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THE CATCH CHARACTERISTICS OF A SET LONGLINE FISHERY IN THE FOÇA SPECIAL ENVIRONMENTAL PROTECTION AREA, TURKEY

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Background. Fisheries activities are rarely documented in the marine and coastal protected areas in Turkey. This study aimed to determine the catch composition of set longline fishery in the Foça Special Environmental Protection Area (Turkey), and to understand the effects of factors (e.g., bait type, hook size, and soak time) on the catch per unit effort (CPUE) and the size of species caught.

Material and methods. Samples were collected by small-scale fishing boats in 2007 at depths ranging from 1 to 50 m. Kruskal–Wallis test was used to understand if the CPUE changes depended on the fishery specific factors (hook size and bait type). Mann–Whitney U test was used to test if CPUE changes depended on sampling seasons (autumn and summer). Chi-square test was used to determine whether hook size influenced the body size of two commonly caught species.

Results. The following 25 fish species were caught, *Diplodus sargus*, *Sparus aurata*, *Diplodus vulgaris*, *Boops boops*, *Lithognathus mormyrus*, *Oblada melanura*, *Conger conger*, *Trachurus* sp., *Spondyliosoma cantharus*, *Pagellus erythrinus*, *Pagrus pagrus*, *Dentex dentex*, *Sciaena umbra*, *Scorpaena scrofa*, *Belone belone*, *Serranus* sp., Myliobatidae gen. sp., *Muraena helena*, *Sarpa salpa*, *Diplodus annularis*, *Coryphaena hippurus*, *Diplodus puntazzo*, *Chelidonichthys lucerna*, *Scomber japonicus*, and *Dicentrarchus labrax*. The most commonly caught species were white seabream, *Diplodus sargus* and gilthead seabream *Sparus aurata*. The hook size and bait type were important factors that influenced the CPUE. Moreover, the hook size significantly influenced the body size of caught white seabream and gilthead sea bream.

Conclusions. The discard level was low in the set longline fishery in the Foça Special Environmental Protection Area. We recommend using 12 sized hooks rather than 13 to reduce the discards of the main target species in the Foça SEPA. Nevertheless, this also needs an economic assessment, and also identification and use any incentives to promote the shift in the use of larger size hooks. Minimum size limits to be set in the fisheries legislation and alternative bait use studies were also recommended.

Keywords: small-scale fisheries, marine and coastal protected area, bait types, hook size, eastern Mediterranean

INTRODUCTION

The small-scale fishery is commonly defined as any fishery with small capital investment, that utilizes fishing boats with an overall length of less than 12 m, and it doesn't operate with towed fishing gear (Maynou et al. 2013, Natale et al. 2015). It is reported that over 90% of the 4.36 million fishing vessels worldwide can be classified as small-scale ones (Schuhbauer and Sumaila 2016). The official reported fishing fleet operating in the Mediterranean and the Black Sea, in 2017, is comprised of around 86 287 vessels (Anonymous 2018b). Small-scale fishing boats constitute the dominant vessel group, representing 77.8% of all vessels in the Mediterranean Sea and 91.3% in the Black Sea.

In Turkey, the total number of fishing vessels with a length not exceeding 12 m is 14 468 (Anonymous 2018b). Small-scale fishery represents over 90% of the total fishing fleet and approximately 80% of onboard employment (Anonymous 2018b). Among them, 90% of small-scale fishing boats use fishing gears which are mainly gillnets (entangling nets) and longlines. Furthermore, approximately 31% of all small-scale fishers in Turkey were actively fishing in the Aegean Sea in 2017 (Anonymous 2018c).

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It is well known that passive fishing gears are considered to have a low impact on habitat and high selectivity, in comparison with active fishing gears such as trawls and dredges (Kaiser et al. 2011). However, many studies indicated that some endangered and vulnerable species, including turtles, sharks, and other fish species, are generally caught by longlines as bycatch in some geographical areas (Musick et al. 2000, Lewison et al. 2004, Hannan et al. 2013). For instance, the loggerhead sea turtle, *Caretta caretta* was recorded in the catch composition of longlines in the Mediterranean Sea (Casale 2010). Nevertheless, static fishing gears, including longlines, are generally permitted to use in marine and coastal protected areas (MCPAs) (Güçlüsoy 2008). Hence, it is critically important to monitor the catch composition of longlines and set nets, such as trammel and gill nets. This is critical in the MCPAs where there are many endangered species and vulnerable habitats, including endemic *Posidonia oceanica* meadows and fan mussel beds. Moreover, previous studies reported that bait type, hook type, hook size, the position of the hook and soak time affected the catch per unit effort (CPUE) and bycatch per unit effort (BPUE), and the size distribution of caught species in the longline fisheries (Woll et al. 2001, Afonso et al. 2011, Hannan et al. 2013, Braccini and Waltrick 2019).

Although in the Aegean coasts of Turkey the fishing fleet mainly consists of small-scale fishing boats (Anonymous 2018c), little is known about the catch composition of longline vessels (Özgül et al. 2015, Soykan et al. 2016, Öztekin et al. 2018). Bottom longlines are described as static and passive fishing gear and set on or close to the sea bed, and typically consisting of a series of baited hooks (occasionally unbaited) on a line (Anonymous 2019). In Turkey, they are commonly used for catching the demersal species including *Sparus aurata* Linnaeus, 1758, *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817), and *Diplodus sargus* (Linnaeus, 1758) (see Soykan et al. 2016). In addition, pelagic longline sets are also used to catch pelagic species such as swordfish, *Xiphias gladius* Linnaeus, 1758 (see Soykan et al. 2016). Concerning the fishing regulations in Turkey, there are no restrictions on longline fishery relating to the number of hooks, length of the set, amount of used bait, soak time, and the closed season (Anonymous 2016). However, there are a few specific restrictions, for example, the ban on using a hook's gap (the distance between shank and point of the barbs) smaller than 7.2 mm, and the use of longlines to catch turbot is also forbidden (Anonymous 2016).

Regarding the monitoring of commercial fisheries in Turkey, catch data was not recorded daily by logbooks in the small-scale fisheries, including longlines. In Turkey, currently, the only data collection scheme is for each small-scale fisher to complete a standard questionnaire and to make annual estimations (Anonymous 2018a). However, it is considered that direct observation (on-board based) is the most reliable sampling method to evaluate catch characteristics of fisheries (Sparre and Venema 1998), and this can be critically important to obtain data, in particular for the data-deficient fishery in MCPAs.

To date, the catch characteristics of commercial fishing gears have rarely been documented in Turkish MCPAs (Dereli et al. 2015). The aim of the presently reported study was to assess the catch characteristics of a set longline fishery in the Foça Special Environmental Protection Area (SEPA). While doing so, we aim to determine the catch composition of the set longline fishery, understand the effects of factors including bait type, hook size and soak time on the CPUE and determine the effects of hook size on the sizes of caught species in this fishery.

MATERIAL AND METHODS

Study area and fisheries. The Foça SEPA is located on the Turkish Aegean coast and encompasses a large part of the Foça District (Fig. 1), one of İzmir Province's 30 districts. The Foça SEPA was established in 1990 (Anonymous 1990), and it was extended in 2007 (Anonymous 2007). The Foça area was declared as a SEPA to protect the natural and historical assets of the region (Güçlüsoy 2015). In particular, Foça, meaning "seal" in Turkish, is presumed as the main habitat for the Mediterranean monk seal, *Monachus monachus*. This was why the main species conservation actions commenced in Foça right after the establishment of the National Monk Seal Committee in 1991. With this attention, the area was also declared as a no purse-seining and trawling zone (Güçlüsoy 2008).

In 2019, a fleet of approximately 90 artisanal fishing boats was based at the port of Foça, however, only 20 of them were actively fishing. Fishers usually work between the coastline and the 60 m isobath. The majority of boats are open-hulled, smaller than 10 m in length, 1.0 to 1.5-tonne displacement, and powered by inboard engines of 7.4 to 30 kW. Fishing trips usually last between 4 and 12 h at night, and operations include one set of bottom longlines (personal communication, Ceyhan Çetin, Head of Foça Fishery Cooperative, 2019).

The bottom longlines, used in the Foça SEPA, consist of a series of baited hooks (size 8 to 14). The hook size depends on the target species: size 8 hooks are mainly used for larger fish such as common dentex, *Dentex dentex* (Linnaeus, 1758), and size 14 hooks are used for white seabream, *Diplodus sargus*; common pandora, *Pagellus erythrinus* (Linnaeus, 1758); red porgy, *Pagrus pagrus* (Linnaeus, 1758); and gilthead seabream, *Sparus aurata* (see Güçlüsoy 2008).

Data collection. The data were collected from eight small-scale fishing boats using bottom set longlines. On-board observations were made from July through October 2007 during the peak time of the longline fishing season, and carried out at depths ranging from 1 to 50 m. Fishermen who predominantly had utilized set longlines in summer and autumn months switched their practices to gillnet or octopus fishery for the remainder of the year. The location of each sampling site was recorded using a GPS. Information related to the hook number, hook size, bait type, soak time, and catch amounts by species, and the total length of specimens were recorded at sea.

The data were collected from 78 random fishing operations. Three different types of baits including mud shrimp (n = 36), octopus (n = 13), and sardine (n = 29), and four different hook sizes including sizes 8, 10, 12, and

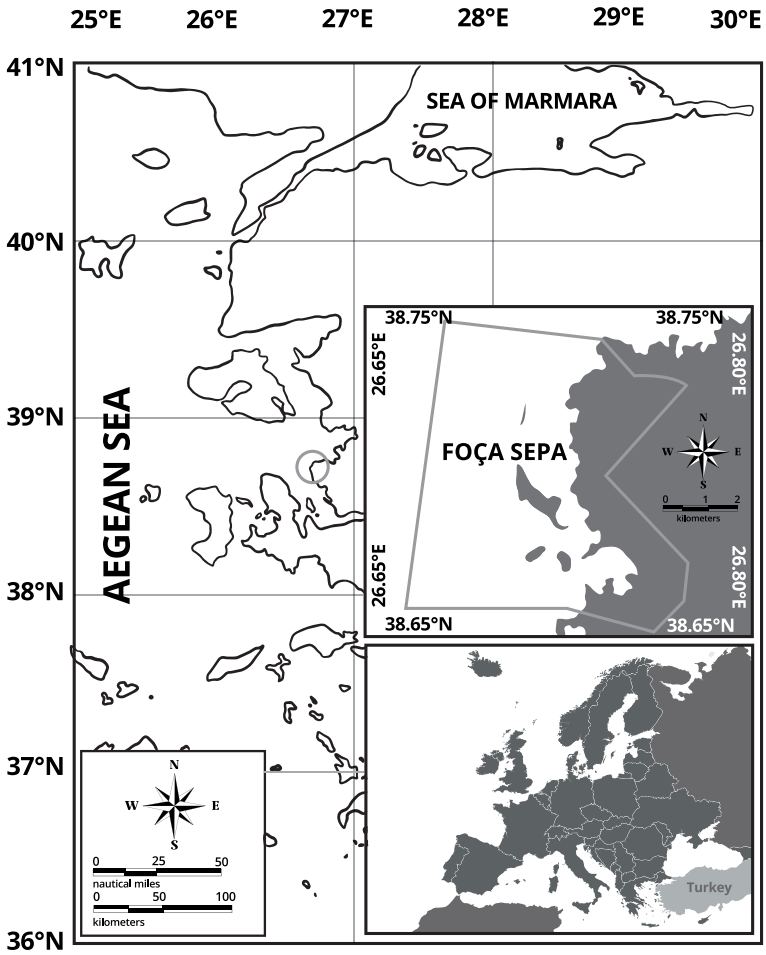

Fig. 1. The study area (Foça SEPA, Aegean Sea, Turkey)

13, shown in Table 1, were used by commercial fishers. The soak time ranged between 2 and 21 h.

Data analysis. All the data were tested for normality and homogeneity of variance using the Kolmogorov–Smirnov K–S test and Levene's test, respectively, and either parametric or non-parametric tests were performed accordingly. Linear regression was used to test the relation between the CPUE of all fish and soak time. Kruskal–Wallis test was used to understand the relations between the CPUE and fishery specific factors, including:

- hook size (size 8, 10, 12, and 13),
- bait type (sardine, octopus, and mud shrimp).

In addition to the Kruskal–Wallis test, Tamhane's T2 post-hoc test was also used to understand which groups show significant differences. A Mann–Whitney U test was also used to test whether CPUE shows a difference in different seasons (autumn and summer). Furthermore, a Chi-square test was used to understand whether commonly used hook sizes (size 12 and 13) influenced the body size of the two commonly caught species, the white seabream and the gilthead seabream. All statistical analyses were performed using the SPSS v. 20. Equation provided below was used to calculate the CPUE estimation

$$\text{CPUE} = 1000N_L \cdot N_h^{-1}$$

where N_L is the total number of individuals per longline and N_h is the total number of hooks used. Moreover, the sizes of the species caught were verified if they fit into the allowable size limits of the Turkish Fishery Communiqué (Anonymous 2016).

RESULTS

A total of 25 species were found to be caught by the set longline fishery in the study and listed according to total number of catches as, *Diplodus sargus*; *Sparus aurata*; *Diplodus vulgaris*; *Boops boops* (Linnaeus, 1758); *Lithognathus mormyrus* (Linnaeus, 1758); *Oblada melanura* (Linnaeus, 1758); *Conger conger* (Linnaeus, 1758); *Trachurus* sp.; *Spondyliosoma*

Table 1

Information on the used hooks including hook size, hook height, and hook gap

Hook size [No.]	Hook height [mm]	Hook gap [mm]	Number of sets
13	28.32	10.78	44
12	31.41	12.52	19
10	41.92	16.88	5
8	53.45	21.09	10

The hook size enlarges with decreasing numbering

cantharus (Linnaeus, 1758); *Pagellus erythrinus*; *Pagrus pagrus*; *Dentex dentex*; *Sciaena umbra* Linnaeus, 1758; *Scorpaena scrofa* Linnaeus, 1758; *Belone belone* (Linnaeus, 1760); *Serranus* sp.; Myliobatidae gen. sp.; *Muraena helena* Linnaeus, 1758; *Sarpa salpa* (Linnaeus, 1758); *Diplodus annularis* (Linnaeus, 1758); *Coryphaena hippurus* Linnaeus, 1758 *Diplodus puntazzo* (Walbaum, 1792); *Chelidonichthys lucerna* (Linnaeus, 1758); *Scomber japonicus* Houttuyn, 1782; *Dicentrarchus labrax* (Linnaeus, 1758) (see Table 2). White seabream, *Diplodus sargus*, was the most common species, accounting for 39% of the catch in weight, and was followed by the gilthead seabream, *Sparus aurata*, and the two-banded seabream, *Diplodus vulgaris*, as shown in Table 2. Figure 2 shows the size distribution of the most common six species caught.

There was a significant relation between the CPUE of all fish and the soak time (linear regression, $r = 0.529$, $P < 0.001$). The CPUE was significantly influenced by the hook size (Kruskal–Wallis test, $\chi^2 = 32.45$, $P < 0.001$) (Table 3) and the highest CPUE estimations was calculated for hook size 13 (50 ± 4 ind. 1000 hooks) (Fig. 3A). The CPUE significantly changed depending on the bait type (Kruskal–Wallis test, $\chi^2 = 29.01$, $P < 0.001$) (Table 4). The mean CPUE value of all fish was calculated for different bait types; octopus (46 ± 30 ind. per 1000 hooks), mud shrimp (47 ± 25 ind. per 1000 hooks), and sardine (13 ± 9 ind. per 1000 hooks) (Fig. 3B). The results indicated that the CPUE of all fish significantly changed during the sampling seasons (Mann–Whitney U test, $U = 440$, $P = 0.001$) and the mean CPUE in summer was 44 ± 26 ind. per 1000 hooks, whereas the mean CPUE in autumn was 25 ± 24 ind. per 1000 hooks (Fig. 3C).

The mean body size of white seabream caught by size 12 hooks was 26 ± 1 cm, whilst the size attracted by a 13 size hook was 24 ± 0.2 cm. The body size of the caught white seabream significantly changed depending on hook size ($\chi^2 = 4.406$, $P = 0.04$). Likewise, the body size of the caught gilthead seabream also significantly changed depending on hook size ($\chi^2 = 4.501$, $P = 0.03$). It was found that the mean body size of gilthead seabream caught by size 12 hooks was 30 ± 0.7 cm, while that of size 13 hook was 28 ± 0.5 cm.

DISCUSSION

Longlines are generally assumed to be environmentally friendly fishing gears due to their associated low energy use, low rate of bycatch species, and high selectivity (Ingólfsson et al. 2017). Horta e Costa et al. (2016) compared the fishing gears used in the marine protected areas in terms of the selectivity and impact levels, and they declared that longlines were placed in the class of highly selective and low impacting gears. Nevertheless,

Table 2

The catch composition and catch in numbers by hook size of a longline fishery in the Foça SEPA

Fish species		No. of fish caught by hook size				
Scientific name	Common name	13	12	10	8	Total
Diplodus sargus	White seabream	528	15	3	1	547
Sparus aurata	Gilthead seabream	167	32	2	0	201
Diplodus vulgaris	Two-banded seabream	152	6	1	0	159
Boops boops	Bogue	144	0	4	0	148
Lithognathus mormyrus	Sand steenbras	111	0	1	0	112
Oblada melanura	Saddled seabream	83	1	0	0	84
Conger conger	European conger	24	3	0	0	27
Trachurus sp.	Mackerel	12	10	2	0	24
Spondyliosoma cantharus	Black seabream	16	3	0	0	19
Pagellus erythrinus	Common pandora	5	9	0	0	14
Pagrus pagrus	Red porgy	1	11	0	0	12
Dentex dentex	Common dentex	5	3	0	4	12
Sciaena umbra	Brown meagre	10	0	0	0	10
Scorpaena scrofa	Red scorpionfish	2	4	0	0	6
Belone belone	Garfish	2	4	0	0	6
Serranus sp.	Comber	1	4	0	0	5
Myliobatidae gen. sp.	Ray	0	0	1	3	4
Muraena helena	Mediterranean moray	3	0	1	0	4
Sarpa salpa	Salema	4	0	0	0	4
Diplodus annularis	Annular seabream	2	1	0	0	3
Coryphaena hippurus	Common dolphinfish	0	2	0	0	2
Diplodus puntazzo	Sharpsnout seabream	2	0	0	0	2
Chelidonichthys lucerna	Tub gurnard	0	1	0	0	1
Scomber japonicus	Chub mackerel	0	1	0	0	1
Dicentrarchus labrax	European seabass	1	0	0	0	1

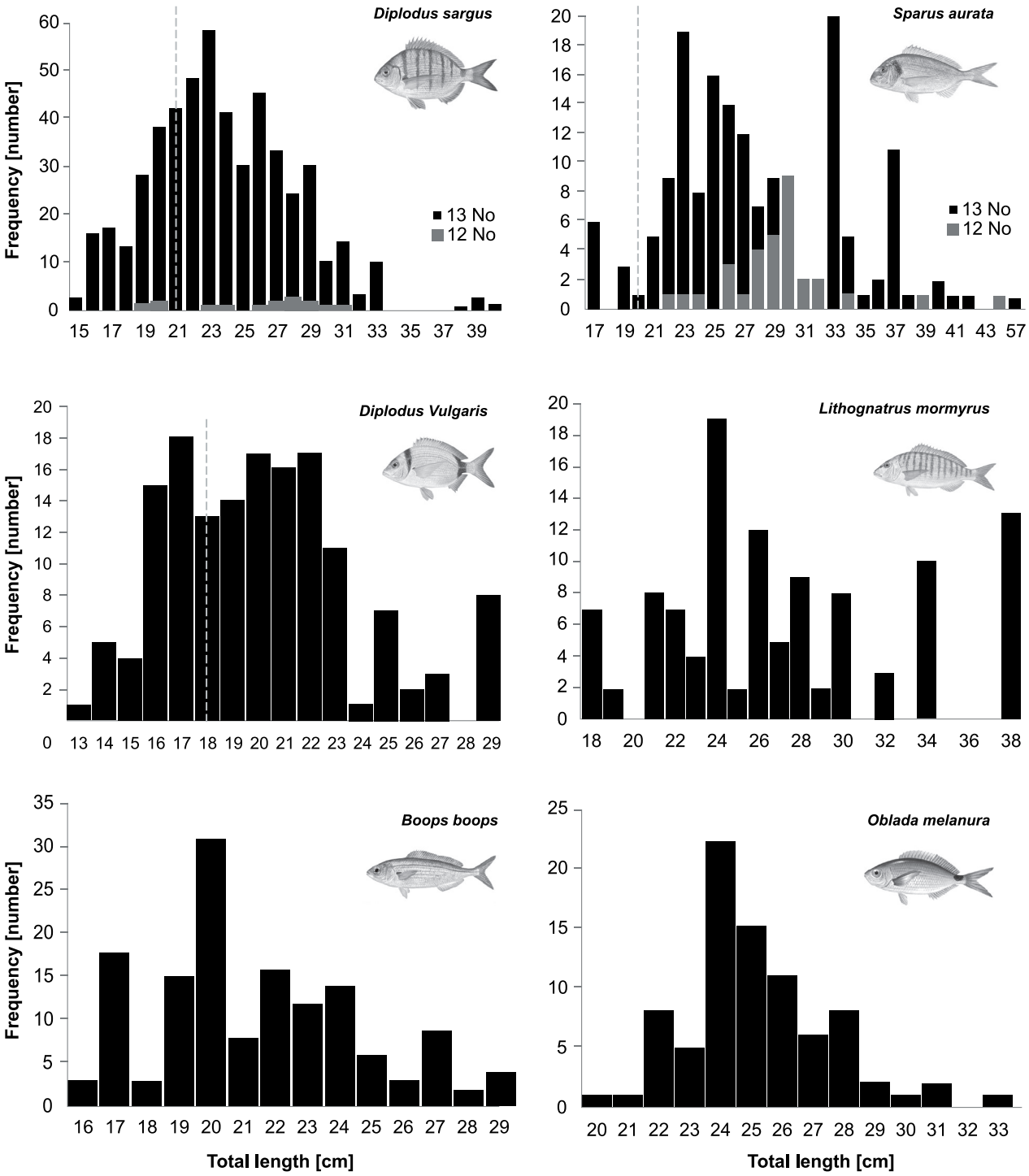

Fig. 2. The size distribution of the six most abundant species (*Diplodus sargus*, *Sparus aurata*, *Diplodus vulgaris*, *Boops boops*, *Lithognathus mormyrus*, and *Oblada melanura*); Dashed lines indicate the minimum landing size values of species

bycatch of undersized fish can be a problem in some fisheries (Ingólfsson et al. 2017). Thus, the fishing gears' characteristics (e.g., hook size, hook type) and operational characteristics (e.g., bait) may influence the catch efficiency and bycatch amounts (Otway and Craig 1993, Pacheco et al. 2011). For example, Cortés et al. (2017) noted that the mortality rate of some seabird species, such as shearwaters, was high among longlines in the northwestern Mediterranean, and the frequency of seabird attacks showed a difference depending on the season and bait type; the highest seabird attacks were reported in spring (windy days) when the longlines were baited by fish species. In our sampling area, fishers rarely caught seabird species by longlines because they generally use gillnets instead of longlines in spring (personal communication, Ceyhan Çetin, Head of Foça Fishery Cooperative, 2020).

In the presently reported study, a total of 25 species, with relatively low numbers, were caught and the white seabream and gilthead seabream were the dominant species. Similarly, a total of 25 species were reported from the Tabarca Marine

Table 3

Summary of post-hoc test, for multiple comparisons of hook size

Hook size		I – J difference		*P* value	95% confidence interval	
I	J	Difference	SE		Lower bound	Upper bound
8	10	–12.500	21.952	0.996	–111.13	86.13
	12	–7.953	5.337	0.657	–24.87	8.96
	13	–37.991[S]	6.121	<0.001	–55.95	–20.04
10	8	12.500	21.952	0.996	–86.13	111.13
	12	4.547	21.451	1.000	–97.81	106.91
	13	–25.491	21.659	0.884	–126.15	75.17
12	8	7.953	5.337	0.657	–8.96	24.87
	10	–4.547	21.451	1.000	–106.91	97.81
	13	–30.038[S]	3.964	<0.001	–40.83	–19.25
13	8	37.991[S]	6.121	<0.001	20.04	55.95
	10	25.491	21.659	0.884	–75.17	126.15
	12	30.038[S]	3.964	<0.001	19.25	40.83

SE = standard error of the mean, [S] = the mean difference is significant at the 0.05 level; the dependent variable is CPUE.

Table 4

Summary of post-hoc test, for multiple comparisons of the bait type

Bait type		Difference (I – J)		*P* value	95% confidence interval	
I	J	Difference	SE		Lower bound	Upper bound
Sardine	Octopus	–32.408[S]	8.426	0.006	–55.42	–9.40
	Mud shrimp	–33.932[S]	4.569	<0.001	–45.24	–22.63
Octopus	Sardine	32.408[S]	8.426	0.006	9.40	55.42
	Mud shrimp	–1.524	9.225	0.998	–25.72	22.67
Mud shrimp	Sardine	33.932[S]	4.569	<0.001	22.63	45.24
	Octopus	1.524	9.225	0.998	–22.67	25.72

SE = standard error of the mean; [S] = the mean difference is significant at the 0.05 level

Reserve (Western Mediterranean Sea) in the sparid longline fishery (Forcada et al. 2010). This study also emphasized that the sparid gillnet, the *Sepia* trammel net, and the *Mullus* trammel net caught 52, 64, and 71 species, respectively. Thus, it was suggested that the sparid gillnet and the sparid longline concentrated along MCPA boundaries, whilst the *Sepia* trammel net and the *Mullus* trammel net may include risk for the protected areas (Forcada et al. 2010). Therefore, it can be very likely that the number of species affected by the bottom set long lines are fewer compared to set nets in use in the Foça SEPA. However, this needs further study.

The presently reported study also reveals that the hook size, bait type, and season were factors that significantly influenced the CPUE of the targeted commercial fish species in the longline fishery in the Foça SEPA, Turkey. Hook size 13 provided the highest CPUE values, and the larger hook size 12 provided lower discard. Similarly, Piovano et al. (2010) suggested that the larger j-style hooks resulted in a lower stingray capture rate. Numerous studies reported that hook type (e.g., j-style, Kahle hook) significantly influenced the CPUE and the BPUE (Özgül et al. 2015, Huang et al. 2016). In the presently reported study, all samples were collected by the same hook type (j-style), which is commonly used by commercial fishers, thus we could not provide comparative results.

Our study noticed that the CPUE changed depending on the bait type; sardine was found to be the least effective bait in comparison with octopus and mud shrimp. Similarly, Foster et al. (2012) highlighted that squid bait and mackerel bait resulted in a significant decrease in the swordfish and loggerhead turtle catch respectively. It should be noted that not only bait type, but also bait size, shape, texture, and physical strength can influence the catch efficiency (Løkkeborg et al. 2014). For instance, bait size significantly affects the size selectivity and catch efficiency in cod and haddock longline fishery (Johannessen et al. 1993, Engås and Løkkeborg 1994). Similarly, Ingólfsson et al. (2017) reported that in the case of larger baits, there was an increase in the catches of large fish, whereas there was a decrease in the amount of undersized fish. It was also revealed that some species use texture to elicit ingestion (Atema 1980, Løkkeborg et al. 2014).

While the presently reported study showed that the soak time was significantly associated with the CPUE of sparids, the other targeted taxa may not have had a notable influence. For example, Echwikhi et al. (2012) noted that the CPUE of target species (groupers *Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817) and *Epinephelus marginatus* (Lowe, 1834)) and BPUE of the

loggerhead turtle was not significantly affected by the soak time in the longline fishery in the Gulf of Gabès, Tunisia. Likewise, Setyadji et al. (2016) reported that there was no significant relation between the soak time and the CPUE of bigeye in a longline fishery in the Indian Ocean. In addition, the presently reported study demonstrated that the CPUE varied by season; the mean CPUE was higher in summer than in autumn. Likewise, seasonal differences in a longline fishery were reported for swordfish in the eastern Mediterranean Sea (Damalas et al. 2007).

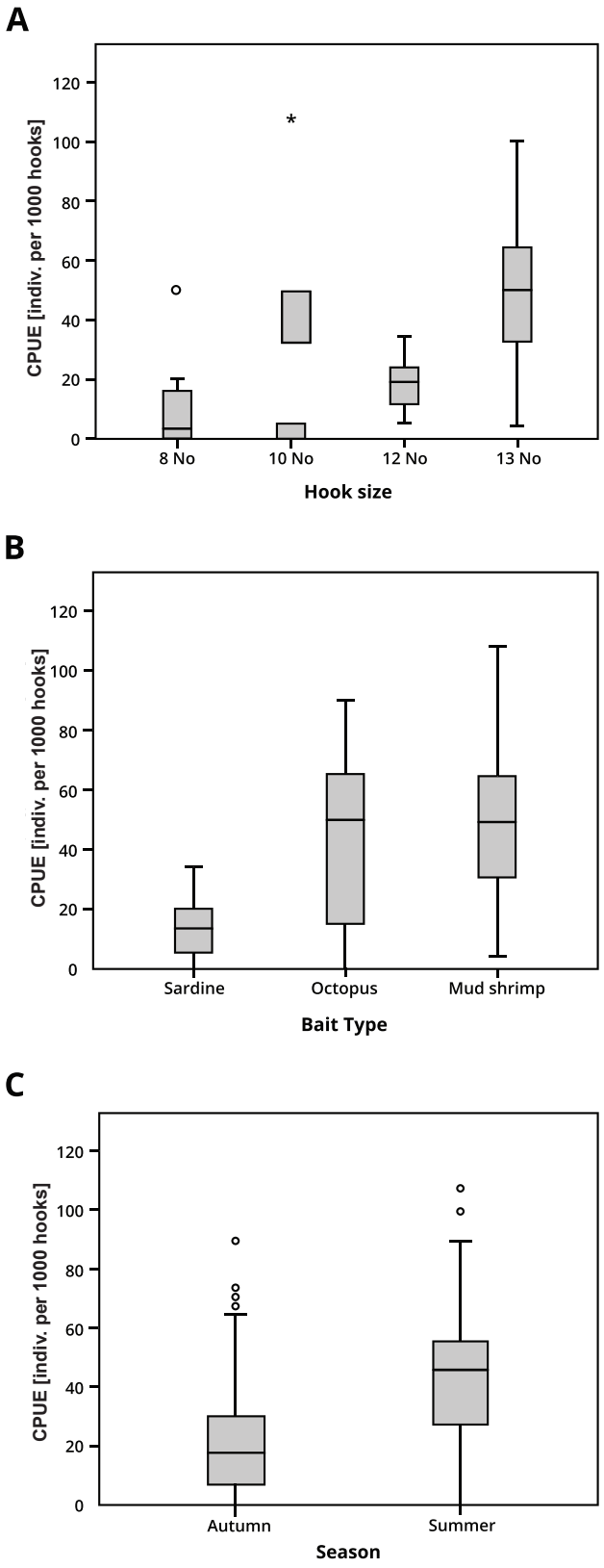

Fig. 3. CPUE of all fish related to (**A**) hook size, (**B**) bait type, and (**C**) sampling season

Generally, the discard ratio was low in the presently reported study. Concerning the most common six species, 23% of *D. sargus*, 5% of *S. aurata*, and 28% of *D. vulgaris* were smaller than the minimum legal size (Fig. 2), while for the other three species (*Lithognathus mormyrus*, *Boops boops*, *Oblada melanura*) there was no regulation related to the minimum legal size. Similarly, low discard ratios in the longline fishery were reported by previous studies in different locations (Dereli et al. 2015, Gülşahin and Soykan 2017). In addition, Gülşahin and Soykan (2017) noticed that a total of 5 bycatch species were in the longline fishery and these species were accounting for 24.6% of the total catch.

Although the Foça SEPA was established in 1990, except for monk seal and fisheries interaction (Güçlüsoy 2008) and daily fish landing recordings of the small-scale fishery from the second half of the 1990s onwards (Güçlüsoy and Tosunoğlu 2019), no parameters on small-scale fisheries' operations were monitored. In addition to this, small-scale fishers are not obliged to record their catch statistics using logbooks neither inside the protected areas nor outside, in Turkey. Hence, this results in a lack of information about the catch composition and fishing effort. We suggest that it should be mandatory, at least within the MCPAs, for small-scale fishers to record their catch. This would provide the fundamental information and help to manage and control allowed fishing activities to protect sensitive and vulnerable species and habitats. Finally, we recommend the use of size 12 hooks rather than size 13 to reduce the discard volume of the main target species in the Foça SEPA. Nevertheless, this also needs an economic identification and assessment, and the use of any incentives to promote the shift in the use of larger sized hooks. Moreover, 50% of the targeted species do not have any size limits, this needs to address in the fisheries notifications, by taking the reproductive biology of these species into consideration. Because of dwindling stocks of octopus and mud shrimp (personal communication, Erdal Kara, Head of Tuzçullu Fishery Cooperative, 2019) that were used as bait, these should also be reconsidered, and alternative bait studies (e.g., Løkkeborg et al. 2014) should also be conducted.

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