

Effect of Fishery Closure on Discard Composition of Rapa Whelk, *Rapana venosa* (Valenciennes 1846) Beam Trawl Fisheries in Black Sea

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How to cite

Erik, G., Dağtekin, M. (2022). Effect of Fishery Closure on Discard Composition of Rapa Whelk Beam Trawl Fisheries in Black Sea. *Turkish Journal of Fisheries and Aquatic Sciences*, 22(5), TRJFAS19046. <http://doi.org/10.4194/TRJFAS19046>

Article History

Received 25 January 2021
Accepted 19 December 2021
First Online 21 December 2021

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Keywords

Rapana venosa
Discard
Fishing closure
Fisheries management
Black Sea

Abstract

Rapa whelk has become significant commercially, as there is a market that makes it export-oriented species. It has also gained special importance because of catching this species in all riparian countries in the Black Sea basin. The various exploitation methods of this species include beam trawl and diving. Here, the experimental beam trawl survey for Rapa whelk fishing was designed monthly in one year. Catch composition was examined spatially and temporally. Differences in estimated biomass of Rapa whelk and abundance of discard species were used to evaluate the effectiveness of seasonal fishing closure. Our results indicated that, discard composition of Rapa whelk fishery strongly reflected seasonal changes. Total estimated abundance and biomass values showed significant regional, seasonal and depth-related differences, also number of species and diversity index changes regionally and seasonally. Discard ratio was found very low in biomass. At the same time, seasonal fishery closure period was benefited for discard species in spring and summer period. The lowest distribution of Rapa whelk and discard species except blood cockle were found in winter season during fishing period. It becomes apparent that seasonal fishery closure is an important management measure both for stock sustainability, species diversity, and ecosystem health. Therefore, all Black Sea countries should consider similar management

Introduction

Discard is defined as the portion of marine animals and plants caught in fishing and thrown back into the sea (Sarda et al., 2013). Fishing discard has been recognized as a serious problem for the last two decades. According to Pérez et al. (2019) annual discards from worldwide marine capture fisheries were 9.1 million tonnes between 2010 and 2014, accounting for 10.8 % of the annual average catch from 2010 to 2014. Due to the growing understanding of its adverse effects on marine ecosystems, accidental catch and discarding have received considerable attention in recent world fisheries research. Today, good fisheries management is defined as serious consideration on ecosystem health and providing the necessary regulations to reduce waste.

The throwing problem poses several related sub-problems for social, economic and environmental goals. While usage of trawling and dredging is very common in fishery, they are accounted for about half of the total fish discards worldwide. Especially, bottom trawling causes serious chronic and widespread problems in the benthic zone due to the removal of the growing epifauna, damage and displacement of the habitat and benthic life (Connolly & Kelly, 1996).

The Rapa whelk species, *Rapana venosa* Valenciennes 1846, is an invasive alien species in the Black Sea ecosystem which was introduced in 1940s from its origin Asian Pacific waters (ICES, 2004). It is thought thanks to ship ballast water and aquaculture transfer native East Asian seas towards Europe and America (Savini et al., 2007). It was successful in its new

environment and became widespread as a notorious predator which feeds on oysters, mussels and other bivalves, and thus exerts a major influence on local populations. During 1980s, in response to an international demand for Rapa whelk, a massive fishery emerged in Turkish waters, and along the Bulgarian coast which helped reduce its predation impact on prey species (Bilecik, 1990). In the Black Sea, Turkey harvests the half of its total catch, and majority of the rest is contributed by Bulgaria and Romania (STECF, 2017). While its catch notably increased in 1990s, number of fishing vessels engaged with its fishery also quickly increased (Erik et al., 2020).

During beam trawl operation, turbot, scorpion fish, horse mackerel, goby fish, sole, ray, sea horse, juvenile gurnard, crabs, mussels, prawns, shrimp and native small whelk were caught as discards (Celik & Samsun, 1996; Düzgüneş, 2001). Estimated discard ratios by abundance in the Black Sea range from 7.5 in Bulgaria (Kelleher, 2005) to 11.4% in Turkey (Eryasar et al., 2018). Recent studies pointed out diminishing of turbot population are closely related with increase in beam trawling (Petrova-Pavlova et al., 2020). General Fisheries Commission of Mediterranean (GFCM) severally emphasizes the importance of discard studies for commercial stocks in the Black Sea (GFCM, 2019).

Rapa whelk fishing in the Turkish Black Sea EEZ is constituted 45% from western part and 55% percent from the eastern. Fishing methods include beam trawl, diving, and rarely pots and traps, however, main fishing is via beam trawling (85%). In 2018, 725 fishing vessels were registered with daily operation of 9 hours during daylight, and approximately 125 active days in one fishing season (BSGM, 2018, Dağtekin et al., 2018). Although the Rapa whelk fishery is important due to its increasing revenue for Black Sea countries, Turkey is the only one applying several management measures both spatially and temporally for its catch. According to

Turkish fishery circular, its fishery is only permitted to operate at a minimum distance of 500 m from shore with 4 m maximum dredge length and 72 mm minimum mesh size. The beam trawls are prohibited to target Rapa whelk between 15 April -1 September annually to protect this species' spawning season (BSGM, 2020). Other methods like hookah diving or pots are used in summer months as this species is known to be aggregated in the shores with great numbers (Saglam et al., 2017).

Here, the experimental beam trawl survey for Rapa whelk fishing were designed monthly in one year period. Catch composition were examined spatially and temporally. Differences in estimated biomass of Rapa whelk, and abundance of discard species were used to evaluate the effectiveness of seasonal fishing closure.

Materials and Methods

Study was performed by participation as an observer in a commercial fishing vessel called "Özşahin" with length of overall (LoA) 8 m with 83 HP. A typical beam trawl with 72 mm mesh size, 40 cm mouth in depth, and overall size 300 cm in height were used for sampling (Figure 1). Rapa whelk fishery is almost closed from December to March due to very low catch and very low meat ratio while meat ratio is very high in summer. Still, market demand and some optimal conditions for its occurrence may change these periods. In this study, fishing vessel was officially permitted for research during seasonal closure period in 2018. All specimens obtained during each fishing haul were sorted, identified, counted and weighted. At least 100 Rapa whelk individual were chosen as subsample from each haul to perform length measurements. If the number is low, all specimens were measured. Length measured to the nearest 0.1 cm.



Figure 1. Beam trawl with Rapa Whelk caught in one haul.

Statistical Analysis

Statistical analysis were performed for Rapa whelk estimated biomass (kg.km⁻²), discard estimated biomass, and abundance (ind.km⁻²) according to sampling season, depth and location.

Non-parametric multivariate techniques were used to determine the spatial and temporal patterns of discard species distribution and abundance. Species abundance data were transformed (logx+1) to construct a similarity matrix using the Bray-Curtis coefficient of similarity. First analysis of similarity (ANOSIM) were applied to five established factors "Region", "Season", "Depth", "Distance" from shore, and "Closure" to determine their significance level (Table 1). Significant factors were then analyzed for similarity of percentages (SIMPER) to identify responsible species for dissimilarities between groups. Non-parametric multi-dimensional scaling (n-MDS) were used to understand species distribution patterns by estimating them as vector which corresponds over 0.5 correlations (Clarke and Warwick, 2001). Group linkage for Bray-Curtis similarities were used for cluster analysis.

The collected data allowed estimating discard abundance (N), number of species (S), and the Shannon diversity index (H', bits). Discard species were categorized into five systematic groups according to their classes, i) Bivalvia, ii) Gastropoda, iii) Crustacea, iv) Teleostei, v) Elasmobranchii. In order to determine the level of significance for variables (B, N, S and H') according to established factors Levene's test for ANOVA were used to identify homogeneity of variance. Non-significant variables were then analyzed for non-parametric Kruskal-Wallis test. Tukey HSD test were

used as post-hoc analyze for each factor to understand which groups are significantly different. Univariate and multivariate analyses were applied using PRIMER v7.1.10. ANOVA were analyzed in R (R Core team, 2020).

Results

Evaluation of *R. venosa* Distribution

During sampling period, 71 trawling operation were achieved. *Rapana venosa* were sampled in all operations. Total lengths ranged from 1.0 cm to 10.5 cm, average length was found 4.8 cm (Figure 2). According to literature, size-at-maturity for this species is given 4.4 cm (Sağlam et al., 2009) which shows almost 25% percent of the samples were immature in this study.

Highest estimated biomass was found in Station 2 while the lowest were in Station 4 (Figure 2). Regional distribution of *R. venosa* were significantly different (p<0.05; Table 2) caused by the lowest value in St.4 (Tukey HSD, p<0.05) while no other regional differences were found. There is no seasonality in *R. venosa* biomass among summer, spring and autumn except winter when the lowest biomass were observed and showed significant difference (Tukey HSD, p<0.01; Figure 3, Table 2). Average biomass were higher in fishery closure period than fishing period and significant difference were found between them (Kruskal-Wallis, p<0.001; Table 2, Figure 3). Biomass estimation shows no significant differences on depth strata and distance from shore (p>0.05; Table2). Still, its distribution was higher around 5-20 m depth, and was more stable in amount in the closest area to the shore (0-150 m) than the outermost distance (Figure 3).

Table 1. Identified factors and their explanations used in analysis of discard distribution.

Factor	Codes	Correspond
Region	St1	Station 1 Yoroz
	St2	Station 2 Kerem
	St3	Station 3 Vakfıkebir
	St4	Station 4 Mersin
	St5	Station 5 Çarşıbaşı
	St6	Station 6 Yalıköy
Season	Au	Autumn September-November
	Wi	Winter December-January-February
	Sp	Spring March-April-May
	Su	Summer June-July-August
Depth	5-10 m	
	10-15 m	
	15-20 m	
	20-25 m	
	25-30 m	
Distance	0-100 m	
	100-150 m	
	150-250 m	Distance from shore
	250-400 m	
	400 m>	Shelf structure
Closure	Non-fishing	15 April - 31 August
	Fishing	1 September - 14 April
Seasonal fishing ban in Turkish EEZ in Black Sea		

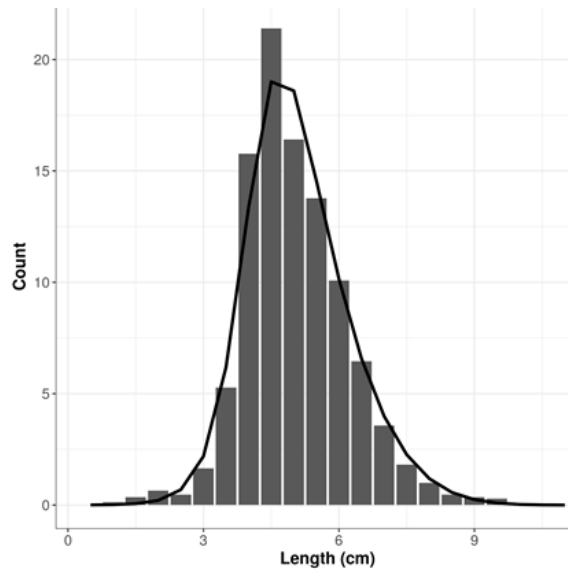


Figure 2. Overall length frequency distribution of *R. venosa* during sampling period.

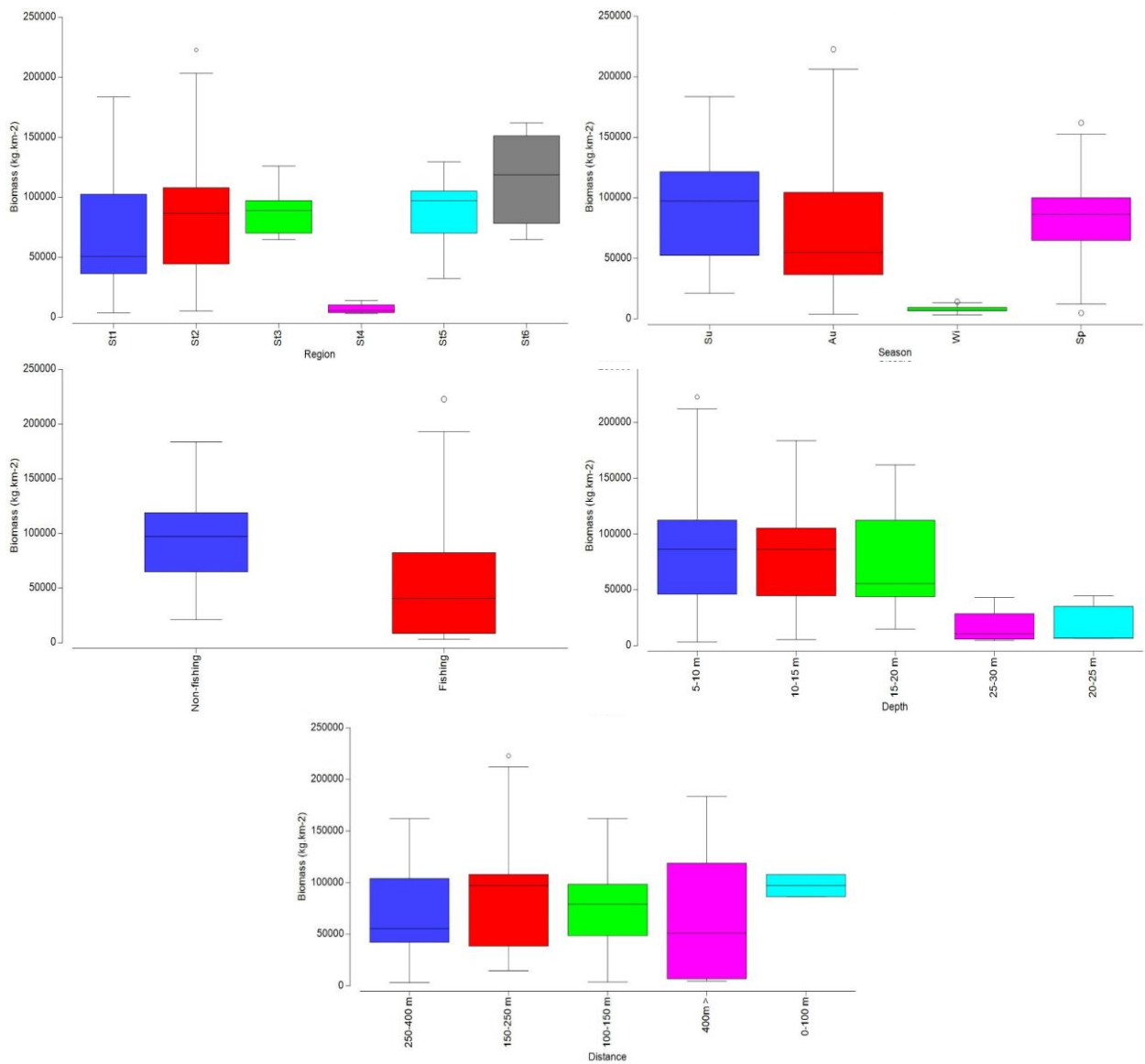


Figure 3. Box plots of estimated abundance of *R. venosa* with 95% CI according to sampling region, season, depth, distance from shore and fishery closure period in the Black Sea.

Discard Composition During *Rapana venosa* Survey

Overall catch composition during one year sampling showed estimated biomass for *R. venosa* constituted 99% of catch and discarded species were 1% (Figure 4). Total *R. venosa* biomass was estimated 674 ton per area while total discard biomass was estimated 7.5 ton per area. Estimated *Rapana venosa* biomass ranged from 4.5 ton.km⁻² with the lowest in December and 125 ton.km⁻² in June, with average of 61 ton.km⁻². On the other hand, estimated discard biomass were found the lowest in June (0.24 ton.km⁻²) and 2.49 ton.km⁻² in May, with average of 0.68 ton.km⁻². Opposite relation were found between Rapa whelk and discard estimations.

For a closer look to the distribution of discard composition, very different distributional pattern than *R. venosa* were noticed in the sampling area and period. Highest estimated discard biomass and abundance were found in St.3, also average values are higher in St.6 while the lowest were in Station 4 (Figure 5). Regional discard distribution were significantly different (p<0.05; Table 2), caused by the highest values in St.5 and St.6 (Tukey HSD, p<0.05). There was a strong seasonality in biomass and abundance of discard showed significant difference in spring by very high values (Tukey HSD, p<0.01; Table 2). Biomass was the lowest during summer while abundance was the lowest during winter (Figure 5).

Discard distribution between seasonal fishery closure and fishing period also show significant difference (p<0.05; Table 2) while very high abundance and biomass observed during closure period (Figure 5). Abundance and biomass were found significantly different according to depth and distance factors (p<0.05; Table 2). Samplings from the 10-20 m depths constituted main distribution of discards with higher values (Figure 5). Around the closest area to the shore (0-150 m), discard distribution were found very low. The highest values were detected around the outermost sampling area (>400 m), also average values were found much higher than other distance from the shore (Figure 4).

Composition of Discard Species

Discard species in the Eastern Black Sea belonged to 25 taxa. Of these, 22 were identified to the species level level (*Scapharca inaequivalvis* (Bruguière, 1789), *Chamalea gallina* (Linnaeus, 1758), *Cerithium vulgatum* (Bruguière, 1792), *Tritia reticulata* (Linnaeus, 1758), *Mytilus galloprovincialis* (Lamarck, 1819), *Raja clavata* (Linnaeus, 1758), *Dasyatis pastinaca* (Linnaeus, 1758), *Ophidium barbatum* (Linnaeus, 1758), *Mullus barbatus* (Linnaeus, 1758), *Scorpeana porcus* (Linnaeus, 1758), *Uranoscopus scaber* (Linnaeus, 1758), *Pegusa nasuta* (Pallas, 1814), *Neogobius melanostomus* (Pallas, 1814), *Arnoglossus kessleri* (Schmidt, 1915), *Parablennius tentacularis* (Brünnich, 1768), *Hippocampus hippocampus* (Linnaeus, 1758), *Liocarcinus depurator* (Linnaeus, 1758), *Liocarcinus navigator* (Herbst, 1794), *Brachynotus sexdentatus* (Risso, 1827), *Eriphia verrucosa* (Forskål, 1775), *Carcinus aestuarii* (Nardo, 1847), *Plimnus hirtellus* (Linnaeus, 1761)), and three to genus level (*Syngnathus sp.*, *Gibbula sp.*, *Callionymus sp.*). Most abundant species was another invasive bivalve *Scapharca inaequivalvis* (72%), following by a decapod species *Liocarcinus depurator* (10%), and a commercially important bivalve *Chamelea gallina* (7%) (Figure 6a). Dominant species order were changed in estimated biomass values, as a small species in weight, *Chamelea gallina* were not dominant, but teleosts *Scorpaena porcus* (6%) and *Uronoscopus scaber* (5%) placed after *S. inaequivalvis* and *L. depurator* (Figure 6b).

Diversity indicators of discard composition were considered according to regional, seasonal and depth related factors. Numbers of species (S) in the discard composition were the highest during summer season, and in the shallowest area. Although, S gradually decreased by depth, the closest area to the shore has the lowest values. Seasonal closure period that covers summer period also has higher values. Only regional and seasonal differences were found significant for S (Kruskal-Wallis, p<0.001; Table 2). An important diversity indicator, the Shannon diversity index (H')

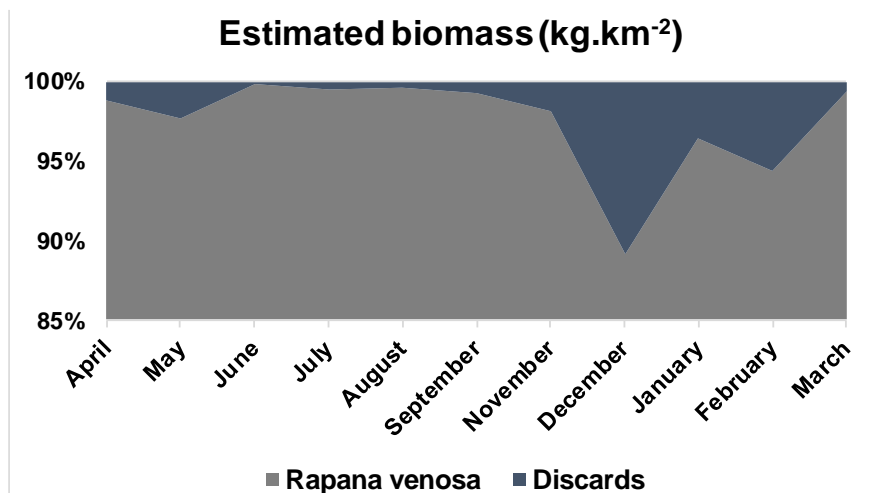


Figure 4. Monthly changes in percentage of a) estimated biomass and of *R. venosa* and discards during beam trawl sampling.

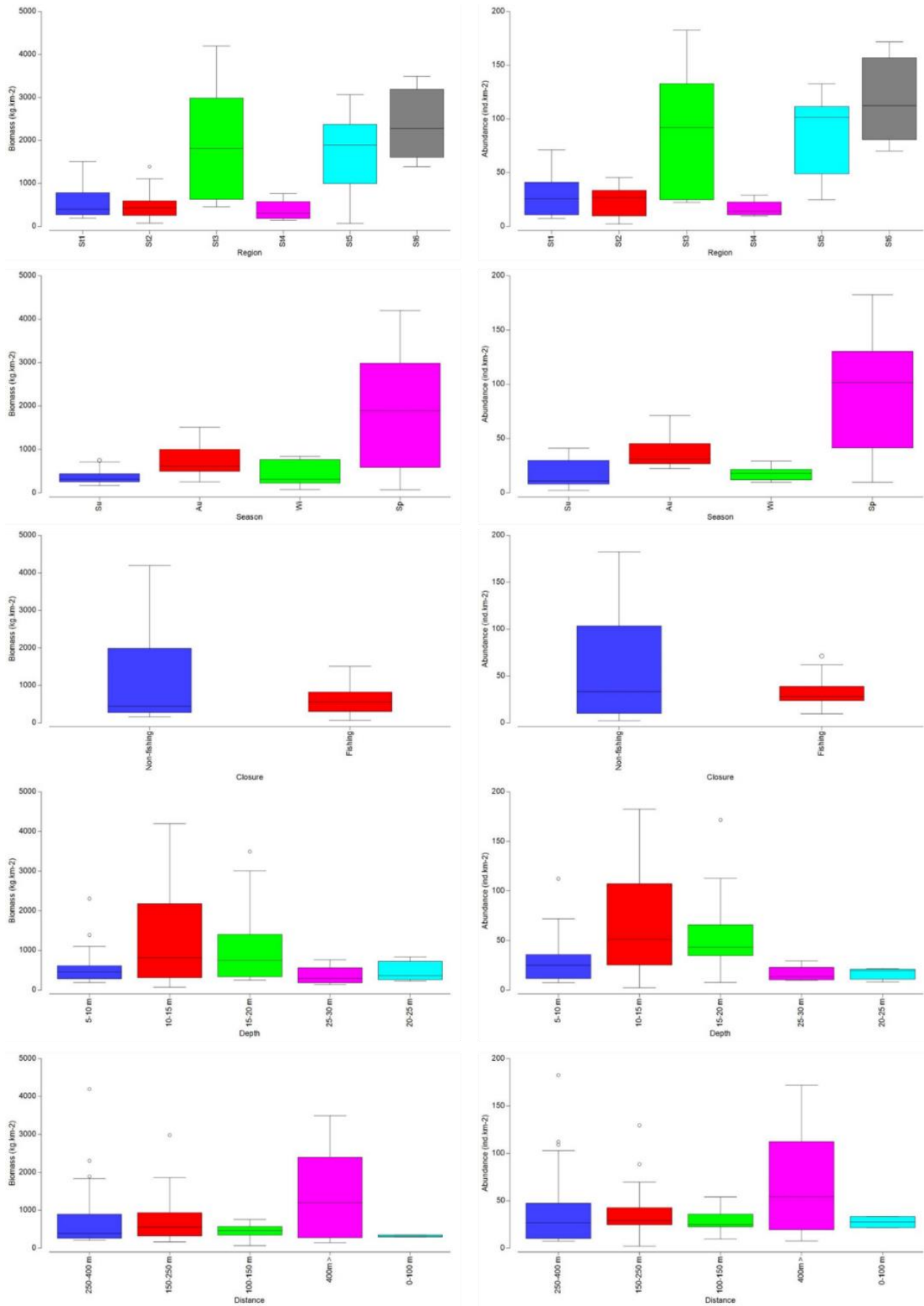


Figure 5. Box plots of estimated total discard abundance and biomass with 95% CI according to sampling region, season, depth, and distance from shore and fishery closure period in Eastern Black Sea.

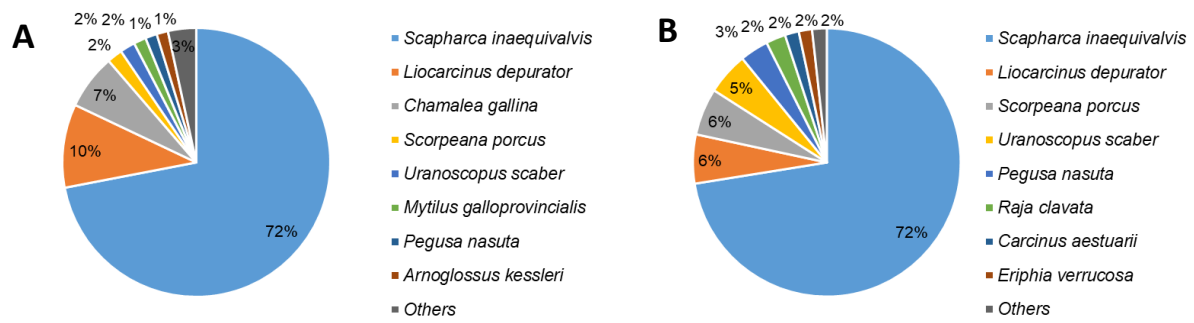


Figure 6. Dominant species of discard composition in a) estimated total abundance, and b) estimated total biomass.

Table 2. Levene’s test results for significance levels of differences in Rapa whelk estimated total biomass, estimated total discard biomass and total abundance in closure and non-closure period. Kruskal-Wallis test results for non-parametric variables, species number (S) and the Shannon diversity index (H’) among factors. Significance level were marked with (* for p<0.05; and ** for p<0.001).

Variables	S.S.	d.f.	F	p
Rapana venosa biomass (kg.km ⁻²)	27331491793		13.20	**
Discard biomass (B - kg.km ⁻²)	7607217	1, 60	34.69	**
Discard abundance (N - ind.km ⁻²)	18278		42.55	**
Species number (S) ¹	-		0.08	0.77
The Shannon diversity index (H’) ¹	-		0.82	0.36

were significant in regional, seasonal and depth related factors (Kruskal-Wallis, p<0.001; Table 2), except for seasonal fishery closure. Although, number of species were not significant among depth and distance from shore, estimated abundance showed a strong differentiation which caused wide range in H’ among depths and distances. According to results, seasonal closure periods from mid-April to end of August covers critical months for species distribution, and results showed S is the highest during August (summer) while significantly highest abundance and biomass were observed during April and May (spring). Even fishing period is two months longer than closure, estimated discard biomass and abundance were much lower (Table 3).

Multivariate analyses were used to understand distribution pattern of discard composition by each species according to seasonal, regional and depth related factors. Significant one-way ANOSIM results for each factor were considered for further SIMPER analysis to determine species contribution for dissimilarity within groups (Table 4). Seasonality of discard species composition was strong, and shaped by two dominant species as *S. inaequivalvis* and *L. depurator* (Table 4). The differences between autumn and winter were strongest (ANOSIM, R=0.681, p=0.01) and caused by occurrence of *Uronoscopus scaber* (Table 4).

Discussion

Our results indicated that, discard composition of Rapa whelk fishery strongly reflected seasonal changes. Total estimated abundance and biomass values showed

significant regional, seasonal and depth related differences, also number of species and diversity index changes regionally and seasonally. *S. inaequivalvis*, and *L. depurator* were dominant species and showed different seasonal distribution while *C. gallina* was spatially distributed. Especially, spring season was dominated by *S. inaequivalvis* with very high abundance and biomass, and *L. depurator* was very abundant in summer season. Summer season was very high in number of species, but low in species abundance. Discard ratio in *R. venosa* fishery was found low in biomass. In addition, seasonal fishery closure period was benefited for discard species in spring and summer period. The lowest distribution of *R. venosa* and discard species except *S. inaequivalvis* were found during winter season.

The spawning period of many commercially important species is between May and September in the near coastal habitat of the Black Sea (Genç et al., 2018; Dağtekin et al. 2020). Our results showed seasonal closure period is beneficial for the ecosystem in this respect. Therefore, it is become apparent that seasonal fishery closure is an important indirect management measures both for stock sustainability and ecosystem health. However, collaborative actions are necessary and other Black Sea countries should considered similar implementations in their EEZs.

Normally, fish and other benthic species discards are returned to the sea, whereas smaller bivalves and crabs are collected with the catches. The mortality ratio was found very high in returned species; especially bivalves were losing their ability to bury themselves to mud or sand (Gaspar et al., 2007). Habitat structure is an

Table 3. Diversity indicators of discard composition during *R. venosa* survey. Species number (*S*), total estimated abundance (*N*), the Shannon diversity index (*H'*) and estimated total discard biomass (*B*) according to each factors as region, season, closure period, depth, and distance from shore.

Factors	<i>S</i>	<i>N</i> (ind.km ⁻²)	<i>H'</i> (log _e)	<i>B</i> (kg.km ⁻²)	
Region	St1	21	686	1.67	12943
	St2	16	428	1.76	8670
	St3	10	546	0.54	11888
	St4	5	67	0.68	1517
	St5	10	605	0.46	12197
	St6	5	354	0.20	7155
Season	Autumn	17	652	1.35	13461
	Winter	7	108	0.77	31020
	Spring	14	1536	0.47	7375
	Summer	21	390	2.07	2513
Closure	Non-fishing	24	1769	1.04	36823
	Fishing	19	916	1.36	17547
Depth	5-10m	22	697	1.75	14020
	10-15m	16	1456	0.75	29584
	15-20m	14	417	1.14	7852
	20-25m	6	49	0.73	1430
	25-30m	6	66	0.69	1485
Distance	0-100 m	9	55	1.72	643
	100-150 m	15	338	1.55	5314
	150-250 m	18	583	1.49	11748
	250-400 m	21	775	1.01	16087
	400 m>	14	935	0.45	20578

Table 4. One-way ANOSIM results for significant group of each factors (p=0.1) with R relation and SIMPER results of significant groups with their average dissimilarity (%) according to species contribution (cut-off 10%).

Groups	R Significance Statistics <0.1	Avg. Dissimilarity %	Species	Contribution %
St.2, St.5	0.405	68.18	<i>Scapharca inaequivalvis</i>	28.87
			<i>Liocarcinus depurator</i>	16.16
			<i>Chamelea gallina</i>	15.11
Summer, Spring	0.614	78.17	<i>Scapharca inaequivalvis</i>	32.36
			<i>Liocarcinus depurator</i>	13.91
			<i>Chamelea gallina</i>	11.04
Autumn, Winter	0.681	52.85	<i>Liocarcinus depurator</i>	23.93
			<i>Scapharca inaequivalvis</i>	17.31
			<i>Uranoscopus scaber</i>	12.56
Autumn, Spring	0.665	55	<i>Liocarcinus depurator</i>	18.81
			<i>Scapharca inaequivalvis</i>	17.53
			<i>Chamelea gallina</i>	12.01
			<i>Uranoscopus scaber</i>	10.51
100-150 m, 400 m >	0.474	61.99	<i>Scapharca inaequivalvis</i>	23.67
			<i>Chamelea gallina</i>	23.65
			<i>Liocarcinus depurator</i>	14.98

important factor in the variation of discard rates and species composition. (Tiralongo et. al. 2021). Although no turbot fish sample was found in our study, it was determined with high discard ratio on the Bulgarian coast of the Black Sea (Petrova-Pavlova et al., 2020). After the collapse of *Mytilus galloprovincialis* stocks, *S. inaequivalvis* and *C. gallina* are known as the main prey of Rapa whelk (Dağtekin et al 2016). Thus, the distribution of this species closely related with the distribution of its prey items. The samplings of this study were designed according the fishers knowledge of Rapa whelk distribution. The changes in the sampling location, depth and distance from shore were followed Rapa whelk migration pattern and varied month by month. Therefore, the results of this study are highly representative of Rapa whelk fishery discard composition.

Conclusion

Several research on discards conducted by different fishing gears in the Black Sea, and many fishing methods have more or less discards (Genç et al.2010; Dalgıç & Ceylan., 2012; Ceylan et al., 2014; Şahin et al., 2015; Eryasar et al., 2018; Petrova-Pavlova et al., 2020). Considering the increase in the Rapa whelk population in the Black Sea, there is a need for studies to support fishing methods with a low discard rate to be accepted by fishers. It is necessary to expand studies on fishing methods such as pot fishery (Saglam et al., 2017), which have been successful in experimental studies in the past. Diving method is preferred in places where the large specimens can be obtained due to the low CPUE and but better profit as the prices of large ones are around 0.5-0.8 USD. There has been a decrease in many species in

the Black Sea in recent years, especially the turbot, which is important for small-scale fisheries (GFCM, 2019). The increase in vessel number will have a greater effect even on discards in the next years which indicate this problem should be addressed separately. Discards is a major problem in EU countries with the level of 25-30% where long term ongoing discussions for implementation of management measures show the solution will not be easy task in near future (EU, 2016). For this, it is recommended to design fishing gear that will protect the resource in the current situation with the support of international organizations such as GFCM and Black Sea Commission and European Union. It is suggested that discard ratios in Rapa whelk fishing should be evaluated in the stock assessment of commercial species. Also, it may be considered to give subsidies to reduce the discard rate in the Rapa whelk fisheries.

Ethical Statement

This article doesn't contain any experiments on humans and animals.

Funding Information

This study was supported by General Directorate of Agricultural Research and Policies (TAGEM/HAYSÜD/2016/A11/P-02/04).

Author Contribution

G.Erik:Conducted field work and data entry, funding Acquisition, Project Administration
M.Dağtekin:Conducted field work, analysis, Writing - review and editing

Conflict of Interest

The authors declare that they have no conflict of interest.

Acknowledgements

The authors thank Özşahin boat's captain and crew for contributing to the sampling. The authors are grateful to the anonymous referee for the valuable input on an earlier version of the article and to Prof. Nazlı Demirel for her valuable contributions analysis and writing process.

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