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# Southern Aegean Sea Trawl Fishery; Discard Ratio and Mortality of Targeted Species

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**Abstract**
This study was conducted between March 2019 and February 2020 in Güllük Bay, southern Aegean Sea. The aim of the study was to determine the fishing mortality rates besides, commercial and discard ratio of Aegean Sea trawl fishery. Samples were obtained from a commercial trawl ship in every month in open season. Length–weight relationships (LWRs) of some discard species, fishing mortality rates of targeted species (*Mullus barbatus barbatus* (Linnaeus, 1758), *Pagellus erythrinus* (Linnaeus, 1758)) and discard ratio were determined. Totally, 113 discard species were captured and discard ratios by weight were varied between 36.9% and 63.3% and mean discard ratio was 50.8%. According to minimum landing size (MLS) of targeted species *M.barbatus barbatus* and *P.erythrinus*, 82.6% of *M.barbatus barbatus* and 97.7% *P.erythrinus* were below MLS in discard. Current fishing mortality (F) of *M.barbatus barbatus* and *P.erythrinus* are seriously higher than $F_{opt}$ and $F_{lim}$ reference points Current exploitation rates (E) of *M.barbatus barbatus* and *P.erythrinus* is higher than optimum exploitation rate. Fishing mortality of targeted species should be decreased around safety limits to ensure sustainability. In order to minimize the discard ratio, technical regulations such as using larger mesh sizes are needed to decrease in fishing mortality. Seasonal closure dates for trawl fishery are different in Aegean (15 April-31 August) and Mediterranean (15 April-15 September). This 15 days gap in Mediterranean causes fleet (Mediterranean trawlers) shift to Aegean trawl areas. Therefore, seasonal closure dates should be organized to prevent fishing pressure on Aegean trawl fishing areas. Stock related and discard reduction studies on trawl fishery are needed in Aegean Sea.

**Keywords** *Pagellus erythrinus* · *Mullus barbatus barbatus* · Industrial fishery · Eastern Mediterranean · Demersal trawl

## Introduction

Catch, bycatch and discard were defined as "*all living biological material retained or captured by the fishing gear, including corals, jellyfish, tunicates, sponges and other non-commercial organisms, whether brought on board the vessel or not*", bycatch; "*the total catch of non-target animals*", discard or discarded catch; "*portion of the total organic material of animal origin in the catch, which is thrown away, or dumped at sea for whatever reason*" (Kelleher 2005). Due to sending of discard to the sea, discard has been a global problem for natural resources and fisheries (Oceana 2011; Tsagarakis et al. 2017). In addition to having no utilization of discard, it has an impact on depletion of marine populations and ecological impacts in marine ecosystems by changes in trophic webs and habitats. This is a potential threat for sustainable fisheries (Bellido et al. 2011).

Trawling is a widely used fishing type all around the world. Otter trawls, shrimp trawls, pair bottom trawls, twin otter trawls and beam trawls are accounted for 45.5% of total annual discard and bottom trawls are responsible for 21.8% of total annual discard. (FAO 2019). Many discard studies have been conducted across the world up to recent years. These studies offer some regulative suggestions to fishery managements. Discarding reasons could be variable and all of these depend on economic, socioecological, environmental or biological factors. Nonetheless, Mediterranean discard ratios are higher due to variety in species diversity (Bellido et al. 2014).

Trawl fishery provides a considerable amount of demersal fish supply in Turkey. Trawl vessels (782 vessels) constitute the 5.52% of total Turkish fishing fleet (14,168 vessels) and percentage of trawl vessels are varied region to region;

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1.28% in Marmara Sea (181 vessels), 0.38% in Aegean Sea (54 vessels), 1.21% Mediterranean (172 vessels), 2.65% in Black Sea (375 vessels) (TUIK 2019). In this concept, Aegean Sea has the lowest number of trawl vessels. In this region, red mullet, common pandora (Keskin et al. 2014), European hake and shrimp species (Soykan et al. 2016) are mostly targeted by trawlers. In study area, Güllük Bay, southern Aegean Sea, longline, trammel net, lagoon, purse-seine and trawl fishers are existed. Trawlers target, especially, red mullet and common pandora due to their commercial importance.

In the Aegean Sea, stock and discard related studies are insufficient. The aim of this study is two-folded; the first aim is to determine the commercial and discard ratio in commercial trawl fishery. The second aim is to reveal length–weight relations of some discard species, fishing mortality and exploitation rates of main targeted species. Combination of these aims reflects the general trawl fishery in southern Aegean Sea trawl fishery. According to estimations, some precautions were offered to fisheries management authority.

## Materials and Methods

**Study Area and Sampling** Study was conducted monthly between March 2019 and February 2020 in Güllük Bay, southern Aegean Sea (Fig. 1). Seasonal closure dates in Aegean for trawl fishery are between 15 April and 31 August. A local commercial trawl ship which was used in samplings, is made from wooden material. Trawl ship used in samplings, represents Güllük Bay trawl ships.

Fish samples were obtained by a traditional 44 mm stretched mesh size trawl net in legal trawl fishery season. Three trawl operations were performed in a sampling day. Each haul was ≈ 3 h with speed of ≈ 2.5 knots. Depths changed between 20 and 87 m.

Total catch included commercial and discard species together. Commercial species were separated and placed in carrying boxes, and commercial catch weight was recorded on board according to species. After this stage, all fish in one fish carrying box (7 kg), were measured one by one and

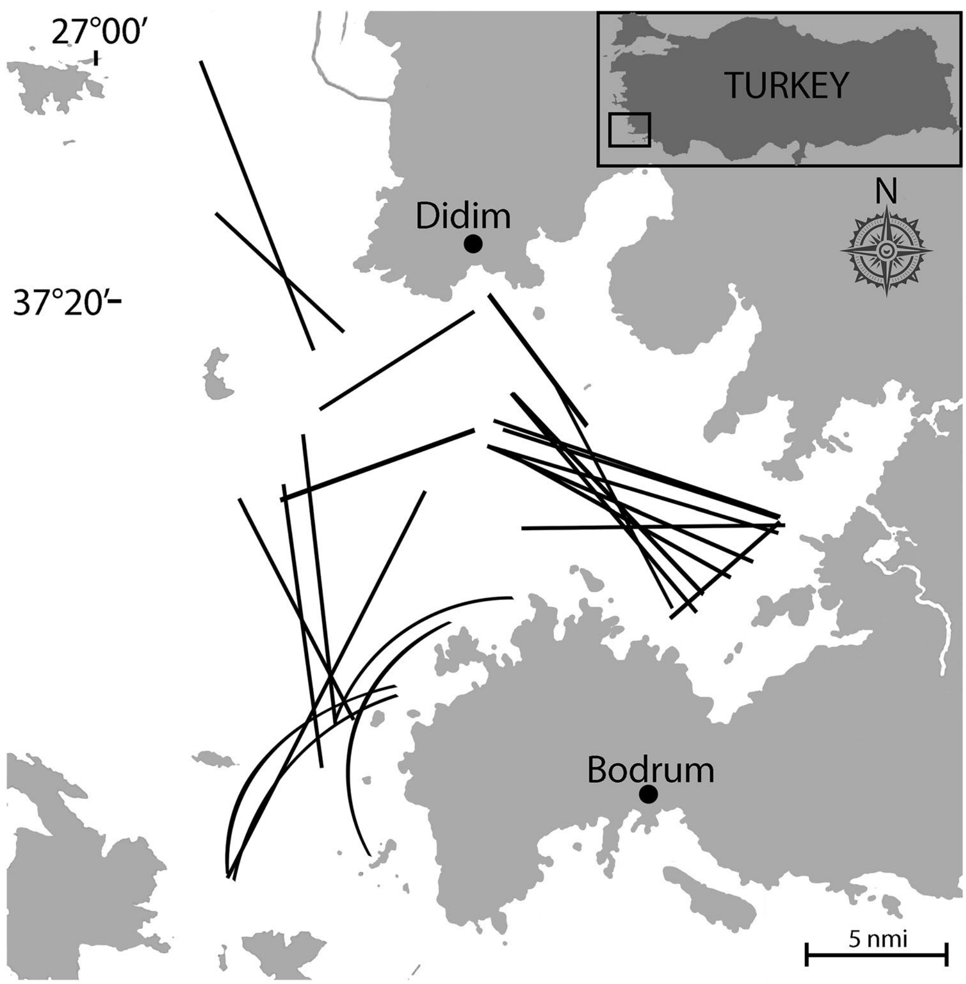


**Fig. 1** Study area and sampling routes of commercial trawl

marked on fish measurement board as for that their length classes. Thus, length-frequencies of each commercial species for one fish box were obtained in this way. Number of boxes of *M.barbatus barbatus* and *P.erythrinus* were recorded for each haul throughout the study, and all length-frequencies of various length classes were obtained for each species by direct proportion method. In other words, all length-frequency values of the species were used in mortality estimations. On the other hand, discard of related sampling was taken as a sub-sample from discard catch. In the first stage, whole discard was mixed well to gain a homogeneity. In the second stage, whole yield was divided into ratios (1/3, 1/5 etc.) and one of the divided ratio (varies according to ratio; ≈3–5 kg) was taken as sub-sample (Soykan and Kınacıgil 2021). Discard sub-samples were brought to laboratory in ice for further examinations.

**Laboratory Examinations** In laboratory examinations, discard sub-samples were identified at the species level and validated by referencing FishBase (Froese and Pauly 2020). To obtain weight and length values, each fish was measured for total length (TL in cm) to the nearest 0.1 cm and weighed (wet weight; W in g) to the nearest 0.01 g. Other species (sponge, crustacea, gastropoda etc.) were just weighed individually by species to the nearest 0.01 g.

**Length–weight Relationships (LWRs)** LWRs of the most abundant discard species were determined. The parameters *a* and *b* of relationships of the equation $W = aTL^b$ (Ricker 1973) which is estimated through logarithmic transformation $\log W = \log a + b \log TL$. Where W is weight (g), TL is total length (cm), *a* is the intercept and *b* is the slope of the linear regression. Parameters *a* and *b* were calculated by least-squares regression, as was the coefficient of determination ($R^2$). The significance of the *b*-values for each species was tested by Pauly's *t*-test to confirm that it was significantly different from the predictions for isometric growth ($b = 3$) (Pauly 1984a). Pauly's *t*-test was calculated as:

$$t = (SD(logTL) \cdot SD(\log W)^{-1} \times [lb - 3|/\sqrt{(1 - r^2)}] \times \sqrt{(n - 2)}$$

where SDlogTL is the standard deviation of the logTL values, SDlogW is the standard deviation of the logW values, "n" is the number of fish species used in the computation. The value of *b* is different from 3 if *t* value is greater than the tabled *t* values for n – 2 degrees of freedom (Pauly 1984a).

**Catch Per Unit Effort (CPUE)** Phiri and Shrikihara (1999) formulae was used to determine CPUE (kg/haul);

$$CPUE = \frac{(\sum Ci(Nh)^{-1})}{(\sum t(Nh)^{-1})}$$

where $C_i$; catch value of each operation, t; hauling time and $N_h$; haul number.

**Discard Estimations** Study area was not stratified, and it was considered as one trawling area. The same formulae that used in catch per unit effort calculation, was used to estimate the DPUE (Discard per unit effort) (kg/haul);

$$DPUE = \frac{(\sum Di(Nh)^{-1})}{(\sum t(Nh)^{-1})}$$

where DPUE; all fish that were undersized and unwanted species (kg/haul), $D_i$; discard value of each operation, t; hauling time and $N_h$; haul number.

Discard ratio (%) was calculated according to Kelleher (2005);

$$dr = \frac{(dt \times 100)}{(dt + lt)}$$

where dr; discard ratio (%), dt; total discard weight (kg) and lt; commercial catch (kg).

**Mortality Estimations** Total mortality (Z; $year^{-1}$) was estimated in Fisat-II with Length-converted catch curve (Pauly 1984b). Furthermore, natural mortality (M; $year^{-1}$) was determined with the Djabali et al. (1993) formulae; $M = 1.066 L_\infty^{-0.1172} \cdot K^{0.5092}$. Where; K; growth coefficient ($year^{-1}$) and $L_\infty$; asymptotic length (cm). While $L_\infty$ obtained by Mathews and Samuel (1990); $L_\infty = L_{max} \cdot 0.95^{-1}$, K values for each species were obtained from that species related studies from close areas. Fisheries related mortality (F; $year^{-1}$) was calculated with $F = Z - M$ (Pauly 1980). Exploitation rate (E) was determined by the formulae $E = F \cdot Z^{-1}$ (Sparre and Venema 1992).

On the other hand, to make interpretations with mortality and exploitation rate, some reference points were estimated; $F_{opt} = 0.5 \cdot M$ and $F_{lim} = (2\ M)3^{-1}$ (Patterson 1992), $E_{opt} = F_{opt} \cdot (M + F_{opt})^{-1}$ (Pauly and Morgan 1987), $E_{0.1}$; maximum economic yield (MEY), $E_{0.5}$; optimum sustainable yield, $E_{max}$; maximum sustainable yield (MSY) (Jakubavičiūtė et al. 2011).

## Results

Totally, 25 trawl operations were conducted in Güllük Bay and 113 discard species which belong to 83 families were obtained. *B.boops* 15.11%, *C.linguatula* 7.09%, *D.annularis* 6.53% and *S.hepatus* 5.59% were the most abundant species in discard catch by weight (Table 1).

**Table 1** Monthly discarded species in trawl hauls and frequency values by weight (kg)

| Pisces | Mar.19 | Apr.19 | Sep.19 | Oct.19 | Nov.19 | Dec.19 | Jan.20 | Feb.20 | %(W) |
|---|---|---|---|---|---|---|---|---|---|
| *D.annularis* | 4.02 | 11.45 | 0.11 | 2.27 | 6.24 | 0.41 | 1.47 | 1.48 | 6.52 |
| *D.vulgaris* | 0.93 | 1.89 | 0.68 | 0.66 | | 0.17 | | | 1.03 |
| *D.maroccanus* | 0.01 | 0.06 | 3.26 | 0.35 | 0.09 | 0.31 | | 1.38 | 1.30 |
| *S.aurata* | 0.09 | | | | | | | | 0.02 |
| *P.erythrinus* | 1.85 | 1.65 | 2.03 | 0.41 | | 0.58 | 2.87 | 0.36 | 2.32 |
| *P.acarne* | 0.24 | 0.80 | 0.22 | 1.17 | | 0.03 | 0.47 | | 0.70 |
| *P.bogaraveo* | 0.30 | | | 1.65 | 0.06 | 0.13 | 0.22 | 0.17 | 0.60 |
| *B.boops* | 7.48 | 7.29 | 3.30 | 6.67 | 2.08 | 3.68 | 13.16 | 19.88 | 15.09 |
| *S.hepatus* | 4.39 | 1.76 | 1.85 | 0.62 | 1.05 | 6.82 | 1.91 | 13.16 | 7.49 |
| *S.cabrilla* | 0.16 | 0.34 | 10.04 | | | | 0.34 | 0.19 | 2.63 |
| *C.linguatula* | 2.93 | 1.79 | 0.08 | 3.84 | 0.55 | 6.02 | 4.26 | 10.35 | 7.08 |
| *A.rueppelli* | 0.56 | 0.05 | 0.17 | 0.52 | 1.44 | 0.32 | 0.32 | 0.72 | 0.97 |
| *M.ocellatus* | 0.43 | 0.11 | | 0.76 | 0.13 | | 0.70 | 0.46 | 0.62 |
| *M.hispidus* | 0.20 | 0.08 | | 0.07 | 0.13 | | | | 0.11 |
| *P.flesus* | | | | | | 0.48 | | | 0.11 |
| *M.surmuletus* | 0.94 | 0.20 | 0.06 | 0.89 | 0.09 | 0.12 | 0.98 | 0.15 | 0.82 |
| *S.pilchardus* | 0.04 | | | 1.37 | | | | | 0.33 |
| *S.aurita* | | | | | 0.02 | | | | 0.004 |
| *E.encrasicholus* | 0.04 | 0.29 | | 0.11 | 0.14 | | | | 0.14 |
| *T.draco* | 0.48 | 0.79 | | 0.66 | 0.23 | 0.56 | 0.69 | 1.15 | 1.08 |
| *T.radiatus* | | | | | | | | 0.15 | 0.04 |
| *U.scaber* | 1.03 | 0.86 | | 0.27 | 0.32 | 0.55 | 0.17 | 1.11 | 1.03 |
| *T.mediterraneus* | 0.29 | | 0.52 | 0.59 | 0.10 | 0.28 | | | 0.42 |
| *S.smaris* | 1.05 | 0.22 | 1.88 | | 0.45 | 0.95 | 2.64 | 4.44 | 2.76 |
| *S.maena* | 1.02 | 1.48 | | 1.63 | 0.05 | | | 1.23 | 1.29 |
| *D.quadrimaculatus* | 0.02 | | | 0.01 | 0.02 | 0.05 | 0.02 | 0.01 | 0.03 |
| *G.niger* | 1.11 | 1.47 | | 0.53 | 2.21 | 0.43 | 0.15 | | 1.40 |
| *S.scrofa* | 0.73 | 0.20 | | 0.27 | | | | 0.64 | 0.44 |
| *S.notata* | 0.92 | | 0.04 | 0.55 | | | | 0.10 | 0.38 |
| *T.lucerna* | 0.28 | | | | | | | | 0.07 |
| *T.lastoviza* | 0.35 | 0.71 | 5.81 | 0.37 | | 0.16 | | 0.22 | 1.81 |
| *L.cavillone* | 2.20 | 0.81 | 3.55 | 2.15 | 0.03 | 1.72 | 6.49 | 4.69 | 5.15 |
| *S.saurus* | | | 0.13 | | | 0.61 | 0.64 | | 0.33 |
| *S.lessepsianus* | | | | | | 0.18 | 0.30 | | 0.12 |
| *Z.faber* | | | 0.16 | 0.47 | | | 0.13 | 0.09 | 0.21 |
| *C.rubescens* | 0.21 | 0.14 | | | 0.10 | 0.02 | | 0.21 | 0.16 |
| *B.ocellaris* | | 0.05 | 0.71 | 0.02 | | 0.17 | | 0.12 | 0.25 |
| *M.merluccius* | | 0.08 | | | | 0.21 | 0.05 | | 0.08 |
| *T.minutus* | | | | | | | | 0.16 | 0.04 |
| *P.blennoides* | | | | | | | | 3.59 | 0.85 |
| *Alosa fallax* | | | 0.04 | | | 0.25 | 0.20 | | 0.12 |
| *Champsodon spp* | | | | 0.10 | | 0.09 | 0.07 | 0.17 | 0.10 |
| *S.colias* | | | | 0.07 | | 0.09 | | | 0.04 |
| *S.rivulatus* | | | | 0.09 | | | | | 0.02 |
| *S.diaspros* | | | | 0.84 | | | | | 0.20 |
| *B.capriscus* | | | | | 0.33 | | | | 0.08 |
| *O.serpens* | 0.09 | 0.13 | 0.32 | 0.14 | 0.13 | | 0.05 | 0.16 | 0.24 |
| *C.conger* | 0.23 | 0.42 | 1.69 | 0.41 | 0.13 | 0.38 | 0.16 | 0.69 | 0.98 |
| *S.canicula* | | | 0.24 | | | | 0.07 | 0.14 | 0.11 |
| *S.acanthias* | | | 0.48 | | | | 0.23 | | 0.17 |
| *R.radula* | 1.08 | 3.05 | | 1.51 | 0.06 | 0.38 | 0.39 | 1.58 | 1.91 |

**Table 1** (continued)

| **Pisces** | Mar.19 | Apr.19 | Sep.19 | Oct.19 | Nov.19 | Dec.19 | Jan.20 | Feb.20 | %(W) |
|---|---|---|---|---|---|---|---|---|---|
| *R.miraletus* | 2.05 | 0.04 | | | | | 0.20 | 0.40 | 0.64 |
| *D.pastinaca* | 1.50 | 0.85 | 1.44 | | 2.58 | 1.01 | | | 1.76 |
| *M.aquila* | 0.71 | | 0.59 | | | | | | 0.31 |
| *T.marmorata* | | | | 0.30 | 1.02 | 0.08 | | 0.33 | 0.41 |
| *G.altavela* | | | | | 0.42 | | | | 0.10 |
| **Cephalopoda** | | | | | | | | | |
| *L.vulgaris* | 0.60 | 0.04 | 0.05 | 0.28 | 0.20 | 0.51 | 0.48 | 0.53 | 0.64 |
| *S.orbignyana* | 0.20 | | | | | | | | 0.05 |
| *E.cirrosa* | 1.26 | 3.53 | 0.06 | 1.08 | 1.83 | 0.83 | 2.93 | 2.12 | 3.25 |
| *S.elegans* | 0.09 | | 0.13 | 0.05 | | 0.61 | | 1.39 | 0.54 |
| *I.coindetti* | | | | | | | 0.90 | 1.27 | 0.52 |
| *Sepiola sp.* | | | 0.02 | | 0.01 | | 0.01 | | 0.01 |
| **Crustacea** | | | | | | | | | |
| *S.mantis* | 2.59 | 5.75 | | 6.09 | 5.77 | 0.39 | 0.32 | 1.07 | 5.23 |
| *P.kerathurus* | 0.03 | | | 0.11 | 0.15 | 0.03 | | | 0.08 |
| *P.aztecus* | | | | | 0.07 | | | | 0.02 |
| *Maja sp* | 0.08 | | | | | | | | 0.02 |
| *Macropodia sp.* | | | 0.03 | | 0.02 | | | | 0.01 |
| *Pagurus sp* | 0.02 | 0.03 | | 0.02 | 0.04 | 0.02 | | | 0.03 |
| *Pilumnus sp.* | 0.02 | 0.04 | | | 0.001 | | 0.02 | | 0.02 |
| *A.cataphractus* | 0.01 | | | 0.003 | | | 0.002 | 0.02 | 0.01 |
| *N.norvegicus* | 0.003 | | | | | | | | 0.00 |
| *M.lonata* | | 0.18 | | 0.06 | 0.09 | | 0.01 | | 0.08 |
| *P.longirostris* | | 0.06 | 0.00 | 0.14 | 0.01 | 0.33 | 0.37 | 0.23 | 0.27 |
| *G.rhomboides* | | 0.08 | | | 0.26 | | | | 0.08 |
| *L.depurator* | | | | 0.09 | 0.11 | | | | 0.05 |
| **Mollusca** | | | | | | | | | |
| *A.pespelicani* | 0.02 | | | | 0.15 | | | | 0.04 |
| *M.trunculus* | 0.23 | 0.35 | 0.08 | | 0.22 | | | | 0.21 |
| *M.brandaris* | 0.22 | 0.25 | | | 0.15 | 0.02 | 0.02 | | 0.16 |
| *Patella sp.* | | 0.01 | | | | | | | 0.00 |
| *Aplysia sp.* | | | 0.05 | | | | | | 0.01 |
| *T.galea* | | | | | 0.14 | | | | 0.03 |
| **Bivalvia** | | | | | | | | | |
| *O.edulis* | 0.14 | 0.05 | | | 0.44 | | | 0.06 | 0.16 |
| *Pecten sp* | 0.45 | 0.49 | | | | | | | 0.22 |
| *P.maximus* | | 0.33 | | 0.27 | 0.27 | | | | 0.21 |
| **Polychaeta** | | | | | | | | | |
| *H.hystrix* | 0.04 | | | | 0.10 | | | | 0.03 |
| ***Echinodermata*** | | | | | | | | | |
| *A.bispinosus* | 0.04 | 0.09 | 0.24 | 0.004 | 0.07 | | | 0.05 | 0.12 |
| *E.sepositus* | 0.02 | 0.99 | | 0.03 | 0.07 | 0.07 | 0.14 | 0.16 | 0.35 |
| *M.glacialis* | 0.02 | 1.60 | 0.34 | | | | 0.01 | | 0.47 |
| *A.aranciacus* | | | | 0.90 | | | | | 0.21 |
| *C.longipes* | 0.05 | | 0.01 | | | | | | 0.01 |
| *C.cidaris* | | | 0.04 | | | | | | 0.01 |
| *A.gibbosa* | | | 0.04 | | | | | | 0.01 |
| *P.lividus* | | | 2.47 | | 0.18 | | | | 0.63 |
| *S.regalis* | | | 0.24 | | | 1.40 | 1.92 | 3.33 | 1.64 |
| **Porifera** | | | | | | | | | |
| *A.acuta* | | | | | 0.41 | 0.47 | 1.10 | | 0.47 |

**Table 1** (continued)

| **Pisces** | Mar.19 | Apr.19 | Sep.19 | Oct.19 | Nov.19 | Dec.19 | Jan.20 | Feb.20 | %(W) |
|---|---|---|---|---|---|---|---|---|---|
| *Axinella Sp* | 0.44 | 0.96 | | 0.06 | 0.18 | 0.22 | 0.35 | 0.31 | 0.60 |
| *A.aerophoba* | 0.56 | 2.77 | | 1.33 | 0.26 | 0.19 | 0.28 | 0.08 | 1.30 |
| *Sarcotragus sp.* | | | | | | 5.00 | | | 1.19 |
| *C.reniformis* | | | | | | 0.06 | | 0.25 | 0.07 |
| *C.nucula* | 0.39 | 0.59 | 0.01 | | | | 0.09 | | 0.25 |
| *Acarnus sp.* | 0.13 | | | | 0.10 | | | | 0.06 |
| *A.oroides* | | 1.07 | | | 0.21 | 0.33 | | | 0.38 |
| *T.aurantium* | | 0.90 | | | 0.24 | 0.55 | 2.79 | | 1.07 |
| *P.ficiformis* | 0.27 | | | | | | 0.45 | | 0.17 |
| *Spongia sp.* | | | 1.38 | 1.00 | 0.87 | 0.35 | 0.62 | 9.56 | 3.28 |
| *P.spinifera* | | | | 0.13 | | | | | 0.03 |
| *Clathria sp.* | | | | | 0.04 | | | | 0.01 |
| *Ircinia sp.* | | | | | 0.38 | | 0.11 | | 0.12 |
| **Cnidaria** | | | | | | | | | |
| *A.palmatum* | 0.16 | 0.01 | | 0.01 | | 0.04 | 0.05 | 0.05 | 0.08 |
| *P.phosphorea* | | 0.01 | | | | | 0.04 | | 0.01 |
| **Tunicata** | | | | | | | | | |
| *H.papillosa* | 0.06 | 0.22 | 0.03 | 0.06 | 0.08 | 0.39 | 0.37 | | 0.29 |
| *Tunicata sp.* | 0.43 | 2.70 | 0.32 | 0.47 | 0.53 | 0.57 | 0.23 | 1.67 | 1.65 |
| **Chlorophyta** | | | | | | | | | |
| *C.bursa* | | | | 0.21 | 0.41 | 0.56 | 0.21 | | 0.33 |

It was found that 1 species of crustacea, 3 species of cephalopoda and 16 species of bony fish were commercial in Güllük Bay trawl fishery. CPUE per haul ranged between 26.4 kg and 94.0 kg. *M.barbatus barbatus* and *P.erythrinus* were the targeted species and they constituted 20.2% and 9.5% of the main commercial catch, respectively (Table 2).

Total length distributions of targeted commercial species, *M.barbatus barbatus* and *P.erythrinus*, were determined. Total lengths of *M.barbatus barbatus* and *P.erythrinus* ranged between 11 cm–22 cm and 13 cm–27 cm, respectively (Fig. 2).

Monthly discard ratios changed between 36.9% and 63.3%. Mean discard ratio was found to be 50.8% for Güllük Bay trawl fishery (Table 3). Seasonal variations were also determined and it was seen that the trawl discard value per haul reached the highest in winter season (62.1 kg) (Table 4).

Mortality, exploitation rates and some population parameters of *M.barbatus barbatus* and *P.erythrinus* were calculated separately (Table 5).

Total lengths of *M.barbatus barbatus* were between 6.6 cm–15.5 cm and *P.erythrinus* was 5.7 cm–17.8 cm in discard samples (Table 6). Minimum landing size (MLS) and total length frequency of discarded target species, *M.barbatus barbatus* and *P.erythrinus*, were compared. It was found that 82.6% of *M.barbatus barbatus* and 97.7% of *P.erythrinus* total lengths were lower than MLS (Fig. 3).

Some of the discard species have enough number to determine LWRs. LWR parameters *a* and *b*, standard error of *b* (SE*b*), 95% confidence interval (CI) for *b*, correlation coefficient ($R^2$), number of sample (n), length range and weight range for discard species were presented in Table 6.

## Discussion

### Length–weight Relationships of Discard Species

LWR of class Actinopterygii were mostly represented with Sparidae (9 species), Triglidae (3 species) and Serranidae (2 species) while LWR of class Cephalapoda and Malacostraca were represented with only 1 species. The *b*-values of the LWRs ranged from 2.0145 (*Cepola rubescens*) to 3.5058 (*Pagellus bogaraveo*). The unexpected *b* value of *C. rubescens* results from its over-proportional increase in length relative to growth in weight (Froese 2006).

Regarding the type of growth including all taxa, 5 species (18.5% of the total species number) showed isometric growth ($b = 3$), 14 species (50.0%) positive allometry ($b > 3$), and 8 species (31.5%) negative allometry ($b < 3$). The LWR parameters may be influenced by a series of factors, such as seasonality, habitat, sex, and maturity of a species (e.g. Yapıcı et al. 2014) as well as the technical characteristics of the sampling gear. Consequently, even if given the lack of such information for the species (e.g. separate estimations of LWRs by season or sex) represented in the present study, estimated LWR of discard species are of high importance

**Table 2** Monthly CPUE (kg/haul) of Commercial species in Güllük Bay trawl fishery

| Family | Latin name | Common name | Mar.19 | Apr.19 | Sep.19 | Oct.19 | Nov.19 | Dec.19 | Jan.20 | Feb.20 | %(W) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sparidae | *Boops boops* | Bogue | 3.2 | 4.3 | 1.8 | 1.2 | 1.2 | 1.1 | 2.3 | 1.6 | 12.1 |
| | *Diplodus vulgaris* | Common two-banded sea bream | 0.3 | | | | | | | | 0.2 |
| | *Pagellus acarne* | Axillary seabream | 2.3 | 0.9 | 0.5 | 0.6 | | 0.8 | | | 3.6 |
| | *Pagellus erythrinus* | Common pandora | 1.0 | 0.5 | 1.4 | 0.9 | 1.0 | 0.6 | 3.9 | 3.5 | 9.4 |
| | *Sparus aurata* | Gilthead sea bream | 0.7 | 0.3 | | 1.1 | 2.3 | 14.0 | 4.7 | 0.4 | 17.1 |
| | *Dentex maroccanus* | Morocco dentex | | | | | | 0.1 | | | 0.1 |
| | *Lithognathus mormyrus* | Striped seabream | | | | 0.1 | 0.1 | | | | 0.1 |
| | *Spicara smaris* | Picarel | 0.9 | 1.4 | 1.4 | 1.9 | 0.1 | 0.3 | | 7.8 | 10.1 |
| Mullidae | *Mullus barbatus barbatus* | Red mullet | 3.2 | 2.1 | 0.9 | 2.3 | 6.2 | 2.3 | 6.2 | 3.9 | 19.9 |
| Trachuridae | *Trachurus mediterraneus* | Mediterranean horse mackerel | | | | 0.8 | 0.2 | | | 9.3 | 7.5 |
| Serranidae | *Serranus cabrilla* | Comber | | | 1.2 | 0.3 | | 0.3 | | 1.6 | 2.5 |
| Lophiidae | *Lophius piscatorius* | Angler | | | | 0.1 | | | | | 0.1 |
| Soleidae | *Solea solea* | Common sole | | | | 0.4 | 0.7 | 0.1 | | | 0.9 |
| Moronidae | *Dicentrarchus labrax* | European sea bass | | | | | 0.1 | | | | 0.05 |
| Gadidae | *Trisopterus minutus* | Poor cod | | | | | | 0.7 | | | 0.5 |
| | *Merlangius merlangus* | Whiting | 0.6 | | | 0.3 | | | | 1.6 | 1.8 |
| Penaeidae | *Penaeus kerathurus* | Mediterranean Shrimp | 0.3 | 0.53 | | | 0.33 | | | | 0.9 |
| Loliginidae | *Loligo vulgaris* | European squid | 0.43 | 0.21 | 1.67 | 3.33 | 0.57 | 0.77 | 0.77 | 2.67 | 7.6 |
| Octopodidae | *Octopus vulgaris* | Common octopus | 1.33 | | | | | 1.00 | 0.77 | 1.33 | 3.2 |
| Sepiidae | *Sepia officinalis* | Common cuttlefish | 0.43 | | | | 1.33 | 0.67 | 0.77 | | 2.3 |
| | | **TOTAL** | 44.1 | 30.7 | 26.4 | 40.2 | 42.4 | 68.2 | 58.3 | 94.0 | |

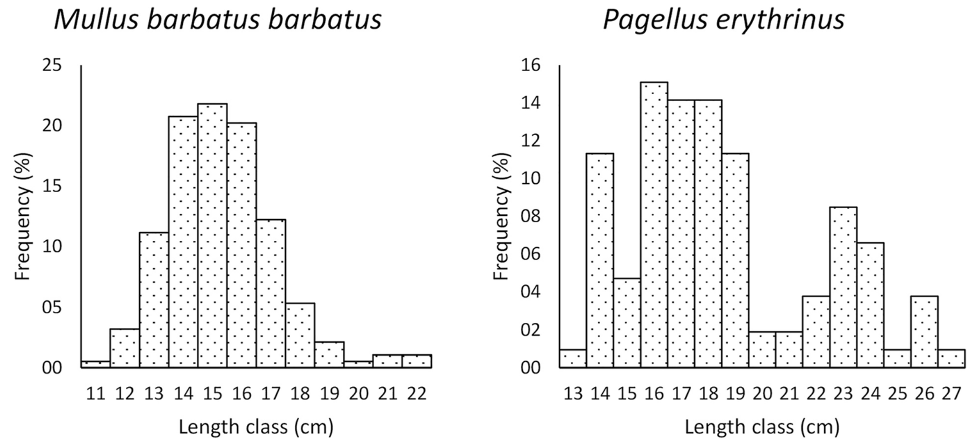


**Fig. 2** Length-frequency of *M.barbatus barbatus* and *P.erythrinus* from Güllük Bay trawl fishery

for further fisheries research and Ecosystem-Based Fisheries Management.

## Discard Problem

As reported by Damalas et al. (2017), among the total 139 discard species for the Aegean Sea, discarded crustaceans were lower than the fish and also invertebrates were largely discarded. In the present study, similar results were obtained. Totally 113 species existed in discard catch (56 pisces, 6 cephalopoda, 13 crustacea, 6 mollusca, 3 bivalvia, 1 polychaeta, 9 echinodermata, 14 porifera, 2 cnidaria, 2 tunicata and 1 chlorophyta). Within the frame of the discarded catch, 16 pisces, 3 cephalopoda and 1 crustacea species have commercial importance. However, these species were considered as discard due to being too small, lack of density in that haul or improper appearance of the individuals (deformed fish) for marketing.

Aegean Sea trawl fishery discard studies have various results. Discard values differ according to regions and mesh sizes or mesh shapes. Kınacıgil et al. (2013) found that total catch includes 28.6% discard species for Aegean Sea trawl fishery (Southern Aegean Sea; 42.7% of Güllük Bay, Central Aegean Sea; 20.3% of Foça, 13.8% of Karaburun, 12.2% of Sığacık- Northern Aegean Sea; 11% of Çanakkale, diamond mesh; 44 mm, 50–400 m deep). Duruer and Tosunoğlu (2012) mentioned that the discard ratio of total catch is 30% and 20% for Aegean trawl fishery (Kuşadası and Sığacık; central Aegean Sea, diamond mesh; 44 mm, square mesh; 40 mm, 137–187 m deep). On the other hand, Soykan et al. (2015) 33.2% of total catch was discarded (Sığacık; central Aegean Sea, diamond mesh; 44 mm, 90–297 m deep). Furthermore, Keskin et al. (2014) determined that the discard was accounted for 33% of the total catch (Northern Aegean Sea, diamond mesh; 44 mm, 70–410 m deep). According to the present study results, discard ratio was found as to be 50.8% (Southern Aegean Sea, diamond mesh; 44 mm, 20–87 m deep). First remarkable reason about difference in discard ratio between present and previous studies in the Aegean Sea could be the hauling depth. In this sense, Damalas et al. (2017) mentioned that higher discards occurred in northeastern part of the Aegean Sea (where shallower than 100 m). Present study depths were shallower than 100 m and also relatively shallower than the other studies' depths. It could be offered to fishery management that discard ratio may decrease by increasing the trawlable depth. Another reason may be latitude. Increase in latitude may also affect

**Table 3** Discard ratio of Güllük Bay trawl fishery

| | Discard (kg) | Standard Dev. (kg) | Standard Err. (kg) | Commercial (kg) | Total catch (kg) | Discard ratio (%) |
|---|---|---|---|---|---|---|
| Mar.19 | 195.2 | 2.39 | 0.20 | 177 | 372.2 | 52.4 |
| Apr.19 | 187.5 | 3.39 | 0.34 | 122.5 | 310 | 60.5 |
| Sep.19 | 85.6 | 2.83 | 0.36 | 49.7 | 135.3 | 63.3 |
| Oct.19 | 134.3 | 2.56 | 0.27 | 124 | 258.3 | 52.0 |
| Nov.19 | 102.9 | 1.48 | 0.14 | 123.9 | 226.8 | 45.4 |
| Dec.19 | 120.5 | 2.41 | 0.25 | 206 | 326.5 | 36.9 |
| Jan.20 | 163.5 | 3.29 | 0.33 | 175 | 338.5 | 48.3 |
| Feb.20 | 275.1 | 5.50 | 0.54 | 246 | 521.1 | 52.8 |
| Total | 1264.9 | 3.20 | 0.12 | 1224.1 | 2489 | 50.8 |

**Table 4** Seasonal discard weights of southern Aegean Sea trawl fishery

| | Total discard (kg) | Standard Dev (kg) | Standard Err (kg) | Mean per haul (kg) |
|---|---|---|---|---|
| Spring | 382.7 | 2.9 | 0.3 | 54.7 |
| Summer | Season Closure | | | |
| Autumn | 322.8 | 2.3 | 0.3 | 40.4 |
| Winter | 559.1 | 4.1 | 0.4 | 62.1 |

discard ratio by decrease in temperature. Present study was conducted in southern Aegean Sea (i.e. study area is close to Mediterranean that warmer than Aegean). According to sea surface temperature studies (Sakallı 2017), this situation makes the study area warmer than northern part of the Aegean Sea. As it is well known, temperature effects species' diversity. In the mentioned studies, discard ratios decrease in higher latitudes in the Aegean Sea. However, discard ratios could increase by shift in southern populations to northward as a result of global warming in the near future.

As a different suggestion, Aegean Sea trawl fishery could be performed in deeper waters. Deeper waters exist in international waters between Turkey and Greece. However, trawling is not profitable in international waters due to long distance between coast and international waters, high expenses and low landings (personal communications with trawlers). On the other hand, may be the most important feature, is deeper waters ($<200$ m) include vulnerable ecosystems and habitats which have slow recovery. Irreversible situations may occur in deep water environment when physically impacted. In this sense, fishery should be sustainable and should not cause to changes (FAO 2008). Therefore, southern Aegean Sea trawl fishery could be managed with different regulations such as larger mesh size to decrease discard ratios. In this respect, various studies on technical design of trawl net were conducted. Özbilgin and Tosunoğlu (2003) found that using double-codend in trawl nets increases catch of immature individuals. Özbilgin et al. (2012) also mentioned that if the diamond mesh size increases from 40 to 48 mm, it leads to increase in length-at-first capture values of some species. Both using one layer codend and increased mesh size could be effective in terms of decrease in discard ratio as well as commercial discard. If MLS's of the captured species were considered, these technical regulations could be suitable to ensure sustainability. Furthermore,

**Table 5** Mortality, exploitation rate and some population parameters of *M.barbatus barbatus* and *P.erythrinus* from Güllük Bay trawl fishery

| | *M.barbatus barbatus*[1] | *P.erythrinus*[2] |
|---|---|---|
| **Mean sea surface temp. (°C)** | 20 | |
| **$L_\infty$** | 23.16 | 28.42 |
| **K** | 0.57 | 0.17 |
| **$t_0$** | -0.35 | -0.86 |
| **Z** | 1.58 | 0.94 |
| **M** | 0.55 | 0.29 |
| **F** | 1.03 | 0.65 |
| **E** | 0.65 | 0.69 |
| **$L_{25}$** | 12.37 | 14.60 |
| **$L_{50}$ ($L_c$)** | 12.89 | 15.35 |
| **$L_{75}$** | 13.41 | 16.12 |
| **$L_{mean}$** | 15.31 | 18.54 |
| **$L_{opt}$** | 17.52 | 18.12 |
| **MLS** | 13.0 | 15.0 |
| **$E_{0.1}$ (MEY)** | 0.61 | 0.70 |
| **$E_{0.5}$** | 0.38 | 0.37 |
| **$E_{maks}$ (MSY)** | 0.71 | 0.81 |
| **$E_{opt}$** | 0.33 | 0.33 |
| **$F_{opt}$** | 0.28 | 0.14 |
| **$F_{lim}$** | 0.37 | 0.19 |

K and $t_0$ values of species were obtained from previous species related studies conducted in Aegean Sea; Özbilgin et al. (2004)[1], Metin et al. (2011)[2]

**Table 6** Length–weight relationships of Güllük Bay trawl fishery discards (+; positive allometry, -; negative allometry, 0; isometry)

| Species | N | $L_{min}$-$L_{max}$ | $W_{min}$-$W_{max}$ | *a* | *b* | SE of *b* | $R^2$ | CI of *b* | Growth |
|---|---|---|---|---|---|---|---|---|---|
| *Alosa fallax* | 30 | 12.0–16.0 | 14.59–30.84 | 0.0142 | 2.7558 | 0.03 | 0.8368 | 2.28–2.23 | - |
| *Arnoglossus rueppelli* | 178 | 4.5–14.1 | 0.90–30.08 | 0.0064 | 3.1409 | 0.05 | 0.9697 | 3.06–3.22 | + |
| *Blennius ocellaris* | 30 | 7.6–14.1 | 5.30–37.95 | 0.0133 | 3.0222 | 0.04 | 0.9443 | 2.74–3.31 | 0 |
| *Boops boops* | 779 | 7.1–16.7 | 5.07–35.96 | 0.0121 | 2.850 | 0.05 | 0.9121 | 2.79–2.91 | - |
| *Cepola rubescens* | 78 | 7.7–32.1 | 0.85–24.91 | 0.0172 | 2.0145 | 0.06 | 0.9609 | 1.92–2.11 | - |
| *Chelidonichthys lucerna* | 33 | 16.2–25.1 | 43.45–146.11 | 0.0143 | 2.8862 | 0.04 | 0.9045 | 2.54–3.23 | - |
| *Citharus linguatula* | 414 | 4.5–19.5 | 1.10–65.41 | 0.0073 | 3.0154 | 0.04 | 0.9783 | 2.97–3.06 | 0 |
| *Dentex maroccanus* | 39 | 5.1–14.5 | 2.08–48.03 | 0.0129 | 3.0814 | 0.03 | 0.9927 | 2.99–3.17 | + |
| *Diplodus annularis* | 223 | 8.8–18.2 | 10.22–117.93 | 0.0067 | 3.3722 | 0.04 | 0.9644 | 3.29–3.46 | + |
| *Diplodus vulgaris* | 67 | 6.0–16.6 | 4.91–72.09 | 0.0717 | 2.4058 | 0.06 | 0.9599 | 2.28–2.53 | - |
| *Gobius niger* | 147 | 6.9–13.4 | 2.69–31.58 | 0.0056 | 3.2882 | 0.05 | 0.9276 | 3.14–3.44 | + |
| *Lepidotrigla cavillone* | 304 | 4.8–13.6 | 1.44–29.25 | 0.0069 | 3.2323 | 0.04 | 0.9609 | 3.16–3.31 | + |
| *Merluccius merluccius* | 36 | 10.9–19.1 | 8.81–46.67 | 0.0049 | 3.1129 | 0.03 | 0.9533 | 2.87–3.35 | + |
| *Mullus barbatus barbatus* | 47 | 6.6–15.5 | 2.66–41.6 | 0.0052 | 3.2894 | 0.03 | 0.9826 | 3.16–3.42 | + |
| *Pagellus acarne* | 108 | 7.9–15.5 | 5.24–75.51 | 0.0053 | 3.4558 | 0.07 | 0.9069 | 3.24–3.67 | + |
| *Pagellus bogaraveo* | 34 | 10.7–15.0 | 17.07–59.10 | 0.004 | 3.5058 | 0.05 | 0.9146 | 3.12–3.89 | + |
| *Pagellus erythrinus* | 90 | 5.7–17.8 | 2.15–72.60 | 0.0115 | 3.0279 | 0.03 | 0.9833 | 2.94–3.11 | 0 |
| *Scorpaena notata* | 49 | 9.9–18.2 | 18.5–108.3 | 0.0228 | 2.9407 | 0.02 | 0.9796 | 2.82–3.07 | - |
| *Serranus cabrilla* | 67 | 9.7–16.3 | 9.42–47.49 | 0.0115 | 2.9832 | 0.04 | 0.9372 | 2.79–3.17 | 0 |
| *Serranus hepatus* | 721 | 5.4–11.0 | 2.35–23.66 | 0.0139 | 3.0892 | 0.04 | 0.9278 | 3.03–3.15 | + |
| *Spicara maena* | 58 | 8.0–16.6 | 4.38–51.56 | 0.006 | 3.2018 | 0.05 | 0.9584 | 3.02–3.38 | + |
| *Spicara smaris* | 180 | 6.6–16.0 | 2.30–55.93 | 0.0069 | 3.1443 | 0.04 | 0.9586 | 3.05–3.24 | + |
| *Trachinus draco* | 30 | 18.5–29.1 | 40.24–178.91 | 0.003 | 3.2562 | 0.02 | 0.9831 | 3.09–3.42 | + |
| *Trachurus mediterraneus* | 35 | 10.5–19.3 | 11.20–57.64 | 0.012 | 2.8818 | 0.05 | 0.9315 | 2.61–3.16 | - |
| *Trigloporus lastoviza* | 31 | 8.0–22.0 | 5.42–123.24 | 0.0084 | 3.0897 | 0.03 | 0.9939 | 3.00–3.18 | + |
| *Squilla mantis* | 275 | 6.0–18.1 | 1.78–59.46 | 0.0127 | 2.9843 | 0.04 | 0.9772 | 2.93–3.04 | 0 |
| *Loligo vulgaris* | 118 | 1.0–9.5 | 0.50–16.85 | 0.2407 | 1.8976 | 0.08 | 0.9348 | 1.81–1.99 | - |

manufacturing material also affects capture statistics. In this context, Tokaç et al. (2004) proved that polyamide material leads to increase in length-at-first capture values compared to polyethylene material. Moreover, taking in consideration of optimum catch length ($L_{opt}$) of the species, technical regulations, especially increase in mesh size, could be applied. $L_{opt}$ assures a healthy spawning activity in populations. If the $L_{opt}$ and $L_{50}$ of *P.erythrinus* and *M.barbatus barbatus* compared with each other, $L_{50}$ should be increased for *P.erythrinus* and also $L_{mean}$ and $L_{50}$ both for *M.barbatus barbatus* (Table 5). Thus, sustainability of the both *P.erythrinus* and *M.barbatus barbatus* may be ensured. Additionally, survival rate of the species is one of the main questions of trawl fishery. Düzbastılar et al. (2010) revealed that survival rates of *M.barbatus barbatus* were 95.1% in square mesh (40 mm) and 81.2% of in diamond mesh (40 mm). Also they mentioned that survival rate of *P.erythrinus* was 100% for both mesh shapes. Increased survival rate could contribute to populations by not killing juveniles for future generations. In relation to size of individuals, marketing value of large individuals is higher than the medium or small individuals. Capturing of medium or large individuals means low

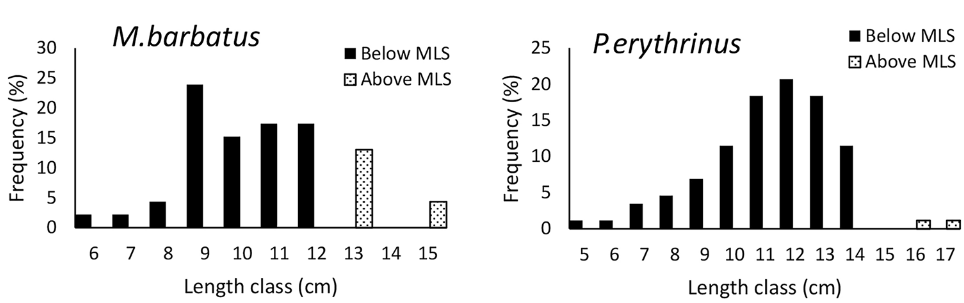


**Fig. 3** Discard length classes of *M.barbatus barbatus* and *P.erythrinus*

expense and more money for the same weight of fish. This is a profitable gain in any case.

According to Council of the European Union (2006), first rule of the Article 13 on "Minimum distances and depths for the use of fishing gears" was "The use of towed gears shall be prohibited within 3 nautical miles of the coast or within the 50 m isobath where that depth is reached at a shorter distance from the coast". In 2019, scope of this article was extended as "In addition to what is provided for in Article 13 of Regulation (EC) No 1967/2006, the use of trawls in the western Mediterranean Sea shall be prohibited within six nautical miles from the coast except in areas deeper than the 100 m isobath during three months each year and, where appropriate, consecutively, on the basis of the best available scientific advice…" and "In order to protect nursery areas and sensitive habitats, and safeguard small-scale fisheries, the coastal zone should be regularly reserved for more selective fisheries. Therefore, the plan should establish a closure for trawls operating within six nautical miles from the coast except in areas deeper than the 100 m isobath during three months each year. It should be possible for other closure areas to be established, where this can ensure at least a 20% reduction of catches of juvenile hake." (The European Parliament and the Council of the European Union 2019). Especially in 2019 regulations, the ecosystem-based fishery management was aimed and the regulation direction was tend to protect nursery and sensitive areas. This approach could ensure a healthy marine reserves. Therefore, in Turkey, distance limitation for trawlers should be applied for mainly three objectives; to reduce fishing mortality, to reduce discard rates and to protect shallow areas for ensuring sustainability of the ecosystems.

## Catch Per Unit Effort

CPUE has the lowest value in September (26.4 kg) and the highest value in February (94 kg). There is a season closure between 15th April and 31st August in all Turkish coasts except Mediterranean. On the Turkish coast of Mediterranean, season closure ends on 15th of September. In the beginning of the trawl season, most of the Mediterranean trawlers come for 15 days to Güllük Bay. Local trawlers (≈10 trawlers) and other trawlers (≈30 trawlers) "attack" together to Güllük Bay till the beginning of the Mediterranean trawl season. This situation generates a higher fishing mortality than normal. Therefore, September has the lowest CPUE value in trawl operations. Nonetheless, February has the highest CPUE value. There is a second local and species-specific season closure for common sole between 15$^{th}$ December and 31$^{th}$ January. After the end of the common sole season closure, trawl operations continue. This season closure (45 days) leads to a fallowing effect for trawl area and affects CPUE values of trawlers, positively.

**Table 7** Comparison of fishing mortality (F) and exploitation rate (E) with reference points

| | | Reference Points | | | |
|---|---|---|---|---|---|
| **Species** | **F** | **$F_{opt}$** | **$F_{lim}$** | | |
| *M.barbatus barbatus* | 1.03 | 0.28 | 0.37 | | |
| *P.erythrinus* | 0.65 | 0.14 | 0.19 | | |
| | **E** | **$E_{0.1}$ (MEY)** | **$E_{0.5}$** | **$E_{max}$ (MSY)** | **$E_{opt}$** |
| *M.barbatus barbatus* | 0.65 | 0.61 | 0.38 | 0.71 | 0.33 |
| *P.erythrinus* | 0.69 | 0.70 | 0.37 | 0.81 | 0.33 |

## Mortality and Exploitation

Another finding about Güllük Bay trawl fishery is that high fishing pressure on targeted commercial fish populations. Current fishing mortality (F) of *M.barbatus barbatus* is seriously higher than $F_{opt}$ and $F_{lim}$ reference points and should be decreased around safety limits. Current exploitation rate (E) of *M.barbatus barbatus* is higher than optimum exploitation rate. In addition, E is lower than $E_{max}$ and looks like it is in safety limits. Similar case is existed for *P.erythrinus* (Table 7). Fishing mortality and exploitation rate of both species should be decreased to around safety limits to ensure sustainability.

As it was mentioned by Link et al. (2010), stock boundaries are important. Outcomes of the study reflect the Güllük Bay trawl fishery. However, targeted stock boundaries are not known due to limited study area. If the stock boundaries are determined in whole parts of the Aegean Sea, more precise fishery management decisions can be taken for sustainability.

## Conclusion

Consequently, discard ratios of Güllük Bay trawl fishery may be decreased by some methods; a) technical regulations should be applied on trawl gears such as using larger mesh sizes to decrease in fishing mortality, b) regulations on distance prohibition for nonlocal trawlers (i.e. nonlocal trawlers should not leave from their registered harbours within a certain distance) c) seasonal closure dates that differ region to region, should be organized. According to study results and Aegean Sea trawl discard literature, stock related and discard reduction studies on trawl fishery are needed.

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SY; sampling, laboratory examinations – identifying species, investigation, supervision, writing – review and editing, IR; supervision, review and editing, CA; Revision – English editing. All authors read and approved the final manuscript.

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## Declarations

**Conflict of Interest** The authors declare that they have no conflict of interest.

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