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The dominance of non-indigenous species in the catch composition of small-scale fisheries: A case study from the Kaş–Kekova Special Environmental Protection Area, Türkiye, Eastern Mediterranean

Fikret ÖNDES[1], Vahdet ÜNAL[2]

1 *Faculty of Fisheries, İzmir Katip Çelebi University, Balatçık, Izmir, Türkiye*

2 *Faculty of Fisheries, Ege University, Bornova, Izmir, Türkiye*

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Corresponding author: Fikret Öndes (fikret.ondes@ikcu.edu.tr)

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Abstract

This study aimed to determine the catch composition and compare the catch per unit effort (CPUE) of indigenous and non-indigenous species in longline and trammel net fisheries in the Mediterranean coasts of Türkiye. The data were collected weekly from May 2020 to September 2021 by commercial fishing vessels (n = 62 days for trammel nets, n = 75 days for longlines). The results of the study indicated that more than 90% of the catch composition consisted of non-indigenous species in trammel net fishery and *Pterois miles* (Bennett, 1828), *Siganus rivulatus* Forsskål et Niebuhr, 1775, *Siganus luridus* (Rüppell, 1829), and *Scarus ghobban* Forsskål, 1775 were the most commonly caught species. Although indigenous species were more common in longlines compared with trammel nets, non-indigenous species *Lagocephalus sceleratus* (Gmelin, 1789) and *Lagocephalus suezensis* Clark et Gohar, 1953 were represented by relatively high catch ratios. The results also revealed that the CPUE of non-indigenous species exhibited seasonal differences. Although some non-indigenous species caught within this study have a market value, some other highly invasive species do not. Therefore, it is critically important to develop effective management tools to control bio-invasion. This study provides the first comprehensive research by utilizing basic data with relatively long-term surveys in the small-scale fishery on the Mediterranean coasts of Türkiye. The outcomes of this study can provide guidance to decision-makers.

Keywords

fisheries management, invasive species, *Lagocephalus sceleratus*, marine invasion, *Pterois miles*, *Siganus luridus*, *Siganus rivulatus*, small-scale fisheries

Introduction

The Mediterranean basin has a high human population density and is considered a hotspot for climate change consequences (Macias et al. 2015). Numerous studies have also underlined that this ecosystem has been facing an increased threat of pollution and overfishing which have caused certain changes over the last several decades (Danovaro 2003; Tsikliras et al. 2013; Compa et al. 2019). Furthermore, some other anthropogenic factors like the opening and enlargement of the Suez Canal directly affected marine ecosystems and fisheries, mostly SSF (small-scale fisheries) (Galil et al. 2015; Penca et al. 2021). The impacts of these aforementioned factors have resulted in significant ecological changes. For instance, collapsed and decreased stocks, mass mortality in sessile organisms, increased numbers of threatened and endangered species, and altered prey–predator relations are commonly observed and decreased stocks have also caused economic changes such as a decrease in vessel numbers in SSF (Maynou et al. 2013; Tsikliras et al. 2015; Stergiou et al. 2016; Garrabou et al. 2019; Moullec et al. 2019; Birkan and Öndes 2020; Ramírez et al. 2021; IUCN 2022; OECD 2022). Another important indicator of the changes occurring in the Mediterranean ecosystem is the increased abundance and diversity of non-indigenous species (NIS) whose effects are starting to be better understood (Kletou et al. 2016; Çınar et al. 2021; Ulman et al. 2021; Zenetos et al. 2022). Similarly, Öztürk (2021) reported that the biota of the Mediterranean and the Black Sea has started to change significantly over the last few decades due to the introduction of NIS.

There is no doubt that in recent years some Lessepsian species are a major threat to biodiversity and ecosystem functioning, as well as causing an economic loss in some fisheries and are also causing a negative influence on human welfare (Ünal et al. 2015; Ünal and Göncüoğlu Bodur 2017; Öndes et al. 2018; Öndes and Gökçe 2021; Kourantidou et al. 2021). As in the aforementioned studies, researchers generally focused on the negative impacts of NIS, whilst their potential or realized benefits were scarcely discussed in the literature (Gozlan 2008; Oficialdegui et al. 2020; Vimercati et al. 2020; Kourantidou et al. 2022). Indeed, NIS comprise between 50%–90% of the total fish biomass in some areas of the Eastern Mediterranean Sea (Goren and Galil 2005; Edelist et al. 2011; Bronstein et al. 2017). A more recently published study (Çınar et al. 2021) highlighted that a total of 539 marine NIS were recorded in Türkiye until the end of 2020 and among them, 413 species were reported from the Levantine coasts of Türkiye. Çınar et al. (2021) also stated that 58% of NIS migrated from the Red Sea. Previous studies apparently indicated that the number of NIS increased over the last several decades in the Mediterranean ecosystem (Zenetos et al. 2012; Zenetos et al. 2022). Even though the literature included many studies on the occurrence, distribution patterns, and biological characteristics of Lessepsians (e.g., Golani 1998; Mavruk and Avsar 2008; Arndt and Schembri 2015; Iglésias and Frotté 2015), information on their catch characteristics in artisanal fisheries is very limited (e.g., Carpentieri et al. 2009), and there is also a big gap related to their seasonal catch per unit of effort (CPUE). Furthermore, in contrast to indigenous species, government statistics do not include regular information on the catch, effort, and prices of NIS (TURKSTAT 2022). Hence, only scientific studies provide that kind of data on the catch characteristics of these species at present. Therefore, in the presently reported study, we aimed to fill the existing gap to some extent. Thus, we assessed the catch composition, and also analyzed and compared the CPUE of indigenous and NIS in the SSF using trammel nets and longlines based on weekly onboard observations in the Mediterranean coasts of Türkiye between May 2020 and September 2021.

Materials and methods

This study was carried out in Kalkan, Kaş, and the Kaş–Kekova Special Environmental Protection Area (SEPA) located on the southern Mediterranean coasts of Türkiye (Fig. 1). This area is known as one of the most important locations for SSF for many years and the main target species of the longline fishery are *Lichia amia* (Linnaeus, 1758), *Epinephelus costae* (Steindachner, 1878), and *Pagrus pagrus* (Linnaeus, 1758), whereas the main target species in trammel net fishery are *Siganus luridus* (Rüppell, 1829), *Siganus rivulatus* Forsskål et Niebuhr, 1775, and *Epinephelus costae*. The Kekova SEPA was created in 1990 and became the Kaş–Kekova SEPA in 2006. The overall area covers 258 km^2 and the marine area covers 166 km^2 (Mangos and Claudot 2013). A total of 51 active fishers fished in the Kaş–Kekova SEPA (including Kalkan) and the mean number of days at sea for fishers was estimated as 141 days (Ünal unpublsished[*]). Regarding the habitat structure of the Kaş–Kekova SEPA, Akçalı et al. (2019) reported a total of 10 habitat types and it was determined that the broadest area was covered by *Halophila stipulacea*, *Posidonia oceanica*, and Corallinales gen. spp.

The data were collected weekly from May 2020 to September 2021 by commercial fishing vessels which included trammel nets and longlines. Each month, both trammel net and bottom set longline surveys were attempted four times. However, the data were limited (n = 62 days for trammel nets and n = 75 days for longlines) due to adverse weather conditions in some months, and the commercial landings of the fleet were also negatively affected by these weather conditions at certain times of the year. Regarding the trammel net surveys, the mesh sizes of used gear were 28 and 36 mm and the length of the daily used net ranged between 1000 and 2600 m. On the other hand, concerning the longline surveys, the number of hooks deployed was 10 and pilchard, *Sardina pilchardus* (Walbaum, 1792), was used as bait, which is most commonly used by commercial fishers. The hook number of longlines ranged between 250 and 550 during the survey. The longline surveys were carried out between 20 and 150 m at depth (mainly higher than 50 m), whereas the depth of trammel net surveys varied between 15 and 100 m (mainly lower than 50 m). During the onboard observation, details relating to fishing operations (hook number, net length, soak time) and habitat structure were recorded. The catch composition in terms of wet weight was recorded onboard by observers. The total length (TL) of all specimens of species was measured using calipers and the wet weight of these specimens was recorded using

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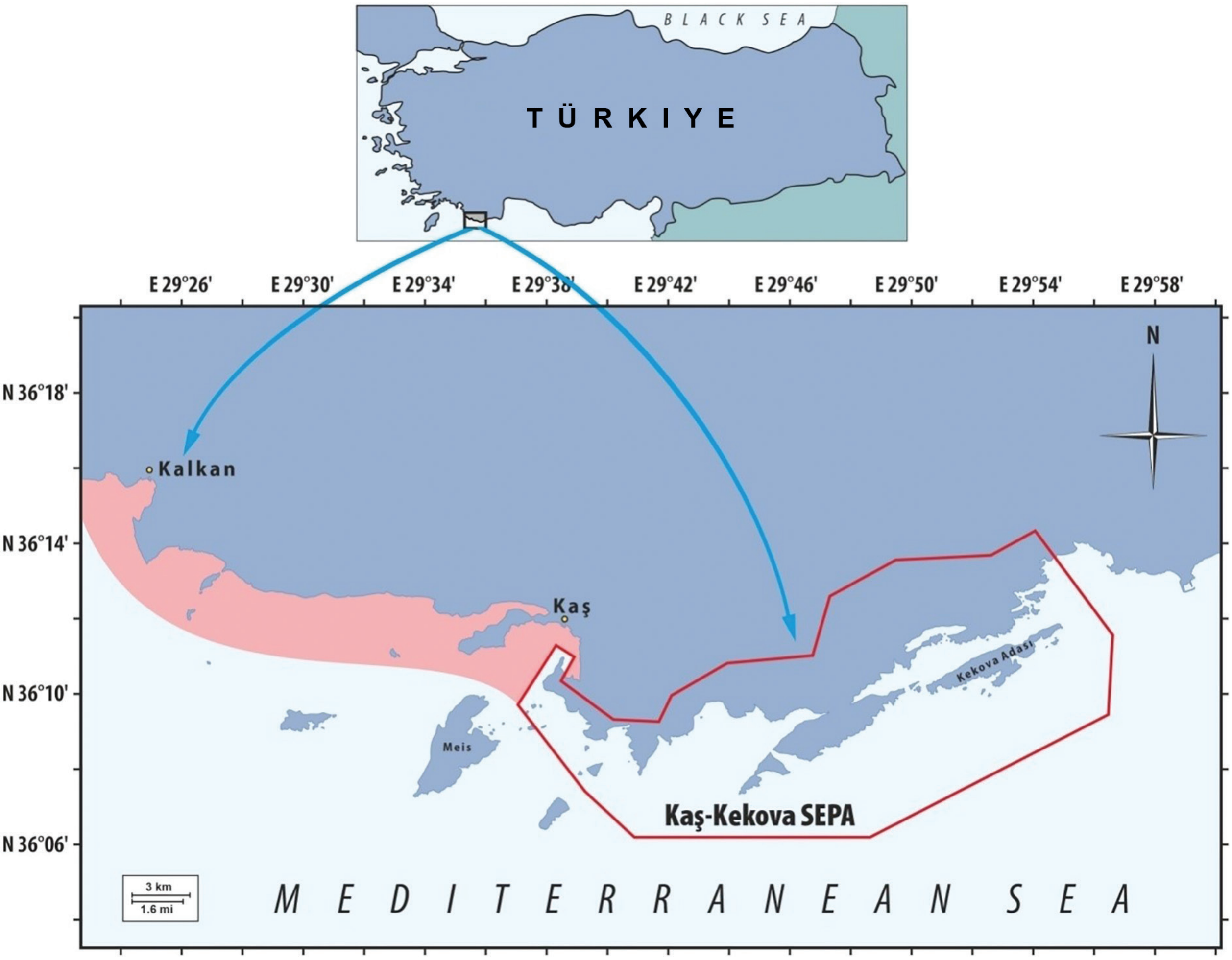

Figure 1. Map of the study area.

electronic balances. The CPUE values were calculated by standardization of the used net length and hook number; the zero catches were also taken into account in CPUE calculation. For longline surveys, the CPUE estimation was standardized for 1000 hooks (Güçlüsoy et al. 2020), while concerning the trammel net surveys, the standardized net length was 1000 m. The Kruskal–Wallis test was used to analyze whether CPUE of indigenous species and NIS shows significant differences depending on sampling seasons. SPSS software (Version 20) was used in this study.

Results

The results indicated that the mean CPUE of indigenous species was markedly high compared to NIS in longlines (Fig. 2A). The mean CPUE of indigenous species was 18 ± 2 kg, whilst the mean CPUE of NIS was calculated as 3 ± 1 kg. On the contrary, the mean CPUE values of indigenous species were low in trammel nets (Fig. 2B, 2C). The mean CPUE of indigenous species and NIS was reported as 0.3 ± 0.2 kg and 3.9 ± 0.7 kg, respectively in a trammel net with 28 mm mesh size, whereas the mean CPUE of indigenous species and NIS was reported as 0.1 ± 0.1 kg and 3 ± 0.4 kg, respectively in trammel net with 36 mm mesh size. There was a marginally significant difference in the CPUE of indigenous species among the different sampling seasons, with the CPUE highest in autumn (Kruskal–Wallis test, $\chi^2 = 19.89$, $P < 0.001$), while the CPUE of NIS did not change seasonally in the longline surveys and the highest mean value was found in winter (Kruskal–Wallis test, $\chi^2 = 2.99$, $P = 0.394$) (Fig. 2D). Concerning the trammel net with 28 mm mesh size, there was no significant difference in the CPUE of indigenous species in different seasons (Kruskal–Wallis test, $\chi^2 = 1.48$, $P = 0.477$). Similarly, for the same fishing gear, the CPUE of NIS did not significantly change by season (Kruskal–Wallis test, $\chi^2 = 4.59$, $P = 0.101$). The highest mean CPUE of indigenous species and NIS was found in summer and spring respectively (Fig. 2E). According to the trammel net survey data regarding mesh size 36 mm, the CPUE of both indigenous species and NIS showed significant differences across all seasons (indigenous species: Kruskal–Wallis test, $\chi^2 = 17.77$, $P < 0.001$, NIS: $\chi^2 = 18.16$, $P < 0.001$) and the highest mean values were recorded in summer for both groups (Fig. 2F).

Regarding the catch composition, 32 species were observed throughout the longline surveys and the percentage of indigenous species was 74% (Table 1). *Lichia amia*, *Pagrus pagrus*, and *Muraena helena* Linnaeus,

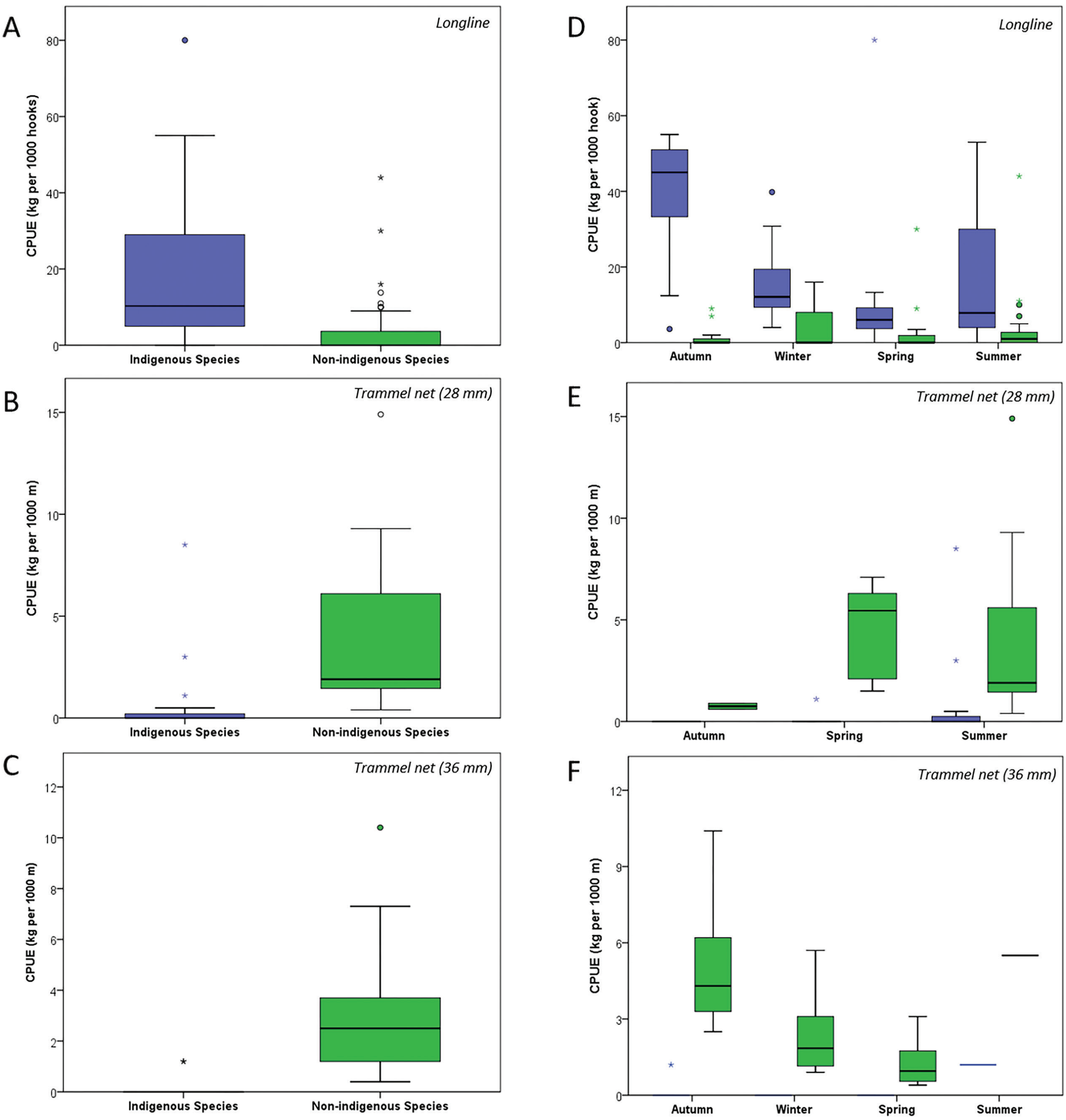

Figure 2. The CPUE values of indigenous and non-indigenous species: **A**) longline, **B**) trammel net (28 mm mesh size), **C**) trammel net (36 mm mesh size), seasonal CPUE values of indigenous and non-indigenous species: **D**) longline, **E**) trammel net (28 mm mesh size), **F**) trammel net (36 mm mesh size). The blue and green box-plots indicate indigenous species and non-indigenous species, respectively.

1758 were the common indigenous species, whereas the highest catches of NIS were represented by *Lagocephalus sceleratus* (Gmelin, 1789), *Lagocephalus suezensis* Clark et Gohar, 1953, and *Pterois miles* (Bennett, 1828) (Fig. 3A). In addition, NIS were common in trammel nets (mesh size 28) and they accounted for 94%. Nine NIS were observed in the nets; *Siganus luridus*, *Siganus rivulatus*, *Pterois miles*, *Scarus ghobban* Forsskål, 1775, *Lagocephalus sceleratus*, *Sargocentron rubrum* (Forsskål, 1775), *Saurida lessepsianus* Russell, Golani et Tikochinski, 2015, *Upeneus moluccensis* (Bleeker, 1855), and *Parupeneus forsskali* (Fourmanoir et Guézé, 1976) (Fig. 3B). Similarly, the composition of trammel nets with a larger mesh size (36 mm) mainly consisted of NIS (98%). The most prevalent, among the species caught in the above-mentioned gear was lionfish *Pterois miles*, followed by *Siganus luridus*, *Scarus ghobban*, *Siganus rivulatus*, *Sargocentron rubrum*, *Lagocephalus sceleratus*, *Fistularia commersonii* Rüppell, 1838, *Upeneus pori* Ben-Tuvia et Golani, 1989, *Lagocephalus suezensis*, *Upeneus moluccensis*, and *Saurida lessepsianus* (Fig. 3C). The results also showed that ecologically important fish species including *Pagellus erythrinus* (Linnaeus, 1758), *Conger conger* (Linnaeus, 1758),

Table 1. Catch composition (finfish and shellfish), percentage, and biomass information of bottom set longline and trammel nets 28 and 36 mm for 75, 27, and 35 fishing days, respectively.

Catch composition of longline	Percentage [%]	Biomass [kg]	Catch composition of trammel net (28 mm)	Percentage [%]	Biomass [kg]	Catch composition of trammel net (36 mm)	Percentage [%]	Biomass [kg]
Lichia amia	18.85	101.2	*Siganus luridus*	25.66	48.7	*Pterois miles*	34.62	63
Pagrus pagrus	13.38	71.85	*Siganus rivulatus*	25.5	48.4	*Siganus luridus*	23.08	42
Muraena helena	12.24	65.7	*Pterois miles*	22.13	42	*Scarus ghobban*	16.98	30.9
Epinephelus costae	10.47	56.2	*Scarus ghobban*	7.38	14	*Siganus rivulatus*	8.96	16.3
Pagellus erythrinus	9.04	48.5	*Lagocephalus sceleratus*	6.43	12.2	*Sargocentron rubrum*	6.26	11.4
Lagocephalus sceleratus	8.63	46.3	*Sargocentron rubrum*	5.22	9.9	*Lagocephalus sceleratus*	4.18	7.6
Conger conger	5.10	27.4	*Sparisoma cretense*	2.11	4	*Fistularia commersonii*	2.03	3.7
Lagocephalus suezensis	4.30	23.1	*Pagellus erythrinus*	1.48	2.8	*Lichia amia*	1.15	2.1
Xiphias gladius	3.37	18.1	*Epinephelus costae*	1.21	2.3	*Upeneus pori*	1.04	1.9
Dentex macrophthalmus	2.85	15.3	*Torpedo marmorata*	0.58	1.1	*Lagocephalus suezensis*	0.55	1
Pagrus caeruleostictus	2.44	13.1	*Saurida lessepsianus*	0.53	1	*Epinephelus costae*	0.55	1
Epinephelus aeneus	2.12	11.4	*Scorpaena porcus*	0.42	0.8	*Upeneus moluccensis*	0.38	0.7
Phycis blennoides	0.78	4.2	*Sepia officinalis*	0.37	0.7	*Saurida lessepsianus*	0.11	0.2
Pterois miles	0.75	4	*Upeneus moluccensis*	0.34	0.7	*Scorpaena porcus*	0.11	0.2
Homarus gammarus	0.75	4	*Parupeneus forsskali*	0.32	0.6			
Sargocentron rubrum	0.63	3.4	*Diplodus vulgaris*	0.21	0.4			
Saurida lessepsianus	0.63	3.4	*Spicara smaris*	0.11	0.2			
Loligo vulgaris	0.56	3						
Scarus ghobban	0.52	2.8						
Dentex dentex	0.43	2.3						
Nemipterus randalli	0.37	2						
Diplodus sargus	0.34	1.8						
Torpedo marmorata	0.30	1.6						
Raja sp.	0.24	1.3						
Oblada melanurus	0.20	1.1						
Parupeneus forsskali	0.17	0.9						
Diplodus vulgaris	0.15	0.8						
Pagellus acarne	0.11	0.6						
Serranus cabrilla	0.10	0.55						
Siganus luridus	0.09	0.5						
Serranus scriba	0.04	0.2						
Sparisoma cretense	0.04	0.2						

Dentex macrophthalmus (Bloch, 1791), *Phycis blennoides* (Brünnich, 1768), *Diplodus sargus* (Linnaeus, 1758), *Pagellus acarne* (Risso, 1827), *Serranus scriba* (Linnaeus, 1758), *Sparisoma cretense* (Linnaeus, 1758) and invertebrate species *Homarus gammarus* (Linnaeus, 1758) and *Loligo vulgaris* Lamarck, 1798 were observed in longline catch composition (Table 1). Similarly, *Scorpaena porcus* Linnaeus, 1758 and *Spicara smaris* (Linnaeus, 1758) were caught by trammel net (Table 1).

Discussion

This study provided evidence of a predominance of NIS in trammel net catches, while the same were less prevalent in the longlines in Kalkan, Kaş, and the Kaş–Kekova SEPA, Eastern Mediterranean. Traditionally, trammel net fishery is generally performed in shallow waters compared with the longline fishery in the Kaş–Kekova SEPA and Kalkan, and it is well-known that some Lessepsian species prefer to live in shallow waters (Corsini et al. 2005; Öndes et al. 2018). Therefore, this can be considered an important factor resulting in the differences in Lessepsian catches by trammel nets and longlines. Likewise, the relation between changes in the behaviors of fishers and the CPUE of Lessepsians was discussed by Van Rijn et al. (2020). The study noted that fishers preferred to fish in shallower waters where Lessepsians were common; thus, their CPUE values showed an increase. Today it is well-known that the stocks of many indigenous species which could be potential predators or competitors of NIS in the Mediterranean have been markedly reduced by overfishing (Vasilakopoulos et al. 2014; Piroddi et al. 2017). Moreover, according to TURKSTAT's data, the total landings of many indigenous species in the Mediterranean (Levantine) coasts of Türkiye showed a marked decrease over the periods of 2001–2010 and 2011–2020. For instance, the decline percentages of some commonly fished species in the SSF were as follows: *Dentex dentex* (Linnaeus, 1758) (77%), *Pagrus caeruleostictus* (Valenciennes, 1830) (76%), *Pagrus pagrus* (75%), *Oblada melanurus* (Linnaeus, 1758) (72%), *Zeus faber* Linnaeus, 1758 (65%), *Lichia amia* (53%), *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817) (52%), and *Xiphias gladius* Linnaeus, 1758 (29%) (TURKSTAT 2022). On the other hand, the total landings of some species, such as *Sarda sarda* (Bloch, 1793) and *Scomber colias* Gmelin, 1789, showed an increase for the same period (TURKSTAT 2022).

In the presently reported study, the most common two species in the trammel nets with 28 mm mesh size were *Siganus luridus* and *Siganus rivulatus*, and these

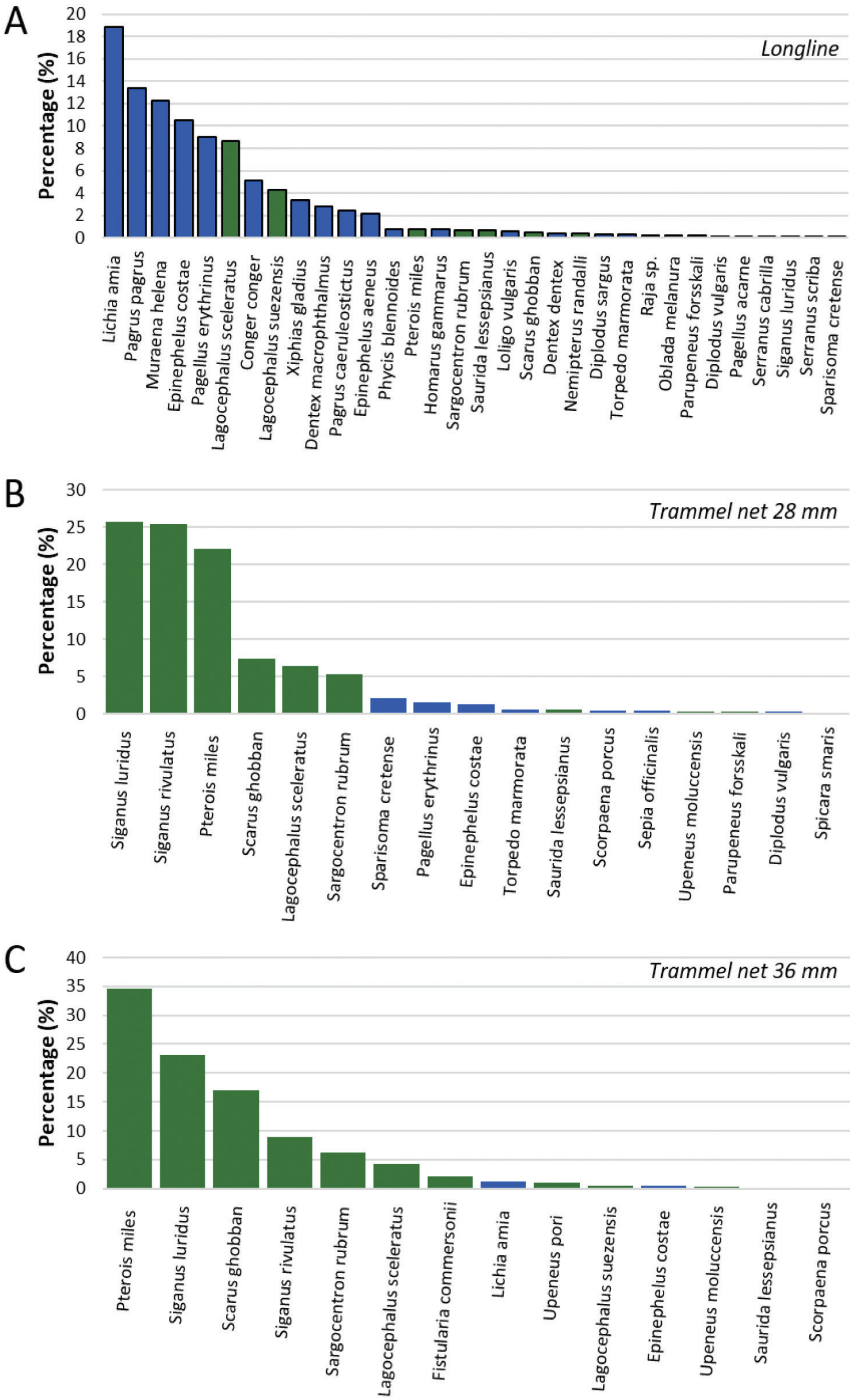

Figure 3. Catch composition (with percentages) of **A**) longline, **B**) trammel net (28 mm), **C**) trammel net (36 mm) in the Levantine coasts of Türkiye. The blue and green bars indicate indigenous species and non-indigenous species, respectively.

consisted of more than half of the total catch. These species also represented significant amounts in the catch of trammel net with a 36 mm mesh size. Akyol et al. (2022) reported that *Siganus rivulatus* and *Siganus luridus* were commonly caught in the gillnet fishery in the southern Aegean Sea. Similarly, Bakhoum (2018) evaluated the catch composition of trammel nets from December 2011 to May 2014 off the Egyptian Mediterranean coast of Alexandria and noticed that Lessepsian fish *Siganus rivulatus* was the most dominant species with an index of the relative dominance of 54.47%. Lessepsian species also started to be an important part of the catch composition of Mediterranean trawl fishery. For example, Mavruk et al. (2017) collected data on the catch composition of trawl fishery from 2004 to 2015 in the Gulf of Iskenderun, in the northeastern Mediterranean, and reported that Lessepsians represented 27%, 62%, and 85% of the total teleost fishes in the number of species, biomass, and abundance, respectively. They also highlighted that the dominance of Lessepsian fishes showed an increase with an annual rate of 2.77 (LW-% (biomass)) per year throughout their study period. Furthermore, Yemisken et al. (2014) investigated the catch composition of trawl fishery in the Gulf of Iskenderun and noted that 27 Lessepsian species were found, and 9 of them began to be target species for trawlers.

The presently reported study demonstrated that the highest CPUE of NIS in trammel nets with 28 mm mesh size was found in the spring and summer months. Similarly, Öndes et al. (2018) reported that the highest bycatch of pufferfish species was observed in the summer months on the Levantine coasts of Türkiye. Furthermore, Akyol et al. (2022) found lower CPUE values for NIS compared with the presently reported study. This situation may be related to the difference in sampling sites; Akyol et al. (2022) collected data further north from our study area where the population structure of NIS were different. Concerning the seasonal difference of CPUE in trammel nets with 36 mm mesh size, the highest values were recorded in autumn in the presently reported study. Similarly, Akyol et al. (2022) reported that the highest CPUE values of NIS were found in autumn.

Our study reports a total of 12 and 9 non-indigenous species in trammel nets and longline surveys, respectively. Among them, 8 species including *Siganus luridus*, *Siganus rivulatus*, *Upeneus pori*, *Upeneus moluccensis*, *Sargocentron rubrum*, *Nemipterus randalli* Russell, 1986, *Pterois miles*, and *Saurida lessepsianus* have been sold at local markets. Undoubtedly, having the market value and demand for these species is desirable for both fishers and ecosystem health. There are some factors that may persuade consumers to consume these new species more. For example, the prices of these species are generally more affordable compared to many native species that show decreased populations due to overfishing. Other reasons may be related to the flavor of these species and people's gastronomic curiosity. Moreover, awareness studies and projects are carried out by some NGOs (e.g., Mediterranean Conservation Society) and their enterprises encouraging the consumption of these species in the region (Pers. comm., Funda Kök). On the other hand, some studies (Ünal et al. 2015; Ünal and Göncüoğlu Bodur 2017) suggested the application of a bounty system, which has been in practice in Northern Cyprus since 2012, (Anonymous 2012) in order to combat species such as pufferfish, which do not have a market value yet. Decision makers would seem to be amenable to implementing these suggestions in Türkiye as well. For this purpose, a communiqué (a notification) was published in the official gazette, and a regulation was made to pay the fishers for each puffer fish tail they provided (Anonymous 2021). In fact, in terms of catch amount and value, the rate of NIS in the SSF should not be disregarded. Ünal (unpublished*) reported that the proportion of NIS within the total catch in the Kaş–Kekova SEPA was 40% and two of the five most important species in terms of total catch amount and value were NIS.

Conclusions

In conclusion, the presently reported study shows that indigenous species are dominant in bottom set longline fishery, while NIS are represented with higher CPUE in trammel net fishery in Kalkan, Kaş, and the Kaş–Kekova SEPA, Eastern Mediterranean. Furthermore, in general, the dominance of indigenous species has shown a dramatic decrease over recent decades. Although there have been measures taken by decision-makers to cope with this situation, they are insufficient. In addition to management measures and practices, it is observed that related scientific studies are also insufficient. Therefore, we suggest further research focusing on the catch composition of both trammel and gill nets that have smaller mesh sizes used by the fleet.

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