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Regional assessment of important biological indices in the population of red cornetfish (*Fistularia petimba* Lacepède, 1803) along the eastern Mediterranean coasts of Türkiye

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A B S T R A C T

The Lessepsian migrants of the family Fistulariidae, which are widely distributed in the Eastern Mediterranean coasts of Türkiye, are represented by two species, *Fistularia commersonii* and *Fistularia petimba*. This study focused on estimating various biological indices of red cornetfish *Fistularia petimba* Lacepède 1803, eastern Mediterranean coast of Türkiye. The biological indices determined were: FI- Fullness index, HSI-Hepatosomatic index, GSI-Gonadosomatic index, EQ-Encephalization quotient, VSI-Visceral index, IWL-Zihler index, Fulton-K: Fulton-Condition. For this study, 65 red cornetfish specimens (♀:40, ♂:23, immature: 2) caught as by-catch in the nets of commercial trawlers, operating in the study area in the winter of 2021 were studied. The estimated length-weight relationship (LWR) was $W=0.0001L^{3.34}$ (R^2= 0.89) and the species exhibits a positive allometric growth. The mean index (M±SD) and range values calculated from the obtained data are as follows: FI 1.05±0.13 (0.83-1.26); HSI 0.43±0.05 (0.23-0.62); GSI 1.27±0.20 (1.08-1.46); EQ 0.0024±0.0003 (0.0022-0.0025); VSI 3.14±0.39 (2.08-4.20); IWL 12.37±1.54 (4.41-20.3) and Fulton-K 0.47±0.06 (0.43-0.51). According to these results, it can be hypothesized that this Lessepsian species is well established and thrives in the eastern Mediterranean coasts of Türkiye. Although it is evaluated as the least concern category (LC) in the IUCN Red List 2013, we believe that the species has an invasive potential. Therefore, this study, in which biological index parameters were presented for *Fistularia petimba*, may be important in terms of fisheries management, planning measures to reduce distribution and combating invasiveness.

INTRODUCTION

Türkiye's eastern Mediterranean coast is home to vital areas for many Lessepsian species, providing feeding and breeding grounds. Over the years, there has been a significant increase in the number of migrating species, with fish being among the top vertebrate migrants. As of 2021, it is known that 80 non-native fish species are distributed along the Mediterranean coast of Türkiye (Çınar et al., 2021). The family Fistularidae is represented by two species in the Mediterranean: *Fistularia commersonii* Rüppell, 1838 and *Fistularia petimba* Lacepède 1803, which are frequently encountered (Stern et al., 2017; Karan et al., 2019; Ergüden et al., 2023). *F. petimba* is a congeneric species with *F.commersonii*, and its distribution area extends to the western and eastern Atlantic coasts worldwide (Froese and Pauly, 2023). The presence of *F.petimba* in Turkish waters is relatively recent, with the first records reported by Ünlüoğlu et al. (2018) and Çiftçi et al. (2019), respectively. Subsequently, Cerim et al. (2021), provided additional

records in Güllük and Gökova Bays, while Crocetta et al. (2021) provided records in Iskenderun Bay and Bandırma Bay (Marmara Sea). It is essential to gather information about the distribution areas, population densities, interspecific and intraspecific interaction indicators of Lessepsian fish species, regardless of their economic values.

The species *F. petimba* is classified as "Least concern" (LC) on the IUCN Red List (Carpenter et al., 2015). However, further research is needed to fully understand its population structure due to insufficient information. Previous studies have examined the length-weight relationship, condition, determination of reproductive season, feeding composition and values of morphometric and meristic (Ragheb, 2022; Ergüden et al., 2023; Papageorgiou et al., 2023), but temporal and spatial detailed examination of these biological data is also necessary.

This study aims to identify and interpret the key indicators that are closely related to the growth and distribution performance of the species found in the eastern Mediterranean coast of Türkiye (legal fishing ground between Narlıkuyu and Yeşilovacık in Silifke along the coastline of Mersin). These indicators include the visceral index (VSI), fullness index (FI), hepatosomatic index (HSI), gonadosomatic index (GSI), Encephalization quotient (EQ), Zihler index (IWL), Fulton-K, and the length-weight relationship (LWR). Therefore, in this study, we aim to address the lack of data on the species' physical performance as well as to determine the potential effects of current fishing activities on this performance, despite being discard species in trawling processes.

MATERIALS AND METHODS

This study was carried out on 65 specimens of red cornetfish commonly found along the eastern Mediterranean coasts of Türkiye, which were caught as bycatch by commercial trawlers operating in the coastal area of Mersin province during the winter season of 2021 (Figure 1). The specimens were transported to the laboratory under cold chain conditions and stored in the freezer for further analysis. The total length measurements (TL, cm) of the samples were taken using a measuring tape, and the weight measurements (W, g) were taken using a scale with a sensitivity of 0.01 g. The sexes of the dissected specimens were identified through macroscopic examination of the gonads (Figure 2).

The weights of the internal organs were measured separately to determine the following indices: VSI index, HSI index, GSI index, EQ Encephalization Quotient, and FI index. Additionally, the relative gut length (RGL) was used to determine the Zihler's index. To determine the length-weight relationship, the equation $W=aL^b$ (Pauly, 1983) was used, where W represents the body weight in grams, L represents the length in centimetres, a represents the intersection point, and b represents the slope. After converting the data to log_{10}, the values of a and b were determined. While $b=3$ indicates isometric growth, values other than 3 represent allometric growth ($b<3$ negative allometry and $b>3$ positive allometry).

Figure 1. The sampling areas along the coastal area of Mersin province (fishing ground between Narlıkuyu and Yeşilovacık in Silifke) in the eastern Mediterranean, Türkiye

The hepatosomatic index (HSI) was calculated as HSI=100 × Liver weight / body weight (Sulistyo et al., 2000). For the gonadosomatic index (GSI) of mature specimens, the formula GSI= Gonad W (g) / total W (g) × 100 was used, along with the Fulton-K= (100×Wt) / Lt^3 equations (Ricker, 1979). Depending on the weight of the consumed food, the stomach fullness index (FI) was calculated as FI =Full gut W / W × 100 (Hureau, 1969), and the visceral index (VSI) was calculated as VSI = all internal organs W / body W × 100 (Cheng et al., 2005) Encephelization quotient EQ= Brain W(mg) / $(W)^{2/3}$ (Pauly et al., 2011). The relative gut length (RGL) and TL relationship were evaluated according to Zar (1999). In the obtained values, RGL<1 represents carnivorous feeding, 1<RGL< 3 represents omnivorous feeding, and RGL>3 represents herbivorous feeding (Karachle and Stergiou, 2010). The obtained data was evaluated using the Statistica package program. The *student-t* test was used to evaluate index values and determine the statistical difference between sexes. All statistical differences were evaluated according to $p<0.05$.

Figure 2. The red cornetfish, *Fistularia petimba* Lacepède, 1803. (Photographed by S. Bozkaya)

RESULTS

The sample group included 40 females, 23 males, and 2 immature specimens. The length-weight relationships for females, males and all individuals were calculated as $W=0.0006L^{2.93}$ $R^2=0.89$; $W=7e\text{-}06L^{4.08}$ $R^2=0.92$; $W=0.0001L^{3.34}$ $R^2=0.89$, respectively. The findings showed negative allometric growth in females the winter season, while males and all specimens (males+females+immature specimens) showed positive allometric growth as illustrated in Figure 3.

The determination of red cornetfish's stomach fullness index (FI) has been conducted separately for males and females. Upon examining stomach fullness ratios, it was found that approximately 24.62% of females had empty stomachs, 21.54% had full stomachs, and 15.38% had half-full stomachs. In males, these values were determined as 13.85%, 9.23%, and 12.31%, respectively. Empty stomachs were more common (38.5%) depending on season and sample size.

Table shows that although females have a higher index value in terms of average stomach fullness values, the difference is not statistically significant ($t_{(40)}$:0.98, p:0.332, p>0.05). The feeding frequency of females is higher than males, and it was determined that the TL-FI regression relationship is positive in females (FI= 0.0219L+0.186, R^2= 0.056).

Hepatosomatic index values, which reflect changes in liver tissues depending on feeding in the habitat, show that the average HSI value of females is relatively higher than males, but statistically insignificant ($t_{(40)}$: -0.475, p:0.635 p>0.05). Accordingly, the TL-HSI regression relationship is positive in females depending on the increase in body size (HSI= 0.0101L+0.0311 R^2= 0.035).

The Female/Male ratio in the samples is 1:0.57. There was no difference between sexes in terms of GSI values, which represent gonad development during reproduction ($t_{(40)}$: 0.735 p:0.464 p>0.05). According to the TL-GSI regression relationship of females, it is understood that the oocyte production capacity decreases with increasing body size of females (GSI= 0.0716L-2.542 R^2= 0.3062).

The Encephalization quotient values indicating the index of brain development, which have been determined for the first time for *F. petimba*, show higher results in males compared to females although there is no significant variation between the sexes ($t_{(23)}$: -1.111, p: 0.272, p>0.05). In males, there is a low regression in the EQ-TL relationship (EQ = -8E-05L + 0.0064, R^2= 0.147).

The visceral index, which reflects the results of food causing fat accumulation in internal organs, is higher in females than males; however, this does not create any difference between the sexes ($t_{(40)}$: 1.165, p: 0.248, p>0.05). In females, there is a positive regression relationship in the VSI-TL relationship (VSI= 0.0724L + 0.0017, R^2 = 0.297). The Zihler's index values indicate that both males and females show a carnivorous diet tendency (1<RGL), with male individuals having a higher index value than females. However, this does not indicate any statistical difference between the sexes ($t_{(23)}$: -0.737, p: 0.463, p>0.05). In males, there is a positive regression value in the GL-TL relationship (GL= 0.0039L+1.999, R^2 = 0.5792).

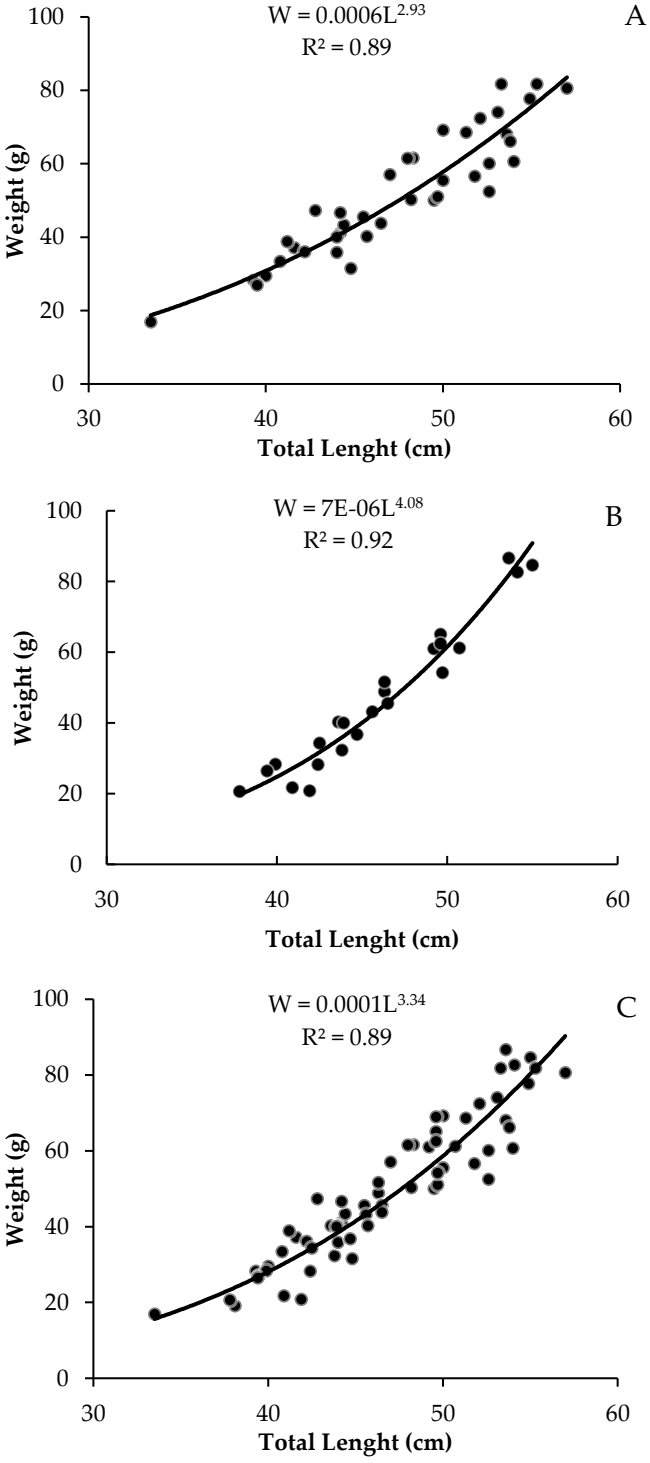

Figure 3. The length-weight relationships of *Fistularia petimba* caught sampling area (A: Female, B: Male, C: All specimens)

Table 1. Biological index results of *Fistularia petimba* (Mean ± SE)

Biological Indexes	Female	Male	All	P
Fullness Index	1.43±0.23	1.05±0.22	1.05± 0.13	p>0.05
Hepatosomatic Index	0.46± 0.07	0.43±0.09	0.43±0.05	p>0.05
Gonadosomatic Index	1.27±0.20	1.16±0.24	-	p>0.05
Encephalization quotient	0.0016±0.0003	0.0024±0.0005	0.0024±0.0003	p>0.05
Visserasomatic Index	4.02±0.64	3.14±0.65	3.14±0.39	p>0.05
Zihler Index	0.03± 0.01	0.05±0.01	0.05±0.01	p>0.05
Fulton- K	0.51±0.08	0.47±0.10	0.47±0.06	p>0.05
Sample size	**40**	**23**	**65**	

Lastly, the Fulton-K condition value, which is an interpretation of the body mass index values of the species in the region, was examined. Although the average condition of females is higher than that of males, the values found do not indicate any statistical difference between the sexes ($t_{(40)}$: 1.23, p: 0.220, p>0.05). In both males and females, the regression is positive, and it is understood that they show a carnivorous diet tendency in the IWL-TL relationship. In females, the TL-Fulton-K relationship was found as Fulton-K = -6E-05L + 0.0502, R^2= 0.003.

DISCUSSION

In this study, we examined the body index values of *F. petimba*, a closely related species to *F. commersonii*, along the coasts of the Eastern Mediterranean. The species was first observed in Spanish coasts in 1996 (Cárdenas et al., 1997), and subsequent studies have been conducted in Israel, Cyprus, and the Eastern Mediterranean coasts (Papageorgiou et al., 2023). When comparing the length-weight relationship calculated in this study with those provided by the existing studies, we concluded that female specimens generally exhibit a larger size and weight in comparison to males, however, no statistically significant difference was observed between the sexes. The length-weight relationship indicates positive allometric growth (*b*=3.34) for all specimens examined, suggesting that the weights of individuals increase as they grow in size. According to Tesh (1971), the values that *b* takes typically range from 2 to 4, often close to 3. In this case, several factors can influence the values that *b* takes. According to Bagenal and Tesch (1978) and Froese (2006), the important factors are as follows: season, habitat structure, sample size, sampling method, physico-chemical parameters, sex, gonad development, food, fish condition, and stomach fullness. According to Froese (2006), when the *b* value is higher than 3.5, it suggests that there is a significant increase in weight relative to the size of the fish. In our study, we found a high *b* value (*b*: 4.08) in the LW relationship of male individuals. This could be because we evaluated a small number of male individuals that were captured and also due to the higher Zihler index value among male specimens, which supports the idea of excessive proportional growth in weight. These findings align with the values given for *F. petimba* along the coasts of Cyprus and the Eastern Mediterranean (Ergüden et al., 2023; Papageorgiou et al., 2023). Actually, when evaluating its distribution on the eastern Mediterranean coasts, it is evident that the species *F. petimba*, similar to *F. commersonii*, has the potential to adapt well to the Mediterranean geography in the future. The studies conducted on the advantages that the eastern Mediterranean coasts offer for *F. petimba* are noteworthy, although they have not presented body index values. *F. petimba* is a carnivorous species, just like *F. commersonii*. The conducted studies have determined that commercially important fish species such as Sparidae and Mullidae (Corsini et al., 2002; Bariche et al., 2009), as well as invertebrate species (Froese and Pauly, 2023), are found in the stomach contents of *F. petimba*. This serves as an important indication that invasive fish species are exerting population pressure on the existing economic species in the region.

In our study, we found that female individuals consumed more prey than males during the winter period when examining stomach contents. The relationship between total length (TL) and fullness index (FI) showed that as the size of females increased, their stomachs were fuller. This suggests that larger females have higher metabolic needs, as discussed by Odum and Odum (1959), indicating a connection between metabolic activity and energetic requirements based on fish size.

We also observed higher values for hepatosomatic index (HSI) and Fulton-K values in females. Therefore, we expect the fish to improve their condition by actively feeding even during the winter season. They will allocate energy towards both gonadal development and metabolic activities using their energy reserves. However, in order to fully confirm this prediction, it would be beneficial to monitor monthly or seasonal index values throughout the year.

Stomach morphology also plays a significant role in the trophic relationships of species. Different methods, including

the analysis of stomach and intestinal contents, are used to determine feeding patterns and trophic positions in animals (Planas, 2022). The visceral index serves as an indicator of the effects of carbohydrates and proteins in the fish's diet on their internal organs (Gurkan et al., 2021). For instance, a high-fat diet can lead to lipid accumulation in internal organs, such as muscles and liver (Imsland et al., 2003). Some pelagic fish, like tuna (Scombridae) and herring (Clupeidae), store glycogen between their muscles for energy purposes (Timur, 2006). In our study, we observed that females have higher index values (mean 4.02) compared to males, and these values (mean 3.14) increase with body size. This suggests that the higher values may be attributed to the metabolic and energetic needs of females (Odum and Odum, 1959). A condition value close to *1* indicates optimal growth conditions for the fish species in the region. When examining the condition values of the *F. petimba* species, it is observed that females generally have a higher condition. The condition of all individuals ranges from 0.47 to 0.51, which is relatively lower compared to the population in İskenderun Bay. However, several factors such as habitat, food composition, sex, sample size, season, and physicochemical parameters influence the variation in these values (Ragheb, 2022; Ergüden et al., 2023). Therefore, in our study, the lack of a sexual difference based on condition between males and females may support this opinion. Encephalization quotient values in the *F. petimba* species show higher results in males, but there is no significant difference between the sexes. This study is the first to determine encephalization quotient values associated with the brain of the *F. petimba* specimens captured from the Turkish coasts.

CONCLUSION

In conclusion, we conducted a pioneering study to determine some sex-related biological parameters and body indices of the *F. petimba* species, which is widely distributed around Taşucu Bay, the eastern Mediterranean coast of Türkiye. In our study, we attempted to correlate the developmental level of the invasive species *F. petimba* with body indices. Although the obtained results are based solely on the winter season, they may help to fill the data gap concerning fish biology. Therefore, besides completing the missing information on the species, it is also important to consider the presented results in the near future for fisheries management.

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COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

This study was derived from the master's thesis titled "*Determination of Biometric Features of Red Cornet, Fistularia petimba Lacepède,1803 in Tasucu Bay (Eastern Mediterranean)*" of the first author, and the contributions of the authors are as follows: **SB:** examination of the specimens in the laboratory, preparation of the article; **SG:** statistical calculations, writing of the article, **ET:** obtaining the specimens, preparing the text for publication.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

The authors declare that formal consent is not required for this type of study. All relevant international, national, and/or institutional guidelines for the care and use of animals were adhered to.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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