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Research Article

Length-Weight Relationships and Condition Factors of Eight Exotic Fish Species from Türkiye

Türkiye'de Bulunan Sekiz Egzotik Balık Türünün Boy-Ağırlık İlişkisi ve Kondisyon Faktörü

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Abstract

Length-weight relationships and condition factors were estimated for eight exotic fish species, including *Oreochromis niloticus*, *Coptodon zillii*, *Carassius auratus*, *C. gibelio*, *Pseudorasbora parva*, *Gambusia holbrooki*, *Lepomis gibbosus*, and *Oncorhynchus mykiss* from 10 river basins in Türkiye. A total of 1958 specimens were sampled between 2014 and 2019 from 29 populations, and their length-weight relationships, Fulton's relative, and mean condition factors were estimated. The estimated values of the parameter *b* ranged from 2.732 (*C. auratus*) to 3.319 (*C. gibelio*) with the mean and median values estimated at 3.013 and 3.047, respectively. The R^2 values varied from 0.753 to 0.998, indicating a high degree of the positive relationship between length and weight. The Fulton's condition factor ranged between 0.882 (*P. parva*) and 2.002 (*L. gibbosus*) with the mean and median values of 1.397 and 1.453, respectively. This situation reveals that the condition values of all alien species except *P. parva* are quite high. In addition, the condition factor values of exotic fish species and native species live with in Lake Çıldır were compared to observe their competition with indigenous fishes of the lake. As a result of this comparison, it was found that *C. gibelio* has the highest condition factor value.

Keywords: *condition factor, exotic fish species, river basin, growth pattern*

Öz

Bu çalışmada Türkiye'nin 10 farklı nehir havzasından, *Oreochromis niloticus*, *Coptodon zillii*, *Carassius auratus*, *C. gibelio*, *Pseudorasbora parva*, *Gambusia holbrooki*, *Lepomis gibbosus* ve

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Oncorhynchus mykiss olmak üzere sekiz egzotik balık türünün boy-ağırlık ilişkileri (L-WRs) ve kondisyon faktörü değerleri tahmin edilmiştir. 2014, 2017, 2018 ve 2019 yılları arasında 29 populasyondan 1958 birey örneklenmiştir. Boy-ağırlık ilişkisi sabitlerinden *b* değerinin 2,732 (*C. auratus*) ile 3,319 (*C. gibelio*) arasında değişim gösterdiği belirlenmiş olup çalışılan populasyonlar için ortalama ve ortanca değerler sırasıyla 3,013 ve 3,047 olarak hesaplanmıştır. Regresyon analizi sonucunda boy-ağırlık değerleri arasında yüksek bir pozitif ilişki belirlenmiş olup R^2 değeri 0,753 ile 0,998 arasında bulunmuştur. Fulton'un kondisyon faktörü değerinin 0,882 (*P. parva*) ile 2,002 (*L. gibbosus*) arasında değişim gösterdiği belirlenmiş ve ortalama ve ortanca değerler sırasıyla 1,397 ve 1,453 olarak hesaplanmıştır. Bu durum *P. parva* dışında diğer tüm egzotik türlerin kondisyon değerlerinin oldukça yüksek olduğunu ortaya koymaktadır. Bunun yanı sıra Çıldır Gölünde egzotik balık türleri ile birlikte yaşadıkları yerli türlerin kondisyon faktörü değerleri de karşılaştırılmıştır. Bu karşılaştırma sonucunda *C. gibelio*'nun en yüksek kondisyon faktörü değerine sahip olduğu belirlenmiştir.
Anahtar sözcükler: *kondisyon faktör, egzotik balık türleri, nehir havzası, büyüme paterni*

Introduction

Exotic species in new environments can threaten native species due to resource competition, predation, and disease, driving them to decline or even extinction. Their adverse effects are seen not only in the aquatic environments where they enter but also in the local economies. Exotic species' influence on biodiversity is rising and becoming a global threat. To date, 39 exotic fish species have been reported from Turkish inland waters (Çetinkaya, 2006; Innal & Erkakan, 2006; Innal, 2012; Tarkan et al., 2015; Çiçek et al., 2021), of which 19 of them have established populations in the wild (Çiçek et al., 2020, 2022). So, it is important to keep an eye on the spread of exotic species and how they affect the freshwater ecosystem in Türkiye.

The length-weight relationships (LWRs) are a valuable tool for estimating the weight of a given length, biomass from length data, comparing them to relative conditions among species, regions, even years and life histories, and population dynamics of given species (da Costa et al., 2014). The condition factor of fish indicates the degree of food source availability, environmental condition and stress, state of sexual maturity, age, and sex (Anibeze, 2000; Liang & Cai, 2020). Therefore, estimations of population biology traits are a crucial part of fisheries biology and management (Froese et al., 2011). These estimations for exotic species may help us to take measures to prevent their effects on native biodiversity and conservation biology.

The knowledge on the length-weight relations of the exotic freshwater fishes in Türkiye is limited (Innal & Gianetto, 2017; Kurtul & Sarı, 2020). Therefore, this study aimed to investigate the length-weight relationships and condition factors of exotic fish species collected from some freshwater habitats in Türkiye.

Materials and Methods

Fish samples were collected in the spring, summer, and fall of the years 2014, 2015, 2017, 2018, and 2019 from 10 river basins (West and East Mediterranean, Çoruh, Seyhan, Aras, Asi, East Black Sea, Fırat, Konya and North Aegean) in Türkiye. Fish were caught using a backpack electrofishing device (SAMUS 1000) in lotic waters and gillnets in lentic aquatic ecosystems. The collected fish specimens were fixed into 10% formaldehyde solutions after anaesthesia and then transferred to the laboratory for further study. In the laboratory, total length (L) and total weight (W) were measured to the nearest 0.01 cm and 0.01 g, respectively.

The LWRs function was fitted with a simple linear regression model using log-transformed data:

$$W=a*L^b \qquad (1)$$

where a is the intercept and b is the allometric coefficient (LeCren, 1951). The 95% confidence interval (CI) was determined for parameters a and b (Froese, 2006). Before to regression analyses, log-log plots of the length-weight pairs were performed to identify outliers (Froese et al., 2011). Outliers perceived in the log–log plots of all these eight species were eliminated from the analysis. Fulton's condition factor (K_F) was estimated using the formula (Ricker, 1975; Froese, 2006):

$$K_F=(W/L^3) \times 100 \qquad (2)$$

The relative condition factor (K_R) was calculated using the equation (Froese, 2006):

$$K_R = W/(a \times L^b) \qquad (3)$$

The mean condition factor (K_M) for a given length was derived from the respective WLR (Froese, 2006) using the formula:

$$K_M = 100 \times a \times L^{b-3} \qquad (4)$$

The form factor (a3:0) was used to assess if a population's or species' body shape differs significantly from that of others, which was calculated using the formula (Froese, 2006):

$$a_{3:0}=10^{\log a\text{-}S(b\text{-}3)} \qquad (5)$$

where S was the slope of the regression of log a vs b. This value was used as a -1.358 proxy for estimating the form factor (Froese, 2006).

All statistical analyses were performed in Excel 2016 and Past 3.26 software.

Results and Discussion

During the study period, a total of eight exotic fishes, *Oreochromis niloticus* (Linnaeus, 1758), *Coptodon zillii* (Gervais, 1848), *Carassius auratus* (Linnaeus, 1758), *C. gibelio* (Bloch, 1782), *Pseudorasbora parva* (Temminck & Schlegel, 1846), *Gambusia holbrooki* Girard, 1859, *Lepomis gibbosus* (Linnaeus, 1758), and *Oncorhynchus mykiss* (Walbaum, 1792) were collected. *C. auratus* is the first exotic fish introduced into Türkiye's inland waters (Deveciyan, 1926), followed by *G. holbrooki* for biological control of mosquitos (Geldiay & Balik, 2007). Aquaculture, as the main reason for introducing egzotic fish species with a relatively short history in Türkiye, was began with the farming of rainbow trout (Food and Agriculture Organization of United Nations [FAO], 2005) and then seven tilapia species such as *C. zillii* and *O. niloticus* were imported to improve aquaculture production (Çetinkaya, 2006; Innal & Erkakan, 2006). All of these eight species have been successfully naturalized and become exotic in the freshwater basins of Türkiye (Özcan, 2007; Tarkan et al., 2012; Yerli et al., 2014; Özcan & Tarhan, 2019, Çiçek et al., 2022).

The distribution of fish populations and total number fish caught from each basin and and year classes are given in Table 1. Their descriptive statistics including the length, weight, and LWRs parameters are indicated in Table 2. Estimated values of b varied from 2.732 (*C. auratus*) to 3.319 (*C. gibelio*) with a mean and median of 3.013 and 3.047, respectively. A total of 18 populations displayed isometric growth (b = 3), 2 populations had negative allometric growth (b < 3) and 9 populations had positive allometric growth (b < 3) patterns. For the studied populations, the b values ranged within the expected range of 2.5–3.5 (Froese, 2006). All relationships were highly significant (P < 0.005), with R^2 values being greater than 0.75, indicating a high degree of a positive relationship between length and weight.

Table 1

Information of Eight Exotic Species from 29 Populations

ID	Species	Basins	Habitat	Sampling Year	n
CICHLIFORMES (1 family)					
Cichlidae (2 species)					
1	*Oreochromis niloticus* (Linnaeus, 1758)	Asi	Lotic	2019	20
2	*Coptodon zillii* (Gervais, 1848)	Batı Akdeniz	Lotic	2014	206
CYPRINIFORMES (1 family)					
Cyprinidae (2 species)					
3	*Carassius auratus* (Linnaeus, 1758)	Çoruh	Lotic	2019	26
4	*Carassius auratus* (Linnaeus, 1758)	Fırat	Lotic	2019	71
5	*Carassius auratus* (Linnaeus, 1758)	Seyhan	Lotic	2019	13
6	*Carassius gibelio* (Bloch, 1782)	Aras	Lotic	2014	233
7	*Carassius gibelio* (Bloch, 1782)	Asi	Lotic	2019	34
8	*Carassius gibelio* (Bloch, 1782)	Batı Akdeniz	Lotic	2014	95
9	*Carassius gibelio* (Bloch, 1782)	Çoruh	Lotic	2019	38
10	*Carassius gibelio* (Bloch, 1782)	Doğu Akdeniz	Lotic	2019	19
11	*Carassius gibelio* (Bloch, 1782)	Fırat	Lotic	2019	159
12	*Carassius gibelio* (Bloch, 1782)	Fırat	Lotic	2014	12
13	*Carassius gibelio* (Bloch, 1782)	Konya	Lotic	2017	29
14	*Carassius gibelio* (Bloch, 1782)	Seyhan	Lotic	2019	32
Gobionidae (1 species)					
15	*Pseudorasbora parva* (Temminck & Schlegel, 1846)	Aras	Lotic	2014	94
16	*Pseudorasbora parva* (Temminck & Schlegel, 1846)	Batı Akdeniz	Lotic	2014	97
17	*Pseudorasbora parva* (Temminck & Schlegel, 1846)	Konya	Lotic	2017	15
18	*Pseudorasbora parva* (Temminck & Schlegel, 1846)	Kuzey Ege	Lotic	2014	35
CYPRINODONTIFORMES (2 families)					
Poecilidae (1 species)					
19	*Gambusia holbrooki* Girard, 1859	Batı Akdeniz	Lotic	2014	122
20	*Gambusia holbrooki* Girard, 1859	Fırat	Lotic	2014	71
PERCIFORMES (2 families)					
Centrarhidae (1 species)					
21	*Lepomis gibbosus* Linnaeus, 1758	Batı Akdeniz	Lentic	2014	48
22	*Lepomis gibbosus* Linnaeus, 1758	Batı Akdeniz	Lotic	2014	182
SALMONIFORMES (1 family)					
Salmonidae (1 species)					
23	*Oncorhynchus mykiss* (Walbaum, 1792)	Aras	Lentic	2014	21
24	*Oncorhynchus mykiss* (Walbaum, 1792)	Aras	Lotic	2014	12
25	*Oncorhynchus mykiss* (Walbaum, 1792)	Ceyhan	Lentic	2014	19
26	*Oncorhynchus mykiss* (Walbaum, 1792)	Çoruh	Lotic	2019	22
27	*Oncorhynchus mykiss* (Walbaum, 1792)	Batı Akdeniz	Lentic	2014	5
28	*Oncorhynchus mykiss* (Walbaum, 1792)	Ceyhan	Lentic	2019	41
29	*Oncorhynchus mykiss* (Walbaum, 1792)	Doğu Karadeniz	Lentic	2018	67

Note. ID: Species Identification Number; n: Number of Specimens

Table 2

Descriptive Statistics of Eight Exotic Fish Species from 29 Populations in Türkiye (Froese & Pauly, 2022)

ID	Species	Total Length				Total Weight			
		Min	Max	Mean	SD	Min	Max	Mean	SD
1	*Oreochromis niloticus*	3.8	17.5	8.60	3.29	0.98	117.06	15.48	25.60
2	*Coptodon zilli*	6.6	15.3	10.74	1.45	4.92	58.23	23.23	8.30
3	*Carassius auratus*	8.3	13.5	10.25	1.37	6.60	28.90	14.87	5.57
4	*Carassius auratus*	8.3	23.7	13.15	3.94	7.71	232.62	41.14	40.71
5	*Carassius auratus*	10.3	16.8	12.76	1.86	14.51	69.14	33.89	16.29
6	*Carassius gibelio*	4.7	32.5	17.09	8.68	1.44	727.45	183.03	221.11
7	*Carassius gibelio*	16.2	21.6	19.06	1.29	66.82	167.14	119.41	25.39
8	*Carassius gibelio*	5.1	27.2	14.41	4.32	2.15	280.25	65.40	59.26
9	*Carassius gibelio*	8.1	21.8	9.22	2.14	8.34	143.45	14.67	21.52
10	*Carassius gibelio*	7.4	23.0	14.44	6.66	6.14	222.04	89.12	96.66
11	*Carassius gibelio*	7.6	25.5	13.23	4.41	7.60	246.43	49.55	48.13
12	*Carassius gibelio*	5.4	20.0	13.51	5.28	1.69	140.73	59.48	52.31
13	*Carassius gibelio*	9.4	24.2	18.53	3.49	12.06	240.80	112.56	51.57
14	*Carassius gibelio*	10.0	20.3	14.28	2.93	14.58	140.97	50.03	35.05
15	*Pseudoraspora parva*	4.8	10.2	7.81	1.41	0.87	11.10	5.19	2.42
16	*Pseudoraspora parva*	4.2	6.5	5.46	0.62	0.68	2.80	1.48	0.50
17	*Pseudoraspora parva*	6.0	10.4	8.27	1.55	2.12	12.00	6.63	3.64
18	*Pseudorasbora parva*	5.0	9.8	7.69	1.53	1.16	9.94	4.62	2.67
19	*Gambusia holbrooki*	2.3	5.3	3.07	0.50	0.11	1.67	0.41	0.26
20	*Gambusia holbrooki*	2.3	4.4	3.21	0.46	0.12	1.36	0.45	0.22
21	*Lepomis gibbosus*	2.7	10.7	6.54	1.54	0.20	23.54	6.60	4.42
22	*Lepomis gibbosus*	3.9	13.2	6.74	2.21	0.93	42.70	7.16	7.97
23	*Oncorhynchus mykiss*	11.0	19.1	15.15	2.65	17.05	89.97	46.24	24.82
24	*Onchorhyncus mykiss*	14.2	27.0	18.27	3.38	41.55	297.20	88.83	69.72
25	*Onchorhyncus mykiss*	9.0	30.0	19.31	5.96	7.56	393.03	103.44	92.26
26	*Onchorhyncus mykiss*	12.9	29.7	20.81	3.16	25.50	285.87	100.95	44.09
27	*Oncorhynchus mykiss*	9.8	25.8	17.67	3.76	12.36	205.57	82.45	47.93
28	*Onchorhyncus mykiss*	6.7	22.8	16.45	3.78	4.80	196.42	73.30	44.04
29	*Onchorhyncus mykiss*	8.5	18.5	13.86	2.00	7.82	90.76	35.31	14.41

Note. min: minimum; max: maximum; SD: standard deviation

Table 3

Estimated Parameters of the Length–Weight Relationships for Eight Exotic Fish Species from 29 Populations in Türkiye

ID	Species	Length-weight relationship parameters					Growth Type	In FishBase	
		a	***b***	R^2	**SE of *b***	**CI of *b***		***a***	***b***
1	*Oreochromis niloticus*	0.013	3.061	0.967	0.133	2.751-3.404	I	0.0257	2.93
2	*Coptodon zilli*	0.014	3.093	0.978	0.033	3.031-3.159	A+	0.0245	2.99
3	*Carassius auratus*	0.025	2.732	0.952	0.125	2.474-2.967	A-	0.0145	3.06
4	*Carassius auratus*	0.019	2.886	0.964	0.067	2.731-3.29	I	0.0145	3.06
5	*Carassius auratus*	0.009	3.191	0.954	0.212	2.476-3.483	I	0.0145	3.06
6	*Carassius gibelio*	0.009	3.259	0.998	0.010	3.239-3.778	A+	0.0151	3.09
7	*Carassius gibelio*	0.014	3.070	0.863	0.217	2.806-3.424	I	0.0151	3.09
8	*Carassius gibelio*	0.016	3.034	0.990	0.032	2.966-3.106	I	0.0151	3.09
9	*Carassius gibelio*	0.023	2.830	0.978	0.071	2.661-3.268	I	0.0151	3.09
10	*Carassius gibelio*	0.011	3.156	0.998	0.031	3.103-3.211	A+	0.0151	3.09
11	*Carassius gibelio*	0.013	3.060	0.971	0.043	2.983-3.129	I	0.0151	3.09
12	*Carassius gibelio*	0.007	3.319	0.998	0.048	3.238-3.491	A+	0.0151	3.09
13	*Carassius gibelio*	0.017	2.982	0.981	0.080	2.862-3.235	I	0.0151	3.09
14	*Carassius gibelio*	0.009	3.171	0.949	0.133	2.971-3.378	I	0.0151	3.09
15	*Pseudoraspora parva*	0.013	2.884	0.962	0.060	2.729-3.026	I	0.0085	3.11
16	*Pseudoraspora parva*	0.012	2.823	0.901	0.096	2.643-3.008	I	0.0085	3.11
17	*Pseudoraspora parva*	0.006	3.253	0.996	0.058	3.151-3.363	A+	0.0085	3.11
18	*Pseudorasbora parva*	0.007	3.135	0.981	0.076	2.970-3.256	I	0.0085	3.11
19	*Gambusia holbrooki*	0.012	3.063	0.753	0.160	2.664-3.406	I	0.0087	3.32
20	*Gambusia holbrooki*	0.009	3.270	0.956	0.084	3.183-3.559	A+	0.0087	3.32
21	*Lepomis gibbosus*	0.008	3.491	0.950	0.103	3.199-4.013	A+	0.0120	3.18
22	*Lepomis gibbosus*	0.013	3.138	0.987	0.027	3.091-3.185	A+	0.0120	3.18
23	*Oncorhynchus mykiss*	0.013	2.970	0.897	0.279	2.325-3.334	I	0.0100	3.02
24	*Onchorhyncus mykiss*	0.014	2.972	0.907	0.301	2.435-4.217	I	0.0100	3.02
25	*Onchorhyncus mykiss*	0.007	3.138	0.980	0.062	3.026-3.252	A+	0.0100	3.02
26	*Onchorhyncus mykiss*	0.018	2.831	0.927	0.084	2.632-3.045	I	0.0100	3.02
27	*Oncorhynchus mykiss*	0.025	2.788	0.990	0.061	2.603-2.999	A-	0.0100	3.02
28	*Onchorhyncus mykiss*	0.018	2.917	0.973	0.139	2.467-3.280	I	0.0100	3.02
29	*Onchorhyncus mykiss*	0.021	2.814	0.967	0.066	2.683-3.001	I	0.0100	3.02

Note. I: Isometric growth; A+: positive allometry: A-: negative allometry; SE: standard error; CI: Confidence intervals

Table 4

Estimated Parameters of Condition Factors and Form Factor for Eight Exotic Fish Species from 29 Populations in Türkiye

ID	Species	Fulton's Condition Factor (K_F)				Relative Condition Factor (K_R)				Mean Condition Factor (K_M)				Form Factor (F_F)
		Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	
1	*Oreochromis niloticus*	1.03	2.18	1.52	0.31	0.67	1.40	1.02	0.20	1.42	1.56	1.49	0.03	0.0159
2	*Coptodon zilli*	1.52	2.09	1.78	0.12	0.84	1.18	1.01	0.07	1.69	1.83	1.77	0.02	0.0190
3	*Carassius auratus*	1.15	1.57	1.33	0.12	0.82	1.17	1.00	0.08	1.23	1.40	1.33	0.05	0.0107
4	*Carassius auratus*	1.02	1.85	1.44	0.22	0.72	1.39	1.01	0.16	1.32	1.49	1.42	0.05	0.0133
5	*Carassius auratus*	1.29	1.86	1.53	0.16	0.85	1.21	1.00	0.10	1.47	1.61	1.53	0.04	0.0171
6	*Carassius gibelio*	1.19	2.53	1.76	0.31	0.77	1.25	1.01	0.09	1.28	2.12	1.75	0.25	0.0193
7	*Carassius gibelio*	1.30	2.02	1.70	0.14	0.76	1.19	1.00	0.08	1.68	1.71	1.70	0.01	0.0172
8	*Carassius gibelio*	1.30	2.04	1.71	0.15	0.77	1.20	1.00	0.09	1.65	1.74	1.71	0.02	0.0173
9	*Carassius gibelio*	1.38	1.82	1.58	0.11	0.90	1.15	1.00	0.07	1.36	1.61	1.58	0.04	0.0135
10	*Carassius gibelio*	1.41	1.94	1.69	0.16	0.88	1.12	1.01	0.06	1.53	1.83	1.68	0.12	0.0182
11	*Carassius gibelio*	0.72	2.21	1.56	0.26	0.47	1.47	1.01	0.17	1.49	1.60	1.54	0.03	0.0159
12	*Carassius gibelio*	1.07	1.84	1.58	0.23	0.89	1.11	1.00	0.07	1.20	1.82	1.58	0.22	0.0190
13	*Carassius gibelio*	1.28	1.90	1.62	0.15	0.79	1.18	1.00	0.09	1.61	1.63	1.61	0.01	0.0161
14	*Carassius gibelio*	0.96	1.82	1.48	0.21	0.65	1.21	1.01	0.14	1.38	1.56	1.46	0.05	0.0159
15	*Pseudoraspora parva*	0.79	1.27	1.01	0.12	0.74	1.29	1.00	0.11	0.97	1.06	1.00	0.02	0.0088
16	*Pseudoraspora parva*	0.61	1.17	0.88	0.10	0.71	1.37	1.01	0.11	0.85	0.92	0.88	0.02	0.0068
17	*Pseudoraspora parva*	0.94	1.14	1.05	0.06	0.95	1.08	0.99	0.04	0.98	1.12	1.05	0.05	0.0137
18	*Pseudorasbora parva*	0.76	1.16	0.89	0.09	0.85	1.26	1.00	0.09	0.84	0.92	0.89	0.02	0.0104
19	*Gambusia holbrooki*	0.69	3.76	1.31	0.49	0.54	3.04	1.05	0.39	1.23	1.30	1.25	0.01	0.0142
20	*Gambusia holbrooki*	0.87	1.60	1.26	0.14	0.70	1.25	1.00	0.10	1.15	1.37	1.26	0.05	0.0214
21	*Lepomis gibbosus*	0.92	2.36	2.00	0.35	0.64	1.29	1.02	0.16	1.29	2.53	1.97	0.24	0.0367
22	*Lepomis gibbosus*	1.31	3.04	1.65	0.23	0.82	1.92	1.01	0.13	1.53	1.81	1.64	0.07	0.0196
23	*Oncorhynchus mykiss*	0.82	1.48	1.22	0.20	0.68	1.22	1.01	0.17	1.20	1.22	1.21	0.01	0.0119
24	*Onchorhyncus mykiss*	1.10	1.86	1.30	0.23	0.85	1.43	1.01	0.18	1.28	1.30	1.29	0.01	0.0128
25	*Onchorhyncus mykiss*	0.86	1.70	1.07	0.19	0.81	1.51	1.01	0.17	0.96	1.14	1.06	0.05	0.0109
26	*Onchorhyncus mykiss*	0.79	1.66	1.06	0.15	0.77	1.60	1.01	0.14	0.99	1.14	1.05	0.03	0.0103
27	*Oncorhynchus mykiss*	1.20	1.71	1.36	0.11	0.86	1.17	1.00	0.06	1.25	1.53	1.36	0.06	0.0128
28	*Onchorhyncus mykiss*	1.31	1.70	1.45	0.12	0.90	1.18	1.01	0.08	1.40	1.55	1.45	0.04	0.0140
29	*Onchorhyncus mykiss*	1.01	1.53	1.26	0.11	0.84	1.21	1.00	0.08	1.19	1.38	1.26	0.04	0.0115

Note. min: minimum; max: maximum; SD: standard deviation

The length-weight relationship parameters depend on food availability, environmental conditions, environmental stress, geographic region, and climatic changes (Matos et al., 2019; Prestes et al., 2019; Sampaio et al., 2019; Oliveira et al., 2020). Our results revealed that the parameters of the exotic fishes collected from Türkiye fall within the range of previous reports (Çetinkaya, 2006; Innal & Erkakan, 2006; Innal, 2012; Tarkan et al., 2015; Çiçek et al., 2021, 2022) indicating that likely inhabit ecosystems that are suitable for them, e.g., cichlid species were discovered in the Mediterranean region during field surveys conducted between 2014 and 2019 due to their preference for tropical climates. In addition, *G. holbrooki* is found in a range of water bodies, demonstrating its high tolerance for aquatic conditions. Other successful exotic fishes such as *C. auratus*, *C. gibelio*, *P. parva*, and *L. gibbosus* were collected in lentic waters and used to release common carps into natural environments for stocking programs, demonstrating that restocking programs are the primary cause of exotic species spread in many Turkish waters.

Fulton's, relative and mean condition factors, and form factors were calculated for the 29 studied populations (Table 4, Figure 1). The values of K_F were in the range of 0.875 (*P. parva*) to 1.973 (*L. gibbosus*) with a mean and median of 1.376 and 1.445, respectively. We found out that Fulton's and mean condition factors were similar. As is seen from Table 4, the values of K_R varied from 0.993 (*P. parva*) to 1.047 (*G. holbrooki*). Le Cren (1951) proposed the relative condition factor (K_R), which is considered changes in form or condition as length increases and assesses an individual's divergence from the sample's average weight for length. The condition factor for all species was found to be high, except for *P. parva* (Table 5). This shows that the studied exotic species have been established successfully, i.e., they are in good condition in the new habitats.

Figure 1

Box Plot of (A) Allometric Co-Efficient b Values, (b) Fulton's Condition Factor (K_F) for 29 Population Belongs to Eight Exotic Fish Species from Türkiye

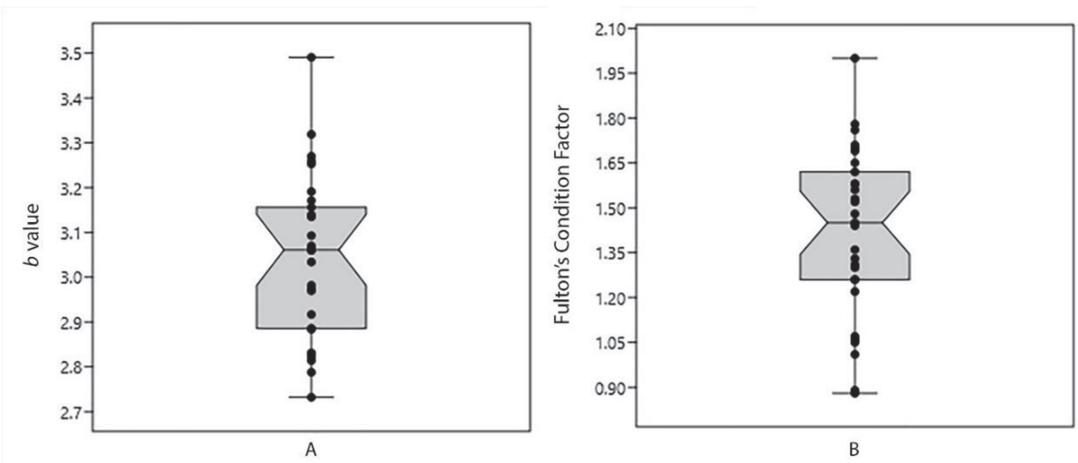

Table 5

Fulton's Condition Factor (K_F) for Eight Exotic Fish Species from Türkiye

Species	Range	Mean	SD
Oreochromis niloticus (n: 1)		1,52	
Coptodon zilli (n: 1)		1,78	
Carassius auratus (n: 3)	1.33-1.53	1,43	0,12
Carassius gibelio (n: 9)	1.48-1.76	1,63	0,09
Pseudoraspora parva (n: 4)	0,88-1,05	0,96	0,08
Gambusia holbrooki (n: 2)	1.26-1.31	1,29	0,04
Lepomis gibbosus (n: 2)	1.65-2.00	1,83	0,25
Oncorhynchus mykiss (n: 7)	1.06-1.45	1,25	0,14

Note. SD: standard deviation; n: number of population

As an example, we compared the condition factor of *C. gibelio* with other coexisting indigenous species in Çıldır Lake (Table 6) to observe their competition with indigenous fishes of this lake. Based on our findings, the highest K_F value was calculated as 1.76 for *C. gibelio* as well as *C. carpio*. There was a strong positive relationship between Fulton's and the mean condition factors. Froese (2006) and Clark (1928) showed that if *b* is not significantly different from 3, K_F can be compared directly. Additionally, to make such comparisons easier, Le Cren (1951) proposed the relative condition factor (*K*R). The values of KR were generally close to 1, showing an overall state of well-being for the studied species. However, the *K*R value of *C. gibelio* is significantly higher than that of other species. Therefore, it can be argued that the condition of the natural species is negatively affected by the occurrence of *C. gibelio*. Indeed, with the introduction of *C. gibelio* to lake Çıldır, the catch composition changed by increasing the catch value of *C. gibelio* and declining those indigenous species sharply (A. Ağbulak, personal communication, August 13, 2014).

Table 6

Condition Factor and Form Factor Values for Sampled Species in Lake Çıldır

Species	O	K_F		K_M		K_R		Form Factor
		Range	Mean	Range	Mean	Range	Mean	
Acanthobrama microlepis	N	0.58-1.11	0.80±0.09	0.73-0.85	0.80±0.03	0.74-1.41	1.00±0.10	0.0084
Alburnoides eichwaldii	N	0.63-1.34	0.96±0.14	0.65-1.16	0.95±0.08	0.79-1.44	1.01±0.12	0.0152
Alburnus filippii	N	0.65-0.92	0.77±0.07	0.72-0.85	0.77±0.03	0.83-1.18	1.00±0.09	0.0087
Capoeta capoeta	N	0.63-1.58	0.91±0.13	0.80-1.02	0.90±0.04	0.69-1.60	1.01±0.14	0.0087
Luciobarbus mursa	N	0.74-1.33	1.01±0.13	0.95-1.05	1.00±0.02	0.75-1.32	1.00±0.13	0.0103
Squalius turcicus	N	0.79-1.44	1.11±0.11	0.98-1.21	1.09±0.05	0.71-1.24	1.01±0.09	0.0111
Cyprinus carpio	T	0.94-2.48	1.76±0.34	1.56-2.02	1.73±0.09	0.57-1.49	1.02±0.20	0.0165
Carassius gibelio	E	1.19-2.53	1.76±0.31	1.13-1.48	1.33±0.10	0.99-1.74	1.32±0.15	0.0140
Pseudoraspora parva	E	0.79-1.27	1.01±0.12	0.97-1.06	1.00±0.02	0.74-1.29	1.00±0.11	0.0088

Note. O: Occurrence; N: Natural; T: Translocated; E: Exotic; K_F: Fulton's Condition Factor; K_R: Relative Condition Factor; K_M: Mean Condition Factor

Therefore, the possible impacts of the introduced fishes on the native fish biodiversity in Türkiye are yet unknown and further research is crucial.

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Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Türkiye'de Bulunan Sekiz Egzotik Balık Türünün Boy-Ağırlık İlişkisi ve Kondisyon Faktörü

Bu çalışma egzotik balık türlerinin bazı popülasyon dinamiği parametrelerinin belirlenmesi amacıyla yapılmıştır. Bu kapsamda örnekler 2014, 2015, 2017, 2018 ve 2019 yıllarında Türkiye'deki 10 farklı havzadan (Batı ve Doğu Akdeniz, Çoruh, Seyhan, Aras, Asi, Doğu Karadeniz, Fırat, Konya ve Kuzey Ege) toplanmıştır. Örnekler, Tarım ve Orman Bakanlığı Su Yönetimi Genel Müdürlüğünün finansal desteği ile gerçekleştirilmiş olan iki projenin (Project on Establishment of Ecological Assessment System of Water Quality Specific for Türkiye" ve "Project on Establishment of Reference Monitoring Network in Türkiye) alan çalışmaları esnasında toplanmıştır.

Örnekleme çalışmaları akarsularda elektroşoker (SAMUS 1000) ile durgun su ekosistemlerinde ise uzatma ağları (12 farklı göz açıklığına sahip) kullanılarak yapılmıştır. Toplanan örnekler %4'lük formaldehit solüsyonu içerisinde muhafaza edilerek laboratuvara taşınmıştır. Laboratuvarda muhafaza edilen örnekler bir gün süre ile çeşme suyu altında tutulduktan sonra total boy 0,1 cm ve total ağırlık ise 0,01 g hassasiyetle belirlenmiştir. Örneklemeler sonucunda *Oreochromis niloticus*, *Coptodon zillii*, *Carassius auratus*, *C. gibelio*, *Pseudorasbora parva*, *Gambusia holbrooki*, *Lepomis gibbosus* ve *Oncorhynchus mykiss* türlerinin bulunduğu sekiz egzotik balık türüne ait 29 populasyondan incelenen toplam 1958 adet birey için boy-ağırlık ilişkileri (L-WRs) ve kondisyon faktörü değerleri hesaplanmıştır. Boy-ağırlık ilişkisi sabitlerinden *b* değerinin 2,732 (*C. auratus*) ile 3,319 (*C. gibelio*) arasında değişim gösterdiği belirlenmiş olup çalışılan populasyonlar için ortalama ve ortanca değerler sırasıyla 3,013 ve 3,047 olarak hesaplanmıştır. Regresyon analizi sonucunda boy-ağırlık değerleri arasında yüksek bir pozitif ilişki belirlenmiş olup R^2 değeri 0,753 ile 0,998 arasında bulunmuştur. Fulton'un kondisyon faktörü değerinin 0,882 (*P. parva*) ile 2,002 (*L. gibbosus*) arasında değişim gösterdiği belirlenmiş ve ortalama ve ortanca değerler sırasıyla 1,397 ve 1,453 olarak hesaplanmıştır. Fulton'un kondisyon faktörü değerleri ile ortalama ve nispi kondisyon faktörü değerlerinin de benzer bir özellik sergilediği görülmüştür. Hesaplanan değerlere bakıldığında *P. parva* dışında diğer tüm egzotik türlerin kondisyon değerlerinin oldukça yüksek olduğu ortaya çıkmaktadır.

Bunun yanı sıra Çıldır Gölü'nde egzotik balık türleri ile birlikte yaşadıkları yerli türlerin kondisyon faktörü değerleri karşılaştırılmıştır. Karşılaştırma sonucunda yerli türlere göre *C. gibelio*'nun türünün en yüksek kondisyon faktörü değerine sahip olduğu belirlenmiştir. Çıldır Gölünde tespit edilmiş olan *P. parva*'nın kondisyon faktörünün ise bazı doğal türlerden yüksek olsa da genelde benzer olduğu görülmüştür. Bu durum yerli türlerin büyümeleri üzerinde *C. gibelio*'nun olumsuz etkilere sahip olduğunun işareti olarak değerlendirilebilir. Türkiye'de yerli balık çeşitliliği ile tanıştırılan yabancı türlerin etkileri hala bilinmemekte olup bu alanda çalışmalar yapılması kritik önem taşımaktadır.