Mediterranean Marine Science

Vol 19, No 1 (2018)

Vol 19, No 1 (2018)

By-catch in the commercial beam trawl fishery for Rapa Whelk in the Black Sea

AHMET RAIF ERYASAR, YUSUF CEYLAN, GOKTUG DALGIC, TUNCAY YESILCICEK

doi: [10.12681/mms.13873](https://doi.org/10.12681/mms.13873)

Research Article

Mediterranean Marine Science
Indexed in WoS (Web of Science, ISI Thomson) and SCOPUS
The journal is available online at http://www.medit-mar-sc.net
DOI: http://dx.doi.org/10.12681/mms.13873

Bycatch in the commercial beam trawl fishery for Rapa Whelk in the Black Sea

AHMET RAİF ERYAŞAR[1], YUSUF CEYLAN[2], GÖKTUĞ DALGIÇ[2] and TUNCAY YEŞİLÇİÇEK[2]

[1] Recep Tayyip Erdogan University, Vocational School of Technical Sciences, Underwater Technology Program, Rize, Turkey
[2] Recep Tayyip Erdogan University, Faculty of Fisheries, Rize, Turkey

Corresponding author: raiferyasar@gmail.com
Handling Editor: Serge Gofas

Received: 22 May 2017; Accepted: 4 November 2017; Published on line: 26 April 2018

Abstract

The current study was aimed to investigate the bycatch in commercial beam trawls used in the rapa whelk (*Rapana venosa*) fishery during September 1, 2015, and April 30, 2016. Four commercial boats using beam trawls were chartered and catch data were recorded from a total of 87 hauls. The hauls were performed at a depth of 7.1–28.3 meters for a duration of 20–77 min and the hauling speed varied between 1.4–2.7 knots. About 28 species were identified as bycatch, on an average this amounted to 11.4% of the total number of specimens. There were identified two different groups in the bycatch (G1: 7–18 m, G2: 19–26 m) based on the depth. Although there was noticed a decline in the volume of bycatch in group G2, it was not significant between the groups ($p>0.05$). According to the results of the Generalized Additive Models (GAM), the variables affecting the by-catch amount were identified as a fishing area, depth, haul duration, and the amount of captured rapa whelk ($p<0.01$). In addition, a large proportion of immature individuals of striped venus clams (*Chamelea gallina*), blood cockles (*Anadara kagoshimensis*), Mediterranean mussels (*Mytilus galloprovincialis*) and wedge clams (*Donax trunculus*) were caught as bycatch during the exploration. The current piece of work discusses the impact of commercial beam trawls on the demersal macrofauna.

Keywords: Beam trawl, rapa whelk, bycatch, Black Sea.

Introduction

The rapa whelk (*Rapana venosa*), a species of East Asian origin, was first noticed in the Black Sea in the late 1940s, and was first reported in 1962 in the eastern Black Sea region (Bilecik, 1975; Knudsen *et al.*, 2010a, b). The rapa whelk is an invasive species and known as the most active predator of oysters and mussels. It has rapidly adapted to the Black Sea and rampant growth has been putting pressure on the existing mussel stocks in the region (Sağlam *et al.*, 2008).

Among the Black Sea countries, the rapa whelk fisheries are actively carried out in Bulgaria, Turkey, Georgia, Ukraine and Russia; however, the largest yields are obtained in the eastern Black Sea region (Türkstat, 2013). Despite the fact that rapa whelk is regarded as the major causative factor in the diminishing of mussel stocks in the eastern Black Sea (Zolotarev, 1996; Salomidi *et al.*, 2012), it still remains one of the most important commercial species and a valuable source of income for small-scale fisheries in the Black Sea. Furthermore, rapa whelk constitutes one of the most important export entities of the regional fishery sector (Akbulut *et al.*, 2012).

In the rapa whelk fishery, the beam trawling is preferred due to the higher catching potential compared to other fishing methods (Altınağaç *et al.*, 2004). However, it has been reported that beam trawl (locally known as algarna) unwantedly catch the juveniles and causes damage to other living organisms on the sea floor due to the clogging of mesh openings by rapa whelk individuals during the fishing operations (Çelik & Samsun, 1996; Sağlam *et al.*, 2008). Kaykaç *et al.* (2014) investigated the structural attributes of drifting fishing gears used in the eastern Black Sea and reported that algarna is closer to the beam trawl definition of Valdemarsen & Suuronen (2003) in terms of net design, technical specifications, and fishing/operational mechanism.

In the recent years, commercial beam trawl fisheries in the eastern Black Sea have faced various problems including overfishing, a below average size of landed rapa whelks and subsequent loss in the commercial value of the products (Knudsen *et al.*, 2010a). Beam trawling is banned during summer (May to September) to protect the benthic-demersal ecosystem; however, this is the breeding period and hence the most optimal time for catching rapa whelk (Janssen *et al.*, 2014). This poses serious tensions and conflicts regarding fishing regulations (Knudsen & Koçak, 2010b) and eventually leads to the violation of rules and regulations related to fishing areas or fishing gears.

The unintentional capture of non-target marine animals during fishing is very common and referred to as bycatch. Discarding is one of the most important issues for fishery management since it is considered as wastage of marine resources, the source of uncertainty for fishery scientists and decision-makers, as well as a factor adversely affecting biodiversity and community structure (Tsagarakis *et al.*, 2014). In general, a larger portion of bycatch thrown back is a great concern threatening the entire marine ecosystem (Gücü, 2012).

Although beam trawl fishery is not a common practice in the Mediterranean Sea, but the magnitude of the discard-generation is very high (Tudela, 2004; FAO, 2016). Rapido trawl, a modified beam trawl, targeting either flatfish or scallops in the Adriatic Sea generates extremely high quantities of the discard (about 69–90% of total catch volume), mostly consisting of benthic invertebrates (e.g., echinoderms, crustaceans, molluscs, and sponges) (Pranovi *et al.*, 2001; Tsagarakis *et al.*, 2014; FAO, 2016). The discard rate of beam trawlers in the Marmara Sea for a mesh size of 36 mm and 40 mm was reported as 28.9% and 27.8%, respectively (Bök *et al.*, 2011). Beam trawls are also used in the rapa whelk fishery in Bulgaria (FAO, 2016). The discard rate of these fisheries has been estimated as 7.5% (Kelleher, 2005), and the negative effects of fishing gear on mussel beds were reported by Konsulova *et al.* (2001). The bycatch rate for the commercial beam trawls used for rapa whelk fishery in Turkish waters is not yet estimated.

In order to understand the ecosystem destruction by commercial beam trawl fleets due to the territorial violation and/or overfishing pressure, it is imperative to monitor the catch composition on a regular basis (Özbilgin *et al.*, 2013). There has not been done so far any thorough study on the bycatch in commercial beam trawl fleets for rapa whelk in the Black Sea, and there are considerable gaps in the estimation of effects of commercial beam trawl fleets on the benthic-demersal ecosystem. Therefore, the present study was aimed at comprehensive assessment of bycatch due to commercial beam trawls used in the rapa whelk fisheries and to provide valid information for future studies on minimizing by-catch in these fisheries.

Materials and Methods

The trials were conducted on commercial fishing grounds between Trabzon and Artvin provinces in the eastern Black Sea region (Turkey) (Fig. 1). A total of 25 trials were performed with four different commercial boats (85–110 HP; 7.8–9.5 m length) from September 1, 2015, to April 30, 2016. During the study, five one-day trials per month (on different days) were conducted during the rapa whelk fishing season (September to December, and April) and catch data were collected from a total of 87 valid hauls. The hauls were performed at a depth of 7.1–28.3 meters for the duration of 20–77 min, and at haul speeds of 1.4–2.7 knots. The bottom of the fishing grounds was sandy, muddy and/or sandy-mud. The areas selected for the beam trawl operations were left to the captain's choice and the researchers were involved only in the observation and data collection.

During the study, two different sizes of beam trawls were used. The frames of the beam trawls were 2.40 and 2.55 m in length, 40 and 45 cm in height, and were made up of Ø 50 and Ø 60 mm pipes (Fig. 2). The steel cables on the frames that provide contact with the ground were

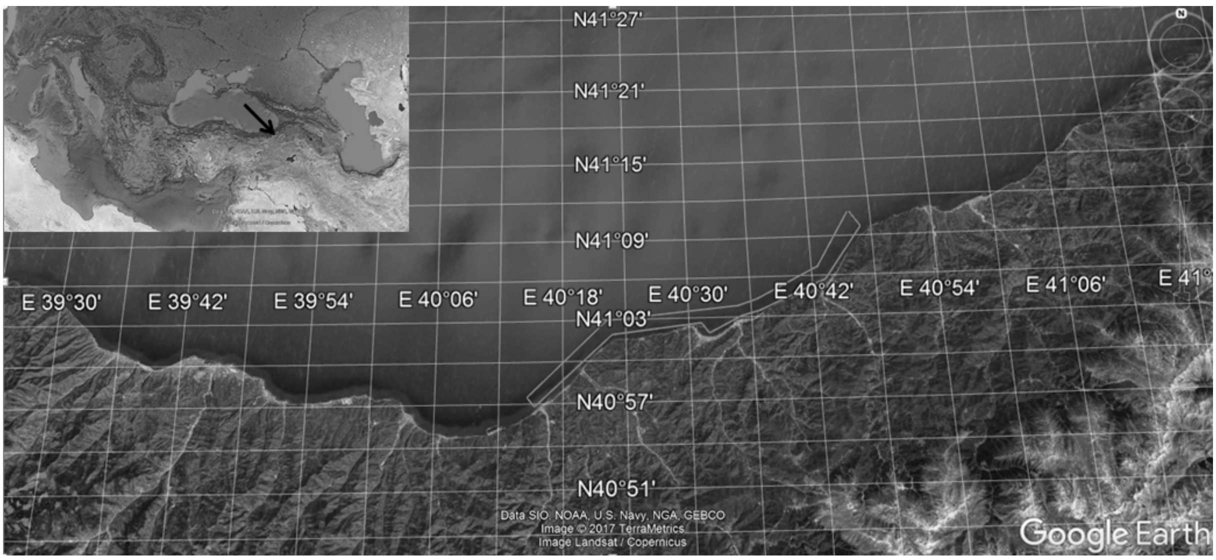

Fig. 1: Study area. (Points shows the middle point of the haul track).

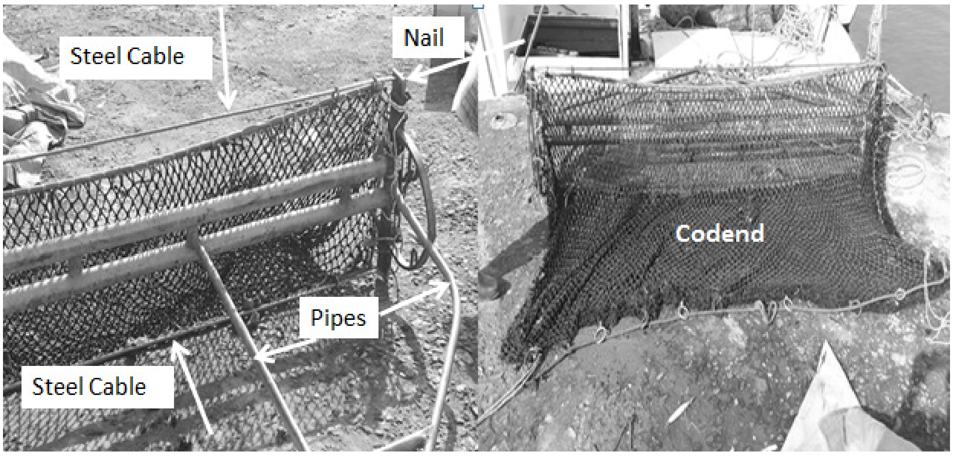

Fig. 2: Fishing gear used for rapa whelk fishery.

7 and 8 mm in diameter. The weight of the fishing gears was 95 and 110 kg. The embedded stretched steel cables on the upper and lower parts of the frame have dual functions. Primarily it detaches rapa whelk individuals from their substrate by scraping, and secondarily it stirs the ground surface to facilitate dragging of the net (Kaykaç *et al.*, 2014). Both the ends of the steel cable were mounted stretched on the legs which are located toward the ground side of the frame and referred to as “nail” (5–6 cm deep, 0.5–1 cm thick) by the local fishermen. The mesh size of diamonds in the codends was 72 mm, the codend length was 1 m, and the twine thicknesses were 4 and 5 mm. In addition, the number of mesh size on codend circumference in beam trawls was 140 and 220.

For each haul, the starting time was considered as the moment when the rope connected to the mast after throwing to a particular length. At the beginning of each haul, coordinates were taken using GPS and time, depth, tow speed, wind speed and direction data were recorded on the bridge. The time when ropes were heaved was considered as the end of the tow, and the same parameters were also recorded at the end of the tow. Garbage, stones, and wood pieces were separated from the catch dumped on the deck. The catch was later spread on the deck to isolate all the large individuals such as jellyfish, crabs, and fish. The sub-sampling ratio for rapa whelk, bivalves, and other species ranged between 1:1 and 1:30. The specimens were bagged separately from each haul and were safeguarded to be measured in the laboratory. The sample species were sorted out for counting and weight estimation. The total length of fish was measured using a fish scaling board. Electronic caliper with 0.01 mm precision was used to measure length in bivalve mollusks and other species such as crabs. The maximum distance along the anterior-posterior axis for mussels and carapace length for crabs were measured for calculating length; however, the length was not measured for hermit crabs due to morphological attributes.

The generalized additive model (GAM) was used to determine the factors affecting the bycatch CPUE (catch per unit effort) due to the non-linear correlation between dependent and explanatory variables. Fishing area, depth, haul duration, haul speed, and the amount of captured rapa whelk were regarded as explanatory variables for examining the changes occurring in the bycatch CPUE. Here, the depth is the average of the tracked line during the haul, and fishing area is denoted as the longitude of the midpoint of the haul track. The data analyses were done using the mgcv software, R program (R Development Core Team, 2013). In the beginning, all variables were included in the model, but later, non-significant ($p > 0.05$) variables were gradually dropped, until retaining the statistically significant ($p < 0.05$) variables. More details for using statistical analysis are described in Eryaşar *et al.* (2014a).

The similarity analysis of the by-catch species composition and their associated mean CPUE obtained by depth contours was performed using the PRIMER-5 program. Multi-dimensional Scaling (MDS) analysis was performed according to the Bray-Curtis similarity matrix (Kruskal & Wish, 1978). Depth was used as a factor in both cluster and MDS analysis in order to categorize the operations in terms of amount and bycatch species composition. The MDS and cluster analysis were performed to determine the effect of fishery activities on the bycatch species depending on depth contours. ANOSIM was performed on the hierarchical agglomerative clustering formed by the similarity matrix. To determine the contribution of each species to the dissimilarity ratio (cut-off percentage = 90) observed between groups, similarity percentage (SIMPER) analysis was used (Clarke, 1993). The differences between depth groups were determined with an independent t-test.

Results

During the study, about 28 species were caught as bycatch, and rapa whelk (*R. venosa*) was the only target species. A total of 303710 individuals were caught comprising 257836 individuals as target species (rapa whelk) and remaining 45874 individuals as bycatch species. The bycatch species constituted 11.4% of the total catch in terms of the number of individuals. The total weight was 4223820.14 g, of which 4180284.12 g was identified as of the target species, and 43536.02 g accounted for bycatch. The average bycatch weight was calculated as 1.22%. The minimum percentage of bycatch in terms of number and weight was recorded as 0.3% and 0.1%, while the maximum was 65.15% and 6.3%, respectively. The total bycatch amount according to class (excluding rapa whelk), given in Table 1, shows that Bivalvia and Malacostraca (essentially decapod crustaceans) were dominant classes in the bycatch.

At the completion of a total of 3392 min of haul, bycatch CPUE of species (from highest to lowest) is shown in Table 2. Striped venus clams (*Chamelea gallina*) and blood cockles (*Anadara kagoshimensis*) were the dominant species in terms of number as well as weight by constituting about 72% of the total bycatch in terms of number. The other commonly captured species were hermit crab (*Diogenes pugilator*), Mediterranean mussel (*Mytilus galloprovincialis*) and wedge clam (*Donax trunculus)*. The size-frequency distributions of the respective bivalve species are presented in Figure 3.

Striped venus clam (C. gallina)

In total, 21748 striped venus clams were caught. Length-frequency distributions showed a peak at 1.1 cm (Fig. 3A). The Minimum Landing Size (MLS) defined by the Turkish Fisheries Regulations (TFR) is 1.7 cm for striped venus clam (Anonymous, 2016). In this study, 98% of the individuals were below the MLS.

Blood cockle (A. kagoshimensis)

In total, 6575 blood cockles were caught. Length-frequency distributions showed a peak at 0.7 cm (Fig. 3B). The MLS of blood cockles is not specified in the TFR. However, the size at first maturity of this species was reported by Şahin *et al.* (2006) as 2 cm for the eastern Black Sea. According to this, 89% of the individuals were below the size at first maturity.

Mediterranean mussel (M. galloprovincialis)

In total, 2734 Mediterranean mussels were caught. Length-frequency distributions showed a peak at 1 cm (Fig. 3C). Yonge (1976) reported the size at first maturity of this species as 4 cm. According to this specification, all captured individuals were below size at first maturity.

Wedge clam (D. trunculus)

In total, 1290 wedge clams were caught, and the 1.7 cm length group represented a peak in the length-frequency distributions (Fig. 3D). The MLS defined by the TFR is 2.5 cm for wedge clam (Anonymous, 2016). According to this, all captured individuals were below the MLS.

According to GAM results, the fishing area, depth, haul duration and the captured rapa whelk quantity were statistically significant ($p < 0.01$). The predictive power of the model was estimated as 82% (Table 3). The variables affecting the bycatch CPUE are separately indicated

Table 1. The bycatch amounts for each class.

	Total Number	%	Total Weight	%
Gastropoda	2380.62	5.2	2634.63	6.1
Bivalvia	37605.75	82.0	22603.48	51.9
Malacostraca	5614.89	12.2	8063.63	18.5
Actinopterygii	213.88	0.5	3082.25	7.1
Others	58.79	0.1	7152.03	16.4

Table 2. List of bycatch species and catch per unit effort values in terms of number.

Species (Class)	CPUE [number/min]
Chamelea gallina (Bivalvia)	6.859
Anadara kagoshimensis (Bivalvia)	2.816
Diogenes pugilator (Malacostraca)	1.449
Mytilus galloprovincialis (Bivalvia)	0.840
Donax trunculus (Bivalvia)	0.398
Tritia reticulata (Gastropoda)	0.379
Tritia neritea (Gastropoda)	0.323
Pitar rudis (Bivalvia)	0.169
Liocarcinus depurator (Malacostraca)	0.100
Liocarcinus navigator (Malacostraca)	0.064
Xantho poressa (Malacostraca)	0.024
Hippocampus sp. (Actinopterygii)	0.019
Arnoglossus kessleri (Actinopterygii)	0.019
Eriphia verrucosa (Malacostraca)	0.015
Uranoscopus scaber (Actinopterygii)	0.014
Tunicata (Ascidiacea)	0.012
Pecten sp. (Bivalvia)	0.004
Scyphozoa	0.004
Callionymus lyra (Actinopterygii)	0.003
Macropodia sp. (Pezizomycetes)	0.003
Trachinus draco (Actinopterygii)	0.003
Scorpaena porcus (Actinopterygii)	0.002
Pegusa nasuta (Actinopterygii)	0.001
Nereis sp. (Polychaeta)	0.001
Raja clavata (Elasmobranchii)	0.001
Diplodus annularis (Actinopterygii)	0.000
Merlangius merlangus (Actinopterygii)	0.000
Solea sp. (Actinopterygii)	0.000

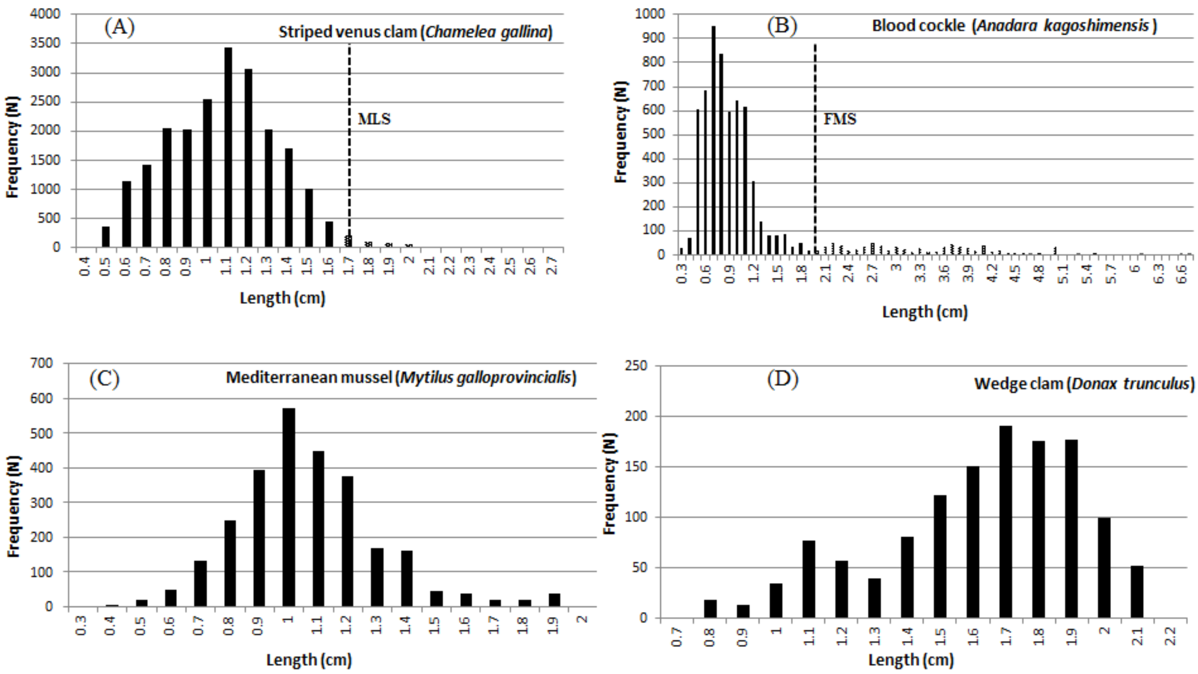

Fig. 3: The length-frequency distribution of the *Chamelea gallina* (A), *Anadara kagoshimensis* (B), *Mytilus galloprovincialis* (C), and *Donax trunculus* (D) [Black bars show the length groups below minimum landing size (MLS) or size at first maturity (FMS)].

by the letters in Figure 4. Figure 4A shows an increase in the bycatch from west to east in the study area. In Figure 4B, the fluctuations could be seen with increasing depth for bycatch CPUE. Figure 4C indicates a negative correlation between the haul duration and bycatch CPUE. Figure 4D shows a positive correlation between the rapa whelk amount and bycatch CPUE.

According to similarity analysis (Cluster, MDS) of the total bycatch species caught by all hauls, 2 different depth groups (G1, G2) were classified (Figure 5, 6), The groups G1 and G2 represented shallow (7–18 m) and deeper areas (19–26 m), respectively. According to MDS analysis, stress value was calculated as 0.11. A stress value less than 0.2 is acceptable and signifies the accordance in the groups (Clarke, 1993), beside ANOSIM test revealed that the groups were significantly different ($p<0.05$). SIMPER analysis (Table 4) showed the species that had an important contribution to identifying G1 and G2 groups, viz., *C. gallina* (31.86%), *A. kagoshimensis* (30.97%), *M. galloprovincialis* (10.39%), and *D. pugilator* (6.83%).

Table 5 shows the CPUE values of species in the G1 and G2 groups. In both the groups, bivalve species are very dominant in bycatch composition. In the G1 group, Striped venus clam was the most captured bycatch spe-

Table 3. GAM results.

N	R-sq.	Explanatory Variables	F	P
87	0.82	Fishing Area	4.347	<0.01
87	0.82	Depth	5.315	<0.01
87	0.82	Haul Duration	8.038	<0.01
87	0.82	Captured Rapa Whelk Amount	13.586	<0.01

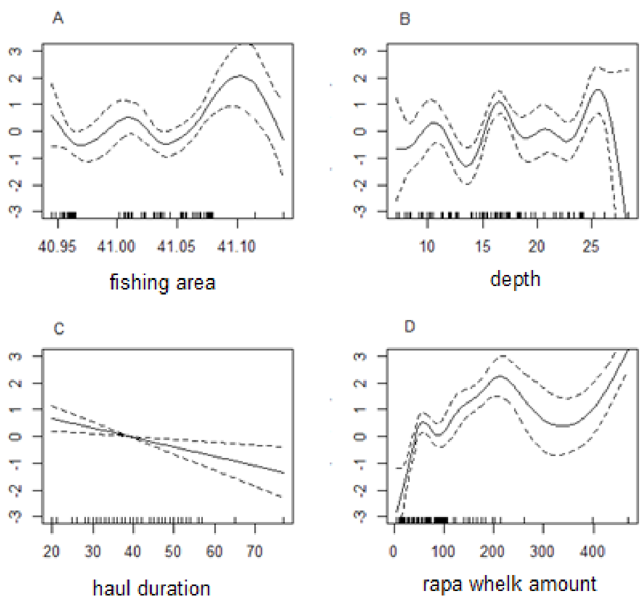

Fig. 4: Smoothing curves for partial effects of the variables (A: fishing area; B: depth; C: haul duration; D: rapa whelk amount) on by-catch amount derived by GAM. The contributions of each variable are represented on the plots. Dotted lines indicate 95% confidence bands.

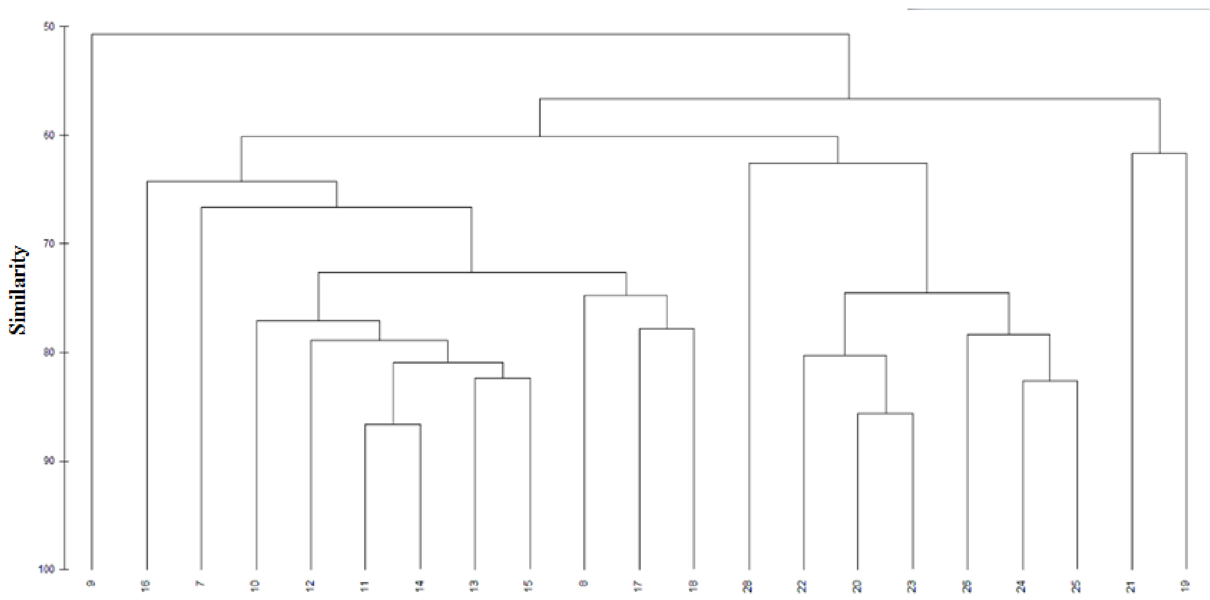

Fig. 5: Similarity dendrogram of by-catch species composition based on depth contours.

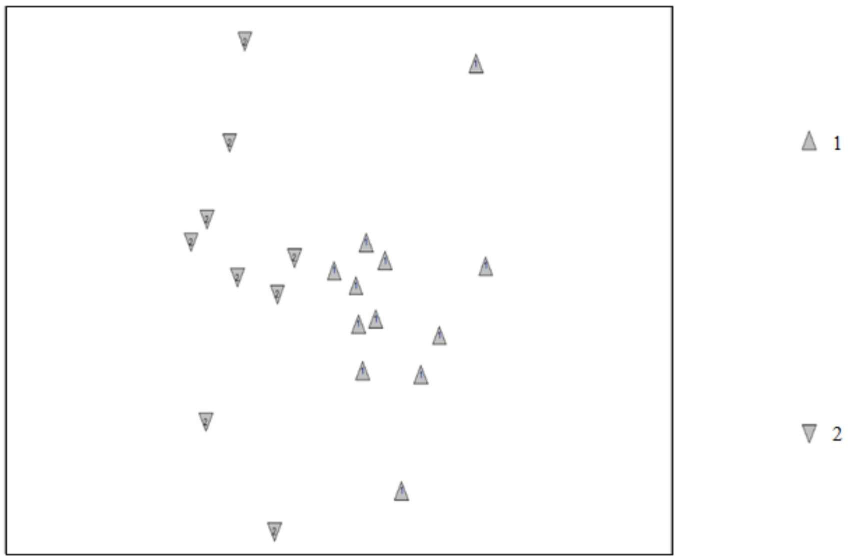

Fig. 6: MDS ordination of the operations of bycatch composition for all the groups. 1 shallow; 2: deep.

cies (8.43%), while whiting (*Merlangius merlangus*) was the least one (0.02%). In the G2, blood cockles (9.19%) was the most abundant bycatch species, while Greater weaver (*Trachinus draco*) was the least. The bycatch CPUE range for fishing operations in the G1 group was 0.3–191.8 number per minute, with an average value of 19.7 ±0.68 number per minute. The bycatch CPUE range for the G2 group was calculated as 0.4–45 number per minute, with an average CPUE of 12.6 ±0.91 number per minute. Although there was recorded a drift in bycatch amount in group G2, however, no significant difference was found between the groups ($p>0.05$).

Among gastropods, R. venosa and Tritia neritea captured were significantly more abundant in G1 group than G2 (independent t-test; $p<0.05$) (Table 5). T. reticulata had relatively higher CPUE value in G1 but non significant ($p>0.05$). For Bivalvia class, C. gallina and M. galloprovincialis had higher CPUE values in G1 than G2, while A. kagoshimensis showed significantly higher CPUE value in G2 ($p<0.05$). All of the Malacostraca species (D. pugilator, Liocarcinus depurator, L. navigator) marked significantly higher CPUE values in G1 ($p<0.05$). For Actinopterygii species, Arnoglossus kessleri and Uranoscopus scaber were notably more in G1 compared to G2 ($p<0.05$). However, Hippocampus sp. had slightly higher CPUE value in G2 group ($p>0.05$).

Table 4. SIMPER analysis results.

Average dissimilarity between groups (G1,G2)= 63.06						
	G1	**G2**				
Species	Av. Abund	Av. Abund	Av. Diss	Diss/SD	Contrib%	Cum.%
Chamelea gallina	6.60	3.09	20.09	1.30	31.86	31.86
Anadara kagoshimensis	1.71	5.60	19.53	1.29	30.97	62.83
Mytilus galloprovincialis	3.18	0.23	6.55	0.53	10.39	73.22
Diogenes pugilator	1.56	0.38	4.31	1.11	6.83	80.05
Pitar rudis	0.09	0.58	2.96	0.89	4.70	84.75
Donax trunculus	0.68	0.20	1.97	1.12	3.12	87.87
Tritia neritea	0.55	0.17	1.80	1.31	2.86	90.73

Table 5. CPUE values of by-catch species in the depth groups.

Species in group G1	CPUE (number/min)	%	Species in group G2	CPUE (number/min)	%
Rapana venosa	103.02	79.87	*Rapana venosa*	68.8	82.48
Chamelea gallina	10.87	8.43	*Anadara kagoshimensis*	7.66	9.19
Mytilus galloprovincialis	3.23	2.50	*Chamelea gallina*	3.54	4.25
Diogenes pugilator	3.16	2.45	*Pitar rudis*	0.69	0.82
Anadara kagoshimensis	2.85	2.21	*Diogenes pugilator*	0.49	0.58
Donax trunculus	1.34	1.04	*Tritia reticulata*	0.41	0.49
Tritia neritea	0.95	0.74	*Donax trunculus*	0.36	0.43
Tritia reticulata	0.94	0.73	*Mytilus galloprovincialis*	0.30	0.36
Pitar rudis	0.80	0.62	*Tritia neritea*	0.26	0.31
Xantho poressa	0.36	0.28	*Tunicata*	0.22	0.27
Macropodia sp.	0.26	0.20	*Pecten* sp.	0.22	0.26
Liocarcinus navigator	0.23	0.18	*Liocarcinus depurator*	0.09	0.10
Liocarcinus depurator	0.19	0.15	*Hippocampus* sp.	0.07	0.08
Callionymus lyra	0.18	0.14	*Nereis* sp.	0.05	0.06
Eriphia verrucosa	0.11	0.08	*Liocarcinus navigator*	0.05	0.06
Tunicata	0.10	0.08	*Uranoscopus scaber*	0.04	0.05
Arnoglossus kessleri	0.10	0.08	*Diplodus annularis*	0.03	0.04
Hippocampus sp.	0.05	0.04	*Eriphia verrucosa*	0.03	0.03
Scorpaena porcus	0.04	0.03	*Pegusa nasuta*	0.03	0.03
Scyphozoa	0.04	0.03	*Scorpaena porcus*	0.03	0.03
Uranoscopus scaber	0.03	0.03	*Raja clavata*	0.02	0.03
Trachinus draco	0.03	0.02	*Trachinus draco*	0.02	0.02
Pegusa nasuta	0.03	0.02			
Solea sp.	0.03	0.02			
Merlangius merlangus	0.02	0.02			

Discussion

To best of our knowledge, this is the first comprehensive study conducted on bycatch of commercial beam trawls for rapa whelk in the Black Sea. The bycatch volume was very low in weight (1.22%); therefore in this study, the data are presented only in terms of numbers of individuals. It is worth to note that the recorded 11.4% bycatch was collected in the legal period (September–April) as defined by the TFR. Zengin *et al.* (2014) reported highest fishing mortality during the summer period and the bycatch constituted 29.7% of the total catch in summer beam trawling in the Black Sea region. Based on this study, it can be inferred, if hauls would have been performed in the summer period, bycatch rate would have been much higher than that observed in our study.

In the present data of 28 non commercial bycatch species, striped venus clams (*C. gallina*) and blood cockles (*A. kagoshimensis)* were the most dominant ones. This differs from the previous report, where Sağlam *et al.* (2008) found a total of 13 bycatch species and blood cockles (*A. kagoshimensis*) and harbor crabs (*L. depurator*) were the most abundant bycatch species from 17 beam trawl hauls conducted between April 2006 and February 2007 in Trabzon Province (eastern Black Sea). However, Sağlam *et al.* (2008) used 90-mm mesh size in beam trawl codends, whereas we used 72-mm mesh size (as per TFR). Therefore, a larger mesh size in the codend might have provided more opportunities to escape for small individuals such as striped venusclams (*C. gallina*) and other bivalve species. Bycatch ratio of beam trawl fisheries in Marmara and Adriatic Sea (Tudela, 2004; Bök *et al.*, 2011) was reportedly very high compared to the present study. The difference between the fishing gears and/or fishing ground could play an important role in this variation.

In the current study, the depth was considered to influence the bycatch biomass, but there was no visible difference in the number of species for depth groups (G1:24; G2:21; Table 5). This contrasts with the studies previously done in bottom trawls in Mediterranean (Sanchez *et al.*, 2004; Gücü, 2012) and Black Sea (Ceylan *et al.*, 2014). It was reported that the composition of bottom trawls used for fish and demersal benthic fauna differs according to the depth. This may be explained by the limited depth range in the present study (7–28 m). As far as species biomass is considered, the bycatch of most species (including rapa whelk) was higher in a shallow area (7–18 m), while that of blood cockle was higher in the deeper area (19–26 m). Şahin *et al.* (2006) reported that blood-cockle can be found at depths of 3–60 m, but density is higher between 5–25 m and this generally prefers substratum composed of mud and sand. These reports indicate that the deeper area (G2) is more suitable habitat for blood cockle. The comparative account of depth groups according to catch volumes of all captured species confers that beam trawls fishery for rapa whelk in G1 region affects a larger number of benthic animals than in G2.

The GAM model indicated an eastward increase in bycatch (Fig. 4A) perhaps due to the technical difference in fishing gears because boats operating in the western region used 140 meshes around the codend circumference against the eastern region (220). The selectivity studies of trawl codends showed that reduction in the number of meshes around the codend increases selectivity (Broadhurst *et al.*, 2004; Eryaşar *et al.*, 2014b). Moreover, Özbilgin *et al.* (2013) showed that increasing the number of meshes around the codend circumference provides fewer openings for individual meshes resulting in a reduced codend selectivity. The second factor may be related to the contact rate of the steel wire of the beam trawl with the bottom, which differs between plain or undulating ground type. Underwater observations performed with a camera placed on the beam trawl showed that the beam trawl lifts up too much sand cloud in undulating ground type where there are more sand dunes than in plain ground type. Consequently, the increased contact rate of the steel wire in undulating ground types results in a higher probability to capture buried Bivalvia species, thereby a higher bycatch at constant abundances.

The current data showed a fluctuation in bycatch amounts with increased hauling depths (Fig. 4B). The depth-based examination of CPUE values of species indicated that the fluctuation is caused by the high catch rate of striped venus clams in 16–17 meters and blood cockles in 25–26 meters.

The increase in bycatch with an increase in the captured rapa whelk (Fig. 4D) might have occurred due to the blockage of codend mesh by the accumulation of rapa whelk. Underwater observations of beam trawl codends showed that the bycatch species lifted up by the steel wire were drifted toward the codend and thrown out with the water flow at the beginning of the haul. Afterwards, a reduction in bycatch escape was observed with increasing capture of rapa whelk in the codend. Gaspar & Chicharo (2007) also obtained similar results in their analysis of the dredges used in mussel fishing in Portugal and reported that escape probability of bycatch species decreases with increased amounts of catch in codends.

The decline in the bycatch observed with increased haul durations (Fig. 4C) could also be explained by the amount of captured rapa whelk, depending on the type of vessel and codend features. Catch efficiencies of rapa whelk are optimal at the beginning of the season, however, the fishing gears of small boats are not strong enough and fishermen cannot use codends longer than 1 m due to legal compliance (TFR). Therefore, codends reach a maximum capture level in a short time in the beginning of the season and mesh is quickly blocked by rapa whelk. Due to the size limitation of boat and fishing gears, haul durations are kept short for ease of operation. However, haul durations can be extended where rapa whelks are scarce and codend mesh remain open for a longer time for bycatch species. Similar findings were also reported by Machias *et al.* (2001), they showed that hauls of long duration usually resulted in lower discard amount, but at sites of higher productivity, hauls were relatively shorter with higher discard ratio.

The examination of length-frequency distributions of the four species (*C. gallina, A. kagoshimensis, M. gallo-provincialis,* and *D. trunculus*) revealed that beam trawls have a serious impact, especially on the bivalve species due to high discard rate of juveniles from the environment without spawning at least once. The high rate of captured bivalve species smaller than the MLS and/or the size at first maturity may be explained by the presence ofsmall individuals closer to the bottom surface compared with larger ones (Gaspar & Chicharo, 2007). In addition, it is important to note that the vast majority of bivalve species are not thrown back into the sea. The surveys of our study revealed that bivalve species were bagged with the predatory rapa whelk individuals without any elimination process after the catch was dumped on the deck. Therefore, the combined effect of bycatch and predation mortality may probably exacerbate the destructive consequences for the bivalve stocks in the region.

The baited pots made for rapa whelk fishing have been demonstrated as an alternative to beam trawls (Sağlam et al., 2008), however, they were not preferred by fishermen due to a very low catch efficiency. The baited pots need to be re-designed for a higher efficiency of catching rapa whelk and the currently used commercial beam trawls require further modifications to be more specific for rapa whelks and to minimize their impact on the demersal macrofauna in the Black Sea. Increasing mesh size and/or changing mesh type (for example, square mesh) in codends is one of the most commonly used methods to reduce the bycatch in beam trawl and bottom trawl fisheries. However, a shift from the commercial diamond codend to modified ones may experience the potential economic loss. However, in order to compensate the predicted economic losses, extending the codend length and/or fishing season may be opted as other possible alternatives.

Acknowledgements

We would like to thank the captains and crews of the commercial vessels. Thanks are also extended to Dr. Kenan Gedik, Dr. Ertuğrul Terzi, and Mehmet Şaban Kutay for their help in the sea trials and laboratory. The authors would like to thank the anonymous reviewers and Dr. Dietrich Schnack for their valuable comments and suggestions to improve the quality of the paper. This study was financed by Recep Tayyip Erdogan University Research-Project Fund (Project No: 2015.53007.103.03.04).

References

Akbulut, B., Kutlu, S., Zengin, M., Aksungur, N., Özkan, B. et al., 2012. TR90 Doğu Karadeniz Bölgesi Su Ürünleri Sektör Raporu. TR90/11/DFD/21, Su Ürünleri Merkez Araştırma Enstitüsü, 107 pp. (In Turkish).

Altınağaç, U., Ayaz, A., Kara, A., 2004. A preliminary study on the whelk fisheries [*Rapana venosa* (Valenciennes, 1846)] using liftnets of various sizes. *Ege Journal of Fisheries and Aquatic Sciences*, 21 (3-4), 295-299 (In Turkish).

Anonymous, 2016. The commercial fish catching regulations in seas and inland waters in 2016–2020 fishing period: circular No.2016/35 (in Turkish). *Ministry of Food, Agriculture and Livestock, General Directorate of Conservation and Inspection*, Ankara, Turkey, 68 pp. (In Turkish).

Bilecik, N., 1975. La Repartition de Rapana thomasiana thomasiana (Grosse) sur le Littoral Turc de la Mer Noire s'etendant d'Ieada jusqu'a Çaltı Burnu. *Rapports et Procès-verbaux des Réunions, Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée,* 23 (2), 169-171.

Bök, T.D., Göktürk, D., Kahraman, A.E., 2011. Bycatch in 36 and 40 mm PA Turkish twin rigged beam trawl codends. *African Journal of Biotechnology*, 10 (37), 7294-7302.

Broadhurst, M.K., Millar, R.B., Kennelly, S.J., Macbeth, W.G., Young, D.J *et al*., 2004. Selectivity of conventional diamond- and novel square-mesh codends in an Australian estuarine penaeid-trawl fishery. *Fisheries Research*, 67, 183-194.

Ceylan, Y., Sahin, C. Kalaycı, F., 2014. Bottom trawl fishery discards in the Black Sea coast of Turkey. *Mediterranean Marine Science*, 15 (1), 156-164.

Clarke, K.R., 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, 18, 117-143.

Çelik, O., Samsun, O., 1996. Investigation of the catch amount and the catch composition of dredges with various design features. *Ege Journal of Fisheries and Aquatic Sciences*, 13, 259-272 (In Turkish).

Eryaşar, A.R., Özbilgin, H., Gücü, A.C., Sakınan, S., 2014a. Marine debris in bottom trawl catches and their effects on the selectivity grids in the north eastern Mediterranean. *Marine Pollution Bulletin*, 81, 80-84.

Eryaşar, A.R, Özbilgin, H., Gökçe, G., Özbilgin, Y.D, Saygu, I. *et al*., 2014b. The effect of codend circumference on selectivity of hand-woven slack knotted codend in the north eastern Mediterranean demersal trawl fishery. *Turkish Journal of Fisheries and Aquatic Sciences*, 14, 463-470.

FAO, 2016. The State of Mediterranean and Black Sea Fisheries. *General Fisheries Commission for the Mediterranean*. Rome, Italy, xiv +, 134 pp.

Gaspar, M.B., Chicharo, L.M., 2007. Modifying Dredges to Reduce By-catch and Impacts on the Benthos. p. 95-140. In: *Bycatch Reduction in the World's Fisheries*. Kennelly, S.J. (Ed.). Springer.

Gücü, A.C., 2012. Impact of depth and season on the demersal trawl discard. *Turkish Journal of Fisheries and Aquatic Sciences*, 12, 817-830.

Janssen, R., Knudsen, S., Todorova, V., Hoşgör, A.G., 2014. Managing Rapana in the Black Sea: Stakeholder workshops on both sides. *Ocean and Coastal Management*, 87, 75-87.

Kaykaç, M.H., Zengin, M., Özcan-Akpınar, İ., Tosunoğlu, Z., 2014. Structural characteristics of towed fishing gears used in the Samsun coast (Black Sea). *Ege Journal of Fisheries and Aquatic Sciences*, 31 (2), 87-96 (In Turkish).

Kelleher, K., 2005. *Discards in the World's Marine Fisheries*. Food and Agriculture Organization (FAO), FAO Fisheries Technical Paper No 470, 131 pp.

Knudsen, S., Zengin, M., Koçak, M.H., 2010a. Identifying drivers for fishing pressure. A multidisciplinary study of trawl and sea snail fisheries in Samsun, Black Sea coast of Turkey. *Ocean and Coastal Management*, 53 (5-6), 252-269.

Knudsen, S., Koçak, M.H., 2010b. Through boom and bust: coping with poverty in sea snail fisheries on the Turkish Black Sea coast. p. 221-249. In: *Poverty Mosaics: Realities and Prospects in Small-Scale Fisheries*. Jentoft, S., Eide, A.

(Eds.). Springer Media B.V.

Konsulova, T., Todorova, V., Konsulov, A., 2001. *Investigations on the effect of ecological method for protection against illegal bottom trawling in the Black Sea –Preliminary results*. Rapports de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée 36, 287 pp.

Kruskal, J.B., Wish, M., 1978. *Multidimensional Scaling*. Sage Publications, Beverly Hills, CA, 96 pp.

Machias, A., Vasilopoulou, V., Vatsos, D., Bekas, P., Kallianotis, A., Papaconstantinou, C., Tsimenides, N., 2001. Bottom trawl discards in the north-eastern Mediterranean Sea. *Fisheries Research*, 53, 181-195.

Özbilgin, H., Gökçe, G., Özbilgin, Y.D., Eryaşar, A.R., Bozaoğlu, A.S. *et al*., 2013. *Investigations to improve species and size selectivity in Mersin Bay trawl fisheries*. The Scientific and Technological Research Council of Turkey (TUBITAK), Project No: 109O684, Final Report, Mersin, 250 pp. (In Turkish).

Pranovi, F., Raicevich, S., Franceschini, G., Torricelli, P., Giovanardi, O., 2001. Discard analysis and damage to non-target species in the "rapido" trawl fishery. *Marine Biology*, 139, 863-875.

R Development Core Team, 2013. R: a language and environment for statistical computing. R Foundation for statistical Computing, Vienna <http://www.rproject.org>.

Sağlam, H., Düzgüneş, E., Kutlu, S., Dağtekin, M., Başçınar, S. *et al*., 2008. *Deniz Salyangozu Avcılığında Direçe Alternatif Farklı Tuzak Modellerinin Geliştirilmesi*. Su Ürünleri Merkez Araştırma Enstitüsü Müdürlüğü, Trabzon, 90 pp. (In Turkish).

Sanchez, P., Demestre, M., Martin, P., 2004. Characterization of the discards generated by bottom trawling in the Northwestern Mediterranean. *Fisheries Research*, 67, 71-80.

Şahin, C., Düzgüneş, E., Okumuş, İ., 2006. Seasonal variations in condition index and gonadal development of the introduced blood cockle *Anadara inaequivalvis* (Bruguiere, 1789) in the southeastern Black Sea coast. *Turkish Journal of Fisheries and Aquatic Sciences*, 6, 155-163.

Salomidi, M., Katsanevakis, S., Borja, Á., Braeckman, U., Damalas, D. *et al*., 2012 Assessment of goods and services, vulnerability, and conservation status of European seabed biotopes: a stepping stone toward ecosystem-based marine spatial management. *Mediterranean Marine Science*, 13(1), 49-88.

Tsagarakis, K., Palialexis, A., Vassilopoulou, V., 2014. Mediterranean fishery discards: review of the existing knowledge. *ICES Journal of Marine Science*, 71, 1219-1234.

Tudela, S., 2004. *Ecosystem effects of fishing in the Mediterranean: an analysis of the major threats of fishing gear and practices to biodiversity and marine habitats*. FAO, GFCM Studies and Reviews, 74, Rome, 58 pp.

Türkstat, 2013. Fishery Statistics, Ankara, Turkey.

Valdemarsen, J.W., Suuronen, P., 2003. Modifying fishing gear to achieve ecosystem objectives. p. 321–341. In: *Responsible fisheries in the marine ecosystem*. Sinclair, M. and Valdimarsson, G. (Eds.). FAO.

Yonge, C.M., 1976. The 'mussel' form and habit. P. 1-12. In: *Marine mussels: their ecology and physiology*. Bayne, B.L. (Ed.). International Biological Programme.

Zengin, M., Gümüş, A., Süer, S., Van, A., Rüzgar, M. *et al*., 2014. *Assessing trawling impact in regional seas (Black Sea Case Study)*. Benthis Deliverable 7. 6, Study Report, June, 25 pp.

Zolotarev V,. 1996, The Black Sea ecosystem changes related to introduction of new mollusc species. *Marine Ecology*, 17, 227-236.