

Analysis of Demersal Fish Fauna off the Sea of Marmara, Turkey

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Abstract: Demersal fish fauna of the Sea of Marmara, Turkey was determined by bottom trawl surveys between March 2017-December 2018 at 34 stations with the monthly samplings. During the study, a total of 61 teleost and 12 cartilaginous fish species belonging to 42 families were sampled. The target, bycatch and discard rates of CPUE were determined as 13.40%, 69.64% and 16.95%, respectively. In total, 53.9% of the CPUE was stemmed from *Trachurus trachurus*. *Mustelus mustelus*, *Raja clavata*, *Merluccius merluccius* and *Merlangius merlangius* had the highest CPUE with a mean of 77.63, 71.86, 71.72 and 72.68 kg/km², respectively. The highest biodiversity was observed in the southwestern part of the Marmara Sea. With increasing depth, the species number of the teleost fish decreased, whereas the species number of the cartilaginous fish increased. The mean CPUE values of the economical demersal fish species were lower in comparison to those reported from other regions in Turkey. Evidence suggests fish stocks with shallower distribution is under heavier threat against fishing pressure. Since commercial trawling is banned in the Sea of Marmara, beam trawl fishery can be considered as the major threat to demersal fish stocks in the region.

Keywords: Bottom Trawl, Biodiversity, Biomass, MEDITS Protocol, Teleost, Cartilaginous

Marmara Denizi'nin Demersal Balık Faunasının Analizi

Özet: Mart 2017 ile Aralık 2018 ayları arasında 34 istasyondan aylık dip trolü örneklemeyle Marmara Denizi'nin demersal balık faunası tespit edilmiştir. Çalışma süresince 42 familyaya ait 61 kemikli balık ve 12 kıkırdaklı balık türü örneklenmiştir. Hedef, hedef dışı ve ıskarta türlerin CPUE oranları sırasıyla %13,40, %69,64 ve %16,95 olarak belirlenmiştir. Toplam CPUE değerinin %53,9'u *Trachurus trachurus* türünden kaynaklanmaktadır. En yüksek CPUE değerine sahip demersal balık türleri sırasıyla 77.63, 71.86, 71.72 ve 72.68 kg/km² ile *Mustelus mustelus*, *Raja clavata*, *Merluccius merluccius* ve *Merlangius merlangius* olarak belirlenmiştir. En yüksek biyoçeşitlilik güneybatı Marmara'da belirlenmiştir. Derinlik arttıkça kemikli balıkların biyoçeşitliliğinin azaldığı, kıkırdaklı balıkların biyoçeşitliliğinin ise arttığı görülmüştür. Ekonomik demersal balık türlerinin ortalama CPUE değerlerinin Türkiye'nin diğer bölgelerine göre düşük olduğu tespit edilmiştir. Bulgular, daha sığ sularda dağılım gösteren türlerin stoklarının avcılık baskısına karşı daha ağır tehdit altında olduğunu göstermektedir. Marmara Denizi'nde trol balıkçılığı yasak olduğundan, algarna avcılığı bölgedeki demersal balık stokları için en büyük tehdit olarak kabul edilebilir.

Anahtar Kelimeler: Dip Trolü, Biyoçeşitlilik, Biyomas, MEDITS Protokolü, Kemikli, Kıkırdaklı Balıkçılık

Introduction

Studying demersal fish composition, biomass and variations over spatial and temporal scales is a basic tool for fisheries management authorities. Long-term changes in physico-chemical parameters of seawater, pollution and excessive fishing pressure are the main determining factors on variations observed in demersal fauna. Changes in physico-chemical parameters caused by global warming may trigger spatial variations in composition of lessepsian species (Bianchi et al., 2002). Although in many cases, these changes usually occur very slowly, sudden effects can also be observed. Pollution is the most important factor that causes sudden changes in demersal life with oil spills (Elmgren et al., 1983) and persistent organic pollutants (PAH, DDT, PCB etc.) (Sole et al., 2013) having proven harmful effects on demersal fish. Apart from these slow and fast emerging variables, there are also continuous harmful variables such as fishing pressure. The damaging impacts of demersal trawls on demersal communities and habitats have been studied by many researchers (Auster and Langton, 1999; Bergman and van Santbrink, 2000; Hinz et al., 2009) Since deep water trawling is a common fishing method, well established scientific knowledge has been obtained from the seas of Turkey (Zengin et al., 2004; Knudsen et al., 2010; Ceylan et al., 2013; Yemişken et al., 2014; Keskin et al., 2014; Çiçek et al., 2014; Yıldız and Karakulak, 2017; Dalyan, 2020). These researches were conducted mostly western part of the Black Sea, North Aegean Sea and northeastern part of the Mediterranean Sea.

Sea of Marmara is a semi-closed basin, which is connected to the Aegean Sea and the Black Sea via the straits of Çanakkale and Bosphorus, respectively (Beşiktepe et al., 1994). Since trawl fisheries is banned in the Sea of Marmara, commercial catches of

demersal fish are caught by beam trawls and deep water gill nets. Therefore, information on demersal fish composition and spatial and temporal variations are limited (Gözenç et al., 1997; Eryılmaz, 2001; Torcu-Koç et al., 2012; Keskin et al., 2011). Beside, Eryılmaz and Meriç (2005), and Demirel and Gül (2016) were reviewed historical and earlier demersal fish records from the Sea of Marmara.

In this study, we investigated demersal fish stocks in the sea of Marmara. Within the scope of this study, CPUE, species richness and spatial and temporal variations in fish compositions were determined.

Material and Methods

In order to make comparisons between earlier studies, technical specifications of the trawl net and trawl door used in this study were determined according to recommendations of MEDITS protocol (Spedicato et al., 2019). Trawl tows were conducted with commercial trawl vessel “Yalçınoğlu”, which is 23.5 m in length with 450 hp engine power. Unlike conventional methods, metallic trawl doors were used. The length, width and height of the doors were 200 cm, 100 cm and 200 kg, respectively. The total length of the trawl net was 28.3 m and vertical and horizontal openings were 2.5 and 15 m, respectively. The float line length was 28 m and the ground rope length was 30 m. The trawl net (polyethylene codend with 200 mesh length with a mesh opening 44 mm; equipped with polyamide cover with 250 mesh length with a mesh opening) were prepared based on “MEDITS International bottom trawl survey in the Mediterranean, Instructional Manual”. Sampling stations covered 3 different depth contours (20-50; 50-100 and 100-200) and broad geographical area (Figure 1).

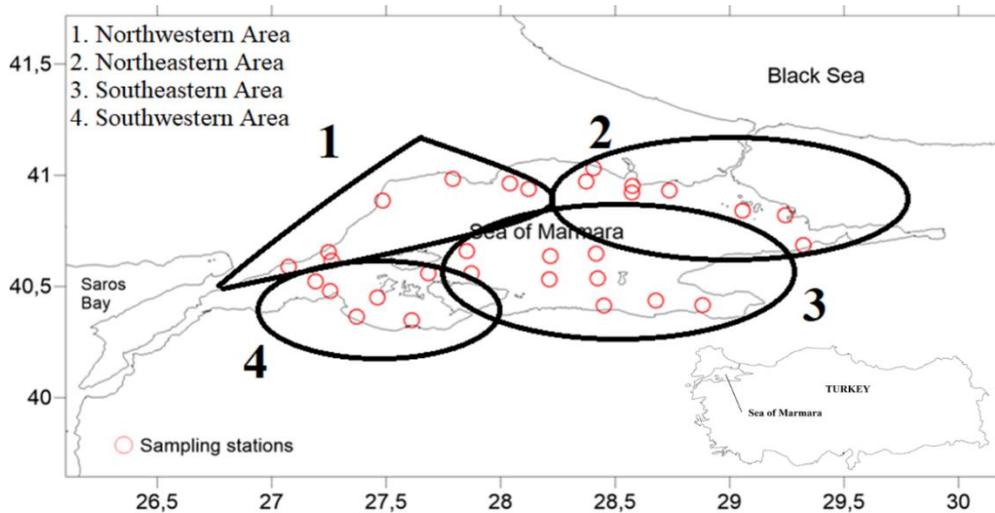


Figure 1. Sampling locations in the Sea of Marmara and the of sampling stations are specified by Gözenç et al. (1997)'s study

Trawling operations were carried out seasonally between March 2017 and December 2018, at 34 stations. In order to make easier and more accurate comparisons, the sampling stations in our study were determined based on an earlier study by Gözenç et al. (1997).

The tow durations were ½ hours with speed of 3 nautical miles per hour. Deck sampling and catch record procedures were carried out as described by Holden and Raitt (1974). Catches in terms of abundance and biomass were standardized to one-hour tows. CPUE (kg/km²) was calculated as the catch weight (Cw) divided by the swept area (a) for each species and for each haul (Spare and Veneme, 1992).

$$CPUE: Cw/a$$

The swept area (a) or the ‘effective path swept’ for each hauling was estimated thus:

$$a=D.h.X$$

where h is the length of the head-rope and D is the cover of distance. X is the fraction of the head rope length and accepted as a 0.5 (Pauly, 1980).

The number of species (S) was determined for each haul. The diversity indices were calculated using the number of specimens to standardize with catch hour per haul. The Dominance, Shannon_H, Margelef and Simpson index were used for assess species richness. Biodiversity indices were calculated by Past Version 2.17 (Harper, 1999). Spatial and temporal variation of species richness were analyzed with ANOVA. The statistical differences between groups were tested with Tukey’s pairwise comparisons.

Results

A total of 61 teleost and 12 cartilaginous fish species belonging to 42 families were sampled. Among them, only 19 species were considered as target species. Thus, 45.2% of the total species richness consisted discard species. Although species number was low, a great majority of mean CPUE value arised from bycatch (69.6%). Although there was less difference than usual, the amount of discard was higher than the target (Table 1).

Table 1. Biomass and species richness of the Sea of Marmara

	CPUE (kg/km ²)	CPUE% (kg/km ²)	Species Number	Species Number %
Discard	264.78	16.9	33	45.2
ByCatch	1083.23	69.5	21	27.6
Target	211.62	13.6	19	25.0

Among all 42 families, families represented by highest number of species were Clupeidae, Triglidae and Sparidae. Gadidae and Soleidae families were represented by 4 and 3 species, respectively.

The mean CPUE values of the species were given in Table 2. CPUE values of the species showed variations with respect to weight and number due to morphological characteristics. For cartilaginous fish species, the highest CPUE values were found for

M.mustelus, *R.clavata* and *Dasyatis pastinaca*, with a mean of 77.63 kg/km², 71.86 kg/km² and 31.46 kg/km², respectively. Due to relatively their higher abundances, *T. trachurus* (841.16 kg/km²) and *Sprattus sprattus* (106.35 kg/km²) had the highest CPUE in teleosts. Also, other small pelagic fishes such as *Trachurus mediterraneus*, *Engraulis encrasicolus*, and *Sardina pilchardus* had relatively higher CPUE (kg/km²) (Table 2, Figure 3).

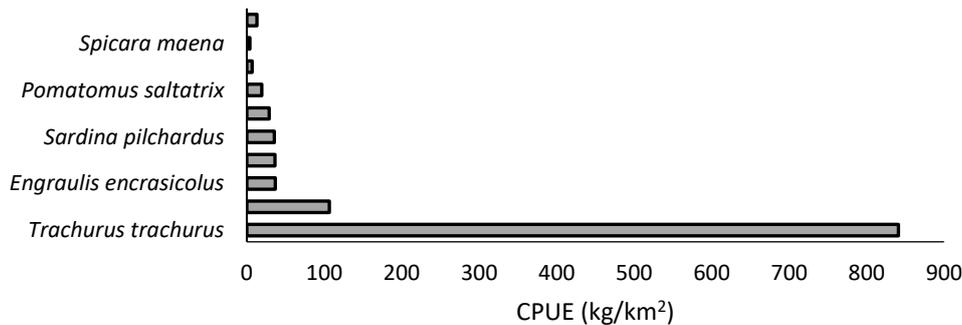


Figure 3. Mean CPUE (kg/km²) values of bycatch and discard teleost fish species in the Sea of Marmara

Table 2. Mean CPUE (kg/km²) values of the trawl catch composition in the Sea of Marmara, Turkey (*D=Discard; T=Target; B=Bycatch)

Family	Species	Attribution (D, T, B)*	CPUE (kg/km ²)
	Cartilaginous Fish		
Hexanchidae	<i>Hexanchus griseus</i>	D	2.47
Scyliorhinidae	<i>Scyliorhinus canicula</i>	D	4.40
Triakidae	<i>Mustelus asterias</i>	D	3.16
Triakidae	<i>Mustelus mustelus</i>	D	77.63
Oxynotidae	<i>Oxynotus centrina</i>	D	1.65
Squalidae	<i>Squalus acanthias</i>	D	5.91
Squalidae	<i>Squalus bleinville</i>	D	3.16
Squatinaidae	<i>Squatina squatina</i>	D	4.12
Torpedinidae	<i>Torpedo marmorata</i>	D	1.51
Rajidae	<i>Raja clavata</i>	D	71.86
Dasyatidae	<i>Dasyatis pastinaca</i>	D	31.46
Myliobatidae	<i>Myliobatis aquila</i>	D	14.15
Teleost Fish			
Congridae	<i>Conger conger</i>	D	0.14
Clupeidae	<i>Alosa fallax</i>	B	1.65
Clupeidae	<i>Alosa immaculata</i>	B	0.14
Clupeidae	<i>Sardina pilchardus</i>	B	35.59
Clupeidae	<i>Sardinella aurita</i>	B	0.01
Clupeidae	<i>Sprattus sprattus</i>	B	106.35
Engraulidae	<i>Engraulis encrasicolus</i>	B	36.69
Gadidae	<i>Gadiculus argenteus</i>	D	0.01
Gadidae	<i>Merlangius merlangus</i>	T	72.68
Gadidae	<i>Micromesistius poutassou</i>	T	0.14
Gadidae	<i>Trisopterus minutus</i>	T	0.01
Lotidae	<i>Gaidropsarus biscayensis</i>	T	0.14
Merluccidae	<i>Merluccius merluccius</i>	T	71.72
Lophiidae	<i>Lophius budegassa</i>	T	12.92
Atherinidae	<i>Atherina boyeri</i>	B	0.14
Zeidae	<i>Zeus faber</i>	T	11.54
Syngnathidae	<i>Syngnathus acus</i>	D	0.14
Scorpaenidae	<i>Scorpaena porcus</i>	B	0.27
Scorpaenidae	<i>Scorpaena scrofa</i>	B	0.01
Triglidae	<i>Eutrigla gurnardus</i>	T	1.51
Triglidae	<i>Chelidonichthys lucerna</i>	T	15.66
Triglidae	<i>Chelidonichthys lastoviza</i>	T	0.14
Triglidae	<i>Lepidotrigla cavillone</i>	D	0.82
Triglidae	<i>Trigla lyra</i>	T	8.52
Serranidae	<i>Serranus cabrilla</i>	D	0.01
Serranidae	<i>Serranus hepatus</i>	D	28.72

Pomatomidae	<i>Pomatomus saltatrix</i>	B	19.24
Carangidae	<i>Trachurus mediterraneus</i>	B	36.27
Carangidae	<i>Trachurus trachurus</i>	B	841.16
Sparidae	<i>Diplodus annularis</i>	B	0.55
Sparidae	<i>Diplodus vulgaris</i>	B	0.01
Sparidae	<i>Boops boops</i>	B	1.24
Sparidae	<i>Pagellus acarne</i>	B	0.01
Sparidae	<i>Pagellus erythrinus</i>	B	0.41
Centracanthidae	<i>Spicara maena</i>	B	3.85
Centracanthidae	<i>Spicara smaris</i>	B	0.82
Sciaenidae	<i>Umbrina cirrosa</i>	T	0.96
Mullidae	<i>Mullus barbatus barbatus</i>	T	0.27
Mullidae	<i>Mullus surmuletus</i>	T	10.17
Cepolidae	<i>Cepola macrophthalma</i>	D	0.14
Labridae	<i>Symphodus cinereus</i>	D	0.01
Labridae	<i>Symphodus rostratus</i>	D	0.01
Trachinidae	<i>Trachinus draco</i>	D	0.06
Uranoscopidae	<i>Uranoscopus scaber</i>	D	1.37
Blenniidae	<i>Blennius ocellaris</i>	D	7.01
Callionymidae	<i>Callionymus lyra</i>	D	0.69
Callionymidae	<i>Callionymus maculatus</i>	D	0.01
Gobiidae	<i>Gobius niger</i>	D	1.65
Gobiidae	<i>Lesueurigobius friesii</i>	D	1.10
Scombridae	<i>Scomber japonicus</i>	B	0.14
Scombridae	<i>Scomber scombrus</i>	B	0.01
Citharidae	<i>Citharus linguatula</i>	T	1.65
Scophthalmidae	<i>Scophthalmus maeoticus</i>	T	1.10
Scophthalmidae	<i>Lepidorhombus boscii</i>	T	0.41
Bothidae	<i>Arnoglossus kessleri</i>	D	1.24
Bothidae	<i>Arnoglossus laterna</i>	D	0.14
Bothidae	<i>Arnoglossus imperialis</i>	D	0.01
Pleuronectidae	<i>Platichthys flesus</i>	T	0.14
Soleidae	<i>Solea solea</i>	T	1.37
Soleidae	<i>Microchirus variegatus</i>	D	0.01
Soleidae	<i>Buglossidium luteum</i>	D	0.01
Total			1559.63

The CPUE values for demersal fish species were shown in Figure 2. *M. mustelus*, *R. clavata*, *M. merluccius* and *M. merlangius* were the most abundant species with CPUE values higher than 70 kg/km². Also *D. pastinaca* and *Serranus hepatus* had CPUE values higher than 25 kg/km². The remaining 55 demersal species had relatively low CPUE values and their collective CPUE value was 119 kg/km².

Variations of CPUE (kg/km²) with respect to depth contour are given in Table 3. In terms of cartilaginous species, *Hexanhus griseus*, *Mustelus asterias* and *Squalus acanthias* had maximum CPUE values at depths between 100-200 m. In contrast, *M. mustelus*, *R. clavata* and *D. pastinaca* had higher CPUE between 20 -50 m. The minimum CPUE values for cartilaginous species were between 50 - 100 m.

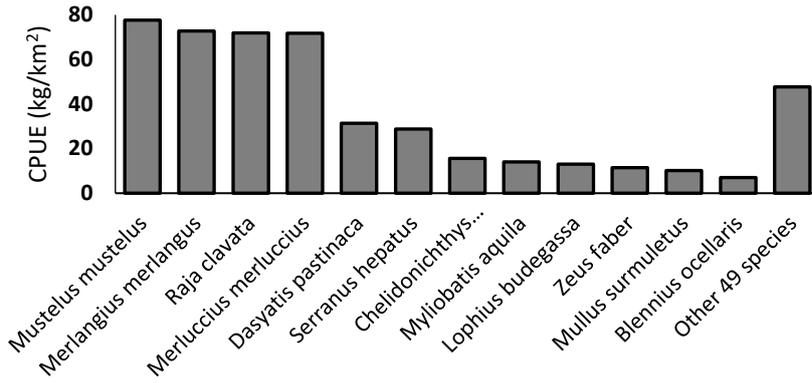


Figure 2. Mean CPUE (kg/km²) values of demersal fish species in the Sea of Marmara, Turkey

Table 3. Mean CPUE (kg/km²) variations of the demersal fish species in the Sea of Marmara, Turkey, depending on the depth contour

Depth	20-50 m	50-100 m	100-200 m
Teleost Species	CPUE (kg/km²)		
<i>Merluccius merluccius</i>	18.14	68.74	137.76
<i>Mullus barbatus barbatus</i>	0	0.55	0
<i>Lepidorhombus boscii</i>	0.14	0.55	1.1
<i>Solea solea</i>	1.52	1.24	0.96
<i>Zeus faber</i>	3.86	6.75	69.01
<i>Lophius budegassa</i>	9.23	12.95	24.93
<i>Scophthalmus maeticus</i>	1.52	1.24	0
<i>Citharus linguatula</i>	0.69	1.79	3.72
<i>Chelidonichthys lucerna</i>	22.87	14.46	3.17
<i>Trigla lyra</i>	0.14	3.99	65.84
<i>Merlangius merlangus</i>	220.8	21.9	4.82
<i>Mullus surmuletus</i>	20.25	7.58	0
All Teleost Species	118.46	103.58	82.23
Elasmobranch Species			
<i>Mustelus mustelus</i>	252.48	5.51	11.16
<i>Mustelus asterias</i>	0	0	39.26
<i>Hexanchus griseus</i>	0	0.14	29.89
<i>Myliobatis aquila</i>	15.98	15.15	1.1
<i>Raja clavata</i>	127.41	51.1	59.09
<i>Oxynotus centrina</i>	1.52	1.52	3.17
<i>Torpedo marmorata</i>	2.48	1.24	2.07
<i>Dasyatis pastinaca</i>	43.25	31.13	0
<i>Scyliorhinus canicula</i>	2.34	4.68	8.54
<i>Scyliorhinus stellaris</i>	0.83	0.83	0.69
<i>Squatina squatina</i>	17.49	0	0
<i>Squalus acanthias</i>	0	1.24	56.48
All Elasmobranch Species	38.71	8.95	16.8
Crustacea Species			
<i>Parapenaeus longirostris</i>	7.02	94.22	173.01
Other invertebrata species	511.03	640.79	1037.63

In teleosts, bycatch and discard rates were higher at shallower waters. CPUE values of different species varied at different depths. *M.merlangus*, *C. lucerna* and *Mullus surmuletus* were abundant between 20-50 m whereas *M. merluccius*, *Zeus faber*, *Lophius budegassa* and *Trigla lyra* reached their maximum CPUE at 100-200 m. In addition, *Mullus barbatus* was seen only between 50-100 m and had relatively wlower CPUE. The seasonal variations of CPUE were summarized in Table 4. The CPUE of target fish species were highest in the summer and lowest in the spring. Besides CPUE of bycatch and discard species were lowest in the winter and highest in the autumn. The proportion of the target rate to discard rate was lowest in autumn (Table 4).

The number of species with respect to depth contour, locaton and season are given in Table 5. The highest species number were observed in autumn but species number were lowest in summer. For both teleosts and cartilaginous fishes, number of species showed significant differences in different seasons. (For teleosts; df=3; F=64.04; p<0.05 and for cartilaginous fishesdf=3; F=11.01; p<0.05).

Tukey’s test showed that teleost species showed differences between winter and spring, winter and autumn, spring and summer, and summer and autumn. Cartilaginous species, on the other hand, showed differences only between summer and autumn.

Table 4. Seasonal variations of the mean CPUE (kg/km²) of demersal fish species in the Sea of Marmara, Turkey

Season	CPUE (kg/km ²)				
	Spring	Summer	Autumn	Winter	
Cartilaginous Fish					
Hexanchidae	<i>Hexanchus griseus</i>	0	0	2.28	9.76
Scyliorhinidae	<i>Scyliorhinus stellaris</i>	3.02	0	0	0
Scyliorhinidae	<i>Scyliorhinus canicula</i>	4.26	4.26	3.16	5.77
Triakidae	<i>Mustelus mustelus</i>	16.76	7.01	262.98	26.38
Triakidae	<i>Mustelus asterias</i>	11.40	1.37	0.14	0.14
Oxynotidae	<i>Oxynotus centrina</i>	3.71	1.10	20.20	20.74
Squalidae	<i>Squalus acanthias</i>	0.00	24.60	20.20	1.65
Squatinaidae	<i>Squatina squatina</i>	0.00	0.00	16.90	0.00
Torpedinidae	<i>Torpedo marmorata</i>	4.12	0.55	1.37	0.14
Rajidae	<i>Raja clavata</i>	14.02	45.75	83.26	25.14
Dasyatidae	<i>Dasyatis pastinaca</i>	77.22	8.79	10.72	30.09
Myliobatidae	<i>Myliobatis aquila</i>	21.30	0.00	28.85	6.73
Total		157.46	70.49	428.28	107.17
Teleosteans					
Gadidae	<i>Merlangius merlangus</i>	16.35	180.41	64.58	32.15
Merluccidae	<i>Merluccius merluccius</i>	65.68	56.75	61.97	103.87
Lophiidae	<i>Lophius budegassa</i>	13.47	10.44	10.72	17.59
Zeidae	<i>Zeus faber</i>	15.25	11.82	14.29	5.08
Triglidae	<i>Chelidonichthys lucerna</i>	20.34	15.94	13.33	13.60
Triglidae	<i>Trigla lyra</i>	8.34	5.91	14.29	5.36
Mullidae	<i>Mullusbarbatus barbatus</i>	0.28	0.00	0.96	0.00
Mullidae	<i>Mullus surmuletus</i>	12.50	2.20	11.82	14.70
Citharidae	<i>Citharus linguatula</i>	2.34	1.37	1.79	1.37
Scophthalmidae	<i>Scophthalmus maeoticus</i>	1.24	0.00	0.28	3.02
Scophthalmidae	<i>Lepidorhombus boscii</i>	0.69	0.28	0.28	0.55
Soleidae	<i>Solea solea</i>	2.20	1.24	1.37	0.55
Target		160.07	286.20	195.52	197.86
Bycatch Fish Species		1134.92	1244.84	1312.17	692.50
Discard Fish Species		205.83	154.30	462.63	138.77
Proportion of Target/Discard		0.78	1.85	0.42	1.43
Proportion of Target/Bycatch		0.14	0.23	0.15	0.29

Table 5. Species number of the trawl catch composition in the Sea of Marmara, Turkey and variations according to season, area and depth contour

Species Number	Teleost	Cartilaginous	Total
Winter	46	8	54
Spring	51	10	61
Summer	45	6	51
Autumn	54	11	65
Northeastern	43	8	51
Southeastern	44	7	51
Southwestern	54	12	66
Northwestern	46	11	57
>100 m	31	11	42
50-100	48	11	59
20-50	53	9	62
Total	61	12	73

In terms of location, western part of the Sea of Marmara had higher species number than the eastern part. The difference in species number were statistically significant among locations for both

teleosts (df=3; F=23.04; p<0.05) and cartilaginous fish species (df=3; 15.42; p<0.05). Tukey test results for teleosts and cartilaginous fish species are given in Table 6 7, respectively.

Table 6. Tukey test results for geographical variations of teleost fish species number in the Sea of Marmara

	Northeastern	Southeastern	Southwestern	Northwestern
Northeastern		0,4835	0,0002307	0,0002306
Southeastern	2,112		0,000231	0,0002306
Southwestern	20,93	18,82		0,0002306
Northwestern	295	297,1	315,9	

Table 7. Tukey test results for geographical variations of cartilaginous fish species number in the Sea of Marmara

	Northeastern	Southeastern	Southwestern	Northwestern
Northeastern		0,5041	0,01004	0,03531
Southeastern	2,056		0,001876	0,005307
Southwestern	6,214	8,27		0,7848
Northwestern	4,883	6,94	1,331	

With regard to depth, it was observed that the number of teleost species decreased with increasing depth. The difference of species number were found statistically important between the depth contour (df=2; F=400.5; p<0.05) for teleost fish whereas the difference of species number were not found statistically important between the depth contour (df=2; F=4.209; p>0.05) for cartilaginous fish.

According to Tukey test the teleost fish species number were showed differences between 20-50 m contour and >100 m contour and 50-100 m contour and >100 m contour.

Species diversity and richness were evaluated with biodiversity indices. The dominance index was determined highest in the winter. This dominance

was mostly stemmed from *T.trachurus* (90% of the total catch). Inherently, the minimum Shannon_H value was observed in the winter. The major demersal representatives were *Serranus hepatus* (2.3%) and *M. merlangus* (1.1.%) in the winter.

Although maximum species number was observed in an autumn. the highest biodiversity indice was determined in the Spring. The minimum dominancy was determined in an autumn (Table 8).

Table 8. Biodiversity indices and seasonal variations of the trawl catch composition in the Sea of Marmara. Turkey

	Spring	Summer	Autumn	Winter
Taxa_S	61	55	65	56
Individuals	210463	369000	242423	224835
Dominance_D	0.4618	0.4896	0.3973	0.7971
Simpson_1-D	0.5382	0.5104	0.6027	0.2029
Shannon_H	1.312	1.133	1.302	0.6089
Margalef	4.895	4.213	5.162	4.463

Discussion

A great majority of the total CPUE (kg/km²) consists small pelagic fish species such as *E. encrasicolus*, *T. trachurus*, *T. mediterraneus* and *S. sprattus* which are defined as pelagic and neritic fish species (Riede, 2004). Small pelagics have well established stocks in the Sea of Marmara and they are known to use the Sea of Marmara as a spawning area (Demirel et al., 2007). The trawl catch composition in this study involved ten pelagic teleost fish species. In addition, these ten species constituted 93% of the total catch in number and composed 75% of the mean CPUE (kg/km²). This uncommon catch rate of pelagic fish species in trawl catch composition may be due to the technical properties of the trawl equipment. According to MEDITS technical properties the trawl net that was used in this study had higher mouth opening than commercial trawls in Turkey.

The best represented demersal fish species were *M. mustelus*, *R. clavata*, *M. merlangus* and *M. merluccius*. These 4 fish species constituted 61% of the total CPUE (kg/km²). Among them *R. clavata* and *M. mustelus* rank as near threatened and vulnerable in the IUCN Red List. Relatively higher CPUE values of these species is encouraging in terms of their threat status and conservation. In contrast, some economically important demersal fish species had lower CPUE values than expected. For instance, *M. barbatus*, *M. surmuletus*, *L. piscatorius* and *L. budegassa* which are important representatives of demersal economic fish species had relatively lower CPUE values. Gözenç et al. (1997) found that the most abundant demersal fish species was *M. merluccius* with a 56% of the total demersal teleost fish and had 425 kg/km² mean CPUE. In the present study, *M. merluccius* was one of the most abundant demersal fish species corresponding to 30% of the total demersal teleost fish catch and 71.78 kg/km²

mean CPUE. Gözenç et al. (1997) reported that *M. merlangius* was the second most abundant demersal fish species corresponding to 18% of total demersal teleost fish and had 93.6 kg/km² mean CPUE. *M. merlangius* was found the most abundant teleost demersal fish species in our study with a 32.9% of the total teleost demersal fish species and 72.74 kg/km² mean CPUE. *M. barbatus* was reported as the third abundant demersal teleost fish species with a 34.5 kg/km² mean CPUE by Gözenç et al. (1997). However, in the present study, *M. barbatus* had relatively lower CPUE (0.27 kg/km²). Gözenç et al. (1997) determined the CPUE of *C. lucerna*, *T. lyra*, *S. solea* and *S. maeoticus* as 46.9 kg/km², 42.2 kg/km², 8.5 kg/km² and 6.2 kg/km², respectively. In this study, the CPUE of these species were found as 15.66 kg/km², 8.5 kg/km², 1.4 kg/km² and 1.2 kg/km², respectively. These results clearly show that the demersal teleost fish stocks in the Sea of Marmara decreased critically over the last two decades. Earlier reports of CPUE reported for *M. barbatus* from other localities were 75.86 kg/km² in the Edremit Bay, 391.4 kg/km² in Saros Bay, Northern Aegean Sea (Ünlüoğlu et al., 2008; İşmen et al., 2010), 4.179 kg/km² in Mersin Bay, Northeastern Mediterranean (Gökçe et al., 2016) and 3.11 kg/km² in the Karataş Coast, Northeastern Mediterranean (Çiçek et al., 2014). In the present study, a mean CPUE value of 0.27 kg/km² was found for *M. barbatus* in the Sea of Marmara. High fishing pressure from beam trawls and nutritional competition may be considered to create difficulties on their sustainability in the Sea of Marmara.

Overall, 13.6% of the total CPUE originated from target fish species. The highest CPUE value was obtained from bycatch (69.5%) fish. CPUE of discard species was 16.9% of the total CPUE and corresponded to 45.2% of the total species number. Similarly, the bycatch and discard rate of the total

catch in weight from the Black Sea coasts of the Turkey was 54% and 42%, respectively (Ceylan et al., 2013). Relatively a higher bycatch rate of 62% from bottom trawls was reported by Kasapoglu and Duzgunes (2017) in the Black Sea. Bycatch and discard abundance with respect to depth showed some variations; the bycatch and discard ratios of teleost fishes were higher in shallower waters. Since beam trawls are extensively used for deepwater rose shrimp (*Parapenaeus longirostris*) and they are highly efficient at depths shallower than 100 m, high discard rate of beam trawls is an important problem that can affect abundance of non-target species and other commercially important species such as *M.merlangus*, *M.surmuletus* and *C.lucerna* in the Sea of Marmara. In the present study, The highest discard ratio was observed in autumn and highest target ratio was in summer. Beside the lowest target to discard ratio was seen in Autumn. This case may related to open and closed fishing season (April to August) in the Sea of Marmara.

The species richness showed significant differences among locations. The Western Sea of Marmara had higher species richness values than the Eastern part. The Southwestern part showed great differences from other areas and was characterized by a higher species richness value. The Kapıdağ Peninsula harbors a total of 14 islands which may play an important role as shelter for many species of fish. Altug et al. (2011) reported 43 fish species at depths between 45-73 m whereas Eryılmaz (2001) reported 49 teleost fish species using a bottom trawl in the Southwestern part of the Sea of Marmara. In this study, 61 teleosts and 12 cartilaginous fish species were reported from the Southwestern Sea of Marmara. Torcu Koç et al. (2012) described 31 fish species using a beam trawl from 10 stations in the Sea of Marmara. The lower species richness in the study of Torcu Koç et al. (2012) may be due to the limited operational depth range of beam trawls. However, in the present study, higher teleost fish species richness was found with increasing depth. Yıldız and Karakulak (2017) detected 22 teleost and 3 chondrichthyes species at depths between 20-50 m and 16 teleost and 3 chondrichthyes species from 50-100 m in the western Black Sea. The lower biodiversity of the Black Sea is a factor of lower salinity and the presence of anoxic zone below 200 m which is considered as the world's largest anoxic marine area (Sorokin, 1983).

In the present study, data indicated that the Northeastern part of the Sea of Marmara had lower richness values. Industrial and domestic pollution in this region is relatively higher than other parts of the Sea of Marmara and is the major factor for the observed lower richness values. Maximum dominancy and minimum species richness were observed in the winter. The observed results were due to the presence of *T. trachurus* which dominated

(90%) the total catch in the winter. The lower temperature values in the water column is a major factor that affects small pelagic fish distribution as many fish species avoid lower temperature zones associated with surface waters in the winter.

Commercial fisheries of all cartilaginous fish species is restricted in Turkish waters. It was observed that the Northwestern and the Southwestern parts of the Sea of Marmara and areas with a depth >50 m are vital areas for the sustainability of these species, in particular *M.mustelus*, *R.clavata* and *D.pastinaca* which ranked among top 5 demersal fish species in terms of biomass. Altug et al. (2011) found 5 species of the Rajidae in this region. However, relatively lower species richness of the Rajidae family in this study may be due to their shallower distribution. Since commercial trawling is banned in the Sea of Marmara, beam trawl fisheries is the major threat for Rajidae and other cartilaginous species that prefer shallow waters. Tighter regulations against illegal trade of cartilaginous fish is critical and will increase their release rates when they are caught as bycatch by the beam trawlers.

In summary, the protocol of MEDITS used in this study will allow making comparisons in the abundance of demersal macrofauna species with the results of other studies in this region or other parts of the Mediterranean. Results indicated that the mean CPUE of economical demersal fishes decreased dramatically over the last two decades. Although the trawl fisheries is banned in the Sea of Marmara, high fishing pressure by extensive use of beam trawls negatively affect the benthic life. The southwestern part of the Sea of Marmara is very important in terms of species richness and further protective measures should be enforced to combat illegal trawling in this area.

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Conflict of interest

The authors declare that they have no conflict of interest.

Authors' contributions

A. İşmen and M. Şirin planned and designed the research. İ. B. Daban wrote the article. M. Arslan İhsanoğlu, B. Daban and C. Ç. Yığın collected and analysed the data. All authors contributed to writing of the final manuscript.

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