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Catch Composition and Catch Per Unit Effort of Small-scale Fisheries on the Coasts of the Bodrum Region (Güllük Bay, South-eastern Aegean Sea)

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Abstract

This study presents the species composition of fish caught using gill/trammel nets in the Bodrum and surrounding areas on the coasts of the southern Aegean Sea, along with the fish catch per unit effort (CPUE) values by fishing area and seasonality. Five types of set nets were examined: gillnets for the bogue (*Boops boops*) fishing, trammel nets for the common sole (*Solea solea*) fishing, bottom trammel nets, bottom gillnets, and trammel nets for the red mullet (*Mullus barbatus*) fishing. Among these, gillnets used for bogue fishing are primarily deployed near fish cages. The study revealed that the highest average CPUE values of gill nets were 50.3±8.3 kg.1000 m^{-1} in spring and 64.5±24.9 kg.1000 m^{-1} around the sea cages, attributed to the increased presence of bogue, particularly during the spring season.

Introduction

Bodrum, located in Muğla Province, is a town associated with fishing (Göncüoğlu & Ünal, 2011; Akyol et al., 2016), tourism (Günaydın et al., 2021), boat building (Turan et al., 2022), and sponge fishing culture (Akyol, 2023). Although fishing and tourism continue to thrive, the outbreak of the 'sponge plague' in the mid-1980s led to a decline in sponge fishing, ultimately resulting in the ban on sponge diving in 1986 (Topaloğlu, 1998; Akyol, 2023). The coastal fisheries on the Bodrum Peninsula are primarily concentrated in Güllük and Gökova Bays. Fishing activities predominantly utilize gillnets, longlines, and handlines. Additionally, a small number of traditional gulet-type wooden trawlers and purse seiners are employed. The favourable structure of the coves along the peninsula's coast has facilitated the expansion of aquaculture activities, despite Bodrum fishermen supplying sufficient fish for tourists (Akyol, 2016). In 2013, Muğla's fishing fleet consisted of 1428 boats, with 97% dedicated to the fishing net and longline operations (Dereli & Belli, 2014).

During the last two decades of fisheries data, Aegean Sea contributes approximately 10.7% (±2.9) to marine finfish capture fisheries production in Türkiye (TurkStat, 2023). Kara and Gurbet (1998) reported that although 566 fishing vessels were involved in diverse fishing activities across the Bodrum Peninsula and adjacent bays, the total number of active fishing boats in the region amounted to 249. Among these three are purse seiners, 24 trawlers, 24 beach seiners, and 198 are small-scale fishing vessels engaged in net and longline fishing. The longline and gillnet/trammel net fisheries, which are fundamental to the Bodrum Peninsula fishery, collectively contribute only 7-8% of the total production. Beach seines, which previously accounted for 11% of the landings, have been prohibited in all Turkish waters since 2001. Trawl fishing contributes 28% to fisheries

landings, while purse seining represents 2% in the peninsula (Kara & Gurbet, 1998). In 2021, the number of fishing vessels operating along the coasts of Muğla Province was reported as 1146 (TurkStat, 2023). Current data indicate that fishing boats ranging 5 to 8 meter length constitute the largest group. Additionally, the region is characterised by dense concentration of marine fish farm units, with over half of all sea cage fish farms in Türkiye located here (TurkStat, 2023). Fishers operating in coastal waters near sea cages can expect high catch rates, as these areas are naturally abundant in fish. Gillnet fishing for bogue is prevalent in these regions, and they are also popular among recreational anglers (Akyol et al., 2017)

In the Bodrum Peninsula, there is a paucity of research on gillnet fishing, despite it being one of the most common fishing gear used in small-scale fisheries (SSF) (Akyol et al., 2016, 2022). For this reason, random samplings were carried out from selected active gillnet fisheries in the region. Therefore, this study aimed to determine the technical specifications of the gill/trammel nets preferred concerning with species, identify the types of bycatch and discarded fish compared to the targeted species, and assess the catch per unit effort (CPUE) of the gillnets across different seasons and fishing areas.

Material and Methods

Between October 2017 and December 2019, data from observations and monitoring activities conducted in fishing ports and aboard fishing vessels in the Bodrum region of Muğla were conducted. The research has been carried out seasonally and periodically, with a primary focus on Gökova Bay, Bodrum, and Güllük Bay (Figure 1). Several fishing ports and cooperatives were monitored, and catch records were primarily documented through direct observations aboard fishing boats.

Catch per unit effort (CPUE) for gill/trammel nets was estimated by the amount of fish caught per standard unit of fishing effort (kg.1000 m^{-1}). Fishing effort (f) and CPUE were computed according to the formula proposed by de Metrio and Megalafonou (1988): f=(a'/1000) × g, where "a'" represents the length of the net used, (a'/1000) denotes the unit of net laid horizontally across the seabed each day, standardized to

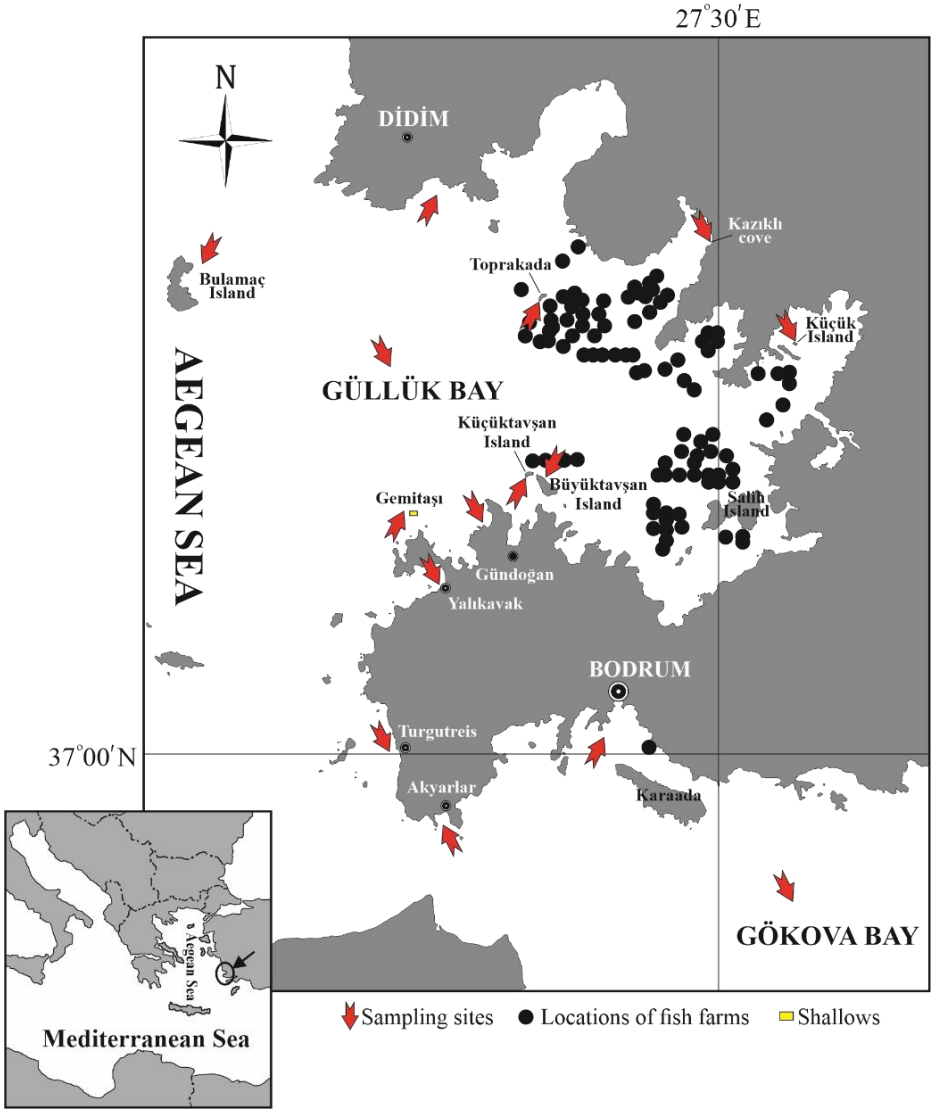


Figure 1. Study site

1 km, and "g" signifies the number of fishing days. CPUE was then calculated as the catch weight per km of net using the formula CPUE=kg/f, with "kg" representing the total weight of the catch. Additionally, the months from both years were aggregated into seasons.

The nonparametric Kruskal-Wallis test was employed to assess the statistical significance of differences observed in the results, as the data did not adhere to normal distribution assumptions. A confidence interval of 95% was utilized for the analysis. All statistical analyses and graphical representations were conducted using the R statistical program (R Development Core Team, 2020) and the Tidyverse package (Wickham et al., 2019)

Results

Fishing Gears and Target/Non-target Species

Gillnet for Bogue

Gillnets were constructed using multifilament-twisted polyamide mesh material (PA, *Naylon*) with a twine diameter ranging from 210d/3-4-6. These nets feature a mesh height of 40-50 and nominal bar lengths of 30-32-34 mm, with a hanging ratio (E) of 0.50. The net lengths (when mounted) vary between 20 and 40 panels, with each set reaching a length of 80 to 100 meters. Fishing seasons typically occur between January and May, October 15th and the end of May, and November and June. Fishing locations encompassed Salih Island, Küçük (Papaz) Island, Toprakada, Küçüktavşan (Apostol) Island, Kazıklı, Büyüktavşan Island, and Didim, as depicted in Figure 1.

Fishing activities were conducted at water depths ranging between 50 and 65 meters, with gillnet fishing targeting the bogue species typically performed in depths between 50 and 60 meters. A total of 37 species were unintentionally caught as bycatch, and 12 species were discarded, as illustrated in Table 1. Furthermore, two species, namely *Siganus rivulatus* Forsskål & Niebuhr, 1775 and *Hemiramphus far* (Forsskål, 1775), were identified as exotic species (Table 1).

Trammel Net for Common Sole

These nets comprised central netting (201d/6) and external netting panels (210d/9-12), constructed from multifilament-twisted PA mesh material. Central net panels have a mesh height of 35-40 and nominal bar lengths of 40-50-90 mm, with a hanging ratio (E) of 0.50. External panels feature a mesh height of 5-6.5 and nominal bar lengths of 160 mm, characterized by a higher hanging ratio than the central panel. The length of mounted nets varies between 30 and 80 panels of nets, with each panel extending 80 to 100 meters in length. Fishing activities primarily occurred between November and February, with fishing locations including Bulamaç Island, Küçük (Papaz) Island, Güllük Bay, and Didim, off the coast of Gemitaşı (the fishing area between Yalıkavak and Didim) (Figure 1). Depths for fishing ranged between 75 and 90 meters, with nets typically set out a few hours before sunset and retrieved at sunrise. A total of 22 species were identified as bycatch, while 8 species were discarded. No exotic species were encountered during the fishery survey (Table 1).

Trammel Net for Bottom Fishes

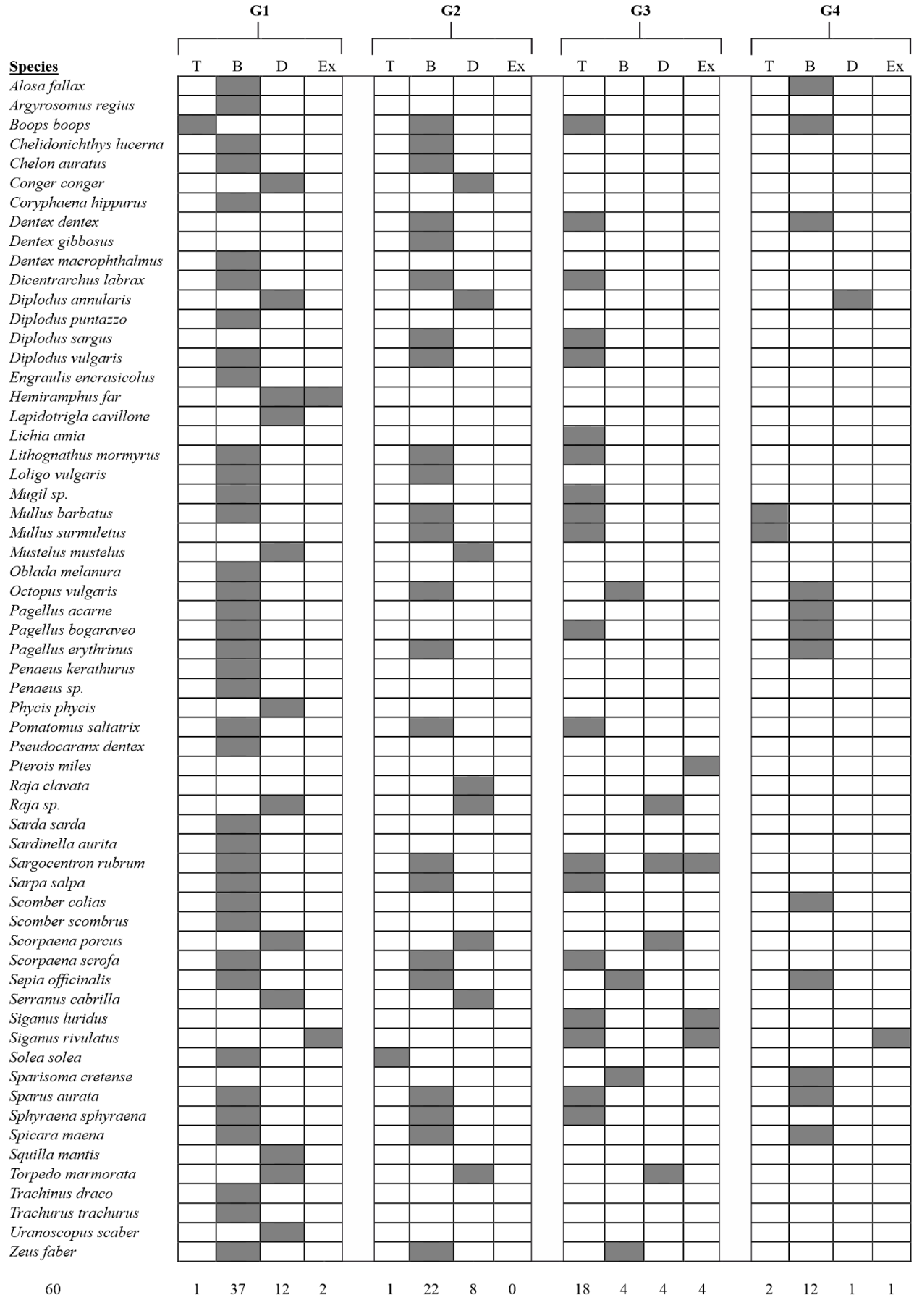
The central (201d/4) and external (210d/6-8-9-12) netting panels of the trammel nets were constructed using multifilament-twisted PA material. Central net panels have a mesh height of 40-60 and nominal bar lengths of 30-32-40 mm, with a hanging ratio (E) of 0.50. External panels of the trammel net feature a mesh height of 5-8-9 and nominal bar lengths of 125-160-180 mm, characterized by a higher hanging ratio than the central panel. The net lengths (when mounted) vary between 4 and 40 sets, with each set extending 80, 90, or 100 meters in length. Local fishermen utilize bottom trammel nets throughout the year. Fishing sites include Turgutreis, Gündoğan, and Kazıklı (Figure 1). Fishing depths range from 10 to 60 meters, with nets typically set a few hours before sunset and retrieved at sunrise. The study identified 18 target species, whereas bycatch species consisted by 4 species and four fish species were discarded. Additionally, four fish species were classified as exotic species, including *Siganus luridus* (Rüppell, 1829), *S. rivulatus*, *S. rubrum* (Forsskål, 1775), and *Pterois miles* (Bennett, 1828) (Table 1).

Similar to bottom trammel nets, bottom gillnets are also used at this site to caught species such as *Mullus barbatus* Linnaeus, 1758, *Boops boops* (Linnaeus, 1758), *Alosa alosa*, (Linnaeus, 1758) and *Pagellus bogaraveo* (Brünnich, 1768). These gillnets are made of multifilament-twisted PA with a twine diameter of 210d/2. They have a mesh height of 33 and nominal bar lengths of 18-20 mm, with a hanging ratio (E) ranging from 0.30 to 0.50. The net lengths (when mounted) vary between 20 sets, with each set extending 60 to 100 meters in length. Fishing activities using bottom gillnets between depths of 30 and 70 meters were conducted year-round in Bodrum and Gökova. Typically, these gillnets were set at 3:00 a.m. and retrieved from the fishing area at 6:00 a.m. However, no operations were observed with these gillnets during the sampling period, thus preventing the detection of species composition.

Trammel Net for Red Mullet

The central (201d/2) and external (210d/3-4-6-7) net panels of the bottom trammel nets were constructed from multifilament-twisted PA material. The central panel features a mesh height of 33-40-50 and nominal bar lengths of 18-20-22 mm, with a hanging ratio (E) of 0.50. External panels of the trammel net have a mesh height of 5-6 and nominal bar lengths of 100-110

Table 1. The species that caught by four different fishing gears (G1: Gillnet for bogue, G2: Trammel net for common sole, G3: Bottom trammel net, and G4: Trammel net for red mullet) in the Bodrum region was categorized into target species (T), bycatch species (B), discarded species (D), and exotic species (Ex).



mm, characterized by a higher hanging ratio compared to the central panel. The net lengths (when mounted) range between 10 and 30 sets, with each set extending 80 to 100 meters in length. Fishing activities occur year-round, with fishing locations including Yalıkavak, Akyarlar, and Turgutreis (Figure 1). The fishing depths ranged from 15 to 60 meters, with the nets typically deployed a few hours before sunset and retrieved at sunrise. The primary target species were *M. barbatus* and *M. surmuletus* Linnaeus, 1758. A total of 12 species were identified as bycatch, and one species i.e. *Diplodus annularis* (Linnaeus, 1758) was discarded. During the fishery survey, only one exotic species, *S. rivulatus*, was encountered (Table 1).

Among the 61 species observed in the catch composition of four different fishing gears, *B. boops* emerged as the most abundant fish by weight, followed by *D. annularis* and *Scomber colias* Gmelin, 1789 (Table 1 and Figure 2). A total of 14 species were discarded, representing approximately 3.6% of all species caught. The most commonly discarded species by weight were *D. annularis*, *Mustelus mustelus* (Linnaeus, 1758), and *Scorpaena porcus* Linnaeus, 1758 (Figure 3).

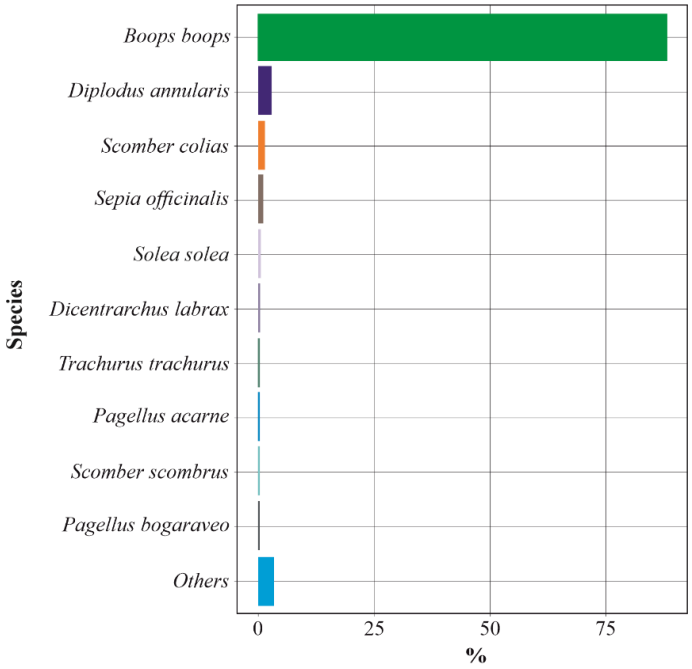


Figure 2. The top ten species caught from gill/trammel nets in the Bodrum region are ranked according to biomass percentage.

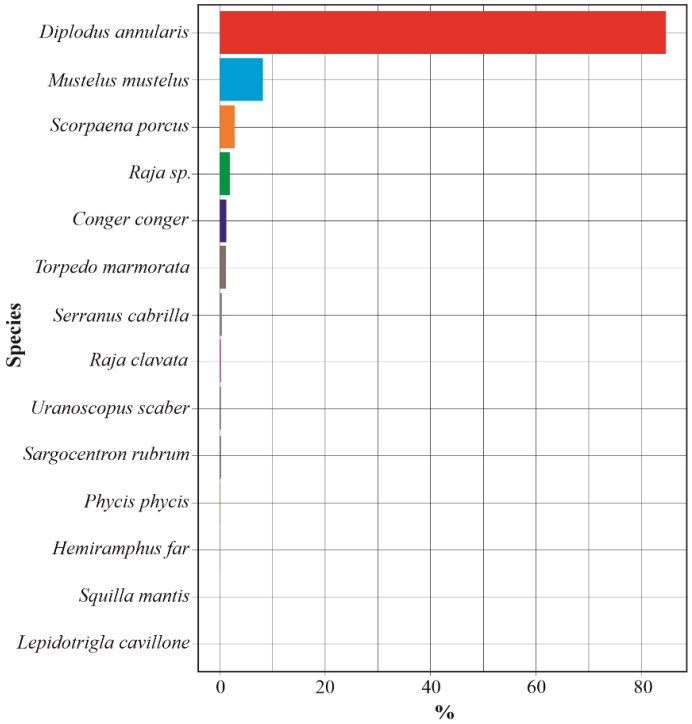


Figure 3. The discarded species caught from gill/trammel nets in the Bodrum region are presented based on biomass percentage.

Catch Rates and Catch Per Unit Effort (CPUE)

A total of 179 valid gillnet operations were assessed in the study. The catch per unit effort (CPUE) values reached to 525.0 kg per 1000 meters of net, with an average CPUE of 38.6±4.17 kg per 1000 meters of net.

The seasons with the lowest average catch per unit effort (CPUE) in gillnet fishing were autumn and spring, as shown in Table 2 and Figure 4. The results revealed a statistically significant difference in CPUE across the seasons ($H=30.99$, $df=2$, $p<0.05$).

The mean CPUE values of gillnets and trammel nets were found to be lowest on the coasts of Bodrum while fishing around the fish cages exhibited the highest mean value (see Table 2 and Figure 4). The analysis demonstrated a significant variation in CPUE across different fishing locations as evidenced by the Kruskal-Wallis H test ($H=31.75$, $df=3$, $p<0.05$).

Discussion

Four different types of gillnets were studied in the coasts of the southern Aegean Sea in the area of Bodrum, including those used for bogue fishing, trammel nets for common sole fishing, bottom trammel nets, and trammel nets for red mullet fishing. Among these, gillnets employed for bogue fishing were frequently operated around the sea cages. Akyol et al. (2016) identified nine types of gillnets and four types of longlines in the Bodrum peninsula. While our study examined fishing gears similar to those classified as common sole fishing trammel net and bogue fishing gillnet, we did not encounter other nets, such as trammel nets for common dentex fishery, two types of trammel nets for common dentex fishery, gillnets for pink dentex fishery, shrimp trammel nets, and gillnets for red porgy fishery.

Table 2. Analysis results of CPUE values of fishing nets by seasons and fishing locations (kg.1000 m^{-1}).

Season	n	Min	Max	Mean ± SE
Autumn	18	0.00	40.00	6.60 ±2.8
Winter	87	0.00	208.3	35.3 ±4.5
Spring	74	0.57	525.0	50.3 ±8.3
Around the islets	136	0.0	525.0	42.9 ±5.00
Coasts of Bodrum	20	0.0	26.70	8.30 ±2.10
Around the fish cages	10	6.7	208.3	64.5 ±24.9
Neighbouring bays	13	0.0	100.0	20.4 ±10.0

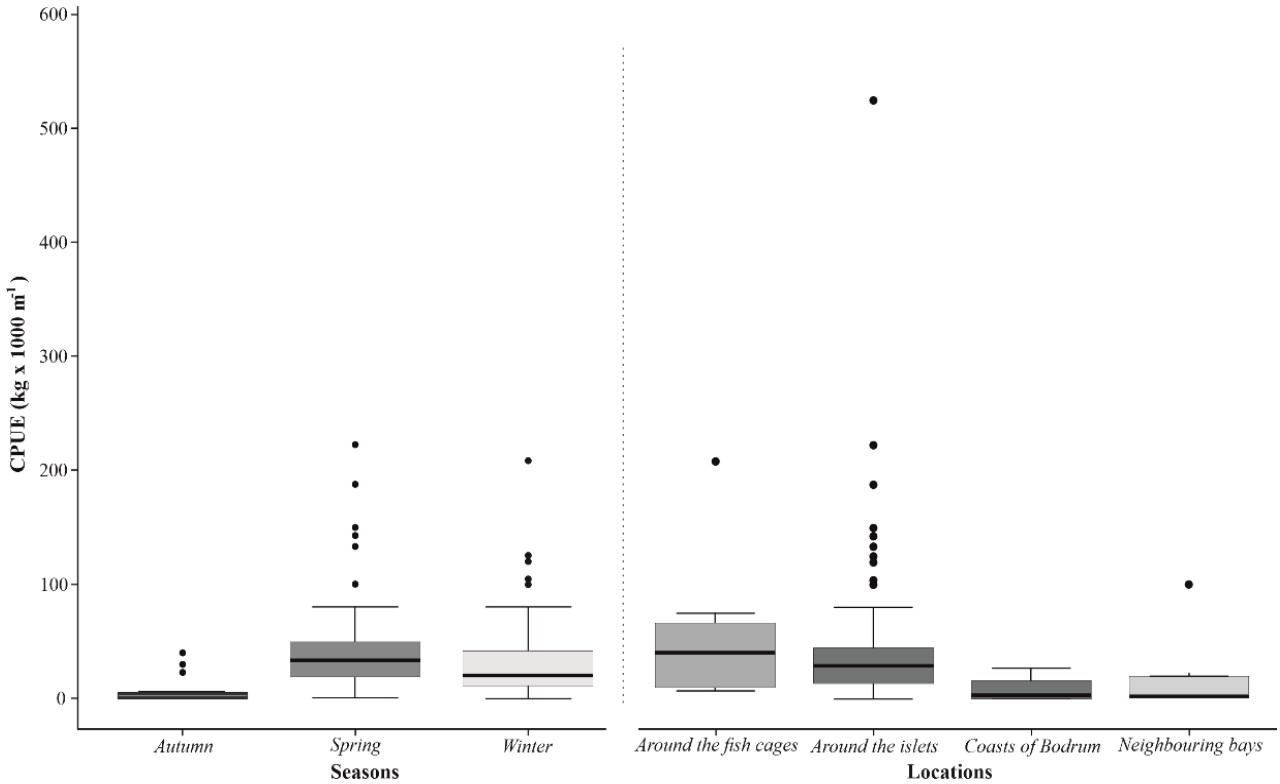


Figure 4. CPUE values by seasons and fishing locations (kg.1000 m^{-1}).

The species examined in this study and caught along the coasts of Bodrum are typical of the Aegean Sea, with fishes primarily belonging to the families Sparidae, Carangidae, Mugilidae, and Mullidae being the main target species. When fishing near sea cages, the bogue becomes the primary target. Akyol et al. (2016) reported that thirty fish species, including the dusky grouper *Epinephelus marginatus* (Lowe, 1834), white grouper *Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817), red mullet *M. barbatus*, gilt-head bream *S. aurata* Linnaeus, 1758, and common dentex *D. dentex* (Linnaeus, 1758), were targeted. The abundance of aquaculture facilities in the region can meet the increased demand for fish during the summer peak in tourism activity.

In recent years, rising water temperatures and global warming have facilitated the increased prevalence of exotic, alien, and invasive species in the Mediterranean region (Azzurro et al., 2019). Notably, species such as the silver-cheeked toadfish *L. sceleratus* (Gmelin, 1789), marbled spinefoot *S. rivulatus*, dusky spinefoot *S. luridus*, redcoat *S. rubrum*, and common lionfish *P. miles* have been identified. Among these, the silver-cheeked toadfish stands out as the most detrimental species in the catch composition. Particularly, longlines suffer the most damage, as silver-cheeked toadfish often attempt to ingest captured fish or live bait, resulting in the ingestion of the fish along with its snoods and hooks. The predominant concerns in this regard include financial losses (bait, snood, and hook) and disruptions to work caused by the breakage of up to half of the 1000 hooks (T. Bıçak, pers. comm., May 30, 2018). While these species historically concentrated along the southern coasts of Türkiye, primarily in the Mediterranean region (Bilecenoğlu et al., 2014), their distribution is shifting northward into the Aegean Sea with increasing temperatures. Among the invasive fishes, the silver-cheeked toadfish and lionfish are notably problematic. Recent reports indicate their presence in the northern Aegean waters (Özgül, 2020), with observations even extending to the Sea of Marmara (Irmak & Altınağaç, 2015) and the Black Sea (Bilecenoğlu & Öztürk, 2018). Ünal et al. (2015) conducted a study on the damage inflicted by silver-cheeked toadfish in coastal fisheries, involving 261 fishermen from İzmir and Hatay. The survey revealed that 78% of fishermen experienced financial losses due to puffer fish, 89% reported reduced catch rates, and 82% believed that puffer fish had a negative impact on marine biodiversity. These findings, corroborated by similar studies (Ünal et al., 2015; Ünal & Göncüoğlu-Bodur, 2017), advocate for a reward system aimed at mitigating the socio-economic effects of these species on fishers and marine ecosystems. The General Directorate of Fisheries and Aquaculture, under the Ministry of Agriculture and Forestry, is currently addressing this issue by implementing a buyback program, offering incentives to fishermen for catching puffer fish and thereby reducing their populations through a tail-based compensation scheme.

The highest mean CPUE values of gillnets during spring (50.3±8.3 kg.1000 m^{-1}) and in proximity to fish cages (64.5±24.9 kg.1000 m^{-1}). This trend can be attributed to the abundant presence of bogue individuals near the cages. Consequently, bogue comprised approximately 88% of the total catch in the gillnet and trammel net fishery along the coasts of Bodrum. Akyol et al. (2020) similarly noted the dominance of bogue individuals around fish cages in the Aegean Sea. Furthermore, bogue fishing activity, which intensifies in the region after January, reaches its peak in April, contributing to the heightened CPUE values observed during the spring months. This association between spawning migration in spring and bogue catch efficiency was also corroborated by T. Bıçak (pers. comm., May 30, 2018). Subsequently, during the summer season, fishermen typically transition away from this type of fishing to engage in the tourism industry.

Gillnet and trammel net fishing operations conducted near sea cages exhibit high catch efficiency while maintaining relatively low catches of non-target species (Ertosluk et al., 2023). According to Ertosluk et al. (2023), fishers achieved a target species catch rate of 92% by utilizing large mesh nets and employing appropriate fishing techniques, particularly targeting larger bogue individuals. However, commercial fishing within 200 meters of the fish cages is prohibited, leading to occasional conflicts between fishermen and aquaculture workers (Akyol et al., 2019). Consequently, it becomes imperative to diversify small-scale fisheries in the region and allocate fishing activities to small islands and various coves as alternative areas. This strategy ensures the conservation of wild fish stocks around fish cages, effectively designating them as conservation zones. In this regard, the involvement of universities and non-governmental organizations plays a crucial role in raising awareness among regional fishers.

Conclusion

Akyol et al. (2022) estimated that the seasonal mean CPUE of exotic fish caught by gillnets in the same region was lower, at 0.7±0.3 kg.1000 m^{-1}. This value suggests that it was 72 times lower than the total seasonal CPUE (Akyol et al., 2022). However, various analyses indicate that the Mediterranean region has entered a process of tropicalization (Bianchi & Morri, 2003; Azzurro et al., 2019). The opening of the Suez Canal in 1869 facilitated a connection to the Indo-Pacific, resulting in a substantial introduction of exotic species into the Mediterranean. Concurrently, fish species of Atlantic origin continued to enter the sea through the Strait of Gibraltar. Moreover, exotic species from both the marine and aquarium trade continue to be imported into the region. We think this phenomenon may change the catch composition in the area over time. The migration of marine species carries significant

ecological, economic, social, and cultural implications, highlighting the importance of ongoing efforts to identify, monitor, and, if necessary, mitigate the spread of these species in a timely manner.

Ethical Statement

Local Ethics Committee Approval was not obtained because experimental animals were not used.

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Author Contribution

(OA): Project administration, conceptualization, methodology, investigating, writing - original draft, writing - review & editing. (TC): Conceptualization, investigating, data curation, writing - original draft, writing - review & editing. (FOD): Conceptualization, writing - original draft, writing - review & editing, visualization. (OE): Data collection, supervision.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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