



Fish Bycatch Rate by *Rapana venosa* (Valenciennes, 1846) Fishery in the Bulgarian Black Sea Waters, with a Special Emphasis on the Bycatch of Turbot *Scophthalmus maximus* (L., 1758)

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Abstract: Catches of the commercial beam trawl fishery for *Rapana venosa* in Bulgarian waters were assessed during summer – autumn 2017. The fish bycatch was analysed, with a particular emphasis on the bycatch rate of turbot juveniles. Four commercial boats were chartered and catch species composition as well as weight and length of turbot bycatch were recorded from a total of 104 hauls. The trawling was performed at a depth of 13–38 meters, with duration of up to 220 min and hauling speed of 2.8–3.6 knots. Nine fish species were identified as bycatch, including 29 turbot specimens, with a total weight of 14.46 kg. The turbot bycatch weight was 0.55 kg/fishing day \pm 0.76 SD, averaged for the whole study period, with a maximum of 3.20 kg/day. The bycatch daily rate of turbot was 0.23 % \pm 0.34 SD of the total catches and the turbot bycatch was dominated by the length class 30 - 40 cm (66 % of all collected specimens). The highest bycatch rate of turbot juveniles was found in the region of Cape Kaliakra, Balchik (off the northern Bulgarian coast), spatially separated from the zones with the highest catches of *Rapana* (off the central coast). Provided this spatial pattern persists in summer – autumn, we suggest that targeted restrictions to *Rapana* fisheries in certain areas might be an appropriate tool to achieve lower catches of turbot juveniles.

Key words: *Rapana*, beam trawls, catch/bycatch, Western Black Sea

Introduction

Rapa whelk *Rapana venosa* (Valenciennes, 1846) (Gastropoda: Muricidae) was introduced into the Black Sea in the 1940s; within a few decades, it spread over the entire basin and in the Azov Sea (GLOBAL INVASIVE SPECIES DATABASE 2020). *Rapana venosa* is a predator of epifaunal bivalves and its proliferation appears a limiting factor of oysters and mussels' populations (CIESM 2000). The species is considered as one of the most dangerous invaders worldwide, blamed for the decline of the

native bivalve fauna in the Black Sea (ZOLOTAREV 1996, HARDING 2003). The industrial exploitation of rapa whelk in the Black Sea has started in Turkey during the 1980s and current Turkish catch varies between 6,000–8,000 tons annually. Recently, all Black Sea countries target *Rapana*, with a total annual catch of 10,000-15,000 tons. In Bulgaria, this fishery has commenced in the 1990s and rapa whelk was originally caught by scuba divers (DASKALOV & RÄTZ 2010), with catches around 90% of the total shellfish catch (FAO, 2000). Since 2012, the catch of *R. venosa* with beam trawl has been allowed in

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Bulgaria (FISHERY AND AQUACULTURES ACT 2012); with catches of 4,000–5,000 tons annually, this species takes a primary place in the country’s marine fisheries.

The term “bycatch” is widely used to refer to the part of the catch unintentionally captured during a fishing operation as an addition to target species. It consists of other commercial species (that may be secondary targets) and non-commercial species that might be returned to the sea (discarded) or landed, in case of a discard ban (FAO 2018). The incidental catch could relate to an impact on species (including vulnerable, endangered and protected non-commercial species and commercially undersized target species) and habitats, with effects on the food web and ecosystem energy pathways (HALL et al. 2000, TUDELA 2004, SEWELL & HISCOCK 2005, PERES et al. 2019). In the Black Sea, discards are estimated around 10–15 % of the total catch (FAO 2016). However, studies on bycatch cover a small proportion of the total fishing activity in the Mediterranean and the Black Sea, indicating a general lack of information (CARBONELL et al. 2003a, FABI & GRATI 2005, MACHIAS et al. 2001, MORANTA et al. 2000, SÁNCHEZ et al. 2007, SANTOJANNI et al. 2005, TZANATOS et al. 2007). SAĞLAM et al. (2008) found a total of 13 bycatch species from 17 beam trawls, in a study conducted between April 2006 and February 2007 in the Trabzon Province, Turkey (the eastern Black Sea). ERYASAR et al. (2018) studied the bycatch in the commercial beam trawl fishery for rapa whelk in Turkey in 2015–2016; in their study, about 28 species were caught as bycatch and some variables affecting bycatch amount were identified such

as fishing area, depth, haul duration and the amount of captured *R. venosa*.

To the best of our knowledge, observations on the bycatch rate of rapa whelk fishery are lacking for the western Black Sea. KONSULOVA et al. (2001) emphasised the negative consequences of beam trawl fishing on invertebrate benthic species (mainly on the black mussels) but the impact on fish species was not assessed. Our research provides an estimation of the fish bycatch and bycatch rate of the beam trawl fishery in the Bulgarian Black Sea zone, addressing bycatch species composition, abundance and impact on turbot juveniles. Additionally, we evaluate the spatial variability of the main catch/bycatch and analyse the length and weight structure of the turbot bycatch.

Materials and Methods

Sampling procedures

The study covered the period between 27 June 2017 and 22 October 2017, including 20 fishing days and 104 bottom trawl hauls in the area between Rusalka and Cape Maslen Nos, within the stratum 13–38 m (Fig. 1). Fishing covered four days and 20 hauls in June 2017, three days and 14 hauls in July, five days and 20 hauls in August, two days and eight hauls in September and six days and 42 hauls in October. Most of the sampling stations were located in front of the northern coast of the Bulgarian coastline, mainly in the region Cape Kaliakra – Byala, while along the southern coast the area with most of the trawling stations was below the Cape Emine.

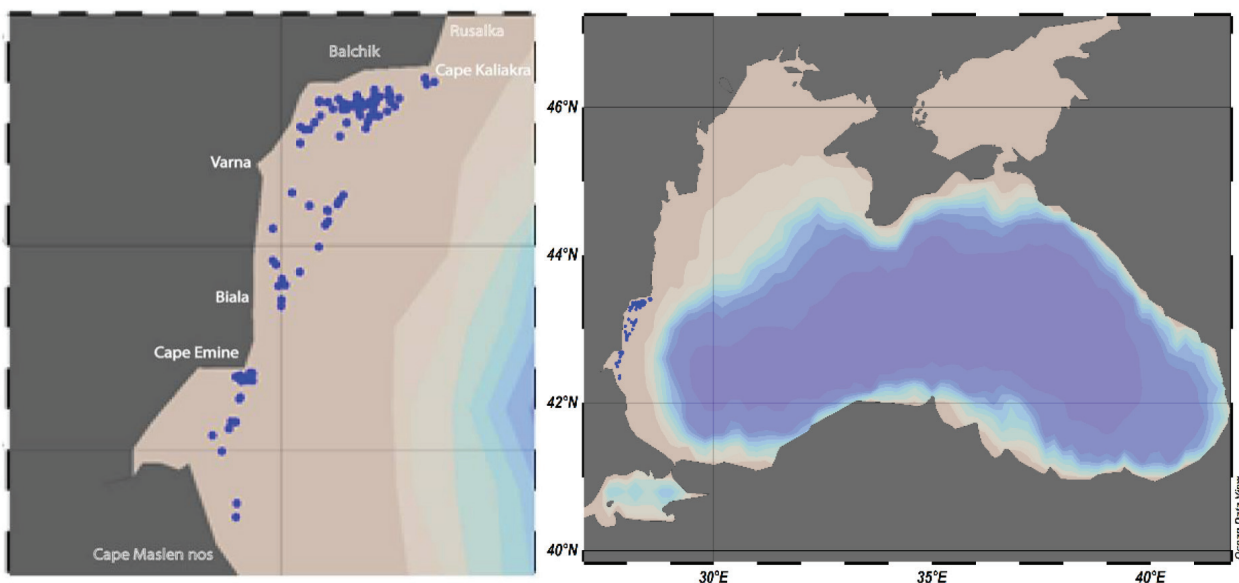


Fig. 1. Map of trawling areas in Bulgarian Black Sea waters and Black Sea.

The study was conducted on four commercial trawl vessels (length class 12–24 m) with comparable capacities (engine power 200–378 kW and tonnage 24.5–46 GT), equipped with standard fishing gear (maximum mouth width 503 mm, maximum depth 6 m, maximum codend length 10 m and mesh size 50 mm) and comprehensive data about the dredge's operations (coordinates, tow duration, depth and time) were recorded. Catch per unit area (CPUA) and bycatch per unit area (BPUA) indices were calculated based on the swept area method (SPARRE & VENEMA, 1992). CPUA and BPUA data from the different vessels were of comparable range and further standardisation was not applied.

We recorded the following measurements after the catch was on board the fishing vessel: the weight of the rapa whelk catch, species identification of the bycatch, individual weight and length of the fish specimens in the bycatch.

Bycatch proportion of the total catch (bycatch rate) was calculated as the bycatch weight divided by the total catch weight (landed + bycatch), (FAO 2019):

$$BC(\%) = (BCW/TCW) * 100, \quad (1)$$

where BCW – bycatch weight (kg/day), TCW – total catch weight (kg/day).

The proportion of the turbot bycatch compared to the total catch (*R. venosa* + bycatch) were estimated and averaged by trawling day. Monthly averages of length and weight of the turbot bycatch were estimated. General statistics of catches of *R. venosa*, turbot bycatch and length-weight data is presented.

Results

Target catch and incidental fish catches

The average catch of *R. venosa* was 255.85 kg/day \pm 125.58 SD for the entire study period, with daily catches varying from 95 to 470 kg/day (Table 1). The biomass index for *R. venosa* ranged between 0.42 and 7.71 t/km², by average CPUA of 2.14 t/km² \pm 1.21 SD (Table 1).

The weight of the daily fish bycatch was 1.04 kg/day \pm 1.30 SD, averaged for the whole study. The daily bycatch rate was assessed to 0.46 % TC \pm 0.65 SD (Table 1). The average fish BPUA index was 0.009 t/km² \pm 0.02 SD (Table 1).

The qualitative composition and distribution of incidental fish catches

Sixty fish specimens, belonging to nine species were observed: turbot *Scophthalmus maximus* (29 ind.), European flounder *Platichthys flesus* (8 ind.), knout goby *Mesogobius batrachocephalus* (8 ind.), black scorpionfish *Scorpaena porcus* (5 ind.), round goby *Neogobius melanostomus* (4 ind.), stargazer *Uranoscopus scaber* (3 ind.), sturgeon *Huso huso* (1 ind.), greater weever *Trachinus draco* (1 ind.) and butterfly blenny *Blennius ocellaris* (1 ind.). The spiny dogfish (Black-Sea shark) *Squalus acanthias* was not detected in the catches.

Common species in the bycatch were turbot, European flounder, knout goby, scorpionfish, round goby (Fig. 2). The stargazer, greater weever,



Fig. 2. Locations of the stations with incidental catches of common species: turbot *Scophthalmus maximus* (red dot), flounder *Platichthys flesus* (blue dot), knout goby *Mesogobius batrachocephalus* (green dot), scorpionfish *Scorpaena porcus* (orange dot), round goby *Neogobius melanostomus* (purple dot).

butterfly blenny and sturgeon were rarely caught (Fig. 3).

Turbot and flounder were found mainly in the summer, while gobies and scorpionfish were detected in autumn. The highest abundance of the turbot bycatch – 4–6 ind./day, was found along the northern coast, under the Cape Kaliakra – Balchik (Fig. 2). In front of Byala and under the Cape Emine, the numbers decreased with a maximum value of 2 ind./day.

Turbot bycatch weight, bycatch rate and length-weight structure of turbot bycatch

The mean weight of the turbot bycatch was 0.55 kg/day \pm 0.76 SD for the study period, with a maximum value of 3.20 kg/trawling day (Table 1). The turbot bycatch comprised on average 22 % of the fish bycatch weight. For the whole period, the turbot bycatch rate was estimated as 0.23 % TC \pm 0.34 SD, with a maximal daily share of 1.37 % TC (Table 1). The average turbot BPUA index in June –

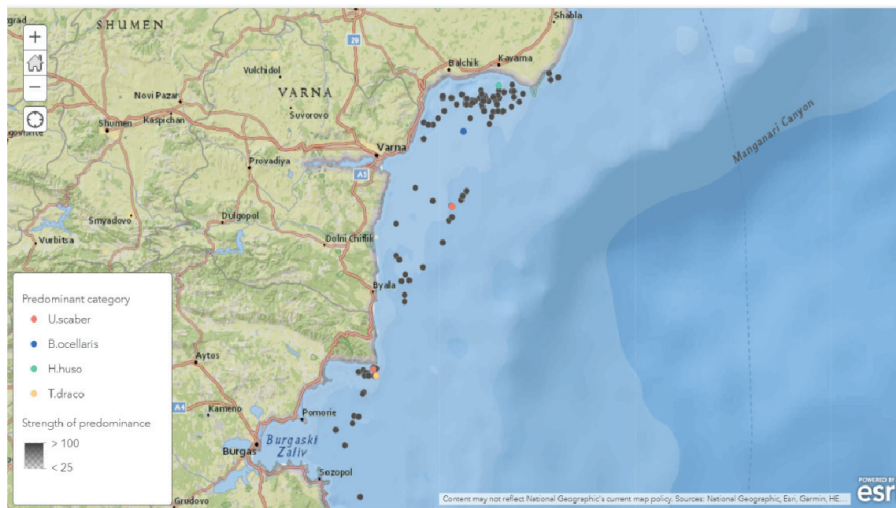


Fig. 3. Incidental catch distribution for rare species: stargazer *Uranoscopus scaber* (purple dot), greater weever *Trachinus draco* (blue dot), sturgeon *Huso huso* (green dot), butterfly blenny *Blennius ocellaris* (yellow dot).

Table 1. Summary statistics of the *Rapana* catch (MC, kg/day) and CPOA (t/km²), fish bycatch (FBC, kg/day) and BPOA (t/km²), turbot bycatch (TBC, kg/day) and BPOA (t/km²), fish bycatch rate (FBC, % from total catch (TC, main catch + bycatch) and turbot bycatch rate (TBC, % TC) in June–October 2017

	<i>Rapana</i> catch (MC, kg/day)	<i>Rapana</i> CPOA (t/km ²)	Fish bycatch weight (FBC, kg/day)	Fish BPOA (t/km ²)	Turbot bycatch weight (TBC, kg/day)	Turbot BPOA (t/km ²)	% FBC from TC	% TBC from TC
Mean	255.85	2.14	1.04	0.009	0.55	0.006	0.46	0.23
Standard Error	28.08	0.12	0.29	0.002	0.17	0.002	0.14	0.08
Median	210.00	1.80	0.65	0.000	0.34	0.000	0.22	0.15
Mode	170.00	1.80	0.00	0.000	0.00	0.000	0.00	0.00
Standard Deviation	125.58	1.21	1.30	0.020	0.76	0.016	0.65	0.34
Sample Variance	15769.71	1.47	1.68	0.000	0.58	0.000	0.42	0.12
Kurtosis	-1.16	5.31	3.32	17.445	7.20	12.736	6.39	5.90
Skewness	0.55	2.06	1.97	3.842	2.38	3.400	2.55	2.31
Range	375.00	7.29	4.49	0.135	3.20	0.091	2.57	1.37
Minimum	95.00	0.42	0.00	0.000	0.00	0.000	0.00	0.00
Maximum	470.00	7.71	4.49	0.135	3.20	0.091	2.57	1.37
Sum	5117.00	223.05	20.86	0.909	11.09	0.627	9.10	4.65
Count	20	104	20	104	20	104	20	20
Confidence Level (95.0%)	58.77	0.24	0.61	0.004	0.36	0.003	0.30	0.16

October 2017 was $0.006 \text{ t/km}^2 \pm 0.02 \text{ SD}$ (Table 1).

The turbot juveniles were predominant in the bycatch, as the only mature male specimen was collected at the end of July, near to the Cape Emine, with a weight of 1.71 kg and length of 48 cm. The mean length of turbot bycatch was $31.57 \text{ cm} \pm 6.48 \text{ SD}$, while the mean weight was $498.62 \text{ g} \pm 301.13 \text{ SD}$.

Two size groups, 30–40 cm (65.52 %) and 20–30 cm (17.24 %), were found most often in the turbot bycatch; the small-sized group (< 20 cm) constituted 6.90 % of all collected individuals, while specimens with size > 40 cm represented 10.34 % of the bycatch (Fig. 4, A). The weight group 250 – 500 g dominated the turbot bycatch with 37.9 %, followed by 500–750 g, which corresponded to

34.5 % of the total number of all collected specimens (Fig. 4, B).

By months, the mean length of the turbot bycatch had minimal changes and ranged between 29.10 and 36.67 cm, while mean weights varied between 330 and 646 g, with a minimum in October (Fig. 5). In August, the mean length and weight of the turbot bycatch were relatively high (Fig. 5). However, only a few specimens were collected in the catches, which resulted in low monthly average of the bycatch rate (Fig. 5).

The most significant turbot bycatch rate was observed in July and September (0.7–0.5 % TC, Fig. 8). In June and August, the bycatch rate was between 0.14–0.16 % TC and minimum levels were registered in October (0.04 % TC, Fig. 6).

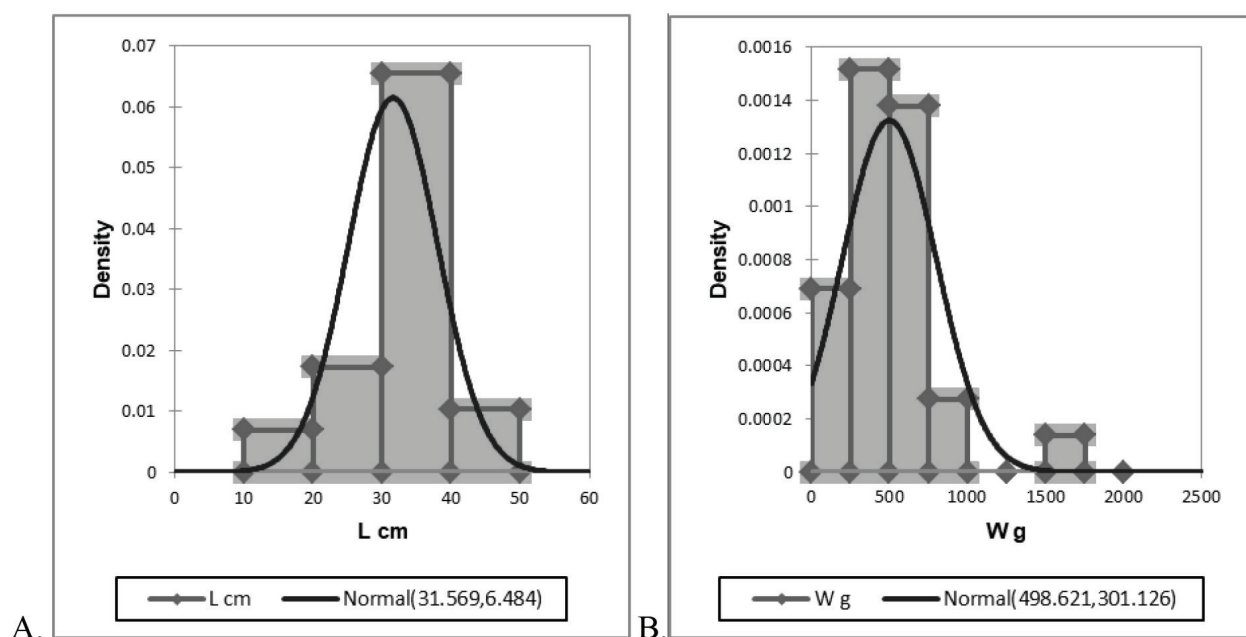


Fig. 4. Histograms of the distribution of size (L, cm, A) and weight classes (W, g, B) of turbot bycatch by *Rapana* fishery in June – October 2017.

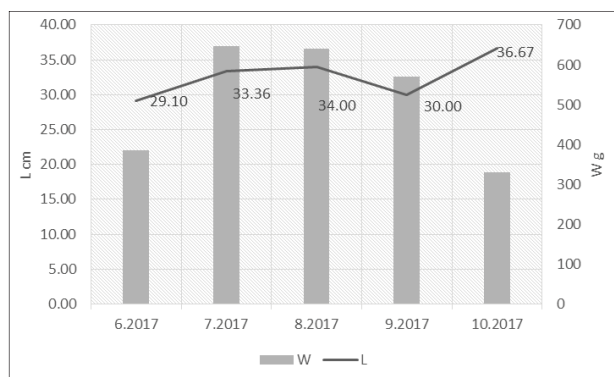


Fig. 5. Monthly averaged data about the length (L, cm) and weight (W, g) of the turbot bycatch.

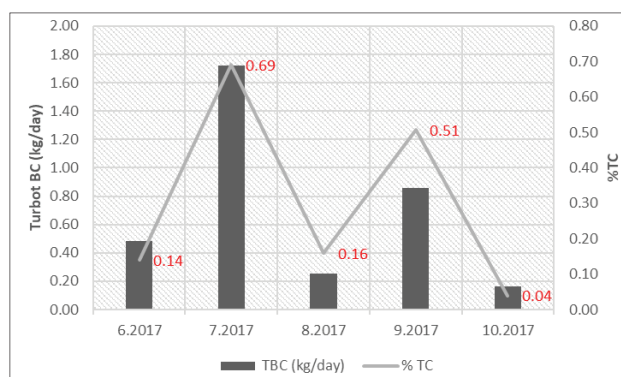


Fig. 6. Monthly changes of the turbot bycatch weight (kg/fishing day) and bycatch rate (% TC, in red) in 2017.

Spatial variations of catches and bycatch rate

The spatial distribution of CPUA of *R. venosa* (t/km²) and the turbot bycatch rate (% TC, per hauls) are presented in Fig. 7. The highest rapa whelk catch-

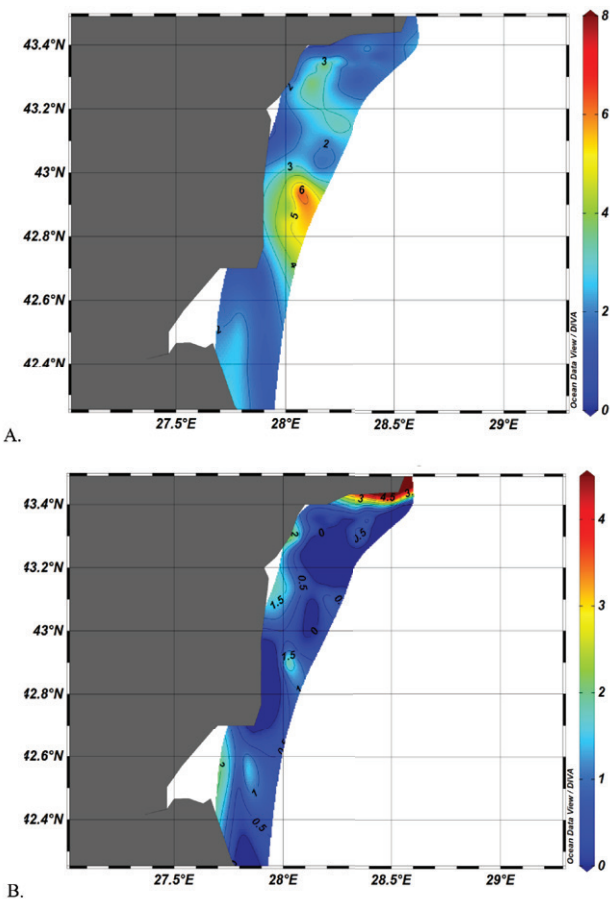


Fig. 7. *Rapana venosa* CPUA (t/km²) in June – October 2017 (A). Turbot bycatch rate (% TC per haul) (B).

es of ~7.71 t/km² were detected along the central part of the Bulgarian coast (Byala – Cape Emine). The highest bycatch rates of turbot (up to 4.3 % TC per haul) were observed along the northern coast, where the catches of *R. venosa* were rather low.

Analysis of the catch/bycatch distribution by depth showed high fish bycatch in the shallow coastal zone, with depths < 15 m and at depth ~35 m (Fig. 8). The first peak of BC (at depth ~ 14-15 m) was associated with a relatively high abundance of gobies (mainly *N. melanostomus*) and red mullet (*M. barbatus ponticus*) in the catches, while turbot dominated the bycatch structure at 35 m depth.

Discussion

The detrimental impact of fisheries bycatches on the marine ecosystems has been well documented in recent years (DAYTON et al, 1995, HALL et al. 2000, TUDELA 2004, KAISER et al. 2002, SEWELL & HISCOCK 2005, PERES et al. 2019). The magnitude of annual discards from marine capture fisheries in the Mediterranean and Black Sea is assessed at 239,824 tonnes (95% C. I.: 206,801–272,848 tonnes) for the period 2010–2014 (PERES et al. 2019).

A common issue related to fisheries bycatch is the need for improvement of the selectivity properties of fishing gears to minimize the amount of bycatch. The major ways for bycatch reduction include improvements of the species and size selectivity of the fishing gear and the usage of the bycatch reduction devices (MATSUOKA, 2008). In addition, targeted spatio-temporal fishery closures can increase

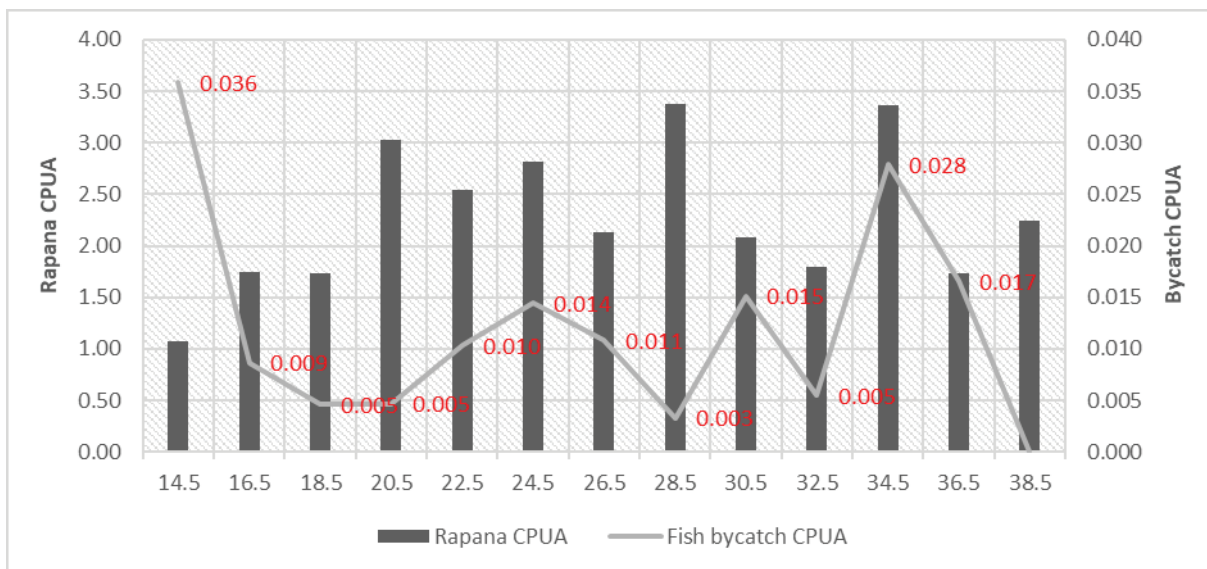


Fig.8. *Rapana* CPUA (t/km²) and fish bycatch CPUA (t/km², in red) averaged for depth zones.

fishing selectivity by prohibiting fishing in areas with high bycatch to catch ratios and are a possible solution for managers (HALL 2002, HALL & MAIN-PRIZE 2005, DUNN et al. 2011). Our study shows that the turbot bycatch rate has increased along the northern Bulgarian coast, near to Balchik – Cape Kaliakra area. The highest catches of *R. venosa* do not correspond spatially to the highest bycatch rates of turbot, which provides an option for implementation of spatial/temporal measures for rapa whelk's fisheries regulation to decrease turbot catchability, providing this spatial pattern is constant in summer and autumn. Taking into account the spatial specificity of turbot bycatch rate, the application of management measures such as spatial or temporal closure of certain areas (corresponding to high turbot bycatch rate) would achieve an effect similar to the use of selective fishing gears. Currently, the Executive Agency of Fisheries and Aquaculture implemented a total ban of marine fisheries within the one-mile zone of the Bulgarian Black Sea waters and designated a number of coastal areas, where fishing is banned within the three-mile zone (mostly along the southern Bulgarian coasts, i.e. from Cape Siviburun to the mouth of Cape Emine, from Chernomorets to the mouth of the Rezovska River). The proper estimation of the spatial range of the zones with high turbot bycatch rate and the introduction of targeted spatio-temporal fishery closures could be a helpful tool for rapa whelk's fisheries management and turbot bycatch reduction.

Further studies on the bycatch-related theme are needed in the Black Sea for a proper evaluation of the fishery impact on the diversity and abundance of marine organisms, as well as for the elaboration of scientific advice and the application of adequate management measures for bycatch reduction.

Conclusion

During the summer and autumn of 2017, nine fish species, belonging to eight families (Scophthalmidae, Pleuronectidae, Gobiidae, Scorpaenidae, Uranoscopidae, Acipenseridae, Trachinidae and Blenniidae) were found as bycatch in the rapa whelk beam trawl fisheries in the Bulgarian waters of the Black Sea. The daily fish bycatch comprised 0.5 % on average of the total catch. The bycatch rate of turbot juveniles increased in July and September. The fish bycatch attained maximal levels in the shallow coastal zone and at depths ~35 m, while turbot juvenile stages were found most often at depths > 15 m, generating on average 22 % of the fish bycatch weight. Spatially, the largest bycatch rate of turbot juveniles

and *R. venosa* are separated spatially, which provides prospects for future studies and designation of areas where targeted closures of fisheries of *Rapana* could be helpful to achieve turbot bycatch reduction.

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