MORTALITY AND EXPLOITATION OF MARBLED SPINEFOOT, *SIGANUS RIVULATUS* (ACTINOPTERYGII: PERCIFORMES: SIGANIDAE), FROM SOUTHERN AEGEAN SEA SMALL-SCALE FISHERY

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Cerim H., Soykan O., Gülşahin A. 2020. Mortality and exploitation of marbled spinefoot, *Siganus rivulatus* (Actinopterygii: Perciformes: Siganidae), from southern Aegean Sea small-scale fishery. Acta Ichthyol. Piscat. 50 (2): 183–190.

Background. In the small-scale fisheries of the Gulf of Gökova (Turkish coast of the southern Aegean Sea) the marbled spinefoot, *Siganus rivulatus* Forsskål et Niebuhr, 1775, is a commercially important species. No sustainability study, however, has been carried out on the stock assessment and management of this species in the gulf. The aim of the presently reported study was to determine the mortality and biological reference points of *Siganus rivulatus* and suggest a proper fishery management plan for fishery regulations.
Materials and methods. The sudy was conducted between July 2016 and June 2018. Fish samples were collected from the Gulf of Gökova small-scale fishery. The total mortality (Z), natural mortality (M), fishing mortality (F_{curr}), and exploitation rate (E_{curr}) were determined and compared with the biological reference points: the optimum fishing mortality (F_{opt}), fishing mortality limit reference point (F_{lim}), optimum exploitation rate (E_{opt}).
Results. Total mortality (Z), natural mortality (M), fishing mortality (F_{curr}), and exploitation rate (E_{curr}) were found to be 0.67, 0.32, 0.35, and 0.52, respectively. Furthermore, biological reference points (F_{opt}, F_{lim}, E_{opt}) attained values of 0.16, 0.21, and 0.33 cm, respectively.
Conclusion. The fishing pressure for *Siganus rivulatus* stocks the Gulf of Gökova should decrease for the sake of the sustainability of this resource.

Keywords: Lessepsian fishery, small-scale fishery, fisheries management, sustainability, Aegean Sea

INTRODUCTION

The family Siganidae, known also as rabbit fishes, includes 29 species. *Siganus rivulatus* Forsskål et Niebuhr, 1775, known as marbled spinefoot, is one of the Lessepsian invaders in the Mediterranean basin. It occurs mostly in the western Indian Ocean, several localities in east Africa, stretching from the Red Sea to the eastern Mediterranean via the Suez Canal (Froese and Pauly 2019). Marbled spinefoot is one of the two siganid species, together with *Siganus luridus* (Rüppell, 1829) occurring along the Turkish coast. *Siganus rivulatus* was first collected in the Mediterranean in 1924 off the coast of Israel (Steinitz 1927), reaching southern Turkey in 1942 (Papaconstantinou 1990) and the Marmara Sea in 2011 (Artüz and Koç 2012).

The marbled spinefoot is a commercial species and it is captured by spears, gillnets, beach seines, small-mesh nets, cast nets, seine nets, traps, and baited hooks and lines (Anonymous 2019b). The global landings of siganids were 86 229 t in 2015 including data from the eastern and western Indian Ocean, Mediterranean Sea, and the western central Pacific (Anonymous 2019a). *Siganus rivulatus* is one of the target species of small-scale (gill nets) and recreational (baited hooks, pots, and traps) fisheries. Although *Siganus rivulatus* and *Siganus luridus* have been marketed for many years especially in the Mediterranean and the southern coast of the Aegean Sea, Turkey, there are no official catch and landings data in Turkey for those species.

Marbled spinefoot, due to its marketable status, has been in the center of scientific attention in the Red Sea and the southern Mediterranean. Ben-Tuvia (1986) and Hussein (1986), focused on the reproduction of the species in the Red Sea. Feeding habits of *Siganus rivulatus*, in the Mediterranean, were reported by Lundberg and Lipkin (1993) and Bariche (2006). Although many studies focused on the mortality and yield per recruit of marbled spinefoot from other locations of the Mediterranean (El-Gammal

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1988, Mohammed 1991, El-Ganainy and Ahmed 2002, Mehanna and Abdallah 2002, Bariche 2005, Gabr et al. 2018, El-Far unpublished*, El-Okda unpublished**) there has been no research regarding the above-mentioned topics on the Turkish coast. Only two studies for Turkish marine waters, including data on the growth and reproduction of the species, were conducted by Bilecenoglu and Kaya (2002) and Yeldan and Avşar (2000) who studied the Mediterranean coast. Therefore, the information regarding the mortality, exploitation, percentage in catch composition, etc. of *Siganus rivulatus* is urgently needed for the Aegean Sea due to the ongoing northward expansion of the species.

The goal of the presently reported study was to determine the mortality and biological reference points of marbled spinefoot from the Turkish coast of the southern Aegean Sea, which would be the first such study in Turkish marine waters. The results of the study may contribute to the proper management of the invasive marbled spinefoot in Turkey.

MATERIAL AND METHOD

Sampling. The study was conducted between July 2016 and June 2018 with 721 samples collected monthly from the small-scale fishery in the Gulf of Gökova, south-eastern Aegean Sea (Fig. 1). Trammel nets, fish traps, and fishing lines were used to obtain various length classes of *Siganus rivulatus*. The fish were captured from the depth range of 1–20 m.

Data analysis. Growth coefficient (K), asymptotic, length (L_{inf}), theoretical age at a length of zero (t_0), length at maturity for sexes (L_m) (the total length at which 50% of individuals are mature), and the water temperature (T) were 0.162 year^{-1}, 27.7 cm, –0.10 year, 16.60 cm (female), 16.84 cm (male), and 19.0°C, respectively (Soykan et al. 2020). A length-converted catch curve was used to estimate total mortality (Z) (Pauly 1983). The natural mortality (M) was calculated according to seven different models; Pauly-I (Pauly 1980), Djabali et al. (1993), Ralston-I (Ralston 1987), Ralston-II (Pauly and Binohlan 1996), Pauly-II (Pauly and Binohlan 1996), Frisk et al. (2001), and Cubillos et al. (1999). However, these parameters lead to two different estimates of F_{curr} and E_{curr}. Therefore, the mean values of natural mortality rates were calculated to estimate F_{curr} and E_{curr} values (Mehanna et al. 2015) (Table 1). The fishing mortality(F_{curr}) was estimated as

$$F_{curr} = Z - M$$

The exploitation ratio (E_{curr}) was calculated with the Gulland (1971) formula

$$E_{curr} = F_{curr} \cdot Z^{-1}$$

The length structured Virtual Population Analysis (VPA) was carried out following Jones and van Zalinge (1981). All stock parameters were estimated using in FISAT-II (Gayanilo et al. 2005) and R software***.

Reference points. Three reference points— the optimum fishing mortality (F_{opt}), fishing mortality limit reference point (F_{lim}), optimum exploitation rate (E_{opt})— were determined according to estimated mortality and exploitation rates for comparison and suggestions:

$$F_{opt} = 0.5M$$

$$F_{lim} = (2M)3^{-1} \text{ (Patterson 1992)}$$

$$E_{opt} = F_{opt} \cdot (M + F_{opt})^{-1} \text{ (Gulland 1971)}$$

$$L_{opt} = 3L_{inf} \cdot (3 + (M \cdot K^{-1}))^{-1} \text{ (Froese et al. 2008)}$$

L_{opt} indicates the length where maximum yield could be obtained.

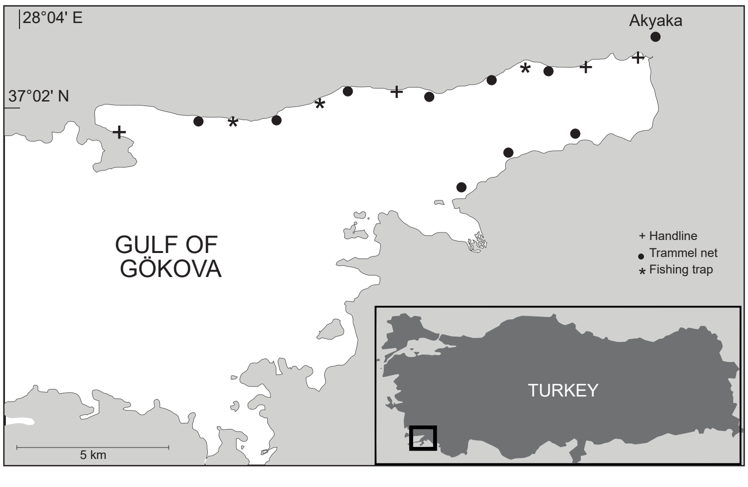

Fig. 1. Sampling locations of marbled spinefoot, *Siganus rivulatus*, from the Gulf of Gökova, south-eastern Aegean Sea

* El-Far A. 2008. Artisanal fisheries along Alexandria coast area with special reference to the fishery biology of *Siganus* spp. MSc Thesis. Department of Zoology, Faculty of Science, Zagazig University, Egypt.

** El-Okda N.I. 1998. Comparative studies on certain biological aspects of Siganus in marine waters of Egypt. PhD Thesis, Faculty of Science, Benha Zagazig University, Egypt.

*** *http://www.rstudio.com*.

RESULTS

Estimated parameters. The total mortality (Z) of *Siganus rivulatus* for the Gulf of Gökova, obtained through the length-converted catch curve, was 0.67 year^{-1}. The natural mortality (M) amounted to 0.32 year^{-1}. The mean value of natural mortality ratios was used to avoid errors of comparison parameter, F_{curr} and E_{curr} (Table 2). The biological reference points were as follows, F_{opt} = 0.16; F_{lim} = 0.21; E_{opt} = 0.33. Total population size (in number) was calculated to be 12 779 660. The VPA analysis showed that fishing pressure starts about 15 cm total length (Fishing mortality; 0.11 year^{-1}, Population size; 1 671 850) and it is focused on 20–25 cm length group. The maximum fishing pressure was found on 23 cm total length group (Fishing mortality; 0.42 year^{-1}, Population size; 99 220) (Fig. 2).

Maximizing the catch. Length at first capture (L_{50}) is the length at which 50% of the fish will be vulnerable to the gear. L_{50} of *Siganus rivulatus* was estimated as 18.76 cm (Fig. 3). The L_{opt} was 16.69 cm for the whole population of the Gulf of Gökova.

Table 1

Estimation of natural mortality (M) with different methods

Reference	Formula	Model
Pauly 1980	$M = 0.9849 L_{inf}^{-0.279} K^{0.6543} T^{0.4634}$	Pauly-I
Djabali et al. 1993	$M = 1.0661 L_{inf}^{-01172} K^{0.5092}$	
Ralston 1987	$M = -0.0666 + 2.52K$	Ralston-I
Pauly and Binohlan 1996	$M = -0.1778 + 3.1687K$	Ralston-II
Pauly and Binohlan 1996	$M = 0.8638 L_{inf}^{-0.279} K^{0.6543} T^{0.4634}$	Pauly-II
Frisk et al. 2001	$M \approx 0.436 K^{0.42}$	
Cubillos et al. 1999	$M = 4.31(t_0 - (\ln(0.05) \cdot K^{-1}))^{-1.01)}$	

L_{inf} = asymptotic length, K = growth coefficient, T = mean annual temperature.

Table 2

Mortality and exploitation rates of marbled spinefoot, *Siganus rivulatus*, from the Gulf of Gökova, south-eastern Aegean Sea

Z	M	Model	Reference	F_{curr}	E_{curr}
0.67	0.46 year^{-1}	Pauly-I	Pauly 1980		
	0.29 year^{-1}		Djabali et al. 1993		
	0.34 year^{-1}	Ralston-I	Ralston 1987		
	0.34 year^{-1}	Ralston-II	Pauly and Binohlan 1996		
	0.41 year^{-1}	Pauly-II	Pauly and Binohlan 1996		
	0.20 year^{-1}		Frisk et al. 2001		
	0.23 year^{-1}		Cubillos et al. 1999		
	0.32 year^{-1}	Mean M		0.35	0.52

Z = total mortality, M = natural mortality, F_{curr} = fishing mortality, E_{curr} = exploitation rate.

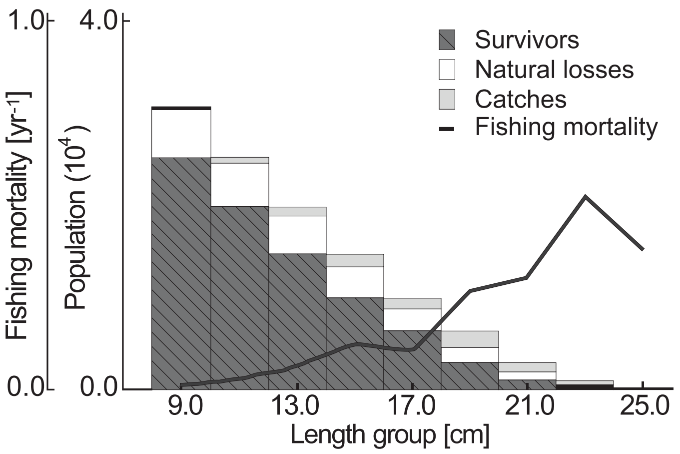

Fig. 2. Virtual population analysis for marbled spinefoot, *Siganus rivulatus*, from the Gulf of Gökova, south-eastern Aegean Sea

DISCUSSION

Effect of expanded distribution on fisheries. *Siganus rivulatus* was first collected in the Mediterranean in 1924 off the coast of Levant reefs (Steinitz 1927), subsequently in Cyprus (1928) (Norman 1929), Syrian Arab Republic (1929) (Gruvel 1931), Rhodes I., Greece (1932) (Brunelli and Bini 1934), southern Turkey (1942) (Papaconstantinou 1990), and Croatia in 2002 (Dulčić and Pallaoro 2004). Boudouresque (1999) mentioned that the Red Sea immigrants entered the Mediterranean and began to spread continuously to the North and this situation was closely associated with water temperature. Seawater surface temperature was reported to increase from 1970 to 2018 in the Mediterranean, periodically (Anonymous 2020) (Fig. 4). Therefore, dispersal of *Siganus rivulatus* northward to higher latitudes is attributable to increasing seawater temperatures. In this context, Artüz and Koç (2012) revealed the presence of the marbled spinefoot in the Sea of Marmara confirming the dispersal of the species.

Eight Lessepsian fish species, *Lagocephalus guentheri* Miranda Ribeiro, 1915; *Siganus rivulatus*; *Stephanolepis diaspros* Fraser-Brunner, 1940; *Alepes djedaba* (Forsskål, 1775); *Lagocephalus sceleratus* (Gmelin, 1789); *Sargocentron rubrum* (Forsskål, 1775); and *Upeneus moluccensis* (Bleeker, 1855) were reported to occur in the Sea of Marmara (northern part of the Mediterranean) (Artüz and Golani 2018, Artüz and Fricke 2019). Five of those Lessepsian species are of commercial importance. This northward spreading may positively affect the fisheries by changing the catch composition thus bringing a new economic approach and contribution. Turan et al. (2017) reported the existence of a specimen of *Alepes djedaba* by gill nets on the shore of Sinop Bay, Western Black Sea. However, Turan et al. (2017) considered the spreading of this species due to climate change, as an issue for marine biodiversity. Even though the main issue of this case is linked to marine biodiversity, it has still some important secondary considerations. Successful establishment of such species to their new environment may bring a potential contribution to fisheries. A very suitable example of this case belongs to marbled spinefoot which was introduced to the Gulf of Gökova and it has become a commercially important species. Moreover, the ongoing northward dispersal of the marbled spinefoot presents a possible future benefit for the Sea of Marmara fishery.

Mortality and exploitation. Biological reference points are widely used (Collie and Gislason 2001) and essential components for the fishery management strategies (Zhang et al. 2017). Biological reference points obtained from the results of the study indicate important cases to discuss. Gulland (1971) suggested the optimum exploitation rate (E_{curr}) to be around 0.5 ($F \approx M$). Patterson (1992) also stated that the exploitation rate above 0.5 ($F = M$) means a decline in spawning stock biomass and an unsustainable fishery of the stock. Froese et al. (2016) offered the ratio of $F \approx 0.5M$ as the precautionary target for a sustainable fishery. Our current exploitation rate (E_{curr} = 0.52) is slightly higher than that of Gulland (1971) and Patterson (1992). Therefore, based on our results and considering the aforementioned pieces of literature, the fishing pressure on *Siganus rivulatus* should be decreased on the Turkish coast of the Aegean Sea (Table 3).

Length at first capture (L_{50}) was found to be higher than maturity lengths ($L_{m(F)}$, $L_{m(M)}$) for both sexes which indicates accordance between current fishing practice, especially the mesh size, and maturity length (Fig. 5). However, L_{opt} value was estimated below than L_m and L_{50} values in the presently reported study. Low value of L_{opt} may be attributable to K which was reported to be higher than our estimation in other studies (Table 4). The M:K ratio was calculated as 1.97. In relation to that, Froese et al. (2018) suggested M:K ratio to be 1.5 ± 0.15 and minimum and maximum limits should be

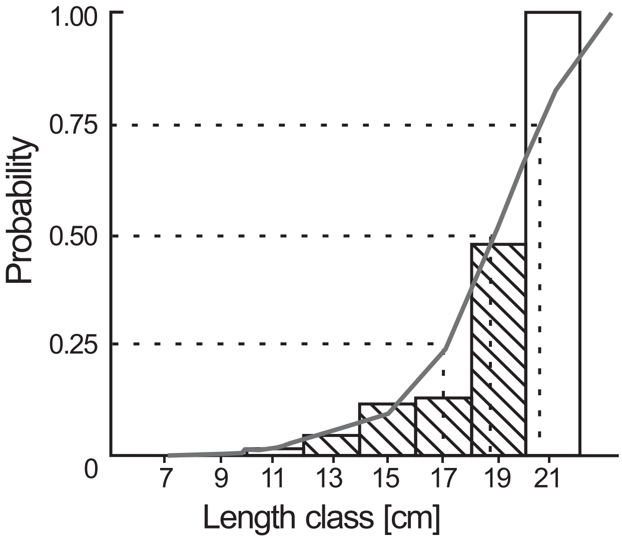

Fig. 3. Probability of capture of marbled spinefoot, *Siganus rivulatus*, from the Gulf of Gökova, south-eastern Aegean Sea (0.25, 0.50 and 0.75 relates to 25%, 50%, and 75%, respectively)

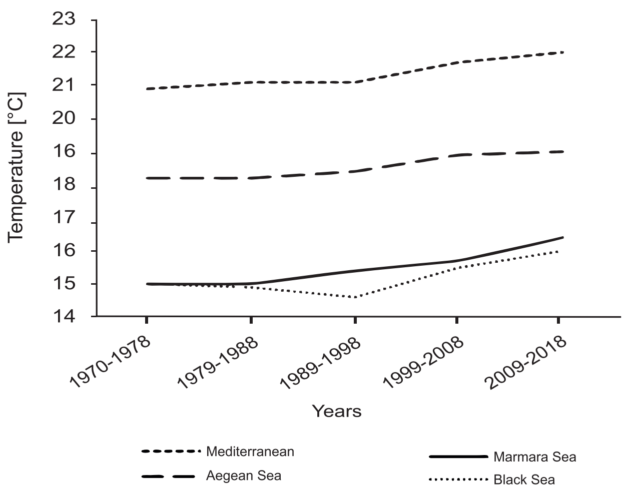

Fig. 4. Variations of sea surface temperature of Mediterranean, Aegean Sea, Marmara Sea, and Black Sea

Table 3

Comparison of the current fishing mortality and the reference points of marbled spinefoot, *Siganus rivulatus*, from the Gulf of Gökova, south-eastern Aegean Sea

Parameter	Value	Result expected
F_{curr}	0.35	
F_{opt}	0.16	Decrease
F_{lim}	0.21	Decrease
E_{opt}	0.33	Decrease
E_{curr}	0.52	

Result expected relates to the fishing mortality; F_{curr} = fishing mortality, F_{opt} = optimum fishing mortality, F_{lim} = fishing mortality limit reference point, E_{opt} = optimum exploitation rate, E_{curr} = exploitation rate

1.2 and 1.8 (95% confidence interval), respectively. In cases where *M*:*K* ratio is higher than 1.5, the mortality is strictly related to growth which results in an increase in fitness as a measure of intrinsic population rate and cohort peaks occurs at earlier ages, while decreasing fitness indicates shortening lifetime reproductive output (Froese et al. 2016). *K* values of the recent studies might be affected by water temperature differences between the Mediterranean and the Red Sea as the original environment of the species. Therefore, the estimated L_{opt} value for *Siganus rivulatus* fishery is not considered to be a suitable parameter in fishing regulations.

On the other hand, *Siganus rivulatus* has commercial importance and is heavily exploited in lower latitudes. The majority of the previous studies reported that this species was overexploited (Table 4). Variations between the studies given in Table 4 could originate from the differences in length distributions, age calculation methods, and locations. More importantly, differences in mortality ratios between studies are considered due to heavy fishing pressure in lower latitudes as *Siganus rivulatus* is not the target species in the southern Aegean Sea.

Ecological and economic approach. The majority of the Lessepsian fishes have high adaptation skills and some of them become economically important for local fishery (Shakman and Kinzelbach 2007). Applying high fishing pressure on Lessepsian fishes can be a path to reduce their population sizes as well as negative ecological effects in their new environment. However, Lessepsian fish migration can also be associated with deadly contagious diseases. Without practical means for preventing further migration of this species from the Mediterranean ecosystem, the local fisheries pressure seems to be the best solution for controlling its population. Among the Lessepsian fishes, *Siganus rivulatus* has high invasiveness potential (Bilge et al. 2019). However, this species is consumed by local people and it contributes a considerable income for local fishermen.

Some of the Lessepsian fish, like *Lagocephalus sceleratus*, damage local fishery (Ünal and Göncüoğlu Bodur 2017). However, *Siganus rivulatus* is an important fish in the small-scale fishery of the Gulf of Gökova due to the preference of the local community. It also constitutes

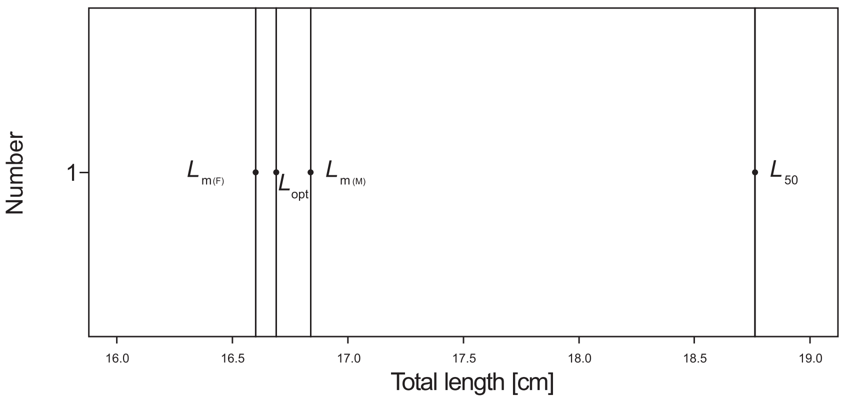

Fig. 5. Comparison of L_{opt} (length where maximum yield could be obtained), L_m (length at maturity for sexes; M = male, F = female), and L_{50} (length at first capture) values of marbled spinefoot, *Siganus rivulatus*, from the Gulf of Gökova, south-eastern Aegean Sea

Table 4

The exploitation of marbled spinefoot, *Siganus rivulatus*, in different countries

Z	M	F_{curr}	E_{curr}	L_m	L_{50}	L_{opt}	K	Country	Reference
1.27	0.26	1.01	0.80		17.04	30.43[P]	0.396	Egypt	Mehanna and Abdallah 2002
3.15	1.43	1.72	0.55	17.4	12.81	17.8	0.735	Egypt	El-Ganainy and Ahmed 2002
2.04	0.41	1.62	0.80		18.35	25.39[P]	0.275	Saudi Arabia	Gabr et al. 2018
2.46	0.64	1.82	0.74	20.0	18.8	22.06[P]	0.380	Egypt	Mehanna et al. 2018
0.67	0.32	0.35	0.52	16.60–16.84	18.76	16.69	0.162	Turkey	Presently reported study

Z = total mortality, *M* = natural mortality, F_{curr} = fishing mortality, E_{curr} = exploitation ratio, L_m = length at maturity for sexes, L_{50} = length at first capture, L_{opt} = length where maximum yield could be obtained, *K* = growth coefficient; [P] = estimated by the authors of the present paper.

a considerable portion in the catch composition of local fishermen (Ünal et al. 2019). The above-mentioned situation and the deficiency of the related biological data prompted us to conduct the presently reported study, with the hope of contributing to the future management of *S. rivulatus*.

Many Lessepsian fish studies have been hitherto conducted to ensure benefits for further fishery management strategies. Bengil (2019) carried out a length–weight relation study on *Upeneus moluccensis*. Other researchers, such as,Taşkavak and Bilecenoglu (2001), studied the length–weight relation of 18 Lessepsian fish species. Özvarol (2016) estimated L_{50} of *Nemipterus randalli* Russell, 1986 for sustainable management of this species. Osman et al. (2013) mentioned that the researchers are interested in fishery management of high commercial Lessepsian fish *Etrumeus teres* (DeKay, 1842).

A similar situation can be seen with the blue crab (*Callinectes sapidus*) which was introduced to the area from the Atlantic. In recent years blue crab has been captured by the local fishing cooperative of Muğla-Köyceğiz-Dalyan. However, fishermen did not know the economic importance of blue crab until the 1980s (Türeli unpublished*). After which, blue crab catches started and catch regulations for the sustainability of the crab fisheries were developed. It is very likely that a similar approach may be implemented for marbled spinefoot in order to ensure the balance between the stock and fishery.

On the other hand, *Siganus rivulatus* catch statistics of many adjacent Mediterranean countries (Israel, Cyprus, Palestine, Syria, Libya, Lebanon, Egypt) have been reported by Anonymous (2019a) indicating the commercial importance of the species at some areas.

Consequently, the tropicalization due to the climate change results in a poleward shift in the species distribution with the overall increase of seawater temperature (Encarnação et al. 2019). Therefore, we may need economically important Lessepsian fish in the future like *Saurida lessepsianus* Russell, Golani et Tikochinski, 2015, *Nemipterus randalli*, and *Siganus rivulatus* in order to take advantage of Lessepsian dispersal. The results of the presently reported study are beneficial in the aspect of fisheries economy. However, the economic impacts and commercial utilization of Lessepsian fishery is definitely in conflict with the ecological aspects. It is possible that *Siganus rivulatus* fishery may be more profitable in the future but the Turkish scenario is still unpredictable. If Turkish fishery management authorities are motivated by the biological reference points, which are firstly revealed with the presently reported study, we can expect a management strategy for *Siganus rivulatus* ensuring the sustainability of its stocks.

ACKNOWLEDGMENT

This study is supported by the Ege University Scientific Research Projects Coordination Unit. Project Number: 2016/SÜF/014.

REFERENCES

Anonymous 2019a. FishStatJ—Software for fishery and Aquaculture statistical time series. FAO, Rome. [Updated 21 July 2016, Accessed 12 February 2019.] *http://www.fao.org/fishery/statistics/software/fishstatj/en*

Anonymous 2019b. #02: Rabbitfish (Siganidae) *In*: Coastal Fisheries Programme. Pacific Community. [Accessed on 12 February 2019.] *http://coastfish.spc.int/en/component/content/article/393-guide-and-information-sheets-for-fishing-communities.html*

Anonymous 2020. Akdeniz [Mediterranean Sea.] T.C. Tarim Ve Orman Bakanliği, Meteoroloji Genel Müdürlüğü. [Republic of Turkey, Ministry of Agriculture and Forestry, General Directorate of Meteorology.] [Accessed on 12 February 2020.] [In Turkish.] *https://www.mgm.gov.tr/FILES/resmi-istatistikler/denizSuyu/Akdeniz-DenizSuyu-Sicakligi-Analizi.pdf*

Artüz M.L., Fricke R. 2019. First and northernmost record of *Upeneus moluccensis* (Actinopterygii: Perciformes: Mullidae) from the Sea of Marmara. Acta Ichthyologica et Piscatoria **49** (1): 53–58. DOI: 10.3750/AIEP/02527

Artüz M.L., Golani D. 2018. First and most northern record of *Sargocentron rubrum* (Forsskål, 1775) from the Sea of Marmara. Thalassas **34** (2): 377–381. DOI: 10.1007/s41208-018-0075-0

Artüz M.L., Koç H.T. 2012. Lesepsiyen/istilacı tür çalışmaları. [Lessepsian/invasive species studies.] P. 211. *In*: Artüz M.L. (ed.) Marmara Denizi'nin değişen oşinografik sartlarının izlenmesi projesi (MAREM) 2011 senesi çalışma verileri (ön raporlar). [Project of Monitoring the Changing Oceanographic Conditions of the Marmara Sea (MAREM) 2011 study data (Preliminary Reports).] Marmara Üniversitesi Yayını, Istanbul, Turkey. [In Turkish.]

Bariche M. 2005. Age and growth of Lessepsian rabbitfish from the eastern Mediterranean. Journal of Applied Ichthyology **21** (2): 141–145. DOI: 10.1111/j.1439-0426.2004.00619.x

Bariche M. 2006. Diet of the Lessepsian fishes, *Siganus rivulatus* and *S. luridus* (Siganidae) in the eastern Mediterranean: A bibliographic analysis. Cybium **30** (1): 41–49.

Bengil E.G.T. 2019. A regional evaluation of Lessepsian migrant *Upeneus moluccensis* (Bleeker, 1855) length and weight relationships from the Mediterranean Sea. Ege Journal of Fisheries and Aquatic Sciences **36** (3): 255–263. DOI: 10.12714/egejfas.2019.36.3.06

Ben-Tuvia A. 1986. Siganidae. Pp. 964–966. *In*: Whitehead P.J.P., Bauchot M.-L., Hureau J.-C., Nielsen J., Tortonese E. (eds.) Fishes of the North-eastern Atlantic and the Mediterranean, Volume 2. UNESCO, Paris.

Beverton R.J.H. 1992. Patterns of reproductive strategy parameters in some marine teleost fishes. Journal of Fish Biology **41** (sB): 137–160. DOI: 10.1111/j.1095-8649.1992.tb03875.x

* Türeli C. 1999. İskenderun Körfezi'ndeki mavi yengeç (*Callinectes sapidus* Rathbun, 1896)'in biyolojik özellikleri. [Biological characteristics of blue crab (*Callinectes sapidus* Rathbun, 1896) in the Gulf of Iskenderun.] PhD thesis. Çukurova Üniversitesi Fen Bilimleri Enstitüsü Su Ürünleri Anabilim Dalı, Adana, Turkey. [In Turkish.]

Bilecenoglu M., Kaya M. 2002. Growth of marbled spinefoot, *Siganus rivulatus* Forsskål, 1775, (Teleostei: Siganidae) introduced to Antalya Bay, eastern Mediterranean Sea (Turkey). Journal of the Fisheries Research **54** (2): 279–285. DOI: 10.1016/S0165-7836(00)00296-4

Bilge G., Filiz H., Yapici S., Tarkan A.S., Vilizzi L. 2019. A risk screening study on the potential invasiveness of Lessepsian fishes in the south-western coasts of Anatolia. Acta Ichthyologica et Piscatoria **49** (1): 23–31. DOI: 10.3750/AIEP/02422

Boudouresque C.F. 1999. The Red Sea–Mediterranean link: Unwanted effects of canals. Pp. 213–228. *In*: Sandlund O.T., Schei P.J., Viken Å. (eds.) Invasive species and biodiversity management. Population and Community Biology Series 24. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Brunelli G., Bini G. 1934. Sulla immigrazione di una specie di? Teuthis? del Mar Rosso al Mar Egeo. [On the immigration of a species from? Teuthis? from the Red Sea to the Aegean Sea.] Atti della Reale Accademia dei Lincei **19**: 255–260. [In Italian.]

Collie J.S., Gislason H. 2001. Biological reference points for fish stocks in a multispecies context. Canadian Journal of Fisheries and Aquatic Sciences **58** (11): 2167–2176. DOI: 10.1139/cjfas-58-11-2167

Cubillos L.A., Alarcón R., Brante A. 1999. Empirical estimates of natural mortality for the Chilean hake (*Merluccius gayi*): evaluation of precision. Fisheries Research **42** (1–2): 147–153. DOI: 10.1016/S0165-7836(99)00042-9

Djabali F., Mehailia A., Koudil M., Brahmi B. 1993. Empirical equations for the estimation of natural mortality in Mediterranean teleosts. Naga **16** (1): 35–37.

Dulčić J., Pallaoro A. 2004. First record of the marbled spinefoot *Siganus rivulatus* (Pisces: Siganidae) in the Adriatic Sea. Journal of the Marine Biological Association of the United Kingdom **84** (5): 1087–1088. DOI: 10.1017/s0025315404010483h

El-Gammal F.I. 1988. Age, growth and mortality of the rabbitfish *Siganus rivulatus* (Forsk., 1775) from the Red Sea. Bulletin of the Institute of Oceanography and Fisheries ARE **14** (1): 13–21.

El-Ganainy A.A., Ahmed A.I. 2002. Growth, mortality and yield-per-recruit of the rabbit fish, *Siganus rivulatus*, From the eastern side of the Gulf of Suez, Sinai coast, Red Sea. Egyptian Journal of Aquatic Biology and Fisheries **6** (1): 67–81. DOI: 10.21608/EJABF.2002.1728

Encarnação J., Morais P., Baptista V., Cruz J., Teodósio M.A. 2019. New evidence of marine fauna tropicalization off the southwestern Iberian Peninsula (southwest Europe). Diversity **11** (4): e48. DOI: 10.3390/d11040048

Frisk M.G., Miller T.J., Fogarty M.J. 2001. Estimation and analysis of biological parameters in elasmobranch fishes: A comparative life history study. Canadian Journal of Fisheries and Aquatic Sciences **58** (5): 969–981. DOI: 10.1139/f01-051

Froese R., Pauly D. (eds.) 2019. FishBase. [Version 12/2019] *http://www.fishbase.org*

Froese R., Stern-Pirlot A., Winker H., Gascuel D. 2008. Size matters: How single-species management can contribute to ecosystem-based fisheries management. Fish Research **92** (2–3): 231–241. DOI: 10.1016/j.fishres.2008.01.005

Froese R., Winker H., Coro G., Demirel N., Tsikliras A.C., Dimarchopoulou D., Scarcella G., Probst W.N., Dureuil M., Pauly D.A. 2018. A new approach for estimating stock status from length frequency data. ICES Journal of Marine Science **76** (6): 461–465. DOI: 10.1093/icesjms/fsy078

Froese R., Winker H., Gascuel D., Sumaila U.R., Pauly D. 2016. Minimizing the impact of fishing. Fish and Fisheries **17** (3): 785–802. DOI: 10.1111/faf.12146

Gabr M.H., Bakaili A.S., Mal A.O. 2018. Growth, mortality and yield per recruit of the rabbit fish *Siganus rivulatus* (Forsskål 1775) in the Red Sea coast of Jeddah, Saudi Arabia. International Journal of Fisheries and Aquatic Studies **6** (1): 87–96.

Gayanilo F.C.jr., Sparre P., Pauly D. 2005. FAO-ICLARM stock assessment tools II (FiSAT II). Revised version. User's guide. FAO Computerized Information Series (Fisheries). No. 8. Revised version. FAO, Rome.

Gruvel A. 1931. Les etats de Syrie, richesses marines et fluviales. Exploitation actuelle et avenire. Societe des editions Geographiques, Maritimes et colonials, Paris, France.

Gulland J.A. 1971. The fish resources of the ocean. Fishing News (Books) West Byfleet, Surrey, UK for FAO, Rome.

Hussein K.A. 1986. Timing of spawning and fecundity of Mediterranean *Siganus rivulatus* (Forsskal). Bulletin of the Institute of Oceanography and Fisheries ARE **12** (1): 187–198.

Jones R., Van Zalinge N.P. 1981. Estimates of mortality rates and population size for shrimp in Kuwait waters. Kuwait Bulletin of Marine Science **2**: 273–288.

Lundberg B., Lipkin Y. 1993. Seasonal, grazing site and fish size effects on patterns of algal consumption by the herbivorous fish, *Siganus rivulatus*, at Mikhmoret (Mediterranean, Israel). Water Science and Technology **27** (7–8): 413–419. DOI: 10.2166/wst.1993.0577

Mehanna S., Abo Elregal M., Aid N. 2015. Critical lengths, mortality rates and relative yield per recruit of the common sole *Solea solea* from the Egyptian Mediterranean coast off Alexandria. Egyptian Journal of Aquatic Biology and Fisheries **19** (2): 13–20. DOI: 10.21608/EJABF.2015.2253

Mehanna S.F., Mohammad A.S., El-Mahdy S.M., Osman Y.A.A. 2018. Stock assessment and management of the rabbitfish *Siganus rivulatus* from the southern Red Sea, Egypt. Egyptian Journal of Aquatic Biology and Fisheries **22** (5): 323–329. DOI: 10.21608/EJABF.2018.22061

Norman J.R. 1929. Notes on the fishes of the Suez Canal. Proceedings of the Zoological Society of London **2** (4): 615–616. DOI: 10.1111/j.1096-3642.1929.tb01445.x

Osman A.G.M., Farrag M.M.S., Akel E.S.H., Moustafa M.A. 2013. Feeding behavior of Lessepsian fish *Etrumeus teres* (Dekay, 1842) from the Mediterranean waters, Egypt. Egyptian Journal of Aquatic Research **39** (4): 275–282. DOI: 10.1016/j.ejar.2013.12.004

Özvarol Y. 2016. Selectivity of Lessepsian fish, Randall's threadfin bream (*Nemipterus randalli* Russell, 1986) in the Gulf of Antalya, eastern Mediterranean. Scientific Papers, Series D Animal Science **59**: 330–335.

Papaconstantinou C. 1990. The spreading of Lessepsian fish migrant into the Aegean Sea (Greece). Scientia Marina **54** (4): 313–316.

Patterson K. 1992. Fisheries for small pelagic species: An empirical approach to management targets. Reviews in Fish Biology and Fisheries **2** (4): 321–338. DOI: 10.1007/BF00043521

Pauly D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal du Conseil **39** (2): 175–192. DOI: 10.1093/icesjms/39.2.175

Pauly D. 1983. Length-converted catch curves: A powerful tool for fisheries research in the tropics (Part I). Fishbyte **1** (2): 9–13.

Pauly D., Binohlan C. 1996. FishBase and AUXIM as tools for comparing the life-history patterns, growth and natural mortality of fish: Applications to snappers and groupers. ICLARM Conference Proceedings **48**: 218–243.

Ralston S. 1987. [8] Mortality rates of snappers and groupers. Pp. 375–404. *In*: Polovina J.J., Ralston S. (eds.) Tropical snappers and groupers: Biology and fisheries management. Westview Press, Boulder, CO, USA.

Shakman E.A., Kinzelbach R. 2007. Distribution and characterization of Lessepsian migrant fishes along the coast of Libya. Acta Ichthyologica et Piscatoria **37** (1): 7–15. DOI: 10.3750/AIP2007.37.1.02

Soykan O., Gülşahin A., Cerim H. 2020. Contribution to some biological aspects of invasive marbled spinefoot (*Siganus rivulatus* Forsskål 1775) from the Turkish coast of southern Aegean Sea. Journal of the Marine Biological Association of the United Kingdom DOI: 10.1017/S0025315420000351

Steinitz W. 1927. Beiträge zur Kenntnis der Küstenfauna Palästinas. I. Pubblicazioni della Stazione Zoologica di Napoli **8** (3–4): 311–353.

Taskavak E., Bilecenoglu M. 2001. Length–weight relationships for 18 Lessepsian (Red Sea) immigrant fish species from the eastern Mediterranean coast of Turkey. Journal of the Marine Biological Association of the United Kingdom **81** (5): 895–896. DOI: 10.1017/S0025315401004805

Turan C., Gürlek M., Özeren A., Doğdu S.A. 2017. First Indo-Pacific fish species from the Black Sea coast of Turkey: Shrimp scad *Alepes djedaba* (Forsskål, 1775) (Carangidae). Natural and Engineering Sciences **2** (3): 149–157. DOI: 10.28978/nesciences.358911

Ünal V., Göncüoğlu Bodur H. 2017. The socio-economic impacts of the silver-cheeked toadfish on small-scale fishers: A comparative study from the Turkish coast. Ege Journal of Fisheries and Aquatic Sciences **34** (2): 119–127. DOI: 10.12714/egejfas.2017.34.2.01

Ünal V., Yıldırım D., Tıraşın M. 2019. Implementation of the ecosystem approach to fisheries for the small-scale fisheries in Gökova Bay, Turkey: baseline report. FAO Fisheries and Aquaculture Technical Paper No. 646. FAO, Rome.

Yeldan H., Avşar D. 2000. A preliminary study on the reproduction of the rabbitfish (*Siganus rivulatus* (Forsskal, 1775)) in the northeastern Mediterranean. Turkish Journal of Zoology **24** (2): 173–182.

Zhang Y., Chen Y., Zhu J., Tian S., Chen X. 2017. Evaluating effectiveness of biological reference points for bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) fisheries in the Indian Ocean. Aquaculture and Fisheries **2** (2): 84–93. DOI: 10.1016/j.aaf.2017.01.004

Received: 23 January 2020
Accepted: 15 May 2020
Published electronically: 1 June 2020