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**ARAŞTIRMA MAKALESİ** **RESEARCH PAPER**

# Length-Weight Relationship of Diamondback Puffer *Lagocephalus guentheri* from the Northeastern Mediterranean Sea

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**Abstract:** The length-weight relationship data is important basic information that helps to compare species between populations and habitats. In this study, we provide detailed information on the length-weight relationships and condition factors of *Lagocephalus guentheri* from the Iskenderun Bay, northeastern Mediterranean Sea. A total of 408 (262 Female, 146 Male) specimens were collected on commercial trawlers by local fishermen caught between December 2022 to December 2023 from Iskenderun Bay. The total length range was 11.0-36.9 cm and 11.2-36.7 cm for females and males, respectively. The total weight values of females and males ranged from 20.30-1080.50 g and 20.50-1012.36 g, respectively. The length-weight relationship of *L. guentheri* was calculated as $W = 0.0098 \times L^{3.2145}$ ($R^2 = 0.9960$) for females, $W = 0.009 \times L^{3.2399}$ ($R^2 = 0.9963$) for males, and $W = 0.0095 \times L^{3.2243}$ ($R^2 = 0.9962$) both sexes. The Fulton's condition factor was observed as 1.2384 for females, 1.2504 for males, and 1.2335 for both sexes. This study is the most recent reference on length-weight relationships and condition factors for *L. guentheri* after correction of species identification. It is very important to determine the population parameters of pufferfish species to shed light on the studies to be carried out to restore the ecological balance in the Mediterranean ecosystem. This study will provide basic information that will be useful for fisheries scientists and managers in the Mediterranean Sea.

**Keywords:** Alien species, *Lagocephalus guentheri*, iskenderun bay, mediterranean sea, pufferfish.

# Kuzeydoğu Akdeniz'den Elmas Sırtlı Kirpi Balığı *Lagocephalus guentheri*'nin Boy-Ağırlık İlişkisi

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**Öz:** Boy-ağırlık ilişkisi verileri, türlerin populasyonlar ve habitatlar arasında karşılaştırılmasına yardımcı olan önemli temel bilgilerdir. Bu çalışmada, kuzeydoğu Akdeniz'de bulunan İskenderun Körfezi'nden *Lagocephalus guentheri'nin* boy-ağırlık ilişkileri ve kondisyon faktörleri hakkında ayrıntılı bilgiler sunuyoruz. Toplam 408 örnek (262 Dişi, 146 Erkek), Aralık 2022 ile Aralık 2023 tarihleri arasında İskenderun Körfezi'nden yerel balıkçılar tarafından avlanan ticari trol teknelerinden toplanmıştır. Toplam boy aralığı dişiler ve erkekler için sırasıyla 11.0-36.9 cm ve 11.2-36.7 cm'dir. Dişilerin ve erkeklerin toplam ağırlıkları sırasıyla 20.30-1080.50 g ve 20.50-1012.36 g arasında değişmektedir. *L. guentheri*'nin boy-ağırlık ilişkisi dişiler için $W = 0{,}0098 \times L^{3.2145}$ ($R^2 = 0.9960$), erkekler için $W = 0.009 \times L^{3.2399}$ ($R^2 = 0.9963$) ve her iki cinsiyet için $W = 0.0095 \times L^{3.2243}$ ($R^2 = 0.9962$) olarak hesaplanmıştır. Fulton'un kondisyon faktörü dişiler için 1.2384, erkekler için 1.2504 ve her iki cinsiyet için 1.2335 olarak gözlemlenmiştir. Bu çalışma, tür tanımlamasının düzeltilmesinden sonra *L. guentheri* için boy-ağırlık ilişkileri ve kondisyon faktörleri üzerine en yeni referanstır. Akdeniz ekosisteminde ekolojik dengenin yeniden sağlanması için yapılacak çalışmalara ışık tutması açısından balon balığı türlerinin popülasyon parametrelerinin belirlenmesi oldukça önemlidir. Bu çalışma, Akdeniz'deki balıkçılık bilimcileri ve yöneticileri için faydalı olacak temel bilgileri sağlayacaktır.

**Anahtar kelimeler:** Akdeniz, balon balığı, *Lagocephalus guentheri*, iskenderun körfezi, yabancı tür.

## INTRODUCTION

The opening of the Suez Canal and the warming of the waters due to climate change are increasing the negative pressure of alien species on the Mediterranean ecosystem day by day (Turan et al., 2016; Turan and Dogdu, 2022; Langeneck et al., 2023). Over 700 species of fish live in the Mediterranean Sea. These include at least 80 non-native migrants from the Red Sea and Indo-Pacific (Gürlek et al., 2016; Turan et al., 2022; Mutlu et al., 2023). The eastern Mediterranean coast of Türkiye is one of the most important stopping points for alien fish species entering the Mediterranean Sea. To date, almost 100 alien fish species have been reported from the coast of Türkiye (Turan et al., 2018; Çinar et al., 2021; Karataş et al., 2021).

Pufferfish have been declared an invasive alien species by the European Alien Species Information Network due to their damage to fisheries and also they were non-commercially important species (Doğdu et al., 2021a). With its strong jaw structure and teeth, it causes great economic damage to small-scale fishermen and is hunted by fishermen. In addition, since it feeds on species of economic importance, it causes serious damage to the stock of native species (Yalnız et al., 2017; Doğdu et al., 2021b). They also cause financial losses by damaging the hunting equipment used in general. Tetrodotoxin (TTX), a potent neurotoxin, is known to be extensively present in the body of the pufferfish species (Kosker et al., 2019). Pufferfish is present in Turkish marine waters and is composed of seven valid species across four genera, namely *Lagocephalus lagocephalus*, *L. guentheri*, *L. sceleratus*, *L. suezensis*, *Sphoeroides pachygaster*, *Torquigener hypselogeneion* and *Tylerius spinosissimus* (Erguden et al., 2017; Turan et al., 2017; Doğdu and Turan, 2021a; Bilecenoğlu and Yokeş, 2022).

The taxonomic status of alien taxa in the Mediterranean Sea is subject to continuous revision in light of the incorporation of new data on species distributions, identification and nomenclature (Vella et al., 2017; Zenetos et al., 2017; Galil et al., 2018; Bilecenoğlu and Yokeş, 2022). According to the results of recent molecular and morphological studies on Tetraodontidae species distributed in the Mediterranean, it was reported that *L. guentheri* was misidentified as *L. spadiceus* (Vella et al., 2017; Zenetos et al., 2017; Giusti et al., 2019; Çinar et al., 2021) and *Torquigener hypselogeneion* was misidentified as *Torquigener flavimaculosus* (Bilecenoğlu and Yokeş, 2022).

The diamondback puffer, *Lagocephalus guentheri* Miranda Ribeiro, 1915 is found from the Indo-Pasific to the Red Sea and Southwest Atlantic. In 2015, the first report of *L. guentheri* from the Mediterranean Sea was reported from Egypt waters (Farrag et al., 2016) and then the presence of the species in Turkey was confirmed with a single record from Çandarlı Bay, İzmir in the northern Aegean Sea (Akyol & Aydın, 2016). After that, *L. guentheri* was recorded a second time in Turkey from Iskenderun Bay (Ergüden et al., 2017).

In fisheries biology, there are several uses of length-weight relationship (LWR) data. As; estimating the weight from the length of the fish with length classes, biomass calculations, calculations of stock assessment models, calculations of condition indices and comparisons of populations (Anderson et al., 1983; Bilge et al., 2017; Ergüden et al., 2023; Doğdu and Turan, 2024). LWR data are essential for assessing the status of fish stocks, providing fundamental information on the condition and growth of fish (Le Cren, 1951; Ricker, 1975). This important basic information helps to compare species between populations and habitats (Ergüden and Doğdu, 2020; Turan et al., 2021; 2023).

In this study, we provide detailed information on the length-weight relationships and condition factors of *Lagocephalus guentheri* from the Iskenderun Bay, northeastern Mediterranean Sea.

## MATERIAL AND METHOD

Specimens were caught between December 2022 to December 2023 from Iskenderun Bay (Figure 1). A total of 408 (262 Female, 146 Male) *L. guentheri* specimens were collected on commercial trawlers by local fishermen (Figure 2). The collected samples were transported to the laboratory in ice in cold transport bags and stored at -21°C until analyses. Species were identified according to Erguden et al. (2017). Once the species had been identified, the total length (to within 0.1 cm) and total weight (to within 0.01 g) of each specimen were measured. The sex of each specimen was determined by macroscopic examination of the gonads. The principles of the Local Ethics Committee have been complied with.

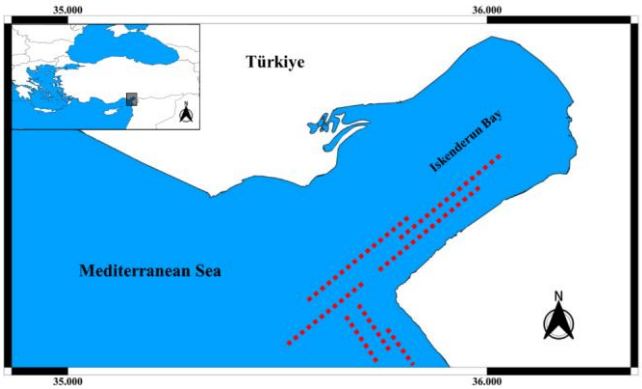


**Figure 1.** Commercial trawling area (red dotted lines) where *L. guentheri* specimens were caught.

The length-weight relationship (LWR) was established following the formula of Ricker (1975):

$W = aL^b$

The abbreviations for the formulation parameters are as follows: $W$ is weight in grams, $L$ is the total length in

centimetres, *b* is the length-weight factor and *a* is a constant. All samples were analysed for the LWR, with separate tests conducted for males and females. Then, the parameters were estimated by linear regression on the transformed equation Ricker (1975):

$$\log\ (W) = \log\ (a) + b\ x \log(L)$$

The parameters a and b were calculated using least-squares regression as the coefficient of determination ($R^2$).

The Fulton's condition factor (K) was calculated following the formula of Sparre and Venema (1992):

$$K = \left(\frac{W}{L^3}\right) x\ 100$$

The abbreviations for the formulation parameters are as follows: *W* is weight in grams, *L* is total length in centimetres. All samples were analysed for the condition factor, with separate tests conducted for males and females.

**Figure 2.** *L. guentheri* samples were collected from Iskenderun Bay.

## RESULTS

In this study, a total of 408 *L. guentheri* specimens were investigated. The total length range was 11.0 - 36.9 cm and 11.2 - 36.7 cm for females and males, respectively. The total weight values of females and males ranged from 20.30-1080.50 g and 20.50-1012.36 g, respectively. For all specimens, the mean total length and total weight were observed as 24.4 ± 6.6 cm and 367.30 ± 249.4 g, respectively (Table 1).

The length-weight relationship of *L. guentheri* was calculated as $W = 0.0098 \times L^{3.2145}$ ($R^2 = 0.9960$) for females (Figure 3), $W = 0.009 \times L^{3.2399}$ ($R^2 = 0.9963$) for males (Figure 4), and $W = 0.0095 \times L^{3.2243}$ ($R^2 = 0.9962$) both sexes (Table 1, Figure 5). The "b" value, which using least-squares regression was higher than "3" for all individuals indicating that this species exhibits positive allometric growth.

The population was composed of 64.21% females (262 specimens) and 35.79% males (146 individuals). The population is dominated by the females (1:1.79). The $\chi 2$ test demonstrated a significant difference between the expected theoretical 1:1 ratio and the observed proportion ($P < 0.001$).

Fulton's condition factor (K) was calculated using the weight. The condition factors were observed as 1.2384 for females, 1.2504 for males, and 1.2335 for both sexes. Condition factor values do not show significant variations ($p>0.001$) for female and male samples.

**Table 1**. Parameters of length-weight relationships of *L. guentheri* for each sex (SD: Standard Deviation).

| Sex | N | ΓL min–max (cm) | Mean TL ± SD (cm) | W min–max (g) | Mean W ± SD | $W = aL^b$ a | b | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| **Female** | 262 | 11.0-36.9 | 24.9±6.58 | 20.30-1080.50 | 373.4±251.04 | 0.0098 | 3.2145 | 0.9960 |
| **Male** | 146 | 11.2-36.7 | 24.5±6.54 | 20.50-1012.36 | 356.52±245.22 | 0.009 | 3.2399 | 0.9963 |
| **Both Sexes** | 408 | 11.0-36.9 | 24.8±6.6 | 20.30-1080.50 | 367.30±249.40 | 0.0095 | 3.2243 | 0.9962 |

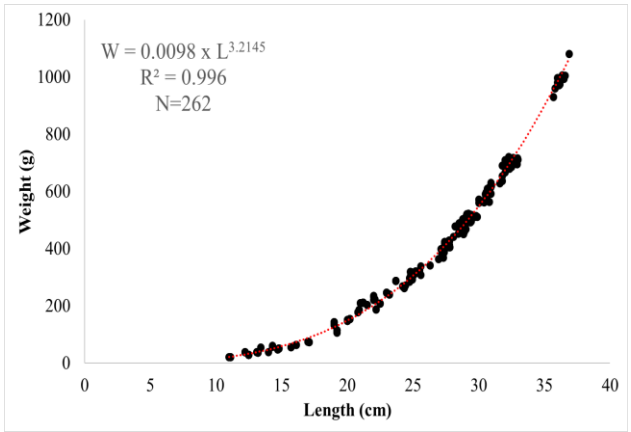


**Figure 3.** Length-weight relationships of *L. guentheri* female specimens.

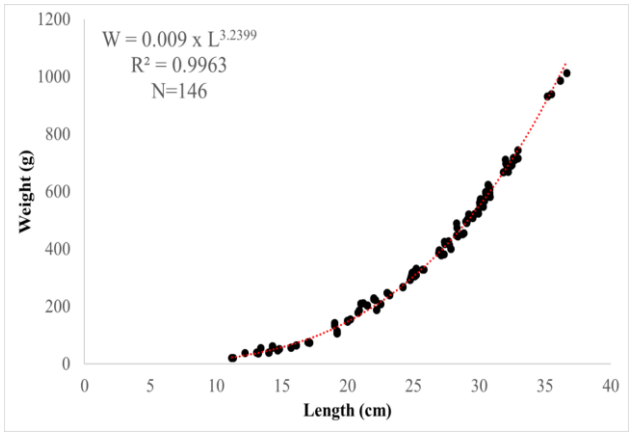


**Figure 4.** Length-weight relationships of *L. guentheri* male specimens.

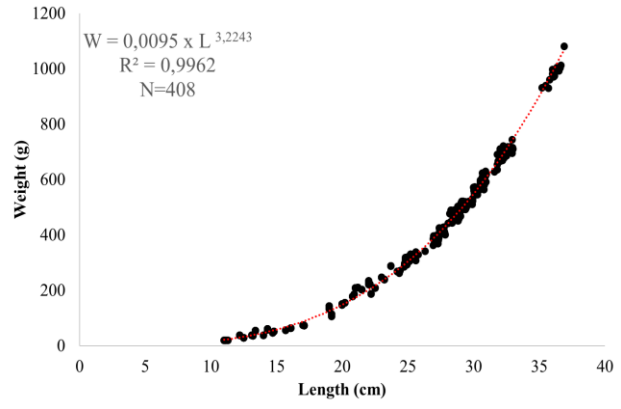


**Figure 5.** Length-weight relationships of all *L. guentheri* specimens.

## DISCUSSION AND CONCLUSION

Non-native fish species have significant negative impacts on human health, biodiversity and fisheries (Çinar et al., 2014). Pufferfish are among the fish species that exhibit these negative effects. (Langeneck et al., 2023; Doğdu et al., 2024). So, it is of great importance to know the biology of invasive species such as pufferfish. Until today, many studies have been carried out on the length-weight relationships of pufferfish distributed in Turkish marine waters (Table 2). This study contributes to bringing the information on the length-weight relationship of the diamondback pufferfish *Lagocephalus guentheri* (misidentified *L. spadiceus*) up to date.

**Table 2.** Previous studies on length-weight relationships of pufferfish distributed on the coast of Türkiye.

| Species | N | a | b | $R^2$ | References |
|---|---|---|---|---|---|
| *Lagocephalus sceleratus* | 27 | 0.0066 | 3.302 | 0.85 | Sangün et al. (2007) |
| *Lagocephalus sceleratus* | 656 | 0.012 | 2.979 | 0.99 | Aydın (2011) |
| *Lagocephalus sceleratus* | 263 | -1.8702 | 3.0028 | 0.993 | Yıldırım (2011) |
| *Lagocephalus sceleratus* | 113 | 0.0228 | 2.9109 | 0.9826 | Tüzün (2012) |
| *Lagocephalus sceleratus* | 545 | 0.0136 | 2.9361 | 0.993 | Irmak (2012) |
| *Lagocephalus sceleratus* | 77 | 0.0293 | 2.7109 | 0.9448 | Başusta et al. (2013a) |
| *Lagocephalus sceleratus* | 208 | 0.012 | 3.021 | 0.989 | Özbay (2015) |
| *Lagocephalus sceleratus* | 997 | 0.0122 | 2.981 | 0.994 | Aydın et al. (2017) |
| *Lagocephalus sceleratus* | 125 | 0.01646 | 2.9272 | 0.974 | Bilge et al. (2017) |
| *Lagocephalus sceleratus* | 69 | 0.0172 | 2.892 | - | Mutlu et al. (2017) |
| *Lagocephalus sceleratus* | 57 | 0.0117 | 2.9646 | 0.9938 | Ayas et al. (2019) |
| *Lagocephalus sceleratus* | 208 | 0.012 | 3.02 | - | Koç et al. (2020) |
| *Lagocephalus sceleratus* | 11 | 0.0304 | 2.649 | 0.9768 | Türker et al. (2020) |
| *Lagocephalus sceleratus* | 100 | 0.0102 | 3.0118 | 0.991 | Zengin and Türker (2020) |
| *Lagocephalus sceleratus* | 1013 | 0.0161 | 2.9140 | 0.954 | Ulman et al. (2021) |
| *Lagocephalus sceleratus* | 751 | 0.0119 | 2.9790 | 0.995 | Ersönmez et al. (2023) |
| *Lagocephalus suezensis* | 86 | 0.0236 | 2.75 | 0.957 | Ergüden et al. ( 2009) |
| *Lagocephalus suezensis* | 1055 | 0.012 | 2.9981 | 0.9957 | Ok (2012) |
| *Lagocephalus suezensis* | 979 | 0.0198 | 2.7946 | 0.858 | Başusta et al. (2013b) |
| *Lagocephalus suezensis* | 15 | 0.0189 | 2.7510 | 0.94 | Yapıcı et al. (2015) |
| *Lagocephalus suezensis* | 150 | 0.0142 | 2.9557 | 0.9608 | Aydın et al. (2017) |
| *Lagocephalus suezensis* | 84 | 0.02138 | 2.7586 | 0.871 | Bilge et al. (2017) |
| *Lagocephalus suezensis* | 196 | 0.0102 | 3.0270 | 0.972 | Ayas et al. (2019) |
| *Lagocephalus suezensis* | 129 | 0.119 | 2.9893 | 0.9859 | Ersönmez (2019) |
| *Lagocephalus suezensis* | 1279 | 0.017 | 2.8900 | 0.95 | Manaşırlı et al. (2020) |
| *Lagocephalus spadiceus* | 19 | 0.0000208 | 2.951 | 0.97 | Taşkavak and Bilecenoğlu (2001) |
| *Lagocephalus spadiceus* | 89 | 0.0204 | 2.901 | 0.943 | Ergüden et al. (2009) |
| *Lagocephalus spadiceus* | 1089 | 0.0364 | 2.6966 | 0.8646 | Başusta et al. (2013a) |
| *Lagocephalus spadiceus* | 78 | 0.0337 | 2.7868 | 0.9826 | Aydın et al. (2017) |
| *Lagocephalus spadiceus* | 117 | 0.03327 | 2.7315 | 0.913 | Bilge et al. (2017) |
| *Lagocephalus spadiceus* | 48 | 0.0301 | 2.7637 | 0.9811 | Ayas et al. (2019) |
| *Lagocephalus spadiceus* | 14 | 0.0215 | 2.888 | 0.984 | Türker et al. (2020) |
| *Torquigener flavimaculosus* | 11 | 0.0403 | 2.9020 | 0.97 | Ergüden et al. (2015) |
| *Torquigener flavimaculosus* | 28 | 0.03761 | 2.8363 | 0.896 | Bilge et al. (2017) |
| *Torquigener flavimaculosus* | 334 | 0.0083 | 3.3267 | 0.9238 | Ayas et al. (2019) |
| *Torquigener flavimaculosus* | 216 | 0.0164 | 3.0656 | 0.9906 | Ersönmez (2019) |
| *Torquigener flavimaculosus* | 504 | 0.013 | 3.0940 | 0.918 | Alagöz-Ergüden et al. (2020) |
| *Torquigener hypselogeneion* | 817 | 0.0165 | 3.0471 | 0.907 | Ulman et al. (2023) |
| *Tylerius spinosissimus* | 6 | 0.0133 | 3.425 | 0.975 | Ergüden et al. (2015) |

The coefficient of determination ($R^2$) for *L. guentheri* was observed as 0.9960 for females, 0.9963 for males and 0.9962 for both sexes. The length-weight relationship (LWR) displayed a strong correlation between the length and weight of the specimens. Human and Al-Busaidi (2008) reported the $R^2$ value of *L. guentheri* at 0.9837 in Oman. Zare et al. (2012) reported the $R^2$ value of *L. guentheri* as 0.978 in Iran. Padmavathi et al. (2017) found of $R^2$ value of *L. guentheri* as 0.83. Taheri Mirghaed et al. (2021) reported an $R^2$ value of *L. guentheri* as 0.981 in the Persian Gulf. Since *L. guentheri* was misidentified in Turkey, *L. spadiceus* was given as the species name in previous studies. Taşkavak and Bilecenoğlu (2001) found of $R^2$ value of *L. spadiceus* as 0.97. Ergüden et al. (2009) reported of of $R^2$ value of *L. spadiceus* as 0.943. Başusta et al. (2013b) found of $R^2$ value of *L. spadiceus* as 0.8646. Aydın et al. (2017) reported of $R^2$ value of *L. spadiceus* as 0.9826. Bilge et al. (2017) found of $R^2$ value of *L. spadiceus* as 0.913. Ayas et al. (2019) reported of $R^2$ value of *L. spadiceus* as 0.9811. Türker et al. (2020) found of $R^2$ value of *L. spadiceus* as 0.984. The study results showed a higher correlation compared to previous studies When we compare with the studies conducted on other puffer fish species in the waters of our country, it is seen that coefficient of determination ($R^2$) results are different in each study but very close to each other (Table 2). These differences can be attributed to various factors such as gonad maturity, gender, nutrition, stomach fullness, health and preservation techniques (Karachle and Stergiou, 2008; Uyan et al., 2024).

The results of growth coefficient values *b* ranged from 3.2145 (females) to 3.2399 (males), and the types of growth are positive allometric. Taşkavak and Bilecenoğlu (2001) found of *b* value of *L. spadiceus* as 2.951. Ergüden et al. (2009) reported of *b* value of *L. spadiceus* as 2.901. Zare et al. (2012) found the *b* value of *L. guentheri* as 2.70. Başusta et al. (2013b) reported of *b* value of *L. spadiceus* as 2.6966. Aydın et al. (2017) reported of *b* value of *L. spadiceus* as 0.7868. Bilge et al. (2017) found of *b* value of *L. spadiceus* as 2.7315. Padmavathi et al. (2017) reported of *b* value of *L. guentheri* as 2.7595. Ayas et al. (2019) found of *b* value of *L. spadiceus* as 2.7637. Türker et al. (2020) found of *b* value of *L. spadiceus* as 2.888. Taheri Mirghaed et al. (2021) reported a *b* value of *L. guentheri* as 2.693. The *b* value is directly related to the body shape of fish and may vary with the habitat and diet (Ricker, 1975). A *b* value close to 3 indicates that the body weight of the fish increases in parallel with the growth in length. Our study showed positive allometric growth. However, previous studies have found negative allometric growth. When we look at other studies conducted in our country, negative allometric growth was generally detected in pufferfish species with a few exceptions; *L. sceleratus* (Sangün et al., 2007; Yıldırım, 2011; Özbay, 2015; Torcu-Koç et al., 2020; Zengin and Türker, 2020), *T. flavimaculosus* (Ayas et al., 2019; Ersönmez, 2019; Alagöz-Ergüden et al., 2020; Ulman et al., 2023), and *T.*

*spinosissimus* (Ergiden et al., 2015). As the body form of pufferfish is fusiform, the *b* values obtained in all studies were close to 3 (Table 2). The minor discrepancies in the *b* values can be attributed to a multitude of factors, including variations in environmental conditions, biological parameters, population size and sampling methodologies e.g. (Ricker, 1975; Doğdu and Turan, 2021b; Ergüden et al., 2023).

The condition factor (K) is an indicator that allows for the assessment of the health and condition of fish, intending to facilitate comparisons in the rates of growth observed across different geographical locations. *K* value exceeding 1 is regarded as an indicator of a robust fish population (Le Cren, 1951). The results of the condition factor analysis revealed values of 1.2384, 1.2504, and 1.2335 for female, male, and both sexes, respectively. These findings indicate that the *L. guentheri* population appears to be in good condition.

In conclusion, this study is the most recent reference on length-weight relationships and condition factors for *L. guentheri* after correction of species identification. It is very important to determine the population parameters of pufferfish species to shed light on the studies to be carried out to restore the ecological balance in the Mediterranean ecosystem. This study will provide basic information that will be useful for fisheries scientists and managers in the Mediterranean Sea.

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