Impact of ground gear design on catch efficiency in demersal trawl fishery

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Abstract

The choice of ground gear design in demersal trawls can significantly affect both catch composition and efficiency. The preference for a specific design depends on the fishing ground. In the North-Eastern Mediterranean, two types of ground gears, Single Line and Double Line are commonly used. Therefore, this study compared the catch performance for trawls using these ground gears during research trials in the Mersin Bay multi-species demersal trawl fishery. Results showed a significant reduction in catch efficiency for common sole (*Solea solea*) and lizardfish (*Saurida lessepsianus*) with more juveniles and target-sized individuals being released by the Double Line trawl compared to the Single Line trawl. Contrary, no difference was obtained for red mullet (*Mullus barbatus*) between the two gears. The present study demonstrates that ground gear design can affect species and size composition in demersal trawl fisheries. Therefore, ground gear design should be considered in the fisheries regulations as well as for demersal sampling trawl configurations.

Keywords: catchability, footrope, bycatch, discard, juvenile fish, Mediterranean

1. Introduction

During demersal trawl operations, the purpose of a ground gear is to maintain seabed contact while passing over obstacles and preventing damage to the gear that might be caused by snagging at the seafloor. The bottom panel of the demersal trawl mouth is rigged with a rope called '*fishing line'* alongside the lower part of the wings (Valdemarsen et al., 2007). This fishing line usually is equipped with a secondary rope named '*footrope'* or '*ground gear*' with additional solid and heavy components such as lead, chain, metal discs or bobbins (Fig. 1) (O'Neill and Mutch, 2017).

Several ground gear designs were developed to optimize the catch efficiency in demersal trawl fisheries (Ingólfsson and Jørgensen, 2006; Grimaldo et al., 2013; O'Neill and Mutch, 2017). The ground gear used until the late 1980s was mostly composed of air-filled metal spheres or rubber bobbins (with mid-link chains) which rotate along the towing direction on the seafloor (Rowling, 2008). By the mid-1980s, a ground gear type called the '*rockhopper'* made of a scrap rubber material was developed. It started to be used by many trawl fisheries worldwide (SINTEF, 2004). Demersal trawls equipped with the rockhopper ground gear were shown to be more efficient in some fisheries, for example, fishery targeting Atlantic cod (*Gadus morhua*) (Engås and Godø, 1986; Engås and Godø, 1989). Further, such ground gear prevents the net from being snagged and damaged during the fishing process. In the 1990s, a raised footrope ground gear was developed for demersal trawling (Brewer et al., 2006). This ground gear modification is used in small-mesh trawl fisheries to reduce bycatch of some bottom-dwelling species (Bayse et al., 2016). Currently, it is a commercially used ground gear design in different trawl fisheries such as fishery targeting European hake (*Merluccius merluccius*) (Dealteris et al., 1996), ocean shrimp (*Pandalus jordani*) (Hannah and Jones, 2000) and longfin inshore squid (*Doryteuthis pealeii*) (Bayse et al., 2016).

In North-Eastern Mediterranean at the beginning of each fishing season, the majority of the registered 260 demersal trawlers operates in Mersin Bay due to its relatively large continental shelf with productive fishing grounds (Gökçe et al., 2016). In this fishery, most vessels use two different ground gear types depending on seabed structure and species targeted (Fakıoğlu et al., 2022). These types are commonly named as 'Single Line' (SL) and 'Double Line' (DL) ground gears because of a secondary rope attached to the DL ground gear configuration. Demersal trawl equipped with the DL ground gear is expected to release more fish under the fishing line than the SL ground gear due to rigging gaps between footrope and fishing line. The SL ground gear is mostly preferred to catch shrimp species (Fakıoğlu, 2018).

Since the DL gear uses a tickler chain, this ground gear type is preferred for targeting different bony fish species such as red mullet (*Mullus barbatus*), brushtooth lizardfish (*Saurida lessepsianus*), common pandora (*Pagellus erythrinus*), goldband goatfish (*Upeneus moluccensis*), and Randall's threadfin bream (*Nemipterus randalli*) (Özbilgin et al., 2015). Furthermore, the DL gear is also used to herd flatfish species and shrimps in areas where marine debris and macrobenthos are highly concentrated (Fakıoğlu, 2018). In this fishery, the two most commercially valuable species, red mullet and common sole (*Solea solea*), have Minimum Landing Size (MLS) of 13 cm and 20 cm, respectively (Özbilgin et al., 2015). In contrast, no MLS is specified for lizardfish, a non-indigenous species in this fishery (Official Gazette, 2020). In Turkish waters, bycatch of undersized individuals is allowed up to 5% (in weight) of the total catch except for European anchovy (*Engraulis encrasicolus*), European pilchard (*Sardina pilchardus*) and Atlantic horse mackerel (*Trachurus trachurus*) (Official Gazette, 2020).

Estimation of catch efficiency of trawls using different ground gears has been of interest ever since researchers started to observe the fishing gear performance (Main and Sangster, 1983) and fish behavior (Main and Sangster, 1981). It was discovered that relatively small individuals (Walsh, 1992; Ingólfsson and Jørgensen, 2006) and some flatfish species (Munro and Somerton, 2002) can escape beneath the ground gear. Catch efficiency of the trawl plays a significant role in estimating fish abundance based on demersal trawl surveys (Hoffman et al., 2009; Walker et al., 2017). The only international sampling of demersal species in the Mediterranean Sea is conducted under the International demersal trawl survey in the Mediterranean (MEDITS) program since 1994 (MEDITS, 2017). Some demersal stock surveys using demersal trawls in Turkey have been conducted by universities and research institutions using MEDITS protocols. However, they have been limited only to some local areas in the Levantine Sea (Gücü, 2012), the Black Sea (Dağtekin et al., 2022) and the Sea of Marmara (Daban et al., 2021), and focused on certain species. The ground gear used in the MEDITS protocol is similar to DL gear regarding specifications except for dimensions (MEDITS, 2017). In the MEDITS trawl, the fishing line and the footrope are fixed with metal rings every 50 cm with a distance of 5 cm. A concern regarding such survey trawl design is potential lack of bottom contact during periods of a fishing operation (Fiorentini et al., 1999), making it unreliable for use in sampling for stock assessments without knowing its catch efficiency compared to other ground gear designs.

The aim of the present study is to compare the catch efficiency of the two most commonly used conventional ground gear types (SL and DL ground gears) for three commercially valuable species in Mersin Bay multi-species demersal trawl fishery (common sole, lizardfish and red mullet).

2. Materials and methods

The most common method to estimate absolute ground gear catch efficiency is to use small auxiliary nets attached behind the fishing line to recapture fish escaping under the ground gear (Krag et al., 2010; Brinkhof et al., 2017; Larsen et al., 2018). This method was first introduced by Engås and Godø (1986; 1989), but it involves several operational challenges such as variable gear performance, debris accumulation, loss of seabed contact and requires short towing time (Dahm and Wienbeck, 1992; Dahm, 1997). Therefore, the relative catch efficiency between the trawls equipped with SL and DL ground gears was estimated with the alternate haul method (Wileman et al., 1996). With this approach, any observed differences in the catch efficiency between the trawls were assumed to originate from the differences in the catch performance between the two ground gear types.

2.1. Sea trials

Sea trials were conducted onboard the research vessel "Lamas-1" (16 m, 240 HP) from the 18th of January to 2nd of May during 2017 in Mersin Bay (North-Eastern Mediterranean) at depths from 7 to 45 m (Fig. 2). Towing speed varied between 2.3 and 2.6 knots. Haul duration was standardized to 60 min. Start of haul was defined by stop of the steal warp release and end by start of the warp hauling.

2.2. Technical specifications of trawls and ground gears

Two identical demersal trawls with 600 meshes in circumference and head rope length of 19.64 m were used for the data collection. This trawl design is used commercially to target red mullet, green tiger prawn (*Penaeus semisulcatus*), lizardfish and other bottom-dwelling species. Hand-woven codends with 44 mm nominal diamond mesh size, 300 meshes in circumference and stretched length of 410 cm were attached to the trawls. Each codend was made of multi-monofilament polyethylene twine (15×Ø 0.35 mm). Footrope length for both, the SL and DL, ground gears was 20.8 m. The footropes were made of polyamide twine (Ø 28 mm) which had 60 pieces of lead with a total weight of 24 kg and a 60 kg mid-link chain (Ø 8 mm) attached to them (Fig. 3).

The only difference between the two trawls was that one was rigged with the SL ground gear while the other with the DL ground gear (Fig. 1). The DL ground gear contained an additional polyamide fishing line (Ø 22 mm) (Fig. 3). The distance between this fishing line and the footrope was 7 cm.

2.3. Data collection

During the sea trials, the SL and DL trawls were fished alternately to create a set of paired hauls (Lomeli et al., 2020). In this study, trawl equipped with the SL ground gear was chosen as a baseline for the analysis. After each haul, the catch was sorted by species and length measurements were taken for the three target species to the nearest half centimeter below.

2.4. Estimation of relative catch efficiency between the SL and DL trawls

Length-dependent catch comparison and catch ratio analyses were conducted to compare the catch efficiency between SL and DL trawls (Lomeli et al., 2020; 2021; Cerbule et al., 2021). The length-dependent catch comparison rate $CC(l,\boldsymbol{v})$ and catch ratio $CR(l,\boldsymbol{v})$ were estimated for the three target species to investigate potential differences in catch efficiency for each. Within each pair both trawls were deployed at the same time of day, depth, and geographical position, enabling a paired catch comparison analysis (Lomeli et al., 2020).

To assess the relative length dependent catch comparison rate (CC_l) of changing from SL to DL ground gear configuration, we used Equation (1) (Lomeli et al., 2021; Cerbule et al., 2021):

$$CC_l = \frac{\sum_{j=1}^{h}\left\{\frac{nd_{lj}}{qd_j}\right\}}{\sum_{j=1}^{h}\left\{\frac{nd_{lj}}{qd_j}+\frac{ns_{lj}}{qs_j}\right\}} \qquad (1)$$

In Equation (1), ns_{lj} and nd_{lj} are the number (n) of fish of length l, caught in the paired haul j for trawls with the SL (s) and DL (d) ground gear configuration, respectively. qs_j and qd_j are factors accounting for the subsampling in the catches with the SL and DL trawls. h is the total number of paired hauls conducted during the study. The modelled catch comparison rate $CC(l,\boldsymbol{v})$ that experimentally was expressed by Equation (1) was obtained using maximum likelihood estimation by minimizing the Expression 2 (Lomeli et al., 2021):

$$-\sum_{j=1}^{h}\sum_{l}\left\{\frac{nd_{lj}}{qd_j}\times ln[CC(l,\boldsymbol{v})]+\frac{ns_{lj}}{qs_j}\times ln[1.0-CC(l,\boldsymbol{v})]\right\} \qquad (2)$$

In Expression 2, $\boldsymbol{v}$ represents the parameters describing the catch comparison curve defined by $CC(l,\boldsymbol{v})$ (Lomeli et al., 2021; Cerbule et al., 2021). The experimental CC_l was modelled by the function $CC(l,\boldsymbol{v})$ using the following equation:

$$CC(l,\boldsymbol{v}) = \frac{exp[f(l,v_0,\ldots,v_k)]}{1+exp[f(l,v_0,\ldots,v_k)]} \qquad (3)$$

In Equation 3, f is a polynomial of order k with coefficients v_0-v_k (Lomeli et al., 2021; Cerbule et al., 2021). We considered f of up to an order of 4. Leaving out one or more of the parameters $v_0 \ldots v_4$ at a time resulted in 31 additional candidate models for $CC(l,\boldsymbol{v})$. Among these models, the catch comparison rate was estimated using the multi-model inference to obtain a combined model (Burnham and Anderson, 2002; Herrmann et al., 2017). The ability of the combined model to describe the experimental data was based on p-value (Wileman et al., 1996; Herrmann et al. 2017). This p-value should be at least 0.05 unless data are overdispersed.

To provide a direct relative value of the catch efficiency between the two trawls using SL and DL ground gears, we used the following catch ratio $CR(l,\boldsymbol{v})$ equation (Lomeli et al., 2021; Cerbule et al., 2021):

$$CR(l,\boldsymbol{v}) = \frac{CC(l,\boldsymbol{v})}{[1-CC(l,\boldsymbol{v})]} \qquad (4)$$

We used a double bootstrapping method with 1000 bootstrap repetitions to estimate the Efron 95% confidence intervals (CIs) for the catch comparison and catch ratio (Efron, 1982). If the catch efficiency of the trawls using the two different ground gears (SL and DL) is equal, the catch comparison rate is equal to 0.5 and the catch ratio is 1.0 (Lomeli et al., 2021; Cerbule et al., 2021).

2.5.Estimation of length-integrated average catch ratio

Based on experimental catch data, length-integrated average values for the catch ratio for fish under and above the MLS ($CR_{average-}$ and $CR_{average+}$, respectively) were assessed utilizing the following equations (Cerbule et al., 2021):

$$CR_{average-} = \frac{\sum_{l<MLS}\sum_{j=1}^{h}\left\{\frac{nd_{lj}}{qd_j}\right\}}{\sum_{l<MLS}\sum_{j=1}^{h}\left\{\frac{ns_{lj}}{qs_j}\right\}}$$
$$CR_{average+} = \frac{\sum_{l\geq MLS}\sum_{j=1}^{h}\left\{\frac{nd_{lj}}{qd_j}\right\}}{\sum_{l\geq MLS}\sum_{j=1}^{h}\left\{\frac{ns_{lj}}{qs_j}\right\}} \qquad (5)$$

Contrary to the length-dependent evaluation based on $CR(l,\boldsymbol{v})$, $CR_{average-}$ and $CR_{average+}$ are specific to the fish population structure encountered during the fishing trials (Cerbule et al., 2021). Therefore, their values cannot be extrapolated to other fishing scenarios with different size structures for the three species investigated.

2.6. Estimation of the discard ratio

The experimental catch data was used to quantify discard ratios (*NDRatio*) for the three target species by:

$$NDRatio_{DL} = 100 \times \frac{\sum_{l<MLS}\sum_{j=1}^{h}\left\{\frac{nd_{lj}}{qd_j}\right\}}{\sum_{l}\sum_{j=1}^{h}\left\{\frac{nd_{lj}}{qd_j}\right\}}$$
$$NDRatio_{SL} = 100 \times \frac{\sum_{l<MLS}\sum_{j=1}^{h}\left\{\frac{ns_{bj}}{qs_j}\right\}}{\sum_{l}\sum_{j=1}^{h}\left\{\frac{ns_{lj}}{qs_j}\right\}} \quad (6)$$

In Equation (6), the outer summations include the length classes of fish that were under the MLS for the three species (in the nominator) and over-all length classes (in the denominator). *NDRatio* quantifies the fraction of the catch (in %) consisting of undersized individuals. In this fishery, the MLS is 20 cm for common sole and 13 cm for red mullet (Official Gazette, 2020). Since there is no regulation regarding MLS for lizardfish, we used length at maturity of 16 cm for this species (İşmen, 2003). Ideally, the *NDRatio* value should be low, meaning that the fraction of the undersized fish in the catch is as small as possible. The values of *NDRatio* are affected by both, the size selectivity of the gear and by the size structure of the fish population. Therefore, the *NDRatio* values are area and season specific and cannot be extrapolated to other fishing situations (Veiga-Malta et al., 2020).

Uncertainties in terms of 95% CIs were estimated for *NDRatio*, $CR_{average-}$ and $CR_{average+}$ by incorporating the estimation of these measures in the double bootstrapping method as described above (Cerbule et al., 2021). The statistical software SELNET was used for all analyses in this study (Herrmann et al., 2012; 2016).

3. Results

A total of ten valid paired hauls were conducted during this study resulting in length measurements of 694 common sole, 2356 lizardfish, and 3248 red mullet (Table 1).

3.1. Catch efficiency between trawls using SL and DL ground gears

The modelled catch comparison rates described the experimental data well for common sole and red mullet (*p*-value >0.05) (Table 2; Fig. 4). For lizardfish, the *p*-value was smaller than 0.05 (Table 2). However, since no systematic structure was found in the deviations between experimental points and modelled curves (Fig. 4), the poor fit statistics noted in this case was due to over-dispersion in the experimental data (Wileman et al., 1996; Lomeli et al., 2021).

The catch comparison and catch ratio analysis showed that the trawl fitted with the DL ground gear caught significantly less common sole above 11 cm compared to the SL ground gear (Fig. 4, Table 2). The DL trawl captured significantly fewer common sole than SL trawl when averaged over all length classes above MLS (20 cm) ($CR_{average+}$ = 22.97% (95% CI: 2.69-43.24%)) (Table 2). The catch of common sole below the MLS was reduced to 16.89% ($CR_{average-}$ = 16.89% (95% CI: 3.48-30.30%)). Majority of captured common sole in both trawls were individuals below MLS (Fig. 4, Table 2).

The DL trawl retained significantly fewer lizardfish compared to the SL trawl (Fig. 4, Table 2). Specifically, for lizardfish above length at maturity (16 cm), the $CR_{average+}$ was 32.52% (95% CI: 8.92-56.13%). Furthermore, for juvenile lizardfish, DL trawl caught significantly fewer individuals than SL trawl ($CR_{average-}$ = 28.02% (95% CI: 3.19-52.84%)) (Table 2).

The comparison of catch efficiency between trawls using DL and SL ground gears did not show any significant differences for capture of red mullet (Fig. 4, Table 2). Specifically, the differences between the two gears were not significant for red mullet above and below MLS ($CR_{average+}$ = 94.98% (95% CI: 46.73-143.24%), and $CR_{average-}$ = 70.42% (95% CI: 10.84-130.01%) (Table 2)).

3.2. Discard ratio

The discard ratio results for common sole indicated that the SL trawl caught slightly more undersized fish (< MLS of 20 cm) ($NDRatio_{SL}$= 74.74% (95% CI: 65.11-84.37%)) compared to the DL trawl ($NDRatio_{DL}$= 68.51% (95% CI: 54.18-82.85%)) (Table 2); however, the difference was not statistically significant.

Further, the results indicated a slight reduction in the bycatch of small lizardfish under 16 cm length when using the DL ground gear. However, this difference was also not statistically significant between the two gears. Specifically, $NDRatio_{SL}$ and $NDRatio_{DL}$ were 33.14% (95% CI: 27.41-38.88%) and 29.92% (95% CI:21.28-38.57%) for DL and SL gears, respectively (Table 2).

Most of the captured red mullet in both gears were above the MLS (13 cm). However, there was a slight indication that the discard ratio in the SL trawl was higher compared to the DL trawl. Specifically, for the SL trawl, the discard ratio was 23.25% (95% CI: 16.05-30.44%) whereas for the DL trawl, it was 18.34% (95 % CI: 13.03-23.64%) (Table 2).

4. Discussion

In this study, we compared the catch efficiency of demersal trawls using two conventional ground gear types for capturing three commercially important species in Mersin Bay multi-species fishery. The present study demonstrated that common sole and lizardfish can escape under the fishing line of the DL trawl. Therefore, our findings demonstrate that ground gear design can affect species and size composition in demersal trawl fisheries.

The observed reduction in the catch efficiency of common sole when using the DL ground gear may be explained by behavioral characteristics of flatfish species, i.e. remaining close to the seabed and attempting to escape beneath the fishing line of an approaching trawl (Rose, 1996; Bublitz, 1996; Munro and Somerton, 2002). Fish behavior and fishing gear geometry are two important factors affecting the catchability of a trawl gear (Dunn, 2006; Hoffman et al., 2009). In this study, reduced catches of common sole and lizardfish when using the DL ground gear could be explained by avoidance behavior of these species by escaping under the fishing line (Munro and Somerton, 2002). However, the behavior of lizardfish in relation to trawl gear has only been examined in few studies (Kalecik, 2018). The results showed that the capture probability would be reduced if the towing speed of the trawl dropped below 2.5 knots. In our study, the towing speed varied between 2.3 and 2.6 knots, potentially affecting catch efficiency of lizardfish.

The findings in this study are consistent with those reported by Fiorentini et al. (1999) for common sole and red mullet. Specifically, the sampling trawl used for the MEDITS program was found to be significantly less efficient catching common sole while difference was negligible for red mullet compared to the Italian commercial trawl. Fiorentini et al. (1999) indicated that the survey trawl's footrope, which corresponds to the DL ground gear used in this study, did not stay in steady contact with the seafloor. These results highlight the importance of considering ground gear design for demersal sampling trawl designs for future stock assessments.

In commercial trawl fisheries, the choice between different ground gears often depends on the seabed type (He, 2007; He and Winger, 2010; Fakıoğlu et al., 2022), target fish (Krag et al., 2010; Brinkhof et al., 2017; Larsen et al., 2018) and presence of marine debris on the seafloor (Eryaşar et al., 2014). Our fishing trials were conducted on soft, flat seabed allowing use of SL and DL ground gears without risking gear damages. However, testing ground gears on different seafloor types where the bottom contact might alter more frequently should be considered in further studies. Furthermore, this study was conducted in shallower fishing depths compared to the areas where the commercial fishery is conducted. Thus, the abundance and size structure of fish in the experiment might be different from that obtained at commercial depths at this period and area. However, since this experiment was conducted as a catch comparison study, this would affect both DL and SL trawls equally and, therefore, does not bias assessing the relative performance between trawls.

Although the results of this study did not show any significant differences in discard ratios between SL and DL gears, the discards were high within each trawl. Results indicated that SL trawl caught slightly more undersized common sole compared to DL trawl (SL: 74.74% (95% CI: 65.11-84.37%), DL: 68.51% (95% CI: 54.18-82.85%)). However, this difference was not statistically significant. Previous findings on fisheries discards in the region have been estimated based on weight proportioning (Özbilgin et al., 2013; FAO, 2021). Specifically, in an earlier study which is representative for the region considered in these trials, the discard ratio for commercial trawlers was found to be 48% in weight and 72% in numbers. Furthermore, based on results obtained from the national discard monitoring program, discards of common sole reached ~12% in the North-Eastern Mediterranean demersal trawl fishery (FAO, 2021).

The preference for using the DL ground gear in some situations is related to fishing areas with higher risk for gear damage while maintaining optimal seafloor contact. Furthermore, some fishers are known to choose the DL ground gear equipped with tickler chains for herding flatfish and shrimp to compensate for the loss in catch efficiency caused by the DL ground gear.

Changing the ground gear from SL to DL design could potentially reduce catches of undersized common sole and lizardfish by allowing them to escape beneath the footrope. However, such modification would not be acceptable in the commercial fishery due to the associated losses of individuals above MLS.

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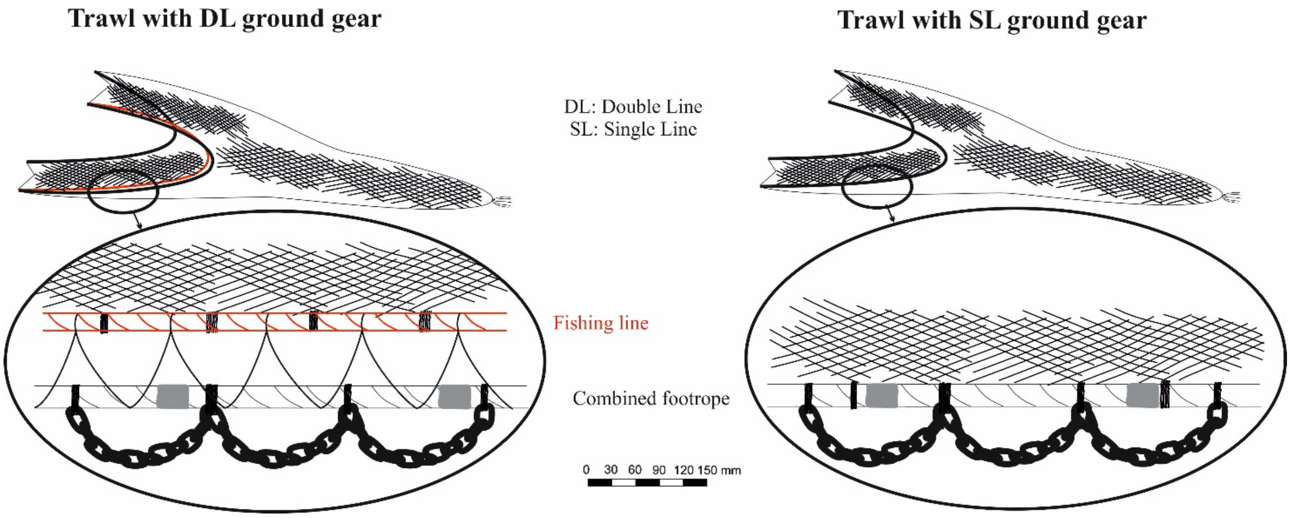

Figure 1. Schematic diagram of DL ground gear (left) and SL ground gear (right).

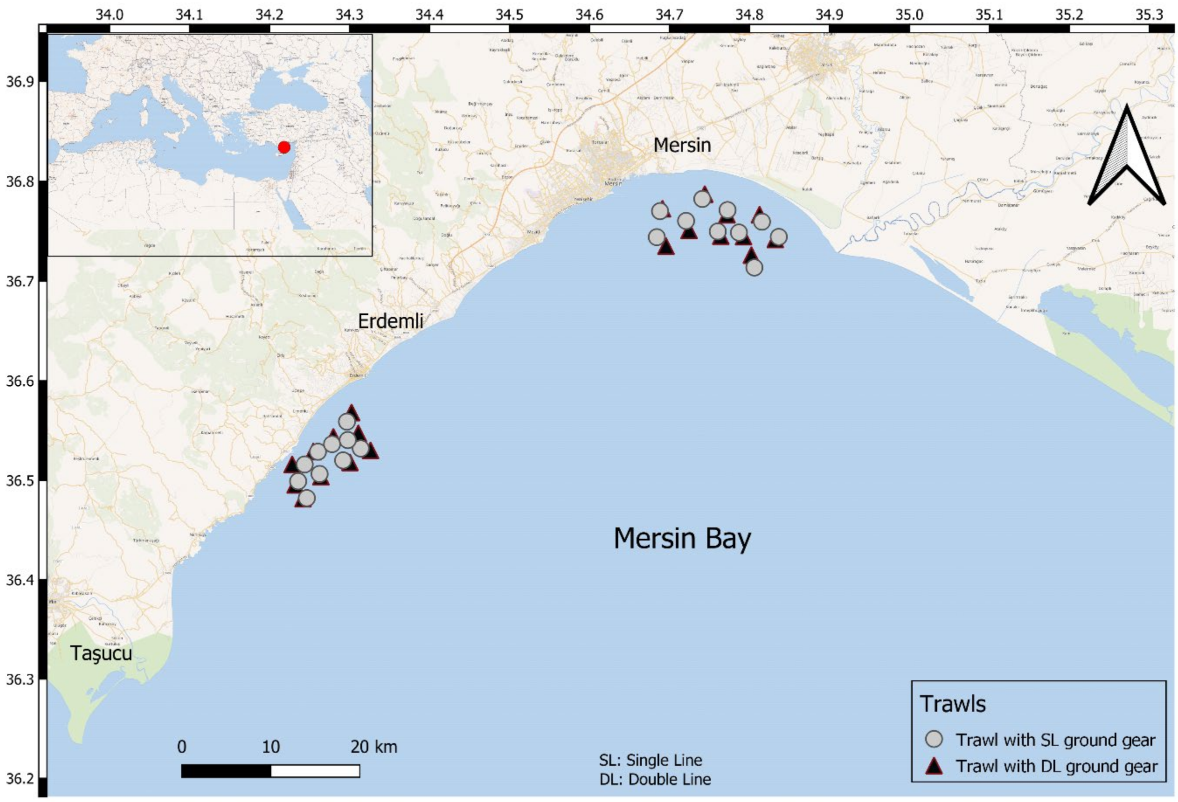

Figure 2. Map of the area off the Mersin coast where tows were started with SL (triangles) and DL (circles) trawls. Map source: QGIS 3.26., 2022.

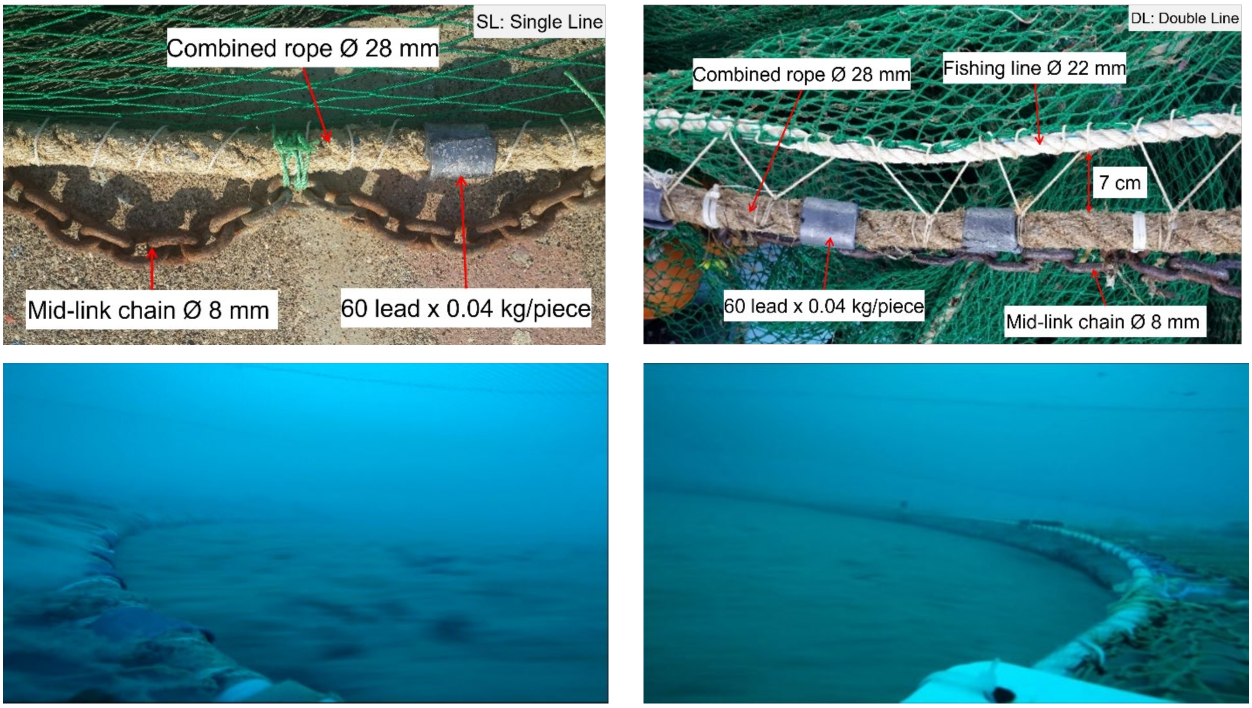

Figure 3. Image of SL ground gear (upper left) and DL ground gear (upper right); underwater images of both ground gears being towed on the seafloor (SL; bottom left, DL; bottom right)

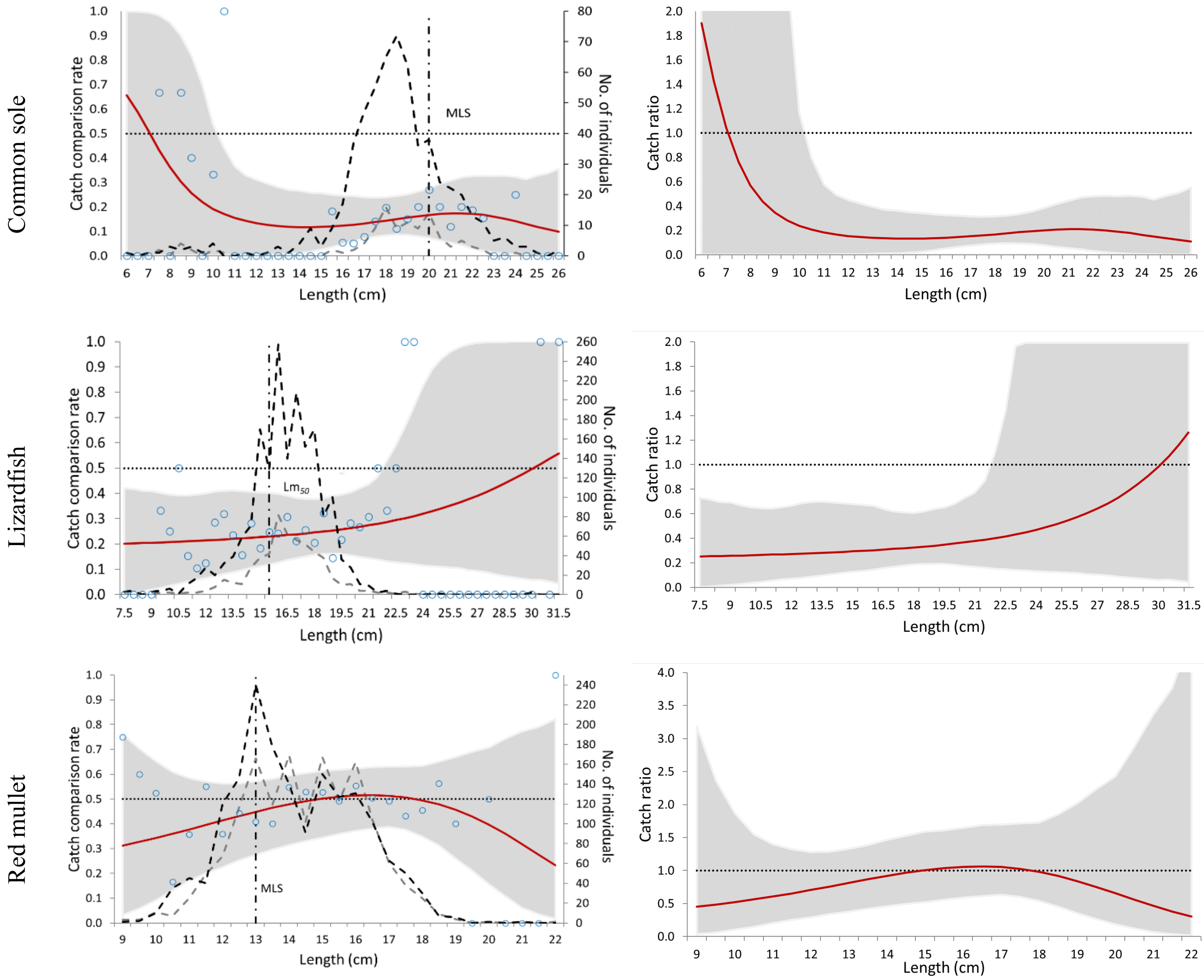

Figure 4. Catch comparison rate and catch ratio for three target species. On the left: the curve (red solid line) represents the modelled catch efficiency fitted to the experimental points (blue circles). The grey band represents 95% confidence intervals and the black (SL trawl) and grey (DL trawl) dashed lines show the length distributions observed in the catch. The 0.5 dotted horizontal line represents equivalence in catch rates between the two trawls. The vertical dashed-dotted line represents the MLS (minimum landing size) for red mullet and common sole while Lm$_{50}$ (length at maturity) for lizardfish. On the right: catch ratio curve (red solid line) with 95% confidence intervals (grey band). The 1.0 dotted horizontal line represents the point at which both trawl gears have an equal catch rate.

Table 1. Number of fish measured for the catch comparison and catch ratio analyses. Mean length measurement subsample ratios from the total catch. Values in parentheses are the range in length measurement subsample ratios.

Pairs of hauls	Common sole		Lizardfish		Red mullet	
	SL	DL	SL	DL	SL	DL
1	20	0	195	94	81	118
2	83	10	121	29	161	136
3	107	9	122	24	130	118
4	58	8	96	93	91	69
5	71	8	122	41	36	22
6	11	0	126	71	165	130
7	35	29	20	16	52	72
8	40	0	22	10	64	33
9	48	33	212	180	117	139
10	113	11	0	0	11	4
Total	586	108	1798	558	1716	1532
Mean subsample ratio	1.00 (1.00 – 1.00)	1.00 (1.00 – 1.00)	0.79 (0.33 – 1.00)	1.00 (1.00 – 1.00)	0.75 (0.25 – 1.00)	0.85 (0.25 – 1.00)

DL: Double Line, SL: Single Line

Table 2. Catch ratio (CR) results (in %) at different lengths and fit statistics for the catch comparison analysis for three target species. Values in brackets represent 95 % confidence limits. *: Out of data range. Catch ratio results marked in bold represent significant difference in catch efficiency between SL and DL ground gear. DL: Double Line, SL: Single Line.

Length (cm)	**CR (%):**		
	Common sole	**Lizardfish**	**Red mullet**
6	190.38 (0.13-131369.18)	*	*
7	104.54 (0.12-14840.07)	*	*
8	56.96 (0.12-2107.92)	**25.4 (0.92-71.45)**	*
9	34.48 (0.13-444.94)	**25.75 (2.07-69.12)**	45.49 (3.38-318.12)
10	23.77 (0.18-116.35)	**26.19 (3.66-65.25)**	52.15 (10.27-186.94)
11	**18.32 (0.24-57.7)**	**26.7 (5.38-64.26)**	60.58 (20.63-139.96)
12	**15.41 (0.35-44.94)**	**27.27 (6.99-66.72)**	70.48 (29.22-127.96)
13	**13.91 (0.67-39.17)**	**27.91 (8.92-69.72)**	81.27 (38.04-132.88)
14	**13.32 (1.2-36.36)**	**28.61 (10.8-69.2)**	91.89 (46.1-146.61)
15	**13.41 (2.59-34.4)**	**29.4 (12.74-67.86)**	100.73 (52.39-158.79)
16	**14.07 (5.14-32.67)**	**30.3 (14.53-66.42)**	105.84 (59.23-164.78)
17	**15.24 (7.53-31.59)**	**31.34 (16.76-62.01)**	105.28 (63.26-169.77)
18	**16.81 (9.19-31.55)**	**32.55 (18.67-60.63)**	97.89 (53.78-172.48)
19	**18.55 (9.37-33.45)**	**33.99 (19.09-63.75)**	83.99 (35.45-202.09)
20	**20.1 (7.97-38.15)**	**35.7 (18.34-67.8)**	65.74 (18.76-242.11)
21	**20.98 (5.66-44.47)**	**37.76 (16.75-77.21)**	46.71 (6.59-337.06)
22	**20.74 (3.23-48.11)**	40.24 (15.19-111.14)	30.34 (1.7-457.92)
23	**19.15 (1.39-48.16)**	43.26 (14.13-196.46)	*
24	**16.49 (0.55-47.67)**	46.95 (13.11-468.2)	*
25	**13.49 (0.22-48.52)**	51.48 (12.32-1319.89)	*
26	**11.05 (0.07-55.19)**	57.1 (11.72-4367.23)	*
27	*	64.12 (10.31-18511.25)	*
28	*	72.95 (8.68-92326.94)	*
29	*	84.13 (7.35-461280.34)	*
30	*	98.32 (6.24-3541993.01)	*
31	*	116.17 (5.41-41190542.2)	*
$CR_{average\,-}$	16.89 (3.48-30.30)	28.02 (3.19-52.84)	70.42 (10.84-130.01)
$CR_{average\,+}$	22.97 (2.69-43.24)	32.52 (8.92-56.13)	94.98 (46.73-143.24)
$NDRatio_{SL}$ (%)	74.74 (65.11-84.37)	33.14 (27.41.38.88)	23.25 (16.05-30.44)
$NDRatio_{DL}$ (%)	68.51 (54.18-82.85)	29.92 (21.28-38.57)	18.34 (13.03-23.64)
p-value	0.21	0.01	0.09
Deviance	38.13	51.92	27.50
DOF	32	32	19