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Condition, Length-Length and Length-Weight Relationships for Four Introduced Freshwater Fish Species from an Island Ecosystem (Gökçeada, Turkey)

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Abstract: The present study aims to investigate the condition, length-weight (LWRs) and length-length relationships (LLRs) of four introduced freshwater fish species (*Carassius gibelio*, *Cyprinus carpio*, *Gambusia holbrooki*, and *Pseudorasbora parva*) inhabited in the inland waters of Gökçeada (Çanakkale, Turkey). Fish samples were collected using electroshocker from one lentic (Büyük Stream) and four lotic (Aydıncık, Dereköy, Gökçeada, and Uğurlu Reservoirs) ecosystems in September 2019, April 2020, May, 2020, and July 2020. The calculated values of parameter *b* in the LWRs were 3.275 and 3.230 for *G. holbrooki* (Uğurlu and Büyük populations, respectively), 3.031 and 2.937 for *C. carpio* (Aydıncık and Dereköy populations, respectively), 3.129 for *C. gibelio* and 3.047 for *P. parva*. Values of Fulton's condition factor (K) varied between 1.72 ± 0.23 (*P. parva*, Gökçeada population) and 3.60 ± 0.33 (*C. carpio*, Dereköy population). The coefficients of correlation (r) for all the LLR equations were greater than 0.95 and significantly linear. The present study provides the first knowledge about the selected biological parameters for four introduced freshwater fish species in Gökçeada.

Keywords: Biological traits, inland waters, insular ecosystem, non-native species.

Bir Ada Ekosistemindeki (Gökçeada, Türkiye) Dört Aşılanmış Tatlısu Balığı Türünün Kondisyon, Boy-Boy ve Boy-Ağırlık İlişkileri

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Öz: Bu çalışma, Gökçeada (Çanakkale, Türkiye) içsularında yaşayan dört aşılanmış tatlısu balığı türünün (*Carassius gibelio*, *Cyprinus carpio*, *Gambusia holbrooki* ve *Pseudorasbora parva*) kondisyon, boy-ağırlık ilişkileri (BAİ) ve boy-boy ilişkilerini (BBİ) incelemeyi amaçlamaktadır. Balık örnekleri Eylül 2019, Nisan 2020, Mayıs 2020 ve Temmuz 2020 aylarında bir lentik (Büyük Dere) ve dört lotik (Aydıncık, Dereköy, Gökçeada, ve Uğurlu Baraj Gölleri) ekosistemden elektroşok cihazı kullanılarak toplanmıştır. BAİ kullanılarak hesaplanan *b* parametresi değerleri *G. holbrooki* için 3,275 ve 3,230 (sırasıyla Uğurlu ve Büyük populasyonları), *C. carpio* için 3,031 and 2,937 (sırasıyla Aydıncık ve Dereköy populasyonları), *C. gibelio* için 3,129 ve *P. parva* için 3,047'dir. Fulton'un kondisyon faktörü (K) değerleri 1,72 ± 0,23 (*P. parva*, Gökçeada populasyonu) ile 3,60 ± 0,33 (*C. carpio*, Dereköy populasyonu) arasında değişiklik göstermiştir. Tüm BBİ denklemleri için korelasyon katsayıları (r) 0,95'ten büyük ve önemli ölçüde doğrusal olarak belirlenmiştir. Bu çalışma, Gökçeada'da tespit edilen dört aşılanmış tatlısu balığı türü için seçilen biyolojik parametreler hakkındaki ilk bilgileri sağlamaktadır.

Anahtar kelimeler: Ada ekosistemi, biyolojik özellikler, doğal olmayan tür, içsular.

INTRODUCTION

Biological invasions are natural events and essentially point out range expansions of species into novel environments (Censky et al., 1998). One of the events for underlying biological invasions is an introduction of non-native species into new areas either intentionally or unintentionally (Copp et al., 2005). When these introductions are accomplished and end up with biological invasions, they have the possible to lead significant

economic and biodiversity losses, such as been sighted globally (Pimentel et al., 2005). Successful biological invasions include complicated relationships between the introduced species and the physical and/or biological traits of the novel environments (Hayes & Barry, 2008). It is important to determine some biological indices (e.g. condition factor, and length-weight relationships) and to evaluate these indices in order to track the invasion success of introduced species. The success of introduced fish species has been correlated with the spatial variability of life-history traits (Havel et al., 2005). Such variabilities support introduced species due to higher toleration to changes in biological indices and plasticity of life-history traits such as condition factor and length-weight relationships (Marchetti et al., 2004).

Condition factors (K), length-length relationships (LLRs), and length-weight relationships (LWRs) are significant instruments in fish biology, ecology, fisheries management, and conservation (Froese, 1998). Condition factors (K) are widely utilized for measuring the condition, fatness, or well-being of fish (Tesch, 1971). Fish condition is a cursor of recent physical and biological states (Le Cren, 1951), therefore, the condition factor ensures significant knowledge about present and future population success with its relationship via growth, reproduction, and survival. Length-weight relationships (LWRs) can be used to change the length to weight and the opposite. Length can be detected more readily than weight during the field surveys. Thus, weight can be determined after field surveys using LWR. Furthermore, LWR is helpful for comparing the life history of an organism in different environments and seasons (Gonçalves et al., 1997) which can be utilized for morphological comparison of species and populations (Petrakis & Stergiou, 1995). Length-length relationships (LLRs) are used for different varieties of fish length measurements in ichthyological explorations. Briefly stated, standard length (SL) is used in taxonomic research, whereas total length (TL) and fork (FL) length are generally utilized for the determination of fish growth (Moutopoulos & Stergiou, 2002). So, it is important to determine these LLRs to be helpful in comparing the results of different studies that use different measurement types in length.

Due to the absence of any native fish species except one species, reservoir ecosystems of Gökçeada are "empty" in terms of native fish species and it is indicated that introduced fish species have successfully filled all these empty niches. Hence, the aim of this study was to identify the K-values, LLRs, and LWRs for four introduced freshwater fish species gibel carp (*Carassius gibelio* Bloch, 1782), common carp (*Cyprinus carpio* Linnaeus, 1758), eastern mosquitofish (*Gambusia holbrooki*, Girard, 1859), and topmouth gudgeon (*Pseudorasbora parva* Temminck & Schlegel, 1846) in the lentic and lotic ecosystems of Gökçeada Island. Growth parameters of the introduced fish species currently living in the inland waters of the island were studied in order to discover the impact of the alterations in the fish composition in view of fish introductions in the inland waters. On the other hand, long-term survey is necessary to track the impacts of alterations in the fish composition on fish populations. The findings of this study would ensure a source for further assessment of the changes in fish growth following deliberately or accidentally introduction of non-native species into the insular ecosystems.

MATERIALS AND METHODS

Fish samples were collected using electrofishing (SAMUS-1000 portable electroshocker; frequency 50-55 Hz) from one lentic (Büyük Stream) and four lotic (Aydıncık, Dereköy, Gökçeada, and Uğurlu Reservoirs) ecosystems of Gökçeada between September 2019 and August 2020 (Figure 1). Data on the sampling sites and sampling dates were listed in Table 1. The map was created using QGIS ver. 3.4 software available from http://qgis.org.

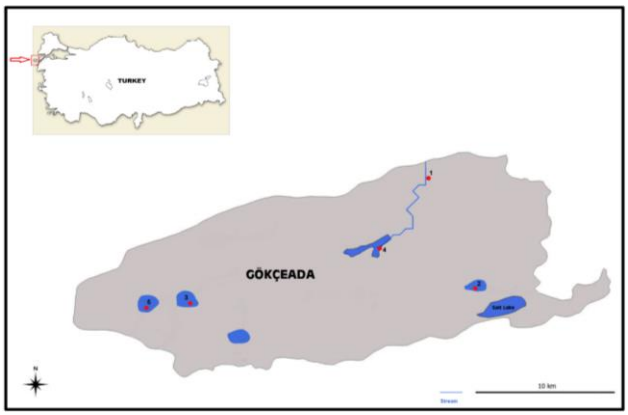

Figure 1. The study area and the sampling stations (1: Büyük Stream, 2: Aydıncık Reservoir, 3: Dereköy Reservoir, 4: Gökçeada Reservoir, 5: Uğurlu Reservoir).

Table 1. Data on the sampling sites and dates of four introduced fish species in Gökçeada.

Sampling Areas			Sampling Dates
Locality	**Locality No**	**Coordinate**	
Büyük Stream	1	40° 13' 24" N, 25° 53' 44" E	September 2019
Aydıncık Reservoir	2	40° 8' 53" N, 25° 55' 42" E	September 2019; May 2020; July 2020
Dereköy Reservoir	3	40° 8' 26" N, 25° 44' 9" E	September 2019; July 2020
Gökçeada Reservoir	4	40° 10' 45" N, 25° 51' 57" E	September 2019; April 2020; May 2020; July 2020
Uğurlu Reservoir	5	40° 8' 12" N, 25° 42' 49" E	September 2019; July 2020

***Statistical Analysis*:** The fish samples were measured for total (TL), fork (FL) and standard length (SL) to the nearest 0.1 cm and weighed for total body weight (W) on a digital balance with a 0.01 g accuracy. The length-weight relationship was calculated using the equation:

$W=aL^b$, where W is the total weight (g), L is the standard length (cm), *a* and *b* are regression parameters (Le Cren, 1951). The equation ($W=aL^b$) was converted into the natural logarithmic form ($lnW=lna+blnSL$)) and parameters *a* (regression intercept) and *b* (slope) were calculated by the regression analysis (King, 2007). 95% confidence intervals (CI) of parameters *a* and *b* were estimated by the equation: $95\%CI=x\pm(t_{0.05}\times SE)$ (x: *a* or *b*; t: table value of t (t-test at 95% confidence); SE: standard error value of *a* or *b*) (King, 2007).

The length-length relationship was calculated using linear regression analysis for being comparable to the results of different studies, which will use different length measures (Gaygusuz et al., 2006). The fish condition was assessed with Fulton's Condition Factor ($K=(W/L^3)\times100$) (Ricker, 1975).

RESULTS

In total, 288 specimens of four introduced fish species were collected from one lentic and four lotic ecosystems of Gökçeada Island (Table 1). The average standard length (SL ± SD) and body weight (W ± SD) of *G. holbrooki* were 1.9 ± 0.4 cm and 0.18 ± 0.12 g for Büyük population and 2.3 ± 0.7 cm and 0.37 ± 0.53 g for Uğurlu population, respectively. For *C. carpio*, the average SL ± SD and W ± SD were 4.5 ± 1.2 cm and 3.84 ± 5.40 g for Aydıncık population, and 4.8 ± 2.5 cm and 8.46 ± 24.20 g for Dereköy population. The average SL ± SD and W ± SD of *C. gibelio* were calculated as 11.8 ± 0.8 and 52.54 ± 12.36 g for Gökçeada population, and they were calculated as 4.7 ± 1.4 cm and 2.18 ± 1.71 g for *P. parva* in the same population. The estimated LWRs and condition factors of four species were listed in Table 2. The calculated values of parameter *b* in the LWRs were 3.230 and 3.275 for *G. holbrooki* (Büyük and Uğurlu populations, respectively), 3.031 and 2.937 for *C. carpio* (Aydıncık and Dereköy populations, respectively), 3.129 for *C. gibelio* and 3.047 for *P. parva* (Figure 2). Fulton's condition factor varied between 1.72 ± 0.23 (*P. parva*, Gökçeada Reservoir population) and 3.60 ± 0.33 (*C. carpio*, Dereköy population). The estimated LLRs of four species were summarized in Table 3. The coefficients of correlation (r) for all the LLR equations were greater than 0.95 and significantly linear.

Table 2. The descriptive statistics, estimated parameters of length-weight relationships and condition factor values of four introduced fish species living in Gökçeada (n: number of individuals, SL: standard length, W: body weight, Min: minimum, Max: maximum, *a:* intercept, *b*: slope, 95% CI: 95% confidence limit, r: coefficient correlation, K: condition factor, SD: standard deviation).

Species	Locality	n	SL, cm	W, g	Regression Parameters		95% CL of *a*	95% CL of *b*	r	K (±SD)
			Min.-Max.	Min.-Max.	*a*	*b*				
Gambusia holbrooki	Büyük Stream	38	1.1 – 3.0	0.02 – 0.56	0.018	3.230	0.016 – 0.021	3.057 – 3.403	0.99	2.14 ± 0.22
	Uğurlu Reservoir	89	1.3 – 5.0	0.03 – 3.40	0.016	3.275	0.015 – 0.018	3.168 – 3.381	0.99	2.02 ± 0.32
Cyprinus carpio	Aydıncık Reservoir	47	2.1 – 10.0	0.28 – 38.74	0.031	3.031	0.025 – 0.038	2.894 – 3.168	0.99	3.27 ± 0.32
	Dereköy Reservoir	51	2.6 – 16.5	0.63 – 162.45	0.039	2.937	0.035 – 0.044	2.863 – 3.010	0.99	3.60 ± 0.33
Carassius gibelio	Gökçeada Reservoir	33	10.4 – 13.9	35.12 – 86.68	0.023	3.129	0.006 – 0.079	2.623 – 3.635	0.92	3.13 ± 0.29
Pseudorasbora parva	Gökçeada Reservoir	30	2.0 – 7.0	0.12 – 6.57	0.016	3.047	0.012 – 0.020	2.889 – 3.204	0.99	1.72 ± 0.23

Table 3. Relationships between total, fork and standard length for four introduced fish species living in Gökçeada (n: sample size, TL: Total length, FL: Fork length, SL: Standard length, *a* and *b* are the parameters of linear regression analysis).

Species	Locality	n	SL = *a* + *b*TL	SL = *a* + *b*FL	FL = *a* + *b*TL
Gambusia holbrooki	Büyük Stream	38	SL = -0.022 + 0.771 TL (r = 0.97)	–	–
	Uğurlu Reservoir	89	SL = -0.094 + 0.815 TL (r = 0.99)	–	–
Cyprinus carpio	Aydıncık Reservoir	47	SL = -0.132 + 0.794 TL (r = 0.99)	SL = -0.130 + 0.887 FL (r = 0.97)	FL = -0.011 + 0.896 TL (r = 0.99)
	Dereköy Reservoir	51	SL = -0.149 + 0.806 TL (r = 0.99)	SL = -0.174 + 0.906 FL (r = 0.99)	FL = 0.026 + 0.890 TL (r = 0.99)
Carassius gibelio	Gökçeada Reservoir	33	SL = 0.755 + 0.732 TL (r = 0.97)	SL = 0.254 + 0.838 FL (r = 0.98)	FL = 0.616 + 0.872 TL (r = 0.98)
Pseudorasbora parva	Gökçeada Reservoir	30	SL = -0.066 + 0.812 TL (r = 0.99)	SL = -0.058 + 0.885 FL (r = 0.99)	FL = -0.008 + 0.918 TL (r = 0.99)

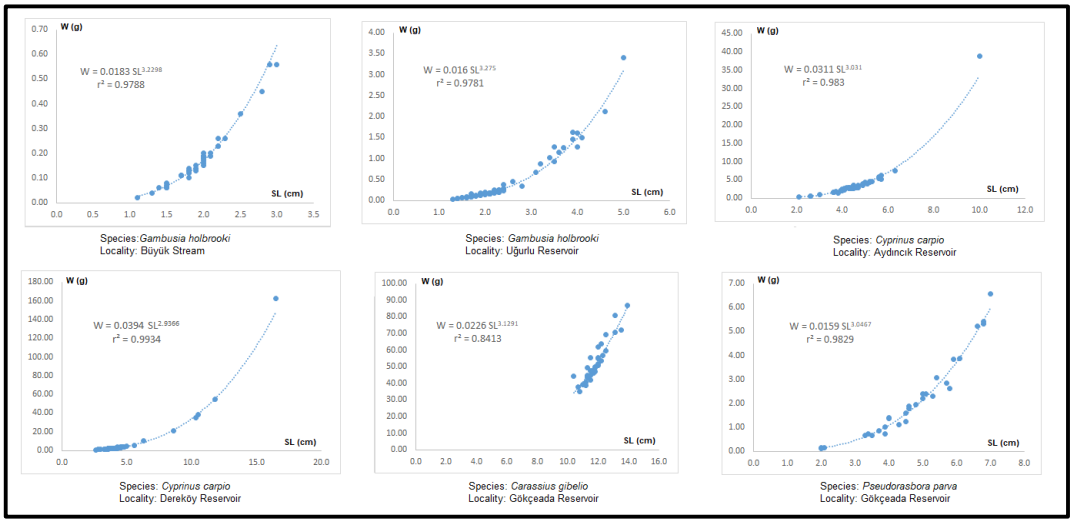

Figure 2. Diagram of the length-weight relationships of four introduced fish species living in Gökçeada inland waters.

DISCUSSION

Biological parameters have been used for ichthyological studies since the beginning of the last century (Froese, 2006) as a basic instrument to evaluate the well-being of species. The parameter of condition factor evaluates the condition of fish and can also be utilized to respectively distinguish and measure the impacts of length condition and other relevant factors (Le Cren, 1951). In the present study, values of K (see Table 2) varied between 1.72 for *P. parva* and 3.60 for *C. carpio* (Dereköy population). The condition factors of examined species found in this study were strikingly higher than the values reported in the previous studies (Table 4). Condition factors of ≥1 show a good status of feeding and suitable environmental factor (Ujjania et al., 2012). The K-values of all examined populations in the present study were ≥1 showing their proper environmental conditions of habitats.

Table 4. The comparison of K and *b* values of the current study and previous studies.

Species	K	References	Species	*b*	References
G. holbrooki	2.02	This study	*G. holbrooki*	3.230	This study
	2.14	This study		3.275	This study
	1.13	Eagderi & Radkhah (2015)		3.230	Öztürk & İkiz (2004)
	1.28	Ergüden & Ergüden (2008)		2.945	İlhan & Sarı (2015)
	1.38	Ergüden (2013)		2.960	Ergüden (2013)
				2.866	Kurtul & Sarı (2020)
C. carpio	3.27	This study	*C. carpio*	2.937	This study
	3.60	This study		3.031	This study
	1.87	Demirkalp (2007)		3.140	Tarkan et al. (2006)
	1.34	Karataş (2007)		3.319	Karataş et al. (2007)
	1.97	Yılmaz et al. (2010)		3.010	Çolakoğlu & Akyurt (2011)
C. gibelio	3.13	This study	*C. gibelio*	3.129	This study
	2.49	Bostancı (2007)		2.856	Birecikligil et al. (2016)
	2.68	Yazıcıoğlu (2013)		2.870	Reis et al. (2019)
				2.571	Ergüden (2015)
P. parva	1.72	This study	*P. parva*	3.047	This study
	0.96	Kırankaya et al. (2014)		3.324	Kırankaya et al. (2014)
	0.95	Arslan & Özeren (2019)		2.867	Benzer et al. (2016)
				3.121	Benzer & Benzer (2020)

In the present study, the coefficient of correlation (r) values for all the LLRs of four introduced fish species were greater than 0.95 (see Table 3) and these results would be useful for comparative growth studies of the same species. On the other hand, the *b* values in LWRs determine the growth type of the fish and when it is 3, the increase in weight is isometric (Bagenal & Tesch, 1978), otherwise it is allometric (positive allometric if $b>3$, negative allometric if $b<3$; see King, 1996). Additionally, this value usually estimated in fishes is within the range of 2.5–3.5 (Froese, 2006). In this study, the estimates of *b* values varied between 2.937 (*C. carpio*, Dereköy population) and 3.275 (*G. holbrooki*, Uğurlu population) for examined fish species (see Table 2) and these values are in the expected range. According to these findings, *C. gibelio, C. carpio,* and *P. parva* showed isometric growth ($b=3$), whereas *G. holbrooki* showed positive allometric growth ($b>3$). When these findings are compared with the results in the literature for the same ecosystems in Turkey, for the examined fish species in this study, the *b* values found in this study was both lower and higher than those reported by different authors (Table 4). Different environmental conditions in the habitat of fish have negative or positive impacts on growth (Nikolsky, 1963). This may clarify same fish species in different habitats can exhibit differences on growth. The other reasons for these differences could be the different TL ranges and different sample sizes (more small or large individuals) of the statistical populations examined in the different researches (Froese, 2006). Additionally, sex, health condition, gonad maturity, and stomach fullness could be thought the other factors that would be effective on these differences.

In conclusion, introduced species are able to survive a broad diversity of environments and adapt to high levels of habitat disruptions, being able to inhabit ecosystems that many other species are incapable to tolerate (Araújo et al., 2003). Thus, introduced species are in good status in terms of condition and other growth parameters. The results of this study stated that introduced species can be survived to different environmental factors by regulating their growth model. On the other hand, this study presented the first information about the selected biological indices (i.e. K and LWR) for four introduced fish species in Gökçeada that would be useful for researchers to better understanding its phenotypic plasticity in lotic and lentic ecosystems of the island.

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REFERENCES

Araujo, F., Fichberg, I., Pinto, B. & Peixoto, M.G. (2003). A preliminary index of biotic integrity for monitoring the condition of the Rio Paraiba do Sul, Southeast Brazil. *Environmental Management*, ***32***, 516-526.

Arslan, P. & Özeren, S. (2019). Growth biology of the topmouth gudgeon (*Pseudorasbora parva*) from Lake Mogan (Ankara, Turkey). *Ankara Üniversitesi Çevrebilimleri Dergisi*, **7**(1), 47-55.

Bagenal, T.B. & Tesch, F.W. (1978). Age and growth. In: Bagenal, T. (Ed), *Methods for assessment of fish production in fresh waters*, 3rd ed., 101-136p, Blackwell Scientific Publications, Oxford, UK.

Benzer, S., Benzer, R. & Gül, A. (2016). Developments in Science and Engineering. In: Efe, R., Matchavariani, L., Yaldır, A. & Levai, L. (Ed). *Artificial neural network applications for biological systems the case study of Pseudorasbora parva*, 53-62p, St. Kliment Ohridski University Press Sofia.

Benzer, S. & Benzer, R. (2020). Growth properties of *Pseudorasbora parva* in Süreyyabey Reservoir: Traditional and artificial intelligent methods. *Thalassas*, **36**, 149-156. DOI: 10.1007/s41208-020-00192-1

Birecikligil, S.S., Çiçek, E., Öztürk, S., Seçer, B. & Celepoğlu, Y. (2016). Length-length, length-weight relationship and condition factor of fishes in Nevşehir Province, Kızılırmak River Basin (Turkey). *Acta Biologica Turcica*, ***29***(3), 72-77.

Bostancı, D. (2007). Bafra Balık Gölü'nde yaşayan havuz balığı, *Carassius gibelio* (Bloch, 1782)'nun kondisyon faktörü ve boy-ağırlık ilişkisinin belirlenmesi. *Süleyman Demirel Üniversitesi Fen Edebiyat Fakültesi Fen Dergisi*, ***2***(2), 117-125.

Censky, E.J., Hodge, K. & Dudley, J. (1998). Over-water dispersal of lizards due to hurricanes. *Nature*, **395**, 556. DOI: 10.1038/26886

Copp, G.H., Bianco, P.G., Bogutskaya, N.G., Eros, T., Falka, I., Ferreira, M.T., Fox, M.G., Freyhof, J., Gozlan, R.E., Grabowska, J., Kováč, V., Moreno-Amich, R., Naseka, A.M., Peňáz, M., Povž, M., Przybylski, M., Robillard, M., Russell, I.C., Stakenas, S., Šumer, S., Vila-Gispert, A. & Wiesner, C. (2005). To be, or not to be, a non-native freshwater fish? *Journal of Applied Ichthyology*, ***21***(4), 242-262. DOI: 10.1111/j.1439-0426.2005.00690.x

Çolakoğlu, S. & Akyurt, İ. (2013). Bayramiç Baraj Gölü'ndeki (Çanakkale) aynalı sazan (*Cyprinus carpio* L., 1758) balıklarının populasyon yapısı ve büyüme özellikleri. *Istanbul University Journal of Fisheries & Aquatic Sciences*, ***26***(2), 27-46.

Demirkalp, F.Y. (2007). Growth characteristics of carp (*Cyprinus carpio* L., 1758) in Liman Lake (Samsun, Turkey). *Hacettepe Journal Biology and Chemistry*, ***35***, 1-8.

Eagderi, S. & Radkhah, A. (2015). Length-weight relationship and condition factor of Mosquitofish (*Gambusia holbrooki*) in three inland basins of Iran. *Poeciliid Research*, ***5***(1), 39-43.

Ergüden, S.A. & Ergüden, D. (2008). A preliminary research on growth features of the mosquitofish *Gambusia affinis* (Baird & Girard, 1853) determined in Seyhan Dam Lake (Adana-Turkey). *Journal of FisheriesSciences.com*, ***2***(3), 312-320. DOI: 10.3153/jfscom.mug.200718

Erguden, S.A. (2013). Age, growth, sex ratio and diet of eastern mosquitofish *Gambusia holbrooki* Girard, 1859 in Seyhan Dam Lake (Adana/Turkey). *Iranian Journal of Fisheries Sciences*, ***12***(1), 204-218.

Ergüden, S.A. (2015). Age and growth properties of prussian carp, *Carassius gibelio* (Bloch, 1782) living in the middle basin of Seyhan River in Adana, Turkey. *Pakistan Journal of Zoology*, ***47***, 1365-1371.

Froese, R. (1998). Length-weight relationships for 18 less-studied fish species. *Journal of Applied Ichthyology*, ***14***(1-2), 117-118. DOI: 10.1111/j.1439-0426.1998.tb00626.x

Froese, R. (2006). Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. *Journal of Applied Ichthyology*, ***22***(4), 241-253. DOI: 10.1111/j.1439-0426.2006.00805.x

Gaygusuz Ö., Gürsoy Ç., Özuluğ M., Tarkan A.S., Acıpınar H., Bilge G. & Filiz, H. (2006). Conversions of total, fork and standard lenght measurements based on 42 marine and freshwater fish species. *Turkish Journal of Fisheries and Aquatic Sciences*, ***6***, 79-84.

Gonçalves, J.M.S., Bentes, L., Lino, P.G., Ribeiro, J., Canario, A.V.M. & Erzini, K. (1997). Weight-length relationships for selected fish species of the small-scale demersal fisheries of the south and south-west coast of Portugal, *Fisheries Research*, ***30***, 253-256.

Havel, J.E., Lee, C.E. & Zanden, M.J.V. (2005). Do reservoirs facilitate invasions into landscapes? *BioScience*, ***55***, 518-525.

Hayes, K.R. & Barry, S.C. (2008). Are there any consistent predictors of invasion success? *Biological Invasions*, ***10***, 483-506. DOI: 10.1007/s10530-007-9146-5

İlhan, A. & Sarı, H.M. (2015). Length-weight relationships of fish species in Marmara lake, west Anatolia, Turkey. *Croatian Journal of Fisheries*, ***73***(1), 30-32. DOI: 10.14798/73.1.784

Karataş, M., Çiçek, E., Başusta, A. & Başusta, N. (2007). Age, growth and mortality of common carp (*Cyprinus carpio* Linneaus, 1758) population in Almus Dam Lake (Tokat- Turkey). *Journal of Applied Biological Sciences*, ***1***(3), 81-85.

Kırankaya, Ş.G., Ekmekçi, F.G., Özdilek, Ş.Y., Yoğurtçuoğlu, B. & Gençoğlu, L. (2014). Condition, length-weight and length-length relationships for five fish species from Hirfanli Reservoir, Turkey. *Journal of*

FisheriesSciences.com, ***8***(3), 208-213. DOI: 10.3153/jfscom.201426

King, R.P. (1996). Length-weight relationship of Nigeria freshwater fishes. *Naga*, ***19***(3), 49-53.

King, M. (2007). *Fisheries Biology, Assessment and Management*, 2nd ed., Blackwell Scientific Publications, Oxford, UK, 382p.

Kurtul, I. & Sarı, H. (2020). Length-weight relationships of invasive mosquitofish *Gambusia holbrooki* Girard, 1859 in 23 river basins of Turkey. *Turkish Journal of Zoology*, ***44***(4), 324-334. DOI: 10.3906/zoo-2002-37

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***, 201-218.

Marchetti, M.P., Light, T., Moyle, P.B. & Viers, J.H. (2004). Fish invasions in California watersheds: testing hypotheses using landscape patterns. *Ecological Applications*, ***14***, 1507-1525.

Moutopoulos, D.K. & Stergiou, K.I. (2002). Length-weight and length-length relationships of fish species from the Aegean Sea (Greece). *Journal of Applied Ichthyology*, ***18***(3), 200-203. DOI: 10.1046/j.1439-0426.2002.00281.x

Nikolsky, G.V. (1963). *The ecology of fishes*. Academic Press, London, UK, 352p.

Öztürk, Ş. & Ikiz, R. (2004). Some biological properties of mosquitofish populations (*Gambusia affinis*) living in inland waters of the Western Mediterranean Region of Turkey. *Turkish Journal of Veterinary and Animal Sciences*, ***28***(2), 355-361.

Petrakis, G. & Stergiou, K.I. (1995). Weight-length relationships for 33 fish species in Greek waters. *Fisheries Research*, ***21***(3-4), 465-469. DOI: 10.1016/0165-7836(94)00294-7

Pimentel, D., Zuniga, R. & Morrison, D. (2005). Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics*, **52**(3), 273-288. DOI: 10.1016/j.ecolecon.2004.10.002

Reis, İ., Cerim, H. & Ateş, C. (2019). Length-weight relationship of 13 fish species from the Lower Sakarya River, Turkey. *Aquatic Sciences and Engineering*, **34**(3), 86-89. DOI: 10.26650/ase2019566636

Ricker, W.E. (1975). *Computations and interpretation of biological statistics of fish populations*. Bulletin of the Fisheries Research Board of Canada, Ottawa, CA, 382p.

Tarkan, A.S., Gaygusuz, Ö., Acipinar, H., Gürsoy, Ç. & Özuluğ, M. (2006). Length-weight relationship of fishes from the Marmara region (NW-Turkey). *Journal of Applied Ichthyology*, ***22***(4), 271-273. DOI: 10.1111/j.1439-0426.2006.00711.x

Tesch, F.W. (1971). Age and growth. In: Ricker, W.E. (Ed), *Methods for assessment of fish production in fresh waters*, 99-130p, Blackwell Scientific Publications, Oxford, UK.

Ujjania, N. & Kohli, M. (2012). Length-weight relationship and condition factors of Indian major carps (*C. catla, L. rohita* and *C. mrigala*) in Mahi Bajaj Sagar, India. *Research Journal of Biology*, ***2***(1), 30-36.

Yılmaz S., Polat N. & Yazıcıoğlu O. (2010). Length-weight and length-length relationships of (*Cyprinus carpio* L., 1758) in freshwaters of Samsun. *The Black Sea Journal of Sciences*, ***1***, 39-47.

Yazıcıoğlu O., Yılmaz S., Yazıcı R. & Polat N. (2013). Condition factor, length-weight and length-length relationships of *Carassius gibelio* (Bloch, 1782) in Ladik Lake (Samsun, Turkey). *The Black Sea Journal of Sciences*, ***3***, 72-80.