Top, N., Dorak, Z., Gürsoy Gaygusuz, Ç., Başkurt, S. and Tarkan, A.S., 2013a.** Length-weight relationships of freshwater fishes from western part of Anatolia, Turkey. *Journal of Applied Ichthyology*, 29, 285–287.

- Gaygusuz, Ö., Emiroğlu, Ö., Tarkan, A.S., Aydın, H., Top, N., Dorak, Z., Karakuş, U. and Başkurt, S., 2013b.** Assessing the potential impact of non-native on native fish by relative condition. *Turkish Journal of Zoology*, 37, 84–91.
- Geldiay, R. and Balık, S., 2007.** Türkiye tatlı su balıkları. Ege University Fisheries Faculty, Izmir 46, 1–644 (In Turkish).
- Gerow, K.G., Hubert, W.A. and Anderson-Sprecher, R., 2004.** An alternative approach to detection of length-related biases in standard-weight equations. *North American Journal of Fisheries Management*, 24, 903–910.
- Gerow, K.G., Anderson-Sprecher, R. and Hubert, W.A., 2005.** A new method to compute standard-weight equations that reduce length-related bias. *North American Journal of Fisheries Management*, 25, 1288–1300.
- Giannetto, D., La Porta, G., Maio, G., Pizzul, E., Turin, P. and Lorenzoni, M., 2011.** Proposed standard mass equations for European chub *Leuciscus cephalus* in Italy. *Journal of Fish Biology*, 78(7), 1890–1899.
- Giannetto, D., Franchi, E., Pompei, L., Lorenzoni, M., Porcellotti, S., Tancioni, L. 2012a** Proposed Empirical Standard Weight Equation for Brook Chub *Squalius lucumonis*. *North American Journal of Fisheries Management* 32 (3), 428-435.
- Giannetto, D., Pompei, L., Lorenzoni, M. and Tarkan, A.S., 2012b.** Empirical standard weight equation for Aegean Chub *Squalius fellowesii*, an endemic freshwater fish species of Western Anatolia. *North American Journal of Fisheries Management*, 32, 1102–1107.
- Giannetto, D., Carosi, A., Franchi, E., Pedicillo, G., Pompei, L. and Lorenzoni, M., 2012c.** Assessing the impact of non-native freshwater fishes on native species using relative weight. *Knowledge and Management of Aquatic Ecosystems*, 404 (03).
- Giannetto, D., Carosi, A., Ghetti, L., Pedicillo, L., Pompei, L. and Lorenzoni, M., 2013.** Ecological traits of *Squalius lucumonis* (Actinopterygii, Cyprinidae) and main differences with those of *Squalius squalus* in the Tiber River Basin (Italy). *Knowledge and Management of Aquatic Ecosystems*, 409 (04).
- Giannetto, D., Tarkan, A.S., Akbaş, F., Top, N., Ağdamar, S., Karakuş, U., Pompei, L. and Lorenzoni, M., 2015.** Length-weight and length–length relationships for three endemic cyprinid species of the Aegean region (Turkey) with proposed standard weight equations. *Turkish Journal of Zoology*, 39, 925–932.
- Gül, A., Yılmaz, M. and Saylar, Ö., 2005.** Growth and breeding properties of *Capoeta capoeta sieboldii* (Steindachner 1864) living in the Delice Branch of Kızılırmak River (Turkey) *Suleyman Demirel Üniversitesi Egirdir Su Urunleri Fakültesi Dergisi*, 1, 7-17 (In Turkish).

- Hermoso, V. and Clavero, M., 2011.** Threatening processes and conservation management of endemic freshwater fish in the Mediterranean basin: a review. *Marine and Freshwater Resources*, 62, 244-254.
- Le Cren, E.D., 1951.** The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 20, 201–219.
- Lorenzoni, M., Giannetto, D., Maio, G., Pizzul, E., Pompei, L., Turin, P., Vincenzi, S. and Crivelli, A., 2012.** Empirical standard mass equation for *Salmo marmoratus*. *Journal of Fish Biology*, 81(6), 2086–2091.
- Lorenzoni, M. Giannetto, D., Carosi, A., Dolciemi, R., Ghetti, L. and Pompei, L., 2015.** Age, growth and body condition of big-scale sand smelt *Atherina boyeri* Risso, 1810 inhabiting a freshwater environment: Lake Trasimeno (Italy). *Knowledge and Management of Aquatic Ecosystems*, 416(09).
- Mermer, A. and Balık, S., 1991.** Investigation on biology of *Chondrostoma nasus* Linnaeus, 1758 in Gediz River. *Ege Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 2(1), 17-23.
- Murphy, B.R., Willis, D.W. and Springer, T.A., 1991.** The relative weight index in fisheries management: status and needs. *Fisheries*, 16, 30–38.
- Nelva, A., 1988.** Origine et biogéographie des deux Chondrostomes français: *Chondrostoma nasus* et *Chondrostoma toxostoma* (Pisces, Cyprinidae). *Cybiurn*, 12, 287–299.
- Ogle, D.H. and Winfield, I.J., 2009.** Ruffe length-weight relationships with a proposed standard weight equation. *North American Journal of Fisheries Management*, 29, 850-858.
- Ogle, D.H., 2012.** Data to support fish stock assessment package: Package FSA. GPL version 2.03 or newer URL (<http://www.rforge.net/FSA>).
- Özcan, G., 2009.** Reproductive biology of the endemic and threatened Menderes Nase, *Chondrostoma meandrense* Elvira, 1987, in Western Anatolia (Osteichthyes: Cyprinidae). *Zoology in the Middle East*, 46,1, 61–67.
- Sülun, Ş., Başkurt, S., Emiroğlu, Ö., Giannetto, D., Tarkan, S., Ağmadar, S., Gaygusuz, O., Dorak, Z., Aydın, H. and Çiçek, A., 2014.** Development of empirical standard weight equation for Pursak chub *Squalius pursakensis*, an endemic cyprinid species of Northwestern Anatolia. *Turkish Journal of Zoology* 38, 582–589.
- Tarkan, A.S., Özuluğ, M., Gaygusuz Ö., Gürsoy Gaygusuz, Ç., 2007.** A New Locality for the Freshwater Fish *Chondrostoma angorense* Elvira, 1987 (Osteichthyes: Cyprinidae) in the Marmara Region (Turkey). *Ege Journal of Fisheries and Aquatic Sciences*, 24 (1).
- Tarkan, A.S., Copp, G.H., Top, N., Özdemir, N., Önsoy, B., Bilge, G., Filiz, H., Yapıcı, S., Ekmekçi, G., Kirankaya, Ş., Emiroğlu, Ö.,**

- Gaygusuz, Ö., Gürsoy Gaygusuz, Ç., Oymak, A., Özcan, G. and Saç, G., 2012.** Are introduced gibel carp *Carassius gibelio* in Turkey more invasive in artificial than in natural waters? *Fisheries Management and Ecology*, 19, 178–187.
- Tarkan, A.S., Marr, S.M and Ekmekçi, F.G., 2015.** Non native and traslocated freshwater fish species in Turkey. *FishMed*, 2015.003, 28.
- Turan, D., Kottelat, M., Ekmekci, FG. and Imamoğlu, H.O., 2006.** A review of *Capoeta tinca*, with descriptions of two new species from Turkey (Teleostei: Cyprinidae). *Revue Suisse de Zoologie*, 113(2), 421–436.
- Turan, C. 2008.** Molecular systematics of the *Capoeta* (Cypriniformes: Cyprinidae) species complex inferred from mitochondrial 16S rDNA sequence data. *Acta Zoologica Cracovica*, 51, 1–14.
- Ünver, B. and Ünver, S., 2004.** Histological examination of ovarium development of shemaya *Chalcalburnus chalcoides* living in Lake Tödürge (Sivas/Turkey). *Folia Zoologica*, 53, 99–106.
- Wege, G.J. and Anderson, R.O., 1978.** Relative weight (W_r): A new index of condition for largemouth bass. In: Novinger GD, Dillard JG editors. *New Approaches to the Management of Small Impoundments* Bethesda, Maryland: Special Publication America Fishery Society. pp. 79-91.
- Willis, D.W., Guy, C.S., Murphy, B.R., 1991.** Development and evaluation of a standard weight (W_s) equation for yellow perch. *North American Journal of Fisheries Management*, 11, 374–380.
- Yıldırım, A., Arslan, M. and Rektav, S., 2008.** Length-weight relationship and seasonal condition in *Capoeta sieboldii* in the upper Çoruh River, Turkey. *Journal of Applied Ichthyology*, 24, 711-712.
- Yılmaz, S., Yazicioğlu, O., Yılmaz, M. and Polat, N., 2010.** Length-weight and length-length relationships of *Capoeta sieboldii* from Hirfanli Dam Lake, Turkey. *Journal of Freshwater Ecology*, 25(2), 205–209.