Mediterranean Marine Science

Vol 19, No 3 (2018)

A novel grid-net design to eliminate bycatch in beam trawl fishing for the veined rapa whelk in the south-eastern Black Sea

AHMET RAIF ERYAŞAR

doi: [10.12681/mms.15351](https://doi.org/10.12681/mms.15351)

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.15351

A novel grid-net design to eliminate bycatch in beam trawl fishing for the veined rapa whelk in the south-eastern Black Sea

AHMET RAİF ERYAŞAR

Recep Tayyip Erdogan University, Vocational School of Technical Sciences,
Underwater Technology Program, Rize, Turkey

Corresponding author: raiferyasar@gmail.com
Handling Editor: Argyro Zenetos

Received: 7 December 2017; Accepted: 19 March 2018; Published on line: 26 September 2018

Abstract

Beam trawl fisheries in the Black Sea target the veined rapa whelk (*Rapana venosa*) while other species of fish and crabs are returned to the sea dead or alive. Smaller bivalves and crabs are also packed with the catch without elimination. In this study, novel grid-net designs (GNDs) with two different bar spacings were tested to reduce the bycatch. Thirty hauls (15 hauls for each bar spacing) were carried out in the south-eastern Black Sea between 17 and 26 August 2017. Bycatch compositions were compared by towing a commercial diamond mesh and one of the grid-net beam trawls simultaneously onboard a commercial vessel. There were statistically significant ($p<0.01$, 78% and 83%) decreases in the mean bycatch weight for 20 mm and 30 mm grid-nets, respectively. The estimated commercial loss was 14% in the 20 mm GND and 39% in the 30 mm GND in the landing values as compared to the commercial gear. In conclusion, the use of grid-net design for beam trawl fishing in the south-eastern Black Sea can significantly reduce the bycatch of most benthic species. There is a trade-off between the reduction in the bycatch and some commercial loss, which could be offset with some compensation to fisheries, such as an extension of the fishing season.

Keywords: Benthic bycatch; grid-net design; beam trawl; Black Sea.

Introduction

The veined rapa whelk (*Rapana venosa*) is an invasive species native to Asian waters and were introduced into the Black Sea through ballast tanks of commercial ships. It is an active predator of oysters and mussels (ICES, 2004), has rapidly adapted, and spread to the Black Sea coasts by encroaching on the mussel populations in the region (Sağlam *et al.*, 2008). Although primarily responsible for the decline of native mussel populations in the region (Zolotarev, 1996; Salomidi *et al.*, 2012) the veined rapa whelk is an economically important species for fishermen in the area with around 80% (10,353 tons) of its total catch in Turkey being caught along the south-eastern Black Sea coast (Türkstat, 2016; Gedik, 2017). The produce is primarily exported to Asia, especially to Japan and China, with no domestic consumption in Turkey (Sağlam *et al.*, 2009).

Traditional beam trawls (locally known as *algarna*) are the preferred capture device for this species due to comparatively higher catch efficiency (Altınağaç *et al.*, 2004). Referred to as dredge by some authors (Çelik and Samsun, 1996; Altınağaç *et al.*, 2004; Sağlam *et al.*, 2008) and as beam trawl by others (Kaykaç *et al.*, 2014; Zengin *et al.*, 2014), the *algarna* better resembles a beam trawl in terms of net design, technical specifications, and operational functions, albeit shorter than conventional beam trawls (Valdermarsen and Suuronen, 2003). The studies in the south-eastern Black Sea have shown that this gear causes damage to small benthic organisms since the diamond mesh openings are clogged by veined rapa whelks during the tow (Sağlam *et al.*, 2008; Eryaşar *et al.*, 2016). For this fishery, only the veined rapa whelk is the target species, while fish and crabs are thrown back into the sea either dead or alive, and smaller bivalves and crabs end up landed with the whelks without any elimination (Eryaşar *et al.*, 2016).

Beam trawling practices result in one of the highest discard rates in the Mediterranean (Tudela, 2004; FAO, 2016). Pranovi *et al.*, (2001) reported that beam trawls for flatfish and scallops in the Adriatic Sea result in higher discards than their landing quantities (FAO, 2016). Zengin and Akyol (2009) reported discard rates of 42% by beam trawling practices in the Marmara Sea for coastal shrimps. Discard rate for the veined rapa whelk beam trawl fisheries have been reported as 7.5% for the Bulgarian coast in the western Black Sea (Kelleher, 2005; FAO, 2016), while Konsulova *et al.,* (2001) reported the negative effects of beam trawling on mussels and other seabed communities that are particularly vulnerable to this type of fishing gear. Eryaşar *et al.* (2016) estimated bycatch value as 11.4% for veined rapa whelk beam trawl fisheries in terms of the number of individuals caught in the south-eastern Black Sea. Bivalve species were reported to be the most frequent bycatch. Besides these, a multitude of non-target crab and flatfish species are caught in these fisheries. Eryaşar *et al.* (2016) also reported that the vast majority of bycatch bivalves that were mostly below first maturity and/or minimum landing sizes were packed with the whelks without elimination due to time limitations.

In the Portuguese commercial mussel fishery, some selectivity experiments were aimed at preventing the harvest of undersized individuals to allow them to reach at least sexual maturity before capture (Gaspar *et al.*, 1999; Gaspar and Chicharo, 2007). Underwater observations show that the diamond mesh design of the net has poor selectivity due to clogging of mesh openings with increasing catch amounts (Gaspar and Chicharo, 2007). This situation leads to the capture of non-target individuals, as well as a great fraction of juvenile commercial bivalves that are unable to escape from the bag (Gaspar and Chicharo, 2007). To circumvent this, rigid structures such as metallic grid cages, instead of net bag had been tested to evaluate their impact on the benthic community (Gaspar *et al.*, 2001). The results showed that capture of juvenile commercial bivalve species was significantly reduced by up to 95% using metallic grid dredges, and mostly legal sized *Callistia chione* individuals were caught (Gaspar *et al.*, 2001). For bottom trawls, metallic grids are effective tools to increase selectivity and have been used widely to reduce the catch rate of bycatch species and juvenile fishes (Eryaşar *et al.* 2014).

To the best of our knowledge, no studies have been conducted on the effect of rigid grids on bycatch species for the veined rapa whelk beam trawl fisheries. This study aimed at evaluating the effect of novel grid-net designs on the bycatch reduction in beam trawl fisheries. In this context, two different grid-net designs with varying bar spacings were compared simultaneously with a commercial beam trawl with conventional diamond mesh codend, aiming to reduce bycatch and attenuate the effect of beam trawl fisheries on benthic species.

Materials and Methods

The sea trials were conducted on commercial fishing grounds off Rize in the eastern Black Sea (Fig. 1) between 17 and 26 August 2017. The catch compositions of conventional codend and GNDs were compared by evaluating the hauls for two beam trawls towed simultaneously by the commercial vessel "Piryoz 53". Thirty hauls (15 hauls for each bar spacing) were carried out at depths ranging from 9.5 m and 20.7 m with hauls lasting 20–22 min. Towing speed ranged between 1.5 and 2.0 knots. Following a tow, location of beam trawls on the vessel was changed.

The frames of the beam trawls were made of 50 mm diameter iron pipes with dimensions 40 cm deep and 2.40 m long. The gear weighed around 90 kg excluding the weight of the mesh. Steel wires of 5 mm in width present on the frames of the beam trawls provided ground contact to reveal the whelks and to facilitate dragging of the net (Kaykaç *et al.*, 2014). Both ends of the steel wires were

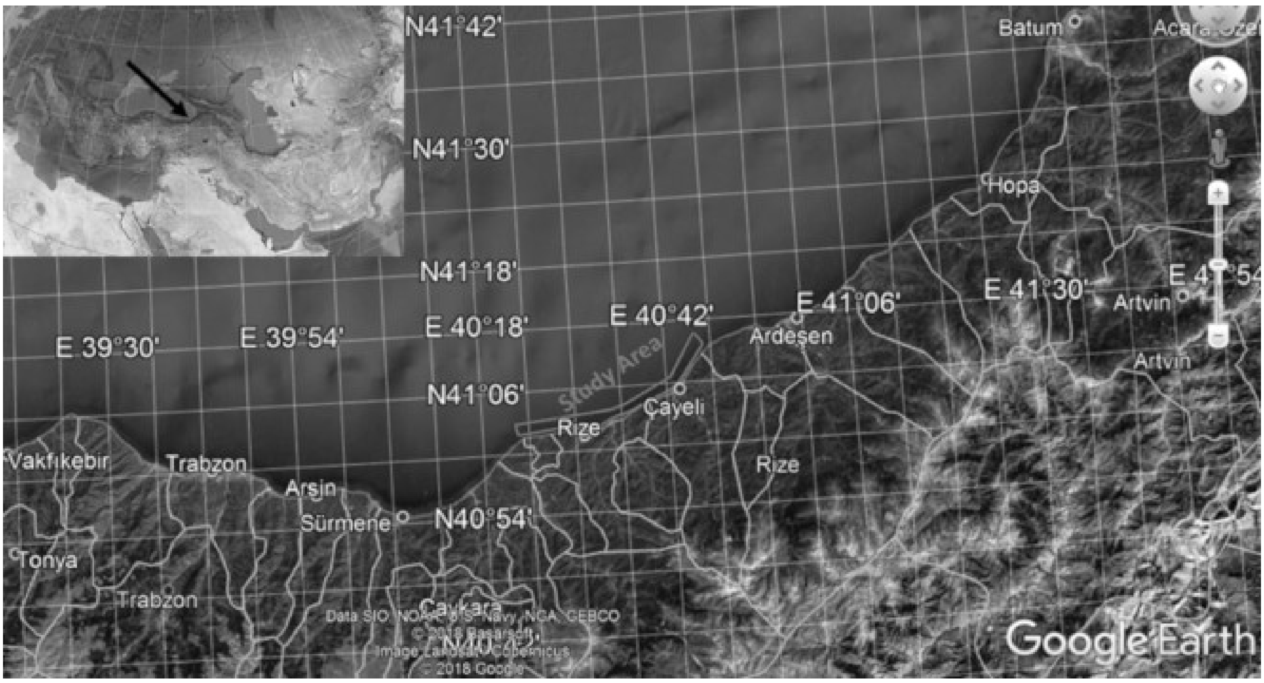

Fig. 1: Study area.

mounted tightly to the feet of the frame (5 cm in depth and 5 mm thickness, Fig. 2). Chains, weighing approximately 5 kg were used to keep the codend grounded (Fig. 2). Additionally, two legs (locally known as knives) 17 cm in length and 1 cm in thickness (Fig. 2) were used to reinforce the steel wire from the top to increase the contact with the ground.

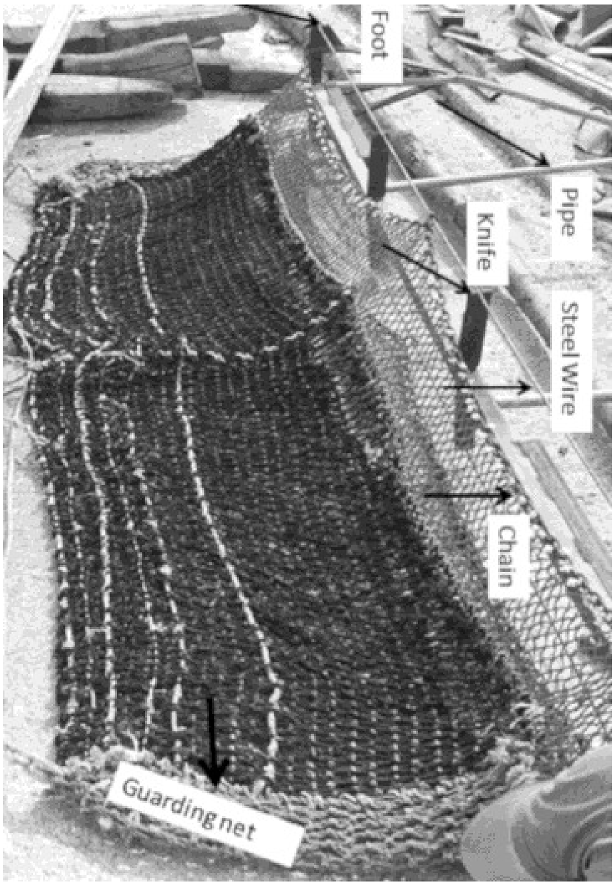

Fig. 2: Commercial beam trawl.

The commercial codend used in this study for comparisons with new GNDs was one meter long and had 72 mm diamond meshes as defined by Turkish Fisheries Regulations (Anonymous, 2016). The commercial codend was constructed of 2 mm-thick double PE twine with a guarding net used to strengthen the mesh made of 5 mm-thick twine.

In the GND, a rectangular metallic grid positioned 6 cm off the bottom replaced half of the codend (Fig. 3); the spacing allowed the release of bycatch species. Two different bar spacings (20 mm and 30 mm) were tested. The grid dimensions were 2.4 m length, 50 cm width, and 40 cm height and the grid bars were 5 mm thickness. The modified gears weighed 90 kg for the 30 mm bar space and 110 kg for the 20 mm bar space. An underwater video camera (GoPro Hero 4) was installed on the beam trawl's frame for each haul during the study to record the operation.

The catch was screened for waste, stones, and wood on the deck, and non-target jellyfish, crab and fish species were separated. The remainder of the catch was weighed by means of buckets. Sub-samples were taken for the veined rapa whelk, bivalves, and other species based on catch volume and the number of each species was calculated by raising with the sub-sample ratio (between 1:1 and 1:64). The samples from both beam trawls were put into separate bags for each haul and transported to the laboratory for counting and weighing based on species. Lengths were measured for fish species, gastropods, bivalves, and crabs using electronic caliper. Spinal canal to apex was considered for the veined rapa whelk, the maximum anterior-posterior distance was considered for bivalves and carapace length of crabs was considered in length measurements. Hermit crabs, due to their unsuitable morphology, were excluded from length measurements although they were caught in abundance.

Fig. 3: Grid-net design.

Paired t-test was used to determine the statistical significance of the percentage catch reductions in grid-net designs (GNDs) compared to commercial codend (CC) for each haul and captured species.

Proportions (P) of the veined rapa whelk and two major bycatch species (*Anadara kagoshimensis* and *Chamelea gallina*) caught at lengths by GNDs were calculated as P = GND count at length/(GND plus CC total count at length). A value of P = 0.5 indicated that there were no differences in the catch for numbers between CC and

GND at length. The proportions (P) were analyzed using Generalized Linear Mixed Models (GLMM) (Holst & Revill, 2009) to determine if the length was a factor contributing to the numbers of retained target and bycatch species from GND (He and Balzano, 2011). The results were fit using the glmmPQL function using a penalized quasi-likelihood approach in the 'R' software's MASS package, into four GLMM models: constant, linear, second order, and third order. Analyses then proceeded by fitting the third order polynomials with subsequent reductions to reach statistical significance ($P<0.05$) for all terms based on the Wald's test (Holst and Revill, 2009; Eryaşar *et al.*, 2015).

A short-term commercial loss for the GNDs as compared to CC was estimated. The income was calculated by multiplying the weight of the whelk catch with its price per kilogram at landing. The weights for the catch in each commercial size group were defined according to the length-weight relationship of this species determined by Sağlam *et al.* (2008). The unit prices of the whelks obtained from invoices of beam trawlers operating in the study area displayed a classification based on size (small: 45–52 mm, medium: 53–62 mm and big: 63–76 mm) that were accounted for in loss calculations in each GND.

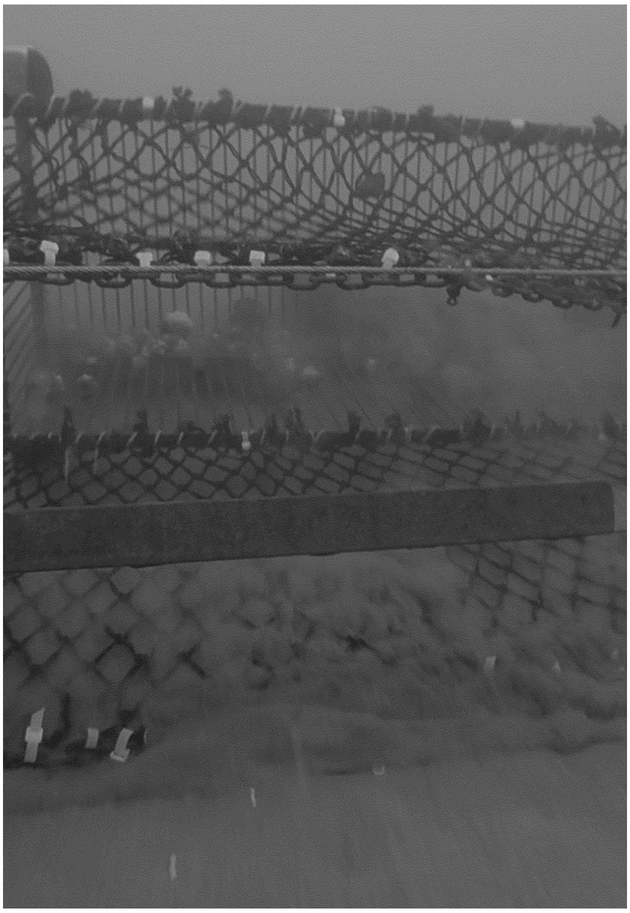

Fig. 4: Underwater observation of the grid-net design.

Results

Underwater observations did not reveal any problems with the operation of the GNDs and they were easily handled by the crew with existing deck machinery (Fig. 4). A 78% reduction in mean weight of the bycatch in 20 mm GND and an 83% reduction in 30 mm GND were found to be statistically significant when compared to CC ($t=3.23$, $df=14$, $p<0.05$ for 20 mm; $t=4.02$, $df=14$, $p<0.05$ for 30 mm). As shown in Table 1, the mean empty shell amount was reduced by 97% in the 20 mm and by 92% in the 30 mm GND with statistical significance ($t=3.23$, $df=14$, $p<0.05$ for 20 mm; $t=4.02$, $df=14$, $p<0.05$ for 30 mm) as compared to CC.

Commercial and experimental gears captured 25 species in total. Osteichthyes was the most frequent taxon (9 species), followed by Malacostraca (6 species) and Bivalvia (4 species) (Table 2).

Table 2 also elaborates the percentage reduction in experimental gears for each species and results of the paired t-test. Eighteen bycatch species showed a reduced catch of 20 mm GND as compared to CC, of which seven were significant ($p<0.05$). The species with the highest reductions (with sufficient numbers in the catch) were *Tritia reticulata* (100%), *Tritia neritea* (100%), *Liocarcinus depurator* (97%) and *Diogenes pugilator* (94%). The least reduction was for *Rapana venosa* (40%).

All bycatch species showed reduced catches for the 30 mm GND with the highest reductions being recorded for *Donax trunculus* (100%), *Tritia reticulata* (100%), *Liocarcinus depurator* (98%), and *Diogenes pugilator* (93%). Statistically significant reductions in catch for

Table 1. Average catch weights of bycatch and empty shell for commercial and experimental gears.

	The mean bycatch amount (g)		The mean empty shell amount (g)	
	Commercial Gear	**Experimental Gear**	**Commercial Gear**	**Experimental Gear**
20 mm GND	1982.73 (s.e.144.49)	432.23 (s.e. 29.68)	1009.20 (s.e. 82.30)	34.72 (s.e. 5.27)
30 mm GND	1339.60 (s.e. 75.82)	234.00 (s.e. 31.08)	1343.27 (s.e. 132.28)	112.67 (s.e. 13.57)

s.e. – standard error

Table 2. Total numbers of benthic species in the catch for all hauls, the percentage reduction in experimental gears and a *p*-value of the paired t-test (GND: grid-net design).

		20 mm GND				30 mm GND			
		Total no. of commercial gear	Total no. of experimen-tal gear	Reduction (%)	*p*-Value	Total no. of commercial gear	Total no. of experimental gear	Reduction (%)	*p*-Value
Gastropoda	*Rapana venosa*	41047	24583	40	**<0.05**	40684	10985	73	**<0.05**
	Tritia neritea	289	0	100	**<0.05**	30	0	100	
	Tritia reticulata	91	0	100	**<0.05**	160	0	100	**<0.05**
Bivalvia	*Anadara kagoshimensis*	6267	2300	63	**<0.05**	4193	658	84	**<0.05**
	Chamelea gallina	3112	515	83	**<0.05**	3318	392	88	**<0.05**
	Donax trunculus	337	81	76	>0.05	295	0	100	**<0.05**
	Pitar rudis	30	0	100		33	0	100	
Malacostraca	*Diogenes pugilator*	16976	1058	94	**<0.05**	18498	1235	93	**<0.05**
	Liocarcinus depurator	64	2	97	**<0.05**	61	1	98	**<0.05**
	Liocarcinus navigator	2	1	50		22	0	100	
	Eriphia verrucosa	3	8	-		5	1	80	
	Pachygrapsus marmoratus	0	2	-		-	-	-	
	Xantho poressa	0	1	-		22	0	100	
Osteichthyes	*Arnoglossus kessleri*	6	1	83		11	0	100	
	Uranoscopus scaber	5	3	40		11	2	82	
	Solea sp.	2	0	100		2	0	100	
	Scorpaena porcus	2	0	100		2	1	50	
	Trachinus draco	2	0	100		-	-	-	
	Gobius sp.	1	0	100		-	-	-	
	Callionymus lyra	1	0	100		-	-	-	
	Hippocampus sp.	-	-	-		2	0	100	
	Gaidropsarus mediterraneus	-	-	-		1	0	100	
Ascidiacea	Tunicata	876	422	52	>0.05	759	193	75	**<0.05**
Scyphozoa	Scyphozoa	1	1	0		1	0	100	
Polychaeta	*Nereis* sp.	-	-	-		4	0	100	

eight bycatch species were also determined (Table 2).

Adequately captured veined rapa whelk (*Rapana venosa*), blood cockle (*Anadara kagoshimensis*), and striped venus clam (*Chamelea gallina*) for both GND and CC were subjected to GLMM analysis. The veined rapa whelk showed a significant reduction in catch for each GND (40% for 20 mm, t=2.95, df=14, p<0.05; and 73% for 30 mm, t=7.47, df=14, p<0.05) . Each GND reduced capture of individuals under the first maturity size (FMS) of 40 mm (Sağlam *et al.*, 2009) compared to CC as seen by the length-frequency distributions for each GND (Fig. 5A and 5B). The results of optimal logit-linear model polynomial curves obtained by GLMM for each GND showed that significantly fewer individuals of length <53 mm for 20 mm, and <58 mm for 30 mm bar spacings were caught (Fig. 5C and Fig 5D). A total of 542 kg obtained from the commercial gear was valued as 519 TL (Turkish Lira) for this species as compared to a 14% drop when using the 20 mm GND (for 452 kg, valued at 444 TL). The 30 mm GND recorded a 39% loss with a total catch of 258 kg, valued at 257 TL (Table 3).

The bycatch amount of blood cockle was significantly lesser in the GNDs as compared to CC (t=2.72, df=14, p<0.05 for 20 mm GND; t=3.14, df=14, p<0.05 for 30 mm GND). As seen in the length-frequency distributions in Fig. 6A and Fig. 6B, the GNDs caught fewer

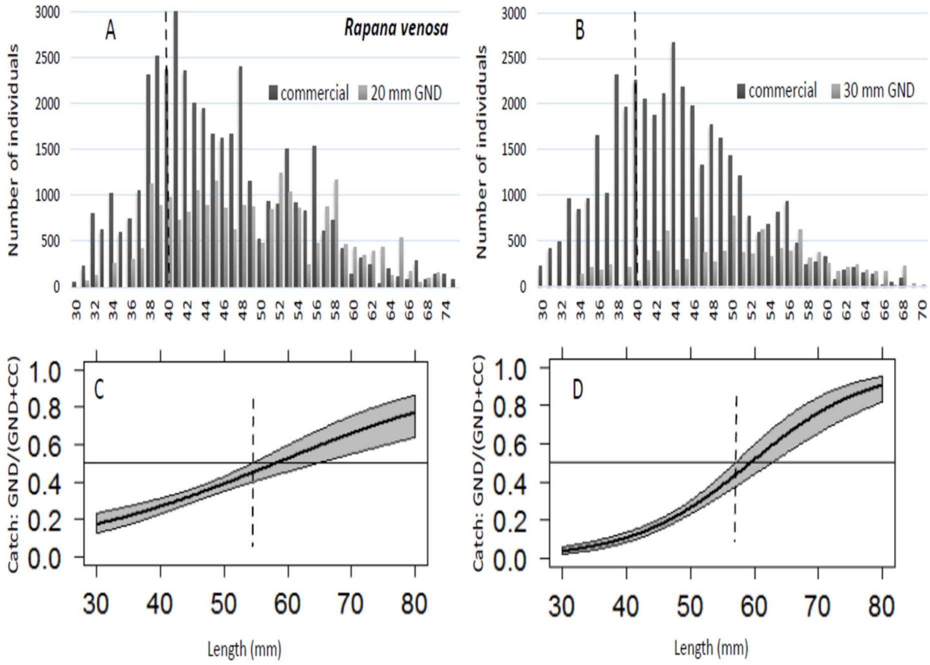

Fig. 5: Length-frequency distributions of the veined rapa whelk (*Rapana venosa*) for 20 mm GND (A) and 30 mm GND (B) with first maturity size (FMS (vertical line). GLMM modeling of the size of the veined rapa whelk for 20 mm GND (C) and 30 mm GND (D), showing differences in the catch at length. Catch ratio of 0.5 (horizontal line) indicates commercial and experimental gears catch at equal numbers. The solid line indicate the mean, the grey band is the 95% confidence level. The vertical line shows the length below which the reduction of the catch is significant.

Table 3. The income by commercial (CC) and experimental (EP) gears [according to Turkish Lira (TL)] and economic loss in a changeover to 20 and 30 mm grid-net design (GND).

		20 mm GND				**30 mm GND**			
Size Groups	Unit Price (TL)	CC Weight (KG)	Income (TL)	EP Weight (KG)	Income (TL)	CC Weight (KG)	Income (TL)	EP Weight (KG)	Income (TL)
Small	0.85	236	201	147	125	268	228	80	68
Middle	1	241	241	236	236	153	153	126	126
Big	1.2	65	77	69	83	32	38	52	63
	Total Value		**519**		**444**		**419**		**257**
	Loss (%)				**14**				**39**

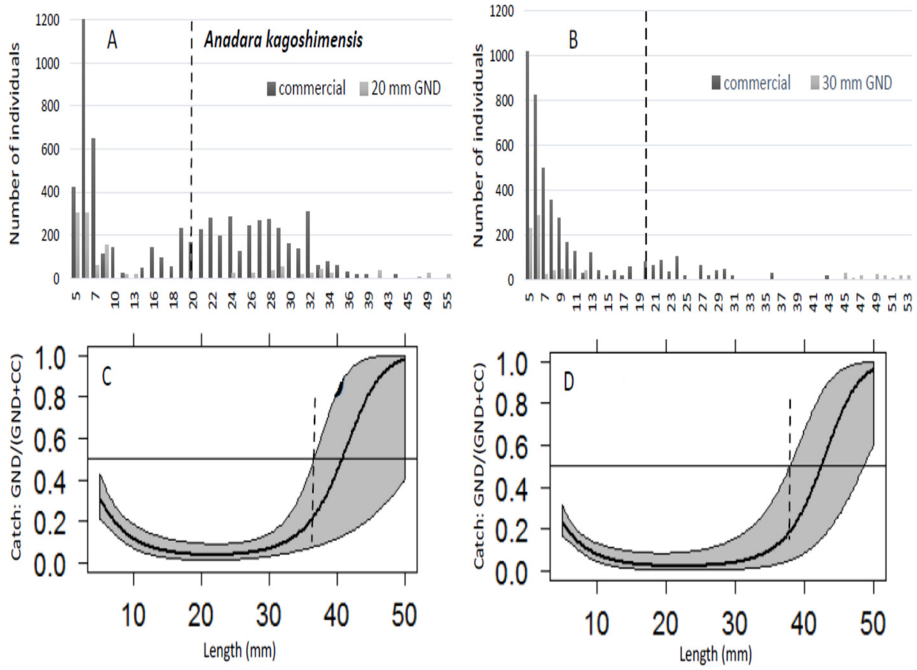

Fig. 6: Length-frequency distributions of the blood cockle (*Anadara kagoshimensis*) for 20 mm GND (A) and 30 mm GND (B) with first maturity size (FMS (vertical line)). GLMM modeling of the size of the blood cockle for 20 mm GND (C) and 30 mm GND (D) showing differences in the catch at length. Catch ratio of 0.5 (horizontal line) indicates commercial and experimental gears catch equal numbers. The solid line gives the mean; the grey band gives the 95% confidence level. The vertical line shows the length below which the reduction of the catch is significant.

Table 4. Coefficient values and significance (p) for veined rapa whelk (*Rapana venosa*), blood cockle (*Anadara kagoshimensis*), and striped venus clam (*Chamelea gallina)* from Generalized Linear Mixed Modeling (GLMM).

			Coefficient	Value	SE	d.o.f.	*t*-Value	*p*-Value
30 mm GND	Rapa whelk	Linear	β 0	–6.44	0.59	39	–10.98	**<0.05**
			β 1	0.11	0.012	39	9.16	**<0.05**
20 mm GND	Rapa whelk	Linear	β 0	–3.20	0.47	40	–6.76	**<0.05**
			β 1	0.06	0.01	40	5.62	**<0.05**
30 mm GND	Blood cockle	Quadratic	β 0	0.49	0.61	33	0.81	**<0.05**
			β 1	–0.38	0.10	33	–3.66	**<0.05**
			β 2	0.01	0.00	33	3.93	**<0.05**
			β 0	0.85	0.63	36	1.36	**<0.05**
20 mm GND	Blood cockle	Quadratic	β 1	–0.37	0.10	36	–3.68	**<0.05**
			β 2	0.00	0.00	36	3.32	**<0.05**
30 mm GND	Striped venus clam	Constant	β 0	–2.19	0.30	5	–7.32	**<0.05**
20 mm GND	Striped venus clam	Constant	β 0	–1.80	0.43	4	–4.15	**<0.05**

SE–standard error; d.o.f.–degree of freedom.

individuals under first maturity length of 20 mm (Şahin *et al.*, 2006). The GLMM analysis best fit the data with the logit-quadratic model (Table 4) showing that significantly fewer blood cockle individuals were caught at lengths <36 mm for 20 mm GND, and <38 mm for 30 mm GND (Fig. 6C and Fig. 6D).

The catch amount of the second most frequent bycatch, the striped venus clam was significantly reduced by 83% in the 20 mm GND and by 88% in the 30 mm GND ($t=2.60$, $df=14$, $p<0.05$ for 20 mm GND; $t=3.72$, $df=14$, $p<0.05$ for 30 mm GND). All striped venus clam individuals caught by CC and GND gears were below the minimum landing size (MLS) of 17 mm (Anonymous, 2016) (Fig. 7A and Fig. 7B). GLMM analysis revealed that although there was a reduction for all length groups, the reduction in each GND was not significantly length-related ($p>0.05$; Table 4).

Discussion

This study showed the use of grid-net design as an alternative to commercial beam trawl to considerably reduce the bycatch of most benthic species with some loss of the veined rapa whelk. This is primarily attributed to the geometry of the gears during the hauling process. Traditional diamond mesh codends tend to close with increasing catch amounts during the tow (Robertson and Stewart, 1988), preventing escape and resulting in a high proportion of unwanted or non-target catch. Metal bars used in the GND remain open and allow high amount of escape during a tow. Additionally, underwater recordings show that small and large individuals are eliminated via the net ramp and parallel bars throughout the tow as the grid is raised up from the bottom. This finding fits with Gaspar's observations (2001) that capture of non-target individuals was significantly reduced by using a rectangular metallic grid system as compared to a net bag collection system in Portuguese dredge fishery. Although the survival of escaped individuals was not determined during this study, Gaspar showed, for the dredge fishery of *Callista chione*, that undamaged escaped bivalves could successfully resume their activity.

Our results showed a commercial loss to fishermen due to the escape of some rapa whelk individuals over the length of 45 mm that have a commercial value. It was estimated to be 25% higher for the 30 mm GND compared to the 20 mm GND. Since the length limit for processing factories which ultimately buy the catch from the fishermen for export to Asian countries may vary with seasonality or different fishing grounds, this loss is expected to fluctuate up or down based on time and region.

The GNDs for each bar spacing significantly reduced bycatch amounts of blood cockle and capture of juvenile individuals. However, smaller 5–6 cm bivalves were caught in greater numbers, being lifted up by the steel wire and drifting toward the aft of the grid. The smaller bivalves may have been stuck on the veined rapa whelk individuals that accumulated and covered the aft bar spacing in the grid. Additionally, prevalent recruitment season beginning in August may also increase the capture of

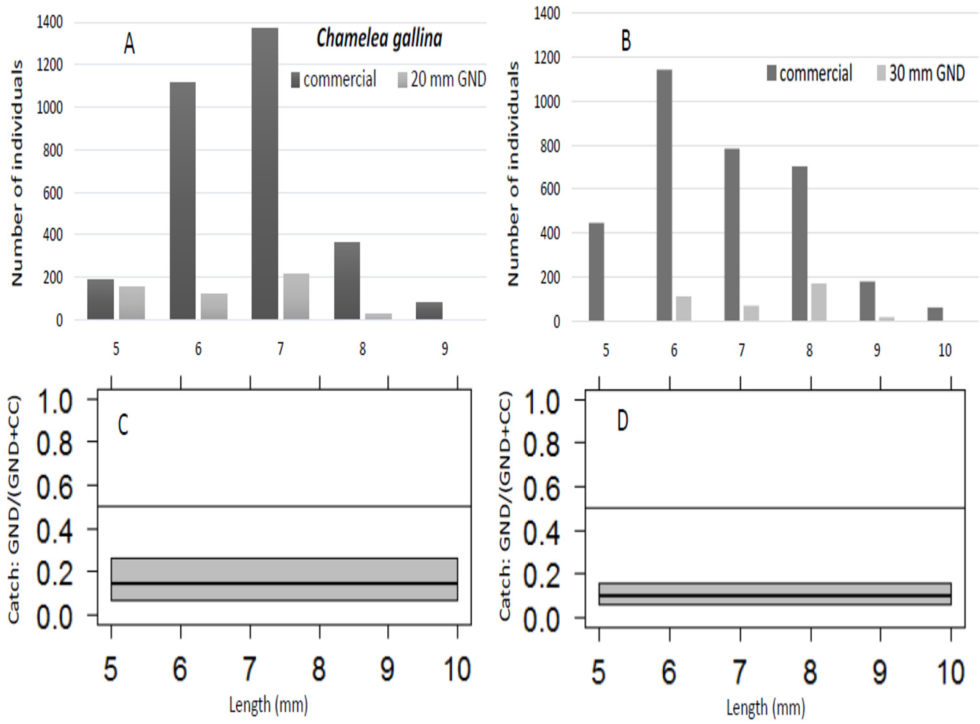

Fig. 7: Length-frequency distributions of the striped venus clam (*Chamelea gallina*) for 20 mm GND (A) and 30 mm GND (B). GLMM modeling of the size of the striped venus clam for 20 mm GND (C) and 30 mm GND (D), showing differences in the catch at length. Catch ratio of 0.5 (horizontal line) indicates commercial and experimental gears catch equal numbers. The solid line gives the mean; the grey band is the 95% confidence level

smaller individuals of blood cockle by both gears (Şahin *et al.*, 2006). Similarly, for the striped venus clam, despite a significant decrease in the number of individuals caught as bycatch, the size of captured ones was generally below MLS. This may be due to the distribution of smaller individuals closer to the bottom surface as compared to larger individuals (Gaspar *et al.*, 2007).

The GNDs for both bar spacings tested were found to be successful in significantly reducing the bycatch amount of small species like the shore crab (*Liocarcinus depurator*) and the hermit crab (*Diogenes pugilator*). The GNDs tested allowed almost all shore crab individuals to escape. The shore crab is one of the most frequent bycatch species in commercial beam trawls in the region (Eryaşar *et al.*, 2016) and given its role as a food source for a number of organisms (Aydın *et al.*, 2013). The ecosystem in the region would be benefited from excluding them from beam trawl catches (Eryaşar, 2017). Each GND could make a significant contribution toward achieving this goal.

GNDs have been found to successfully release both round and flat-bodied fish species. Almost all flatfish species (*Arnoglossus kessleri* and *Solea* sp.) could escape from the GNDs for each bar spacing shortly after entering the beam trawl. The Atlantic stargazer (*Uranoscopus scaber*) was the most abundantly captured fusiform fish species, only the 30 mm bar spacing GND was large enough to release the individuals. Atlantic stargazer is assessed as vulnerable by Yankova *et al*. (2014) for Black Sea and the effective implementations are needed to conserve such species. The implementation of 30 mm GND for use in beam trawls could potentially benefit the population of this species if escaped individuals survive. An assessment of survival of Osteichthyes species after escape from the GND was not conducted during the study; however, one-year-old cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*), showed no mortality when excluded from a metal grid placed in front of the codend (Isaksen and Soldal, 1997).

In conclusion, 20 mm and 30 mm GNDs were successful in reducing bycatch amounts of many benthic species in the region along with a decrease in the whelk amounts being caught. The potential short-term losses that accompany these new designs might cause an opposition to the implementation of the GNDs in the fleet unless management can provide compensation to the fishermen. An extension of the rapa whelk fishing season may be a possible solution for this compensation. The effect of the beam trawls on escaping individuals would need to be further investigated to understand the efficacy of this bycatch reduction device in reducing fishing mortality.

Acknowledgements

I would like to thank the captains and crews of the Piryoz 53 and Dr. Göktuğ Dalgıç for his help in the sea trials. The author would like to thank Dr. Hüseyin Özbilgin for his valuable comments. This study was financed by Recep Tayyip Erdogan University Research Project Fund (Project No: FBA–2017–781).

References

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).

Aydın, M., Karadurmuş, U. ve Mutlu, C., 2013. Preliminary study on Length-weight relationship and condition factor of *Liocarcinus depurator* (Linnaeus, 1758) (Brachyura: Portunidae) craps species existing in the Ordu prefecture. The Black Sea Journal of Sciences, 3 (8), 112-121.

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., 2014. 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. 2015. Implications for catch composition and revenue in changing from diamond to square mesh codends in the northeastern Mediterranean. *Journal of Applied Ichthyology*, 31 (2), 282-289.

Eryaşar, A.R., Dalgıç, G., Ceylan, Y., 2016. Determination of by-catch composition of commercial beam trawl fishery for the veined rapa whelk in the eastern Black Sea. Recep Tayyip Erdoğan University, Research Project Fund, Rize, Turkey, 33 pp. (In Turkish).

Eryaşar, A.R., 2017. A Study of the Behavior of Harbour Crab (Liocarcinus depurator) in Beam Trawl Used in the Rapa Whelk Fishery in Black Sea. *Yunus Research Bulletin*, 2017 (4), 349-360.

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

Gaspar, M. B., Castro, M., Monteiro, C. C, 1999. Effect of tooth spacing and mesh size on the catch of the Portuguese clam and razor clam dredge. *ICES Journal of Marine Science*, 56, 103-110.

Gaspar, M. B., Dias, M. D., Campos, A., Monteiro, C. C., Santos, M. N., Chicharo, A., Chicharo, L., 2001. The influence of dredge design on the catch of *Callista chione* (L. 1758), Hydrobiologia, 465, 153-167.

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.

Gedik, K., 2017. Bioaccessibility of heavy metals in rapa whelk Rapana venosa (Valenciennes, 1846): Assessing human health risk using an in vitro digestion model, Human and Ecological Risk Assessment: An International Journal, doi: 10.1080/10807039.2017.1373329.

He, P., Balzano, V., 2011. Rope Grid: A new grid design to further reduce finfish bycatch in the Gulf of Maine pink shrimp fishery, *Fisheries Research*, 111: 100–107.

Holst, R., Revill, A., 2009. A simple statistical method for catch comparison studies, *Fisheries Research*, 95, 254-259.

ICES. 2004. Alien Species Alert: *Rapana venosa* (veined whelk). ICES Cooperative Research Report No. 264. 14 pp.

Isaksen, B. and Soldal, A.V., 1997. Selection and survival in the norwegian shrimp trawl fisheries. Proceedings of tlie 7& Russian/Norwegian Symposium: Gear Selection and Sampling Gears. pp. 133-143.

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.

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.

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.

Robertson, J.H.B., Stewart, P.A.M., 1988. A comparison of size selection of had-dock and whiting by square and diamond mesh codends. *ICES Journal of Marine Science*, 44, 148-161.

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).

Sağlam, H., Düzgüneş, E., Öğüt, H., 2009. Reproductive ecology of the invasive whelk Rapana venosa Valenciennes, 1846, in the southeastern Black Sea (Gastropoda: Muricidae). ICES Journal of Marine Science, 66: 1865–1867.

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.

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.

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, 2016. 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.

Yankova, M., Pavlov, D., Ivanova, P., Karpova, E., Boltachev, A., Öztürk, B., Bat, L., Oral, M., Mgeladze, M. (2014). Marine fishes in the Black Sea: recent conservation status. *Mediterranean Marine Science*,15 (2), 366-379.

Zengin, M., Akyol, O., 2009. Description of by-catch species from the coastal shrimp beam trawl fishery in Turkey. *Journal of Applied Ichthyology*, 25 (2), 211-214.

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.