

## Grouper fishery in the Northeastern Mediterranean: An assessment based on interviews on resource users



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### ABSTRACT

Grouper are important components of coastal ecosystems as well as a valuable resource for fisheries. Their populations are known to be decreasing throughout the world primarily due to over-exploitation. However, even the basic data for an effective management strategy is lacking. Interviews of a representative sample of 113 fishers in Turkey in the northeastern Mediterranean were conducted with specific questions regarding fishing gears, periods and areas as well as best day's catch and the sizes of fishes caught. Fishermen recognized *Epinephelus marginatus*, *E. aeneus*, *E. costae*, *Hyporthodus haifensis*, *Mycteroperca rubra* and *Polyprion americanus* distributed in the area. "Endangered" *E. marginatus* and "Near Threatened" *E. aeneus* were the dominant species of the grouper fishery. Based on best days' catch values and reported lengths of fish caught, the northern coasts of Iskenderun Bay were found to be important for both species. Demersal longliners, spearguns, traps, anglers and demersal trawlers were reported catching groupers in the study area. Artisanal fishermen, especially demersal longliners contributed the most to the grouper fishery. Fishing pressure were subject to seasonal fluctuations, with decreasing reported catches during summer when threatened groupers spawn. Finally, some critical aspects of fishery pressure were related to the removal of juveniles which may lead to reproduction loss.

### 1. Introduction

The specific knowledge retained by fishermen regarding their resources, environment and fishing practices can provide valuable information to fishery scientists [1]. This knowledge can be extremely useful in order to gather information on behavior [2], diseases [3], population abundance [4], fishing practices [5], spawning grounds [6], nursery-habitats [7] and arguably many other factors that are applicable to the understanding and management of fisheries. In this study, the local knowledge of fishermen was used to acquire information related to the status of grouper populations and to their fishery in the Gulf of Iskenderun and Mersin (northeastern Mediterranean). In the past, participatory approaches have been successfully employed for groupers (Serranidae-Epinephelinae) e.g. [4,9]. However, despite a growing use of Local Ecological Knowledge (LEK) by Mediterranean scientists [10–14], no LEK-related investigations are currently available for Mediterranean groupers.

Groupers are valuable commercial fish [15] that generally inhabit shelf waters with a clear length-related depth distribution in many of

their species [16–19]. As well as their economic importance, they have been well documented with regards to their key structural role and functions within the food web in coastal areas [20].

Their life history traits are generally characterized by long life span, slow growth, late maturation and protogynous hermaphroditism; which render these species more susceptible to fishing pressure than gonochoristic fishes [21]. These attributes make the groupers particularly vulnerable to anthropogenic factors, such as habitat loss, pollution, climate change, introduction of alien species, and particularly fisheries, resulting in low resilience to exploitation [22–24]. Therefore, the implementation of effective management and conservation policies are essential for the sustainability of the grouper fisheries.

The Gulfs of Iskenderun and Mersin are both important fishing grounds for groupers [28], because of the wide continental shelf [25,26] and high diversity of habitats [29]. Small scale fishing is dominant in this area [30], and groupers provide an important source of income for the local fishery.

To date, 13 grouper species have been listed as present in the eastern Mediterranean Sea [31,32]. This number includes six native

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species (*Epinephelus marginatus*, *E. aeneus*, *E. costae*, *E. caninus*, *Hyporthodus haifensis* and *Mycteroperca rubra*) and seven exotic species (*Cephalopholis taeniops*, *E. areolatus*, *E. coioides*, *E. fasciatus*, *E. geoffroyi*, *E. malabaricus* and *M. fuscus*). All native groupers inhabit the Mediterranean coasts of Turkey [33], and *E. coioides* were once reported from the Gulf of Antalya [34].

According to the IUCN's Red List, the conservation status of these groupers varies among species: the dusky grouper, *E. marginatus*, is currently classified as Endangered (EN), whilst the white grouper, *E. aeneus*, is assigned to the Near Threatened (NT) category. The conservation status of other groupers inhabiting the study area are: Least Concern (LC) for *M. rubra*, and Data Deficient (DD) for the other three species (*E. caninus*, *E. costae*, *H. haifensis*) [35]. Additionally, *Polyprion americanus* (DD) is often caught together with groupers [36], and is thus considered in the context of this study even though it belongs to a different taxon: Polyprionidae [37].

Until 2016, the landing size in Turkey was restricted to a minimum 45 cm for *E. aeneus* and *E. marginatus* [38]. Following catch statistics [39] highlighted abrupt declines in populations of *E. aeneus*, policymakers introduced a regulation providing for the permanent prohibition of the catch of these two species until 2020 [40]. This regulation has resulted in much dispute, and major objections have arisen from the fishermen exploiting the study area.

So far, data on Turkish groupers have been mostly gathered through experimental trawl catches [16,41,42], and national fishery statistics [39], which are often hampered by taxonomic uncertainties [43] and underreported catch amounts [44]. Unal et al. investigated the catch records of fishery cooperatives around a special marine protected area in Gökova Bay located in the southern Aegean Sea [9]. However, such data are spatially limited. The improvement of management strategies for effective conservation would ideally require information regarding the status of grouper populations, their spatial distribution, and the characteristics of these fisheries on the large spatial scale.

Here, information on grouper populations and their small-scale fishery in the Gulfs of Iskenderun and Mersin was collected by interviews with local fishermen. Our aims were to: (1) provide a general appraisal on the diversity and abundance of the groupers targeted in the area; (2) document the diversity of fishing practices and their seasonality; and (3) use this information as a complementary tool to develop a general understanding on the status of grouper populations and the effects of both the professional and recreational fisheries.

## 2. Material and methods

Interviews were carried out by the authors (SM, IS, VA) between October 2016 and February 2017. Prior to the interviews being conducted, the fishermen were given a short introductory explanation about the data gaps and how they could contribute to an effective management strategy. After building upon the trust factor with the fishermen, questions were directed to both professional and recreational fishermen operating in the areas of the Gulf of Iskenderun and Mersin (36.0–37.0°N; 34.5–36.5°E). Interviews with professional fishermen mainly took place during either their land activities or break times across ten major fishery ports within the study area (Table 1, Fig. 2). Recreational fishermen were mostly met at diving clubs and at sports fishing stores. In both cases, the purpose of the interview was explained to the fishermen before the questions were asked. Interviews were based on a structured questionnaire (Appendix A), which consisted of their age, experience, type of fishing activity (professional or recreational), and the type of fishing gear used.

In order to assist with the correct identification of species, pictures of 13 grouper species (including the non-indigenous ones) were shown to the fishermen before they were asked whether they had ever caught any of these fishes. For each of the recognized species, and in relation to the last fishing season, a number of questions were asked: the fishing gears used, the depth and bottom type of the fishing area, the best day's

catch in weight (BDC), and the minimum, maximum and usual sizes of the catch. Fishermen were also asked to define the fishing period for each species caught.

The frequency of occurrence (FO%) and the best days' catch values were used as proxies for the abundance of groupers. FO% was calculated based on the number of reports, using the following equation:

$$FO\%_i = 100 \cdot (F_i/N), \quad (1)$$

where  $F_i$  is the number of interviews reporting the presence of species  $i$ , and  $N$  is the total number of interviews.

Differences in the best day's catch and minimum, usual and maximum sizes, were tested among species, fishery ports and fishing gears by using the Kruskal-Wallis test (KW) [45]. A pairwise test was used for multiple comparisons of mean rank sums (Nemenyi Test) by using the R library "PMCMR" [46]. Confidence intervals of medians were calculated by using rank statistics based on the Wilcoxon rank sum test [47]. The frequency of occurrence was analyzed by using Chi-square test [45] after the frequency table was transformed to proportions, since the number of interviews varied among ports. The null hypothesis was that the frequency of each group was proportionally equal. Figures and maps were created by using R library "ggplot2" [48].

## 3. Results

Overall, a total of 113 interviews were carried out in the study area (Table 1; Fig. 2). Four of the interviews were excluded from the analyses due to insufficient answers being received. The median fishery experience of respondents was 27 years, with an inter-quartile range (iqr) of 17–35 years. Most of the respondents were professional, small-scale fishermen (96; 88%), whilst 10 respondents (9%) were recreational fishermen. According to our results, groupers are targeted with six different gears: longliners (72; 59%), spearguns (18; 15%), anglers (14; 12%), nets (7; 6%), bottom trawls (7; 6%) and traps (3; 2%).

### 3.1. Distribution of groupers in the study area

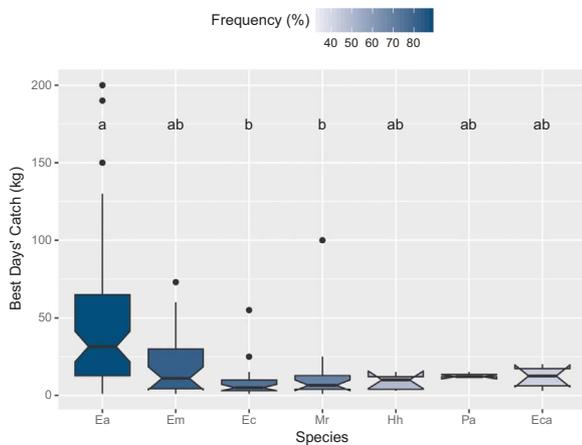
Overall, a total of 6 grouper species were unmistakably recognized by Turkish fishermen plus *P. americanus*. The FO% values were found to be significantly different among species ( $\chi^2 = 51.43$ ;  $df = 6$ ;  $p < 0.001$ ). Two species, *E. aeneus* and *E. marginatus* were more frequently caught than the other groupers. Regarding levels of abundance, median BDC values were also significantly different amongst the species (KW  $\chi^2 = 41.00$ ;  $df = 6$ ;  $p < 0.001$ ) and the highest BDC was reported in *E. aeneus* (31.5 kg). This species was followed by *E. caninus* (12.5 kg), *P. americanus* (12 kg), *E. marginatus* (11 kg) and *H. haifensis* (10 kg) (Fig. 1).

The spatial variations of frequency were not significant in *E. aeneus* (med = 100%), *E. marginatus* (med = 98%) and *E. costae* (med = 85%). Whilst the frequency of *M. rubra* significantly varied among ports ( $\chi^2 = 34.44$ ;  $df = 9$ ;  $p < 0.001$ ), the frequency of *H. haifensis* ( $\chi^2 = 118.92$ ;  $df = 9$ ;  $p < 0.001$ ), *P. americanus* ( $\chi^2 = 127.42$ ;  $df = 9$ ;  $p < 0.001$ ) and *E. caninus* ( $\chi^2 = 107.86$ ;  $df = 9$ ;  $p < 0.001$ ) were reported as being lower in the Yumurtalik and Golovasi fishery ports located around the western coasts of the Gulf of Iskenderun (Fig. 2). With a continued focus on abundance, the reported BDC of *E. aeneus* was significantly higher (KW  $\chi^2 = 19.05$ ;  $df = 9$ ;  $p < 0.05$ ) in the fishery ports located around the northern coasts of the Gulf of Iskenderun (Fig. 3), whereas there were no significant changes found in the other species.

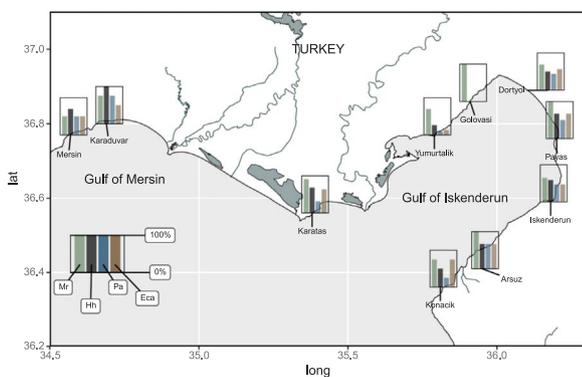
Three descriptors provided information on the size structure of the grouper populations: Minimum, average and maximum size of the targeted species (Fig. 4). There were also significant spatial variations in the reported sizes of fish. The median values of the MaxL were significantly higher towards the Gulf of Iskenderun for *E. aeneus* (KW  $\chi^2 = 26.21$ ;  $df = 9$ ;  $p < 0.001$ ) and *E. marginatus* (KW  $\chi^2 = 17.57$ ;  $df = 7$ ;  $p < 0.05$ ) (Fig. 3) and the MinL was detected as being significantly

**Table 1**  
Locations of fishery ports and number of valid interviews (No of Int.).

Fishery Port	Latitude (°N)	Longitude (°E)	No of Int.	Recreational	Professional
Arsuz	36.41	35.89	6	–	6
Dortyol	36.82	36.17	16	1	15
Golovasi	36.86	35.91	1	–	1
Iskenderun	36.59	36.18	17	1	15
Karaduvar	36.80	34.69	4	–	4
Karatas	36.56	35.38	22	1	21
Konacik	36.36	35.82	4	–	4
Mersin	36.77	34.57	10	–	9
Payas	36.76	36.20	6	1	5
Yumurtalik	36.77	35.79	23	6	16



**Fig. 1.** Best days' catch for 2015 and 2016 and the frequency of occurrence by species (Different letters indicate statistically significant differences in best days' catch. Ea: *Epinephelus aeneus*, Em: *Epinephelus marginatus*, Ec: *Epinephelus costae*, Mr: *Mycteroperca rubra*, Hh: *Hyporthodus haifensis*, Pa: *Polyprion americanus*, Eca: *Epinephelus caninus*).

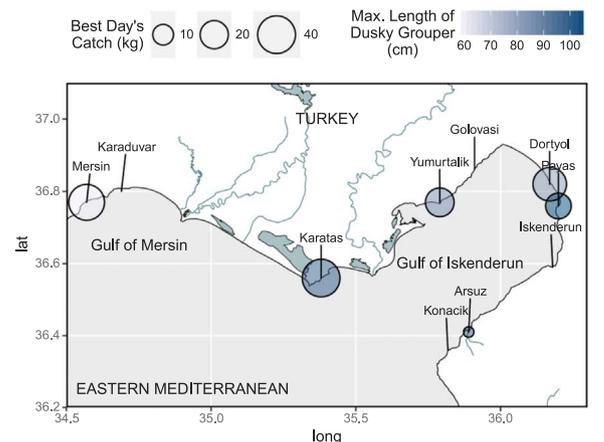
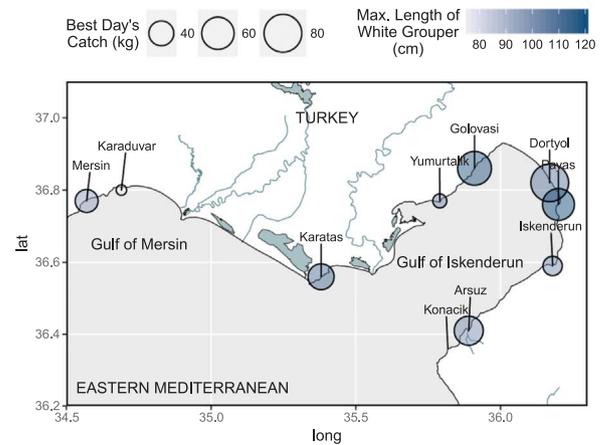


**Fig. 2.** Reported frequency of occurrence (FO%) of groupers in the study area: *Mycteroperca rubra* (Mr), *Hyporthodus haifensis* (Hh), *Polyprion americanus* (Pa) and *Epinephelus caninus* (Eca).

lower in Yumurtalik for *E. marginatus* (KW  $\chi^2 = 15.54$ ; df = 7;  $p < 0.05$ ).

### 3.2. Comparison among fishing gears

According to the respondents, groupers are exploited by six different fishing gears. Longliners, traps and spearguns were particularly important for the grouper fishery, whereas groupers can be only occasionally captured by trawls and nets. The median best days' catch (BDC) values were found to be significantly higher in longliners, in comparison with the other fishing gears in overall (KW  $\chi^2 = 17.31$ ; df = 5;  $p < 0.01$ ) and in *E. aeneus* (KW  $\chi^2 = 15.51$ ; df = 5;  $p < 0.05$ ; Fig. 5). In all reported species, the median of MinL did not significantly differ



**Fig. 3.** Median of reported best days' catch and maximum length values of *E. aeneus* (White Grouper) and *E. marginatus* (Dusky Grouper) for 2015 and 2016.

among fishing gears. The MaxL of *E. marginatus* in anglers was significantly smaller than in other types (median = 50 cm; KW  $\chi^2 = 13.44$ ; df = 4;  $p < 0.01$ ). Additionally, AvL of *E. aeneus* was smaller in trawlers (median = 32.5 cm) and anglers (median = 37.5 cm; KW  $\chi^2 = 9.84$ ; df = 5;  $p = 0.08$ ) with 10% confidence. MaxL of *E. aeneus* was significantly smaller in speargun fishermen (median = 75 cm; KW  $\chi^2 = 26.03$ ; df = 5;  $p < 0.001$ ).

#### 3.2.1. Seasonality

Seasonal variations in fishery pressure on groupers was found to be significant in overall average ( $\chi^2 = 275.05$ ; df = 11;  $p < 0.001$ ), longliners ( $\chi^2 = 238.91$ ; df = 11;  $p < 0.001$ ) and anglers ( $\chi^2 = 41.25$ ; df = 11;  $p < 0.001$ ). It was also significant in nets with 10% confidence ( $\chi^2 = 18.67$ ; df = 11;  $p = 0.07$ ). The grouper fishery became notably higher towards spring and autumn for all fishing gears, except for anglers who reported higher catches during the winter months (Fig. 6).

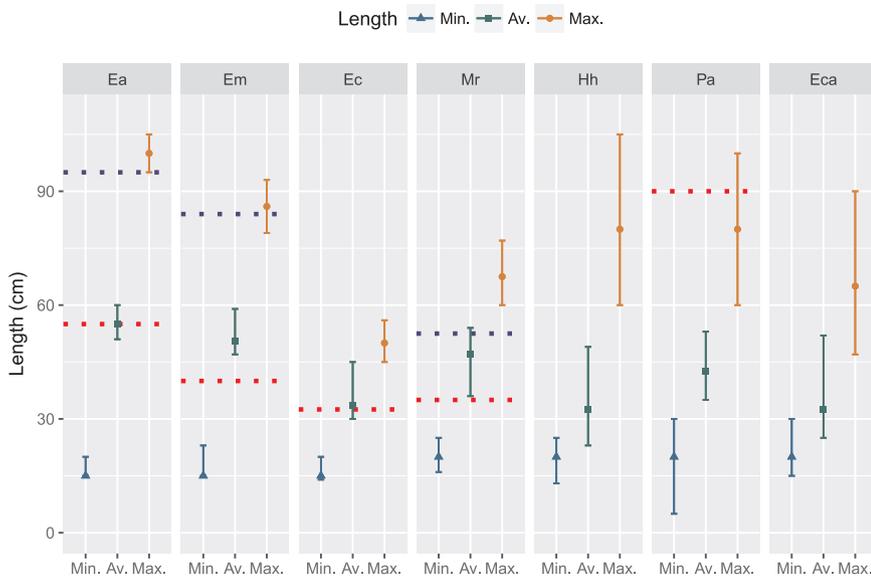


Fig. 4. Minimum, usual and maximum reported lengths of catch by species. Vertical bars show 95% confidence intervals of median length, horizontal lines are length at first maturity (red) and sex reversal (blue) [50–54]. (Ea: *Epinephelus aeneus*, Em: *Epinephelus marginatus*, Ec: *Epinephelus costae*, Mr: *Mycteroperca rubra*, Hh: *Hyporthodus haifensis*, Pa: *Polyprion americanus*, Eca: *Epinephelus caninus*). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

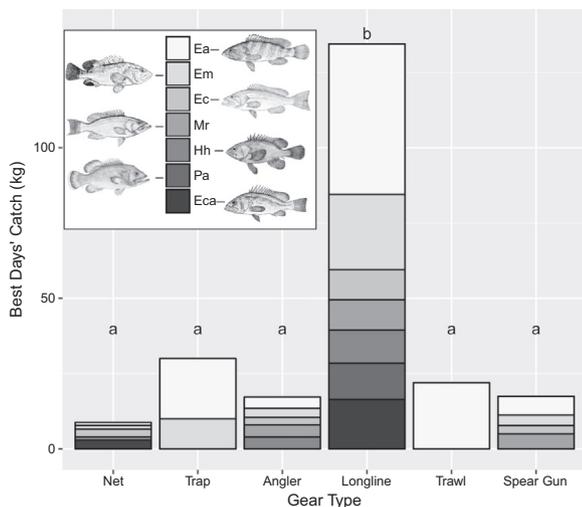


Fig. 5. Cumulative distribution of median best days' catch regarding the species and fishing gear. Different letters indicate statistically significant differences. Drawings are taken from Froese and Pauly [37] and Heemstra and Randall [18]. (Ea: *Epinephelus aeneus*, Em: *Epinephelus marginatus*, Ec: *Epinephelus costae*, Mr: *Mycteroperca rubra*, Hh: *Hyporthodus haifensis*, Pa: *Polyprion americanus*, Eca: *Epinephelus caninus*).

Fishermen reported that the grouper fishery was not economically reliable during the summer period due to the seasonal presence of sharks, which either remove the bait or cut the hooks and lines. Spear gun fishermen also reported a seasonal pattern depending on turbidity and water temperature; however, this was not statistically significant.

#### 4. Discussion

##### 4.1. Grouper abundance and distribution

Along the Turkish coasts, artisanal and recreational fishermen use small boats [30] and have limited ability to use fishing grounds far away from their ports. Their catches can therefore be considered as a valid indicator of the status of local grouper populations. In this study, the frequency of occurrence (FO%) and the best days catch values were employed to provide a proxy for estimating the variability of abundance and distribution of groupers [4,49], that provide key information for their conservation [50].

Our results highlighted that all six species of native groupers that

inhabit the Mediterranean Sea [31,37], plus *P. americanus*, are targeted by the Turkish fishery. According to the FO% and best days catch values, *E. aeneus* (NT; [51]) and *E. marginatus* (EN; [52]) were the most important components of the grouper fishery throughout the study domain. Other species, such as *M. rubra* were relatively rare. This picture was like many other areas of the Mediterranean e.g. [9,53], but different with respect to the adjacent Israeli coasts, where *M. rubra* was reported as the most dominant grouper [54]. The different species may be associated with different depth ranges and habitats [18] with a strong site association [55]. This makes their composition highly variable depending on the bottom types [56]. Considering that the north-eastern Mediterranean has a wide continental shelf with dominant sandy and muddy bottoms [57], these environmental attributes seem to be more suitable for *E. aeneus* [18], than for species such as *M. rubra* and *E. marginatus*, that are typically found in shallow rocky habitats [17,54].

The catch composition also varied significantly within the study domain. Two species of groupers, *E. caninus*, *H. haifensis*, plus *P. americanus* [18,37] were reported with significantly lower frequencies in the catches of the Yumurtalik and Golovasi fishing ports located around the relatively shallower western coast of the Gulf of Iskenderun. As was so obviously seen in grouper catch composition, fishing gears used in these two ports were also reported significantly different in previous considerations [31]. This is probably because of the distinctive bottom structure around these ports.

The reported best days' catches of *E. aeneus* (NT) were significantly higher towards the inside area of the Gulf of Iskenderun. Additionally, larger individuals of both *E. aeneus* and *E. marginatus* (EN) were reported from this area. Considering the importance of large individuals for the reproductive health of grouper populations [22,23], the northern coasts of the Gulf of Iskenderun could be an appropriate location where protection measures could be established, despite the high level of urbanization and anthropogenic pressure [25,58].

Protogynous hermaphroditism, slow growth and late sexual maturity renders Epinephelinae highly susceptible to fishing pressure [15,21]. Length at first maturity (LFM) and sex reversal (LSR) values remarkably vary among species and populations [18,59], and although some information exists for Mediterranean groupers, this is mostly limited to the western basin. For *M. rubra*, Aronov and Goren (2008) [54] reported that mature individuals are present after 35–36 cm, and sex reversal occurs between 42 and 62 cm along Israeli coasts. The results of this study revealed that the reported usual lengths were higher than LFM, and 50% of usual lengths were higher than LSR for

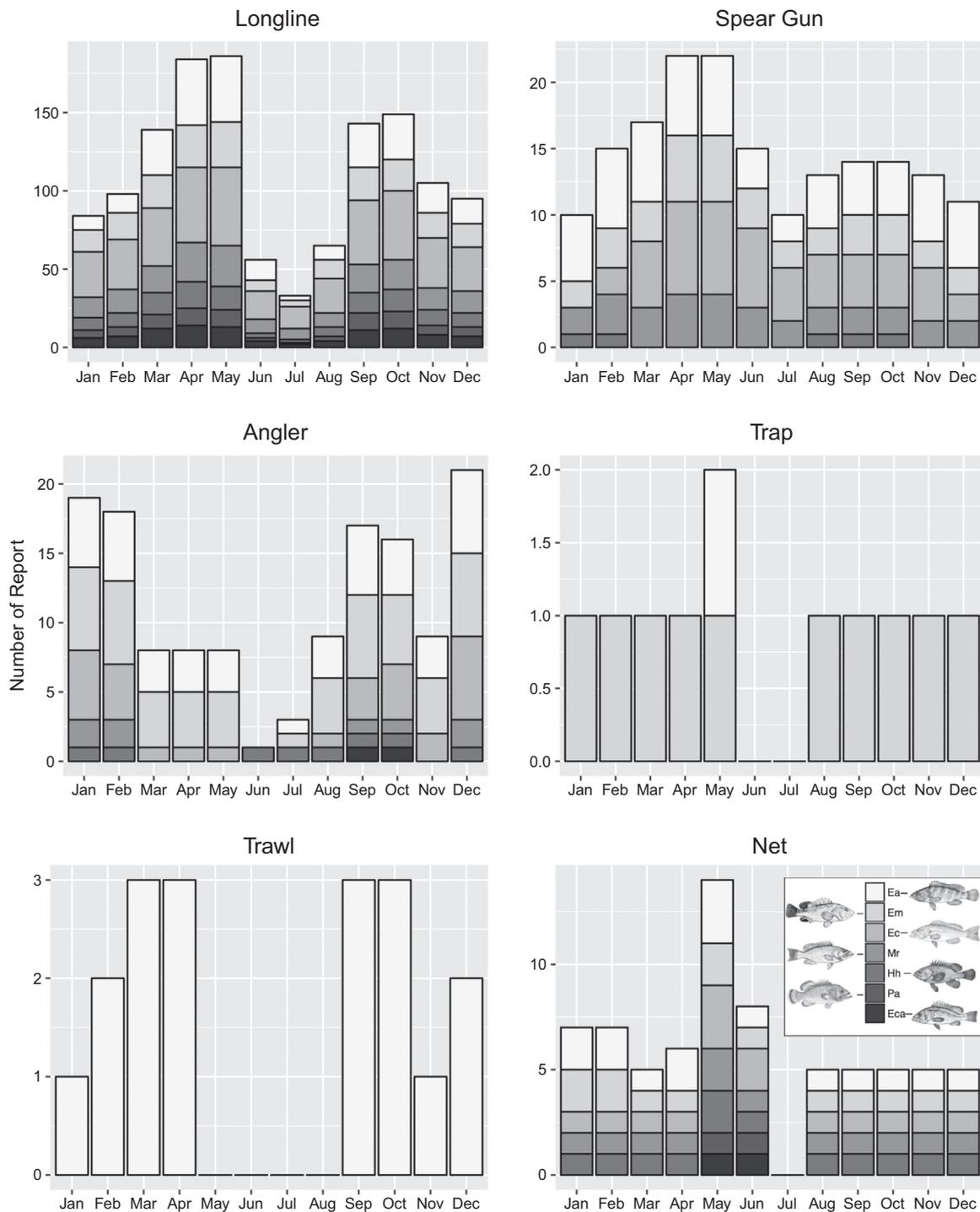


Fig. 6. Reported inter-annual variation in the capture of grouper species. (Ea: *Epinephelus aeneus*, Em: *Epinephelus marginatus*, Ec: *Epinephelus costae*, Mr: *Mycteroperca rubra*, Hh: *Hyporthodus haifensis*, Pa: *Polyprion americanus*, Eca: *Epinephelus caninus*).

this species. The LFM of *E. marginatus* were reported between 43.8 cm in the Sicily Strait [53] and 57.0 cm in Algeria [60] from the western Mediterranean, while the size is notably smaller (39.1 cm) in the Gulf of Antalya, Turkey [61] in the eastern Mediterranean. The median of the reported usual lengths was significantly higher than LFM in the present study, whereas 50% of reported maximum length were smaller than LSR (83.5 cm; [61]).

There is currently no available data on the LFM and LSR of *E. aeneus* and *E. costae* in the eastern Mediterranean. Brusle [62] detected that the LFM is between 50 and 60 cm, and LSR is between 80 and 110 cm for *E. aeneus* in Tunisian coasts, in the central basin. Based on these values,

half of the reported usual lengths were smaller than LFM, and half of the reported maximum lengths were smaller than LSR in the study area. The same situation was also observed in *E. costae*, where maturity occurs after 30–35 cm in the western Mediterranean [63]. The LFM of the gonochoristic Polyprionid, *P. americanus* has been reported between 88.5 and 92 cm in the Ionian Sea [64]. This value is even higher than the median of the reported maximum length in the present study. However, these results should be interpreted with caution, because the individuals inhabiting the eastern Mediterranean are expected to be smaller in size by comparison to the western basin conspecifics referring to Levantine nanism theory [65], despite Aronov and Goren [54]

have not observed such an evident in *M. rubra* in the Israeli coasts. Further exploration is thus essential; especially in the reproductive biology of grouper populations and Polyprionidae in the eastern Mediterranean.

A reduction of grouper sizes in fishery catches has been highlighted all over the world [4,8,15]. Results of the study reveal that fishery pressure on juveniles was also important in the north-eastern Mediterranean. Reported minimum lengths of the catch were significantly smaller than LFM in all species for which data was available. Although the usual length reported by fishermen was equal (*E. aeneus*, *E. costae*) or slightly higher than LFM (*E. marginatus*, *M. rubra*), it was smaller than the size of sex reversal.

#### 4.2. Grouper fishery

A total of six different fishing gears were reported catching groupers in the study area. Groupers are important components of both small-scale and recreational fishery in the Gulf of Iskenderun. This has also been observed in other areas, such as the western Mediterranean [66] and eastern Atlantic [5,6]. Based on best days' catch values, demersal longliners were the main source of fishery pressure on groupers, as was also found in the southwestern Atlantic [6] and southern Aegean Sea [9]. Ozyurt and Kiyaga [30] reported that *E. aeneus* is the main target of demersal longliners in the area of present study. According to Turkish fishery statistics, there were 698 recorded longliners fishing adjacent to all the Mediterranean coasts of Turkey by 2016 [39]. More than half of these (467 boats) are operating around the Gulf of Iskenderun [30]. In addition, this area is characterized by the widest continental shelf extension with respect to other Mediterranean coasts of Turkey.

Traps were another fishing gear particularly targeting groupers, and from which the second highest best day's catch was reported. Even though it is prohibited in local fishery regulation [38,40], 2% of fishermen reported the usage of this gear in grouper fishery. Before this regulation, the rate of usage of traps was reported at about 13% by Ozyurt and Kiyaga [30], but appears to have significantly decreased thereafter.

Fishing pressure on small individuals varied among gears. The maximum length of *E. marginatus* and *E. aeneus* was significantly smaller for anglers and spear guns than other fishing gears. Both fishing techniques are usually used in shallower areas where small sized groupers typically occur [8,16,17]. The reported average length of *E. aeneus* was below 40 cm in trawlers and anglers, which implies fishing pressure on the juvenile stages [62]. *E. aeneus* inhabit sandy and muddy bottoms [18], which are highly exploited by trawl fishery in the north-eastern Mediterranean [27,42,67].

The reported fishing pressure on groupers was found to be significantly higher in spring and autumn compared to the other seasons. In the study area, artisanal fishermen use trammel nets during the winter and summer periods by particularly targeting sole from December to March, and shrimp from June to August [30]. Longliners also reported that the presence of sharks make the grouper fishery unprofitable in the summer season. Apparently, there is a seasonal migration pattern in the distribution of sharks, which may be a contributory factor in the provision of safe spawning habitats for summer spawner groupers such as *E. aeneus*, *E. marginatus* and *E. costae* [61,68,69]. In contrast, the spawning season of *M. rubra* is during the spring period, with a peak in April and May [54] when the fishery pressure was also reported as being of a maximum level. Therefore, a closure may be possible for *M. rubra* during the spring season. There are successful examples of protecting spawning aggregations for the conservation of groupers off the Virgin Islands [70] and the Cayman Islands in the western Atlantic, and Palau in the western Pacific [15].

In the study area, the fishery of *E. aeneus* and *E. marginatus* has been temporarily banned since summer 2016, and this ban has been declared as extended until 2020 [40]. Many fishermen were largely against this closure for several reasons, as they explained that post-release survival

is expected to be low since most of the groupers are usually caught with a strong barotrauma [15] that would need specific care [71] and this reasonable information should be taken into appropriate consideration in future management plans. It must be also considered that the ban is expected to push fishery efforts, especially longliners, towards other grouper species (see also Coleman et al. [22]). This may lead to new concerns, especially on data deficient species whose population status are not yet clear [23]. Well-designed marine protected areas could provide a promising alternative for the conservation of grouper populations [22]. In the western Mediterranean Sea, Hackradt et al. showed the positive effects of MPAs on the biomass, abundance and mean size of grouper populations, not only in the reserve area but also around it (spillover) [72].

#### 5. Conclusions

Fishermen's knowledge allowed us to gather new data on the status of grouper populations and their fishery along the Turkish coasts, providing a practical complement to traditional surveys. These findings will hopefully contribute to stimulate participatory processes, which are particularly needed for adjusting and developing effective measures for the conservation and management of groupers in the study area.

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#### Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.marpol.2017.10.018>.

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