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Effects of bottom trawling on the benthic assemblages in the south Adriatic Sea (Montenegro)

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The purpose of this study is to show the effects of bottom trawling on the benthic assemblages in the south Adriatic Sea as well as to report detailed quantitative and qualitative data on some invertebrate groups of no commercial value that are affected by trawling. Short-term effects of bottom trawling on the soft bottom seafloor were studied on the continental shelf and upper slope in the southeastern Adriatic Sea. Ten sites were trawled in July 2011. A total of 14,069 invertebrate organisms belonging to 44 taxa were collected within the study period. Of these, 93 were Sponges (4 species), 509 Cnidarians (7 species), 3,670 Molluscs (5 species), 48 Bryozoa (1 species), 3,154 Echinoderms (14 species), and 7,054 Tunicates (13 species). Cluster analysis performed with the data from different depth layers showed two clearly separated main groups that corresponded to shelf and slope zone. The shelf zone samples were characterized by higher species richness, while samples taken from the slope contained one species, Pteroeides spinosums. *The obtained results showed that the most common species during the survey were* Pteria hirundo*,* Ascidia virginea, Phallusia mammillata, Botryllus schlosseri*, and* Centrostephanus longispinus*. Species* P. mammillata*,* B. schlosseri*, and* P. regalis *presented the highest value of biomass index (kg/km2). Our results showed that ascidians, cnidarians, and echinoderms are the most vulnerable taxa to trawling.*

Key words: bottom trawling, ecological impact, invertebrates, benthic assemblage, Adriatic Sea

INTRODUCTION

Trawling remains a controversial method of fishing due to the perceived lack of selectivity of the trawl net, which can result in the capture of a huge quantity and diversity of non-target species, including endangered species, and have a significant effect on the marine ecosystem (KUMAR & DEEPTHI, 2006). Trawl fishing has both direct and indirect impacts on the marine ecosystem as well as on biodiversity, as it collects and kills a huge amount of non-target species and young individuals of commercially valuable species, mechanically disturbs the sea bottom, and injures a wide variety of marine benthic organisms (KNIEB, 1991). The environmental damage caused by bottom trawling can be substantial and irreversible (WATLING & NORSE, 1998). Trawling does not cause damage just to the physical attributes of the habitats, therefore implying a reduction in biodiversity, but can also cause changes to the benthic assemblage structure, species abundance, and their size structure (GARCÍA-RODRÍGUES *et al.*, 2011). However, most of the disturbances at the sea bottom remain unrecorded as they are hidden from direct human observation. Benthic communities provide shelter and refuge for juvenile fish, while associated fauna provides food sources for a variety of important demersal fish species. Thus, frequent alterations in the benthic habitats could result in a decline of marine fish landings (DAYTON *et al*., 1995). The benthic faunal composition is critically affected by heavy trawling, mainly through the re-suspension of the surface sediment and through the relocation of shallow burrowing infaunal species to the surface of the seafloor. A single passage of a beam trawl has been reported to kill 5–65% of the resident fauna and mix the top several centimeters of the sediment (DUPLISEA *et al*., 2001). Organisms inhabiting the soft sediments — particularly the biogenic structure-forming ones that are creating mounds, tubes, and burrows — develop much of their habitat's structure and play a critical role in many population, community, and ecosystem processes; the decline and/or elimination of these species and the disturbance to their habitats may affect both structural and functional biodiversity (THRUSH & DAYTON, 2002). Intensive trawling has been reported to decrease the density and abundance of sea grasses, polychaetes, molluscs, and echinoderms (BERGMAN & HUP, 1992).

Even though a series of studies was initiated during the last two decades in various parts of the world, the information on the ecosystem impacts of bottom trawling is still limited, primarily because of the complex nature of benthic habitats and their large spatial and temporal variability combined with methodological limitations in research (DAYTON *et al*., 1995; DEGROOT, 1984; DINMORE *et al.,* 2003; JENNINGS & KAISER, 1998; RAMSAY *et al*., 1998; SCHRATZBERGER *et al*., 2002; TUCK *et al*., 1998). Studies conducted in the Adriatic Sea, mainly in the northern part, provide information on the effects of the “rapido” trawling gear or hydraulic dredge on bottom biodiversity, the impacts of which were usually induced experimentally in pristine areas with environmental features similar to those of actual fishing grounds (GIOVANARDI *et al*., 1998). Data for the southeastern part of the Adriatic Sea, which are scarce and not very precise, have shown that about 50% of the catch consists of non-edible organisms. Such catches consist mostly of invertebrate organisms that have no commercial value, such as Echinodermata, Porifera, Bryozoa, and Mollusca (PETOVIĆ & MARKOVIĆ, 2013).

The aims of the paper were to present the effects of bottom trawling on the benthic assemblages in the south Adriatic Sea as well as to report detailed quantitative and qualitative data of some benthic species of no commercial value that are effected by trawling. Since the MEDITS program is the only survey in the southeastern area of the Adriatic that gives fairly precise data on the abundance and biomass of species caught per surface area up to 800 m in depth, we used the data from this database.

MATERIAL AND METHODS

The study was carried out in the soft bottom area of the Montenegrin shelf zone and upper slope (FAO-GFCM Geographical Subarea 18) (Fig. 1) according to MEDITS INSTRUCTION MANUAL (2012). The stations were distributed by applying a stratified sampling scheme with random drawing inside each stratum. The adopted stratification parameter was depth, with the following bathymetric limits: 10–50 m (total surface 280 km^2), 50–100 m (total surface 1100 km^2), 100–200 m (total surface 1700 km^2), 200–500 m (total surface 1150 km^2), and 500–800 m (total surface 770 km^2).

The survey was conducted in July 2011. The number of hauls in each stratum was proportional to the area of strata. In this study, we

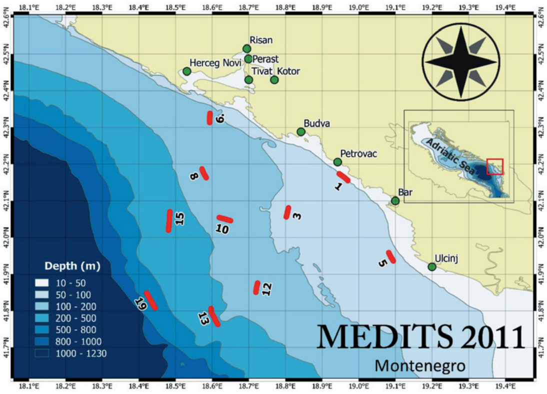

Fig. 1. MEDITS haul positions in Montenegrin waters (south Adriatic; FAO-GFCM Geographical Subarea 18)

considered 10 samples distributed in different depth strata (1 sample from 10–50 m, 2 samples from 50–100 m, 4 samples from 100–200 m, 2 samples from 200–500 m, and one sample from 500–800 m depth layer). The hauls were performed only during daylight hours, and the duration of the haul was 30 minutes at depths less than 200 m and 60 minutes at depths greater than 200 m. Sampling gear as well as vessel type are defined by the MEDITS protocol (INSTRUCTION MANUAL, 2012).

Collected materials were separated on board the vessel into appropriate categories as the INSTRUCTION MANUAL (2012) suggests. After the samples were processed, the data were entered into a computer database. The catch was standardized according to the "swept area" method (SPARRE & VENEMA, 1998), and the swept area was estimated according to the expression:

$$P = 0.001 \cdot a \cdot s$$

where P is the surface area of the haul (km^2), a the horizontal opening of the trawl (m), and s the total length of the haul (km). The obtained values were then used to estimate the biomass and abundance indices, e.g. number of individuals and biomass per surface area unit, km^2. The mean value of the catch was estimated according to the expression:

$$\overline{X}_T = \frac{p_1\overline{X}_1 + p_2\overline{X}_2 + p_3\overline{X}_3 + \ldots + p_n\overline{X}_n}{p_1 + p_2 + p_3 + \ldots + p_n}$$

where $\overline{X}_T$ is the average index value (kg/km^2, N/km^2), $\overline{X}_{1,2,3\ldots,n}$ the average catch in a given depth stratum (number of individuals (N) or kg), and $p_{1,2,3\ldots,n}$ the surface area of a given depth stratum (km^2).

The aim of the MEDITS survey program was to obtain the basic information on benthic and demersal species in terms of population distribution and demersal structure on the continental shelves and along the upper slopes at a global scale in the Mediterranean. For the purpose of analyzing the impact of bottom trawling on benthic biocoenoses, we used the data relating to inedible invertebrates.

For further processing, we used the data of abundance of invertebrate species to construct the file for statistical analysis. Similarity matrices were calculated using the Bray–Curtis index, with square root transformation, and a cluster analysis was performed on the rank similarities. In the identified groups, we analyzed the contribution of species to dissimilarity percentages (SIMPER), assessing the importance of species in each group and making comparisons between them. Finally, data on biodiversity measures were obtained for the selected groups. Average abundance (N), number of species (S), species richness (D-Margalef index), Pielou evenness (J), and Shannon–Wiener diversity (H loge) were calculated for each group of samples. All tests were performed using the corresponding subroutines of the PRIMER program (CLARKE & WARWICK, 2001).

RESULTS

A total of 14,069 invertebrate organisms belonging to 44 taxa were collected within the study period (Table 1). Of these, 93 were Sponges (4 species), 509 Cnidarians (7 species), 3,670 Molluscs (5 species), 48 Bryozoa (1 species), 3,154 Echinoderms (14 species), and 7,054 Tunicates (13 species). The species with the highest mean abundance considering all samples within stratum layer 10–50 m were *Ascidia virginea*, *Phallusia mammillata*, *Botryllus schlosseri*, *Botryllus schlosseri*, and *Modiolarca subpicta*; samples from 50–100 m depth showed *Pteria hirundo*, *Centrostephanus longispinus*, *Ascidia virginea*, and *Phallusia mammillata* as the most abundant; within the stratum of 100–200 m, depth species with the highest abundance were *Parastichopus regalis*, *Stylocidaris affinis*, and *Alcyonium palmatum*; the most numerous species from the depth layer 200–500 m were *Echinus melo*, *Cidaris cidaris*, and *Astropecten irregularis pentacanthus*; and from the deepest stratum, one invertebrate species was collected, *Pteroeides spinosum* (Table 1).

Table 1. List of species collected by bottom trawl with estimation of abundance, biomass and sampling stratum (July, 2011)

Species	Stratum	N/Km^2	Kg/Km^2
Alcyonium palmatum (Pallas, 1766)	10-50	96.06	0.60
Lytocarpia myriophyllum (Linnaeus, 1758)	10-50	96.06	1.32
Pennatula rubra (Ellis, 1761)	10-50	96.06	0.86
Anseropoda placenta (Pennant, 1777)	10-50	72.04	2.40
Astropecten aranciacus (Linnaeus, 1758)	10-50	24.01	7.44
Astropecten irregularis pentacanthus (Delle Chiaje, 1827)	10-50	24.01	0.36
Echinus acutus (Lamarck, 1816)	10-50	72.04	41.54
Frondipora verrucosa (Lamouroux, 1821)	10-50	48.02	0.16
Marthasterias glacialis (Linnaeus, 1758)	10-50	48.03	8.65
Ophiura ophiura (Linnaeus, 1758)	10-50	168.10	3.12
Parastichopus regalis (Cuvier, 1817)	10-50	48.03	19.93
Ascidiella spp.	10-50	96.06	0.24
Ascidia virginea (Müller, 1776)	10-50	1344.81	23.53
Botryllus schlosseri (Pallas, 1766)	10-50	984.59	87.41
Didemnum maculosum (Milne-Edwards, 1841)	10-50	144.09	8.55
Didemnum spp.	10-50	192.12	2.88
Distomus variolosus (Gaertner, 1774)	10-50	504.30	0.96
Halocynthia papillosa (Linnaeus, 1767)	10-50	48.03	1.68
Phallusia mammillata (Cuvier, 1815)	10-50	1128.68	118.51
Pyura spp.	10-50	480.29	3.84
Anomia ephippium (Linnaeus, 1758)	10-50	96.06	0.12
Hiatella arctica (Linnaeus, 1767)	10-50	24.01	0.02
Musculus subpictus (Cantraine, 1835)	10-50	600.36	0.24
Ircinia spp.	10-50	24.01	2.47
Suberites domuncula (Olivi, 1792)	10-50	24.01	0.14
Alcyonium palmatum (Pallas, 1766)	50-100	34.11	0.57
Lytocarpia myriophyllum (Linnaeus, 1758)	50-100	22.74	0.05
Pennatula rubra (Ellis, 1761)	50-100	79.59	0.76
Pteroeides spinosum (Ellis, 1764)	50-100	11.37	0.34
Amphipholis squamata (Delle Chiaje, 1828)	50-100	22.74	0.01
Astropecten aranciacus (Linnaeus, 1758)	50-100	56.85	13.19
Centrostephanus longispinus (Philippi, 1845)	50-100	1011.97	20.47
Chaetaster longipes (Retzius, 1805)	50-100	11.37	0.28
Echinus acutus (Lamarck, 1816)	50-100	56.85	13.64
Marthasterias glacialis (Linnaeus, 1758)	50-100	22.74	5.34
Ophidiaster ophidianus (Lamarck, 1816)	50-100	79.59	1.14
Ophiura ophiura (Linnaeus, 1758)	50-100	341.11	5.23
Parastichopus regalis (Cuvier, 1817)	50-100	397.96	51.74
Stylocidaris affinis (Philippi, 1845)	50-100	193.30	4.55
Ascidia mentula (Müller, 1776)	50-100	386.59	4.89

Ascidia virginea (Müller, 1776)	50-100	602.63	6.25
Botryllus schlosseri (Pallas, 1766)	50-100	375.22	154.52
Diazona violacea (Savigny, 1816)	50-100	22.74	1.82
Phallusia mammillata (Cuvier, 1815)	50-100	523.04	47.76
Pyura dura (Heller, 1877)	50-100	102.33	0.38
Pyura microcosmus (Savigny, 1816)	50-100	56.85	0.28
Glossus humanus (Linnaeus, 1758)	50-100	22.74	8.64
Pteria hirundo (Linnaeus, 1758)	50-100	2922.19	35.70
Tethya aurantium (Pallas, 1766)	50-100	22.74	2.62
Tethya citrina (Sarà & Melone, 1965)	50-100	22.74	0.97
Alcyonium palmatum (Pallas, 1766)	100-200	36.10	0.23
Epizoanthus arenaceus (Delle Chiaje, 1823)	100-200	10.31	0.02
Anseropoda placenta (Pennant, 1777)	100-200	5.16	0.08
Astropecten aranciacus (Linnaeus, 1758)	100-200	10.31	2.48
Astropecten irregularis pentacanthus (Delle Chiaje, 1827)	100-200	15.47	0.15
Chaetaster longipes (Retzius, 1805)	100-200	5.16	0.10
Cidaris cidaris (Linnaeus, 1758)	100-200	25.79	0.39
Ophidiaster ophidianus (Lamarck, 1816)	100-200	25.79	0.31
Parastichopus regalis (Cuvier, 1817)	100-200	103.14	13.90
Stylocidaris affinis (Philippi, 1845)	100-200	56.73	2.04
Ascidia virginea (Müller, 1776)	100-200	10.31	0.08
Diazona violacea (Savigny, 1816)	100-200	15.47	1.25
Phallusia mammillata (Cuvier, 1815)	100-200	5.16	0.88
Pyura dura (Heller, 1877)	100-200	30.94	0.20
Pteria hirundo (Linnaeus, 1758)	100-200	5.16	0.01
Alcyonium palmatum (Pallas, 1766)	200-500	5.22	0.02
Funiculina quadrangularis (Pallas, 1766)	200-500	5.22	1.31
Pelagia noctiluca (Forsskål, 1775)	200-500	5.22	0.13
Astropecten irregularis pentacanthus (Delle Chiaje, 1827)	200-500	26.11	0.10
Cidaris cidaris (Linnaeus, 1758)	200-500	78.32	0.94
Echinus acutus (Lamarck, 1816)	200-500	5.22	0.94
Echinus melo (Lamarck, 1816)	200-500	140.97	3.97
Parastichopus regalis (Cuvier, 1817)	200-500	5.22	0.39
Pteroeides spinosum (Ellis, 1764)	500-800	11.22	0.09

Cluster analysis performed with the data from different depth layers showed two clearly separated main groups that corresponded to shelf and slope zone (Fig. 2). Group A consisted of one station from the deepest stratum (500–800 m). Group B was divided into two subgroups, B1 and B2, with a similarity level of 20%. Subgroup B1 included stations from a depth up to 100 m, upper continental shelf zone, while subgroup B2 consisted of positions from the lower shelf (100–200 m) and the upper slope zone (layers 200–500 m).

The SIMPER analysis showed that upper shelf assemblages (depth from 10 to 100 m) were characterized by the presence of *A. virginea, P. mammillata, B. schlosseri, D. vari-*

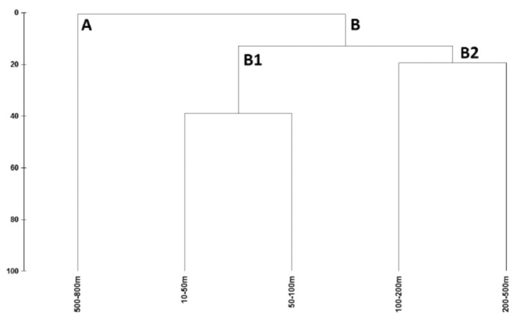

Fig. 2. The dendrogram of sampling stations in different depth stratums obtained with a cluster analysis based on the Bray-Curtis similarity matrix

olosus, O. ophiura, C. longispinus, P. regalis, A. mentula, and *P. hirundo*. On the middle shelf (depth from 100 to 200 m), we observed a dominance of *P. regalis, S. affinis, P. dura*, and *A. palmatum*. At the upper slope (depth range from 200 to 500 m), the dominant species were the echinoderms *E. melo, C. cidaris*, and *A. irregularis pentacanthus*. On the middle slope (500–800 m), *P. spinosum* was present. Some of these species made a considerable contribution to establishing the dissimilarity between the selected samples (Table 2).

The applied univariate analysis (Table 3) showed that the highest abundances were recorded in layers up to 100 m in depth. The number of species varied between 26 from 50–100 m depth to 1 from the deepest layer. The highest diversity (H') was found in the shallow layer (10–50 m) and decreased with depth. The evenness index was the lowest at the sites within 200–500 m depth. The same layer was characterized by the lowest species richness and, consequently, the lowest dominance index.

Table 2. Characteristics of the identified groups-mean dissimilarity values between groups

Group	I	II	III	IV	V
I	-				
II	71.62	-			
III	96.63	92.21	-		
IV	98.83	99.19	88.26	-	
V	100	99.7	100	100	-

Table 3. Univariate analysis parameters for sampling stations

Sample	S	N	d	J'	H'(loge)	1-Lambda'
10-50 m	25	6484	2.734	0.7683	2.473	0.88
50-100 m	26	7418	2.805	0.6686	2.178	0.8031
100-200 m	14	346	2.224	0.8342	2.202	0.8508
200-500 m	8	271	1.249	0.6271	1.304	0.6384
500-800 m	1	11	0	****	0	0

Analysis of the species abundance showed *Pteria hirundo* as the most numerous species (2927.35 N/km^2); less abundant were *Ascidia virginea* (1957.75 N/km^2), *Phallusia mammillata* (1656.87 N/km^2), *Botryllus schlosser* (1359.82 N/km^2), and *Centrostephanus longispinus* (1011.97 N/km^2). The abundance of other species in the total catch was less than 1,000 individuals per square km. Assessment of the quantitative value of harvested inedible invertebrate showed that the maximum quantity of species *Phallusia mammillata* (118.51 kg/km^2) and *Botryllus schlosser* (87.41 kg/km^2) was caught in the layer 10–50 m. In the depth layer from 50 to 100 m, the species *Botryllus schlosser* (154.52 kg/km^2) and *Parastichopus regalis* (51.73 kg/km^2) were dominant by biomass index. Among the species collected at the depth of 100–200 m, the maximum collected amount belonged to *Parastichopus regalis* (13.89 kg/km^2), while in the layer of 200–500 m it was *Echinus melo* (3.96 kg/km^2). From the deepest layer, 0.09 kg/km^2 of the species *Pteroides spinosum*s was collected.

DISCUSSION

The MEDITS program, performed on 10 haul locations in the Montenegrin territorial waters and epicontinental belt, is currently the only project that offers the possibility of collecting samples from depths up to 800 m. The selection of data (number of individuals and biomass per km^2) relating to the benthic species of no commercial value from the catch was made in an attempt to understand the impact of bottom trawling on the structure of benthic biocoenoses in the researched areas.

The research area extends from the shallows to 800 m in depth and is characterized by the biocoenosis of the coastal terrigenous mud ooze in shallow waters close the coast and continues by biocoenosis of the coastal detritic bottom. Going further in depth, the biocoenosis of bathyal mud on mobile substrata is present (facies of soft mud with a fluid surface at depths of 200–350 m and the facies of sandy mud and fine gravel at 400–500 m depths) (GAMULIN-BRIDA, 1983).

Identification of the collected material revealed the presence of 44 species of invertebrates of no commercial value. The highest species richness was registered in the first 100 m of depth (Table 3), as this zone is considered the most suitable for living (GAMULIN-BRIDA, 1967). The most dominant groups were tunicates and echinoderms. As depth increases, the number of species considered as discard decreases. From the depths of 500–800 m, only one cnidarian was collected. Cnidarians were present among all the strata, while echinoderms were absent only from the deepest layer. Cluster analysis showed clear differences between samples collected from the shelf zone (upper and middle) and slope (upper and middle). The samples from the shelf were characterized by the highest species richness, while samples taken from slope contained one species, *P. spinosum*s.

The obtained results showed that the most frequent species were from the groups Bivalvia (*P. hirundo*), Tunicata (*A. virginea*, *P. mammillata*, *B. schlosser)*, and echinoderms (*C. longispinus*). The abundance of other species in the total catch was less than 1,000 individuals per square km. The recorded quantity of the species was to be expected when it is known that the study area is their preferable habitat (GAMULIN-BRIDA, 1967).

Data for the southeastern part of the Adriatic Sea showed that about 50% of the catch belonged to species of no commercial value (PETOVIĆ & MARKOVIĆ, 2013) which matches with results from the Mediterranean area, where it was estimated that the discard rate in the bottom trawl fisheries was 45–50% (TUDELA, 2004). Analysis by FAO (FAO, 2004) based on the discard data during 1992–2002 estimated the discard rate as 8% of the total catch, represented by 7.3 million tons.

The amount of invertebrates caught indicates the significant ecological impact of bottom trawling on the composition and status of benthic assemblages. Benthic communities play an important role in remineralization and release of nutrients in marine ecosystems (ROWE *et al.*, 1975). Disturbances created by mobile fishing gears temporarily alter the redox state of the system, and thus the rate of remineralization (FRID & CLARK, 2000). Our results showed that ascidians, cnidarians, and echinoderms are the most vulnerable taxa to trawling. Holothurians, a major component of the bycatch, are important deposit feeders in many communities, commonly dominating the invertebrate epifauna. Some cnidarians and sponges are long-lived species, so trawling may enable them to increase their rate of colonization (WILSON, 1979).

The intensity of trawling impact on benthic communities depends mostly on the gear used. The trawl net is the most destructive type of mobile fishing gear, as it is dragged across the sea bottom, gathering a wide array of organisms as bycatch. The study carried out by PRANOVI *et al.* (2000) in the Adriatic Sea on the short-term impact of “rapido” trawling on the sea bottom revealed that it causes extensive damage, digging, and furrowing of the sediment to a depth of 6 cm. Negative effects on the structure of the macrobenthos community were recorded as the increase in the abundance and biomass of taxa a week after the perturbation because of the increase in the trophic availability benefiting a few opportunistic scavenger species (PRANOVI *et al.*, 2000).

Commercial exploitation appears to result in cumulative disturbance, as evidenced by the higher biomass of scavenger Crustacea and Echinodermata at the expense of Porifera, Mollusca, and Annelida. The hydraulic dredge, which ploughs sediment to a depth of 20–30 cm, is particularly destructive (RELINI *et al.,* 1999). This fishing practice is especially common in the Adriatic Sea and takes shelled molluscs such as *Ensis minor*, *Callista chione*, *Chamelea gallina*, and *Paphia aurea*. In the southwestern Adriatic, the smooth scallop (*Chlamys glabra*) fishery operating on coastal detritic bottoms inside the Gulf of Manfredonia has a high amount of discard, 395 kg from only an hour’s dredging, principally of green sea urchins (*Psammechinus microtuberculatus*), molluscs, and crustaceans (VACCARELLA *et al*., 1998). In the United States, there appears to be a consensus that bottom trawls not only directly affect the distribution and abundance of target and bycatch species, but also have strong collateral impacts on the physical and biological fish habitat (CHUENPAGDEE *et al*., 2003). However, different seafloor types and benthic communities are affected to different degrees (COLLIE *et al*., 2000; KAISER *et al*., 2002), and the acute impacts of trawling may differ from chronic impacts (AUSTER & LANGTON, 1999). Nonetheless, the National Research Council (2002) concluded that bottom trawling in general (1) reduces habitat complexity, (2) alters benthic communities, (3) reduces benthic productivity, and (4) most strongly affects fauna that live in regimes of low natural disturbance, especially soft-bodied, erect, sessile organisms inhabiting stable deep seafloors (e.g. sea pens on mud).

The obtained results show that the most affected species are sessile and slow-moving organisms such as echinoderms (14 species), tunicates (13 species), cnidarians (7 species), mollusks bivalves (5 species), and sponges (4 species).

Comparative studies of areas of the seabed that have experienced different levels of fishing activity demonstrate that chronic fishing disturbance leads to the removal of high biomass species that are composed mostly of emergent seabed organisms (KAISER *et al*., 2002). Conversely, scavengers and small-bodied organisms, such as polychaete worms, dominate heavily fished areas.

Although there is no information on the effects of deep-sea trawling on muddy bottoms in the Mediterranean (or anywhere else in the world), the few authors touching on the subject warn of the extreme vulnerability of such sea beds to physical perturbations. It appears that recovery rates are much slower and the impacts of trawling may be very long lasting (many years or even decades) in deep water, where the fauna is less adaptable to changes in sediment regimes and external disturbances (BALL *et al*., 2000; JONES, 1992). Analysis showed that the seafloor from 200 m up to 800 m was mostly populated by cnidarians (*A. palmatum, F. quadrangularis*, and *P. spinosum*) and echinoderms (*A. irregularis pentacanthus, C. cidaris, E. melo, E. acutus*, and *E. regalis*). Studies have shown that bottom trawling in the deep sea destroys *Isidella elongata* facies of the bathyal mud biocoenosis (MAYNOU & CARTES, 2011). Trawling can also remove large-bodied, long-lived macrobenthic species and subsequently reduce the bioturbation zone (BALL *et al.,* 2000). This could increase the danger of eutrophication and result in longer recovery rates (RUMOHR *et al*., 1996).

Frequent disturbance of benthos by trawling is likely to favor the more opportunistic recolonizers. Scavenging species may converge on benthos that is left damaged or disturbed on the sea bed as a result of trawling (KAISER & SPENSER, 1994).

CONCLUSIONS

Short-term effects of bottom trawling on the soft bottom seafloor were studied on the continental shelf and upper slope in the southeastern Adriatic Sea. Ten sites were trawled in July 2011. A total of 14,069 invertebrate organisms belonging to 44 taxa were collected within the study period. Of these, 509 were Cnidarians (7 species), 3,154 Echinoderms (14 species), 3,670 Molluscs (5 species), 7,054 Tunicata (13 species), 93 Sponges (4 species), and 48 Bryozoa (1 species). Cluster analysis performed with the data from different depth layers showed two clearly separated main groups that corresponded to the shelf and slope zone. The shelf zone samples were characterized by higher species richness, while samples taken from the slope contained one invertebrate species, *P. spinosum*s. The obtained results showed that the most abundant species during the survey were *P. hirundo*, *A. virginea*, *P. mammillata*, *B. schlosser*, and *C. longispinus*. The abundance of other species in the total catch was less than 1,000 individuals per square km. Total abundance was 14,069.02 individuals per square km. The highest biomass index was recorded for the species *P. mammillata* and *B. schlosser* in the 10–50 m stratum, *B. schlosser* and *P. regalis* in the 50–100 m stratum, *P. regalis* in the 100–200 m stratum, *E. melo* in the 200–500 m stratum, and *P. spinosum*s in the deepest stratum. Our results showed that ascidians, cnidarians, and echinoderms are the most vulnerable taxa to trawling.

Our study showed the huge amount of invertebrate species killed by one haul. Considering the fact that the researched area is a fishing zone where about 20 trawls are active throughout the year could indicate that the problem of bycatch deserves more attention.

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Učinci pridnenog koćarenja na bentoske zajednice u južnom Jadranu (Crna Gora)

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SAŽETAK

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Ključne riječi: pridneno koćarenje, ekološki utjecaj, beskralješnjaci, bentoska zajednica, Jadransko more