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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Estimating length-weight, length-length relationships, and condition factor of eight fish species, a case study of Bashar River, Tigris drainage (Iran)

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Abstract: This study investigate investigated the length-weight, length-length relationships and condition factor of eight fish species collected from Bashar River, Tigris drainage by sampling 341 specimens of *Alburnus sellal* (Heckel, 1843), *Barbus karunensis* (Khaefi, Esmaeili, Geiger & Eagderi, 2017), *Capoeta aculeate* (Valenciennes, 1844), *Capoeta coadi* (Alwan, Zareian & Esmaeili, 2016), *Chondrostoma regium* (Heckel, 1843), *Garra gymnothorax* (Berg, 1949), *Glyptothorax galaxias* (Mousavi-Sabet, Eagderi, Vatandoust & Freyhof, 2021) and *Turcinoemacheilus hafezi* (Golzarianpour, Abdoli, Patimar & Freyhof, 2013). The results showed that the b parameter was form 2.41 (in *C. aculeate*) to 3.88 (in *A. sellal*) and condition factors ranged from 0.74 (in *A. sellal* and *B. karunensis*) to 1.35 (in *C. aculeate*). The coefficient of determination (r^2) in the length-weight and length-length relationships was > 0.83. In conclusion, allometric growth patterns for *A. sellal*, *B. karunensis*, *G. gymnothorax*, and *G. galaxias* were positive while for *C. aculata*, *C. regium* and *T. hafezi*, and *C. coadi* presented negative patterns. This study represents the first data for *G. galaxias*.

Keywords: Length-weight relationship, Bashar River, Iranian inland waters, LLRs, fishery management

INTRODUCTION

Studies of the length-weight relationship (LWR) are vital tools to describe several biological aspects of fishes as well as condition of populations in their habitat (Froese, 2006; Mouludi–Saleh and Eagderi, 2019; Eagderi et al., 2020). The length-weight relationship can be used for (a) conversion of growth-in-length equations to growth-in-weight stock assessment models; (b) biomass estimation from length-frequency data; (c) calculating the total weight of fish caught from length-frequency data; (d) investigating the changes in health status of fish species (compared to past or future samples at the same place and the same sampling season); (e) determining the relative condition factor of small fish compared to those of large fish and (f) for between-region life histories comparisons of certain fish species (Moradinasab et al., 2012). Standing stock, yield, and biomass are frequently estimated from length-frequency data converted with length-weight relationships (LWRs) and length–length relationships (LLRs) are useful for the standardization of length type when data are summarized (Simon & Mazlan, 2008). The condition factor of a fish is an index that reflects the interplay of physical and biological factors and fluctuations in the physiological status of fishes and may vary among fish species in different locations (Getso et al., 2017).

The Bashar River is one of the biggest tributaries of the Tigris-Euphrates basin in Kohkiluyeh and Boyer-Ahmad Province with rich fish diversity, being located in southwest, as the sub-basins of the Karun River, which originates from the Sepidan Mountains in Fars province. It crosses the Pataveh region, joins the Khersan River and finally flows into the Karun River (Jamali et al., 2015; Mortazavi and Hatami, 2018). This river is being exploited for various agricultural, industrial, and recreational activities, thereby greatly contributing to the economy of Yasuj city. Although, the Bashar River has been influenced and polluted by sugar factory, hospitals, agricultural farms, municipal surface runoff and wastewater treatment plants (Boustani and Hojati, 2010; Rahimi et al., 2011). Due to the threats to the aquatic environment of this ecosystem, the abundance and diversity change every year, so sustainable monitoring has become important for sound management.

This study aimed to investigate the parameters of the LWR, LLR, and condition factor of *Alburnus sellal* (Heckel, 1843), *Barbus karunensis* (Khaefi, Esmaeili, Geiger & Eagderi, 2017), *Capoeta aculeata* (Valenciennes, 1844), *C. coadi* (Alwan, Zareian & Esmaeili, 2016), *Chondrostoma regium* (Heckel, 1843), *Garra gymnothorax* (Berg, 1949), *Glyptothorax galaxias* (Mousavi-Sabet, Eagderi, Vatandoust & Freyhof, 2021) and *Turcinoemacheilus hafezi* (Golzarianpour, Abdoli, Patimar & Freyhof, 2013) from Bashar River. The results of the present study may be useful for biology and stock assessment of endemic species. In addition, given that two species, i.e. *T. hafezi* and *G. galaxias* have not been previously investigated, so this study can be beneficial for biological investigations in future studies.

Materials and Methods

During the summer of 2021, some 341 specimens were captured from 16 sampling sites (covering an area of 100 m^2 at each sampling) of the Bashar River, Kohgiluyeh and Boyer-Ahmad Province, Iran (Figure 1), by various types of fishing gear, electrofishing devices (Table 1).

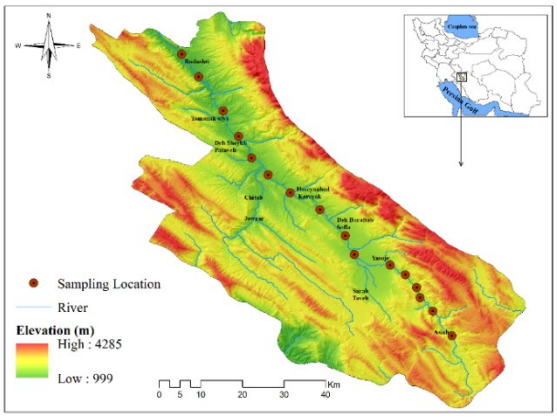

Figure1. Collecting stations of samples in the Bashar River, Kohkiluyeh and Boyer-Ahmad Province, Iran

Table 1. Geographical coordinates of the sampling site stations

Stations	Geographical coordinates	
1	30°32'37.30"N	51°42'38.25"E
2	30°33'29.74"N	51°41'43.82"E
3	30°33'57.64"N	51°37'32.27"E
4	30°34'27.89"N	51°41'07.17"E
5	30°38'13.75"N	51°37'31.41"E
6	30°38'56.86"N	51°36'52.33"E
7	30°40'10.40"N	51°32'06.19"E
8	30°40'36.08"N	51°31'59.63"E
9	30°46'01.12"N	51°27'36.81"E
10	30°46'30.17"N	51°07'36.16"E
11	30°51'20.51"N	51°20'33.42"E
12	30°51'47.15"N	51°20'13.38"E
13	30°55'26.49"N	51°17'13.19"E
14	30°58'31.91"N	51°15'10.58"E
15	30°01'55.42"N	51°13'15.48"E
16	31°02'25.53"N	51°13'02.58"E

All the procedures were performed based on the approved protocol guidelines and procedures employed by the Iranian Environmental organization. The species were identified according to Coad (2016) and Esmaeili et al. (2018).

Some morphometric characteristics were measured in the field including total length (TL), standard length (SL), and fork length (FL), using digital calipers to the nearest 0.01 cm. The specimens were weighed (W) to the nearest 0.01 g using an electronic balance. The length-weight relationship (LWR) was calculated using below mathematical equations (Froese, 2006):

$$W=aL^b$$

Where W= whole body weight (g), L= the total length (cm), *a* = intercept, and b = the slope of the regression line. The log-log plots of the length-weight pairs were used to find outliers (Froese et al., 2011). The following relationships were found using linear regression analysis: (a) FL versus TL; (b) SL versus TL as FL= a + bTL and SL = a + bTL, respectively (Mouludi-Saleh and Keivany, 2018). Also, the following formula was used to calculate the condition factor (Fulton, 1904; Nikmehr et al., 2021):

$$K= (W/L^3) \times 100$$

Where W= total body weight (g), L= total length (cm), and the scaling factor of 100 were used to bring the K close to the unit. To estimate whether the b-value is significantly different from the expected or theoretical value of 3 (i.e. b = 3), a student's t-test (ts) was performed. All analyses were performed in Excel v2019 and PAST v2.17b.

Results and Discussion

To the best of our knowledge, this is the first study to evaluate the length-weight relationships and the condition factors of the eight studied species in the study area. The descriptive statistics i.e. ranges of the total length (TL) and weight (W), calculated length-weight relationship parameters including a, b, r^2, and condition factor (K) of the studied species are presented in Table 2. Our finding indicated that b-value, coefficient of determination (r^2) and mean condition factor ranged 2.41-3.88, 0.83-0.95 and 0.66-1.35, respectively.

The values of a, b, and r^2 of the species and related statistics for LLRs are shown in Table 3. The b value for FL-TL ranged 0.884-0.978 and for SL-FL 0.875-0.977, respectively.

A total of 341 specimens, representing eight fish species, were analyzed and the first LWRs data are reported for *G. galaxias* and other studied species belonging to new localities. In LWRs parameter, the b value ranges between 2.5 and 3.5 (Froese, 2006) or 2-4 (Tesch, 1971). In this study, the b-values of the studied fish species were within the expected ranges. For example, the LWRs for *A. sellal* was $W= 0.0009L^{3.88}$ (r^2 = 0.93), for *C. aculeate* was $W= 0.06L^{2.41}$ (r^2 = 0.87) and for *T. hafezi* was $W= 0.007L^{2.9}$ (r^2 = 0.95).

Table 2. LWR data, regression parameters, 95% confidence limit (CL) and condition factor (K) for eight fish species in Bashar River of Iran during the summer season of 2021

		Total length (cm)	Total weight (g)		Regression parameters						Condition factor (Mean ± SD)	P	t-test	Growth pattern
Species	N	Min- Max	Min	Max	a	a 95% CL	*b*	b 95% CL	±SE	r^2				
A. sellal	43	6.99-15.03	1.57	31.4	0.0009	0.0004-0.0016	3.88	3.67-3.92	0.116	0.92	0.74±0.17	<0.05	51.86	positive allometric
B. karunensis	23	5.76-15.18	1.03	29.4	0.002	0.0005-0.014	3.40	2.75-3.62	0.165	0.83	0.74±0.22	<0.05	12.62	positive allometric
C. aculeate	47	10.86-20.12	15.04	93.5	0.060	0.03-0.11	2.41	2.19-2.67	0.012	0.87	1.35±0.25	<0.05	-22.11	negative allometric
C. coadi	83	4.26-23.59	1.11	144.3	0.018	0.017-0.03	2.69	2.48-2.86	0.232	0.87	0.90±0.34	>0.05	-0.248	isometric
C. regium	21	7.68-14.79	1.64	16.84	0.006	0.0023-0.02	2.86	2.39-3.28	0.133	0.90	0.48±0.12	<0.05	-23.2	negative allometric
G. gymnothorax	89	5.27-13.78	1.05	31.3	0.004	0.002-0.007	3.37	3.15-3.64	0.123	0.90	1.00±0.25	<0.05	25.43	positive allometric
G. galaxias	23	5.62-14.49	0.69	32.3	0.004	0.0005-0.015	3.34	2.8-4.15	0.118	0.90	0.90±0.20	<0.05	15.34	positive allometric
T. hafezi	12	3.69-5.28	0.35	0.9	0.007	0.005-0.013	2.90	2.51-3.12	0.128	0.95	0.66±.05	<0.05	2.21	negative allometric

N: number of species; Min: minimum; Max: maximum; a: intercept; b: slope; r^2: coefficient of determination

Table 3. Length–length relationships of TL, FL, and SL for eight species in Bashar River of Iran during 2021

Species	Total length	Fork length	Standard length	Equation	*b*	*a*	r^2
A. sellal	10.96±1.88	10.11±1.72	9.00±1.66	FL= a+b×TL	0.917	0.056	0.99
				SL= a+b×FL	0.924	-0.342	0.99
B. karunensis	10.76±2.41	10.12±2.14	9.09±2.19	FL= a+b×TL	0.923	0.177	0.99
				SL= a+b×FL	0.956	-0.579	0.99
C. aculeate	13.73±2.35	12.56±2.17	11.20±1.91	FL= a+b×TL	0.922	-0.102	0.99
				SL= a+b×FL	0.908	-0.208	0.98
C. coadi	13.19±4.30	12.08±3.95	10.61±3.46	FL= a+b×TL	0.917	-0.012	0.99
				SL= a+b×FL	0.875	-0.034	0.99
C. regium	11.06±2.73	10.01±2.46	8.73±2.23	FL= a+b×TL	0.903	-0.027	0.99
				SL= a+b×FL	0.903	-0.313	0.99
G. gymnothorax	8.53±1.88	8.05±1.79	7.15±1.71	FL= a+b×TL	0.952	-0.078	0.99
				SL= a+b×FL	0.947	-0.467	0.98
G. galaxias	10.66±2.24	9.75±1.98	8.95±1.94	FL= a+b×TL	0.884	0.324	0.99
				SL= a+b×FL	0.977	-0.581	0.99
T. hafezi	4.32±0.53	4.18±0.52	3.70±0.47	FL= a+b×TL	0.978	-0.050	0.99
				SL= a+b×FL	0.898	-0.057	0.99

The b-value, a, and r^2 parameters of the studied species in the previous studies are presented in Table 4. For example, the b-value for *A. sellal* reported to be 2.95 (Zare-Shahraki et al., 2020), Zamani-Faradonbe et al. (2018) reported a b-value of 3.11 for *G. gymnothorax* in Iranian basins, almost similar to our results i.e., 3.11. In Beheshtabad River (Tigris basin, Iran) b-value for *C. coadi* had been reported to be 2.91 (Keivany and Siami, 2020) and Zare-Shahraki et al. (2020) reported a b-value of 2.97 for *B. karunensis* from the Karun River system, southwestern Iran.

Table 4. Length-weight relationship parameters and condition factor (K) data about studied species in previous studies in Iranian Inland waters

Species	N	Sampling Site	*LW* parameters				References
			a	b	r^2	K	
A. sellal	1435	Karun River system	0.009	2.95	0.97	-	Zare-Shahraki et al. 2020
B. karunensis	25	Karun River system	0.01	2.97	0.98	-	Zare-Shahraki et al. 2020
C. coadi	1084	Karun River system	0.014	2.92	0.99	-	Zare-Shahraki et al. 2020
C. coadi	32	Iranian inland waters	0.018	2.80	0.99	-	Zareian et al. 2018
C. coadi	426	Beheshtabad River	0.02	2.91	0.97	-	Keivany and Siami, 2020
C. regium	135	Iranian inland waters	0.009	3.03	0.99	1.01	Abbasi et al. 2019
C. regium	-	Zayandeh River	0.009	3.21	0.97	-	Kashkooli et al. 2018
C. regium	335	Bibi-Sayyedan River	0.007	3.08	0.98	-	Keivany et al. 2016
C. regium	335	Beheshtabad River	0.008	3.10	0.94	-	Keivany et al. 2015
C. aculeata	50	Gamasiab River	0.06	2.92	0.99	0.85	Radkhah and Nowferesti, 2016
G. gymnothorax	45	Iranian basins	0.008	3.11	0.99	-	Zamani-Faradonbe et al. 2018

N: number of species

The reported LWR parameters for *C. regium* in different rivers of Iran ranged from 3 to 3.21 which was higher than those of the current study (Table 4). However, no LWRs and condition factor data were available for *G. galaxy* from the Iranian inland waters for comparison purposes.

The LWR data of fish species is a critical index to estimate population and biomass dynamics that play a key role in fisheries management evaluation including storage population, age at maturity, life period, and mortality (Jafari-Patcan et al., 2018; Sorosh Hadad et al., 2018). In addition, the length-weight relationships are not constant over the year and biological factors, seasons, ecological properties of the study areas, sex, gonad maturity, stomach fullness, health, and even sampling can affect the LWR parameters (Tesch, 1971; Bagenal and Tesch, 1978; Froese, 2006; Kamal et al., 2009; Suiçmez et al., 2011; Jalili et al. 2015), and also environmental conditions of habitats such as temperature and photoperiod (Keivany and Soofiani, 2004; Hasankhani et al., 2013).

Generally, a b value >3 indicate positive allometric growth, though the value can vary between 2.5 and 4, depending on the changes in fish shape, age, season, dietary behavior, competition, feeding, habitat geographical location and growth (Özcan, 2011; Suiçmez et al., 2011; Esmaeili et al., 2014). In our study, there were positive allometric growth (A+) patterns for *A. sellal* (b= 3.88), *B. karunensis* (b = 3.40), *G. gymnothorax* (b = 3.37), and *G. galaxias* (b = 3.34), and negative values for *C. aculata* (b = 2.41), *C. regium* (b = 2.86) and *T. hafezi* (b = 2.90), while *C. coadi* had isometric growth pattern.

The condition factor index indicated the relationship between biological and non-biological factors on fish physiology that can be used to compare various populations in different conditions and life cycles (Bagenal and Tesch, 1978;

Tran et al., 2021). With regards to the importance of growth studies in effective management and conservation of fish populations in this aquatic ecosystem, which is affected by environmental and human pollution, the present study may help to design and perform better conservational plans and studies for endemic species (González Acosta et al., 2004; Kashkooli et al., 2018). Condition factors (K) > 1 (*C. aculeate* and *G. gymnothorax*) can indicate a proper condition in their habitats (Radkhah and Eagderi, 2015) for these species inhabiting the Bashar River. Variation of the condition of factor is related to environmental parameters, such as seasonal changes of the gonads and nutritional conditions (Biswas, 1993; Muchlisin et al., 2010; Tran et al., 2021).

This study presented the first basic information on length-weight relationship (LWRs), length–length relationships (LLRs), and Condition factors (K) data for eight fish species from the Bashar River, therefore, these results may be useful for future fisheries management, ecological investigations, conservation and fish population dynamic studies.

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Authorship Contributions

All authors certify that they have taken part sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Material preparation and investigation were performed by Saeid Shahbazi Naserabad. Data analysis was done by Saeid Shahbazi Naserabad and Hadi Poorbagher. Data curation was done by Soheil Eagderi. The writing/editing was carried out by Hadi Poorbagher, Soheil Eagderi and Saeid Shahbazi Naserabad. Hadi Poorbagher and Soheil Eagderi supervised and Project administration of this study. Also, all authors have read and approved the article.

Conflicts of interest/Competing interests

There is no conflict of interest to declare.

Ethics approval

The authors confirm that all procedures performed in their study involving animals were in accordance with the ethical standards. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All experiments were performed following the protocol approved by the committee of ethics of the faculty of sciences of the University of Tehran (85A1672; 20 May 2021).

Data availability

The datasets in this study are available from the corresponding author on reasonable request. All data and materials are available for publication.

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