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Spatio-temporal density of the demersal Chondrichthyes assemblage in an upper bathyal of the eastern Mediterranean Sea

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Abstract

Chondrichthyans are a very important taxon that plays a top predator role in the trophic level of the food web, and species are particularly vulnerable to exploitation in the marine ecosystem. The deep waters of the eastern Mediterranean Sea have been less studied than the continental shelf, especially for the chondrichthyans. Therefore, the present study was conducted to investigate the spatio-temporal distribution of chondrichthyans collected monthly in eight different (200–900 m) depth strata during different periods (2010–2011 and 2019–2021) using an otter bottom trawl. A total of 17 species were identified in upper bathyal, composed of 6 batoids, 10 sharks, and one chimaera. The constant species (dominance: DO% > 50) in the study area were *Galeus melastomus*, *Scyliorhinus canicula*, *Etmopterus spinax*, and *Raja clavata*. The most abundant species was *E. spinax*, followed by *G. melastomus*. Fourteen and 15 species were caught during the first and the second survey, respectively. Biodiversity characteristics (number of species, abundance, and diversity indices) varied only with bottom depth. Two different depthwise assemblages were estimated along the bottom depth gradient; ≤ 500 m and > 500 m. The discriminator species were *R. clavata*, *S. canicula*, *G. melastomus*, *Dipturus oxyrinchus*, and *Squalus blainville* found on the upper slope and *E. spinax*, *G. melastomus*, and *Centrophorus cf. uyato* found on the lower slope. With our results, total number of demersal chondrichthyan species found in the bottom (bathyal and continental shelf) of Antalya Bay was reached to 26 species.

Keywords Abundance · Commercial bottom trawling · By-catch · Sharks · Batoids · Antalya Bay

Introduction

Chondrichthyans are widely regarded as one of the most vulnerable species, even in the face of low fishing pressure (Ragonese et al. 2013). This vulnerability is due to their biological characteristics including slow growth, late maturation, low fecundity and productivity, and long gestation periods (Peristeraki et al. 2020). These factors contribute their susceptibility to population declines, despite their high natural survivorship in all age classes, long life span, and role as top predators in the trophic food web (Galván-Magaña et al. 2019). The Mediterranean Sea is recognised as a basin rich in chondrichthyan species with a total of 88 species (Serena et al. 2020) of which at least 53% of them are at risk of extinction, which require urgent action to conserve their populations and habitats (Dulvy et al. 2016).

In the last two decades, numerous studies have been published on the distribution and abundance of demersal chondrichthyan assemblages in the western (e.g. Moranta et al. 2008; Guijarro et al. 2012; Cartes et al. 2013; Barría et al. 2015; Ramírez-Amaro et al. 2015, 2020), the central (e.g. Sion et al. 2004; Bottari et al. 2014; Ragonese et al. 2013; Marongiu et al. 2017), and the eastern Mediterranean (e.g. Maravelias et al. 2012; Tserpes et al. 2013). In addition, other specific studies have been carried out on a broad Mediterranean scale, including different geographical sub-areas (Follesa et al. 2019; Serena et al. 2020; Ruiz-García et al. 2023) using data from the Mediterranean International Trawl Survey (MEDITS, Bertrand et al., 2002). However, in Turkish Mediterranean waters (GSA 24), current species-based studies have mainly focused on length–weight relationships (e.g. İşmen et al. 2009; Güven et al. 2012), population dynamics (e.g. Özütemiz et al. 2009; Özcan and Başusta

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2018), stomach contents (e. g. Özcan and Başusta 2015; Bengil et al. 2018), discards (Deval et al. 2016), and post-release survival (Saygu and Deval 2014), and there is still a lack of comprehensive information on deep chondrichthyan assemblages in GSA 24 of the eastern Mediterranean Sea. In addition, over the last three decades, deep-water trawl fisheries have developed off the southern coasts of Turkey, exploiting deep-water red shrimp (*Aristaeomorpha foliacea* and *Aristeus antennatus*) resources that could be nutritionally utilised by chondrichthyans (Deval et al. 2016; Deval 2020a). The commercial importance of these shrimp species, together with more than 15 other commercially exploited by-catch species (crustaceans, cephalopods and fish species), has led to increased interest in deep-water resources (Deval et al. 2009; Deval and Kapiris 2016). In this multi-species fishery conducted along a bathyal part from the upper slope down to a depth of 750 m in the Antalya Bay (the eastern Mediterranean Sea), chondrichthyans make up a significant proportion of the by-catch. The most commonly discarded elasmobranch species are *Etmopterus spinax*, *Dipturus oxyrinchus*, *Scyliorhinus canicula*, *Galeus melastomus*, and *Raja clavata* (Deval et al. 2016).

The spatio-temporal density and ecology of chondrichthyan assemblages on the continental shelf of Antalya Bay (a part of GSA 24), which is one of the low-diversified regions in regard to the chondrichthyans (Coll et al. 2010), have recently been studied by Mutlu et al. (2022a, b). Therefore, the present study area is very important stating the chondrichthyan diversity. The aim of the present study is to provide a continuity of the recent coastal studies by focusing on the spatial (depth) and temporal (two different periods) qualitative and quantitative distribution, diversities, and assemblages of demersal chondrichthyans found at the greater depths in an upper part of the Turkish Mediterranean bathyal that has not yet been studied for these species.

Material and methods

Demersal chondrichthyans were sampled during two scientific surveys conducted in the slope in the Antalya Bay (Eastern Mediterranean; Geographical Sub-Area, GSA 24) by the R/V 'Akdeniz Su' (26.5 m, 160 GRT, 670 kW) (Fig. 1). The first survey (S1) took place between July 2010 and June 2011 and sampled the eight bathymetric layers (between 200 and 900 m). The second survey (S2) was carried out between November 2019 and January 2021in six depth layers (between 200 and 700 m). A standard otter trawl with a polyethylene codend and a polyamide codend-cover with a stretch mesh size of 24 mm was used in 122 successful hauls for a total trawling time of 157.8 h. The towing time varied from 60 to 300 min depending on the bottom structure, with an average speed of 2.6 knots. The number of hauls per survey is shown in Table 1.

Chondrichthyans from each haul were sorted out and the number of individuals (n) for each species was counted. Female (F) and male (M) specimens were distinguished (for the first survey only) by the presence or absence of claspers, and their total length (TL) was measured in 0.1 cm on board and then released to the sea. Individuals of the seven species

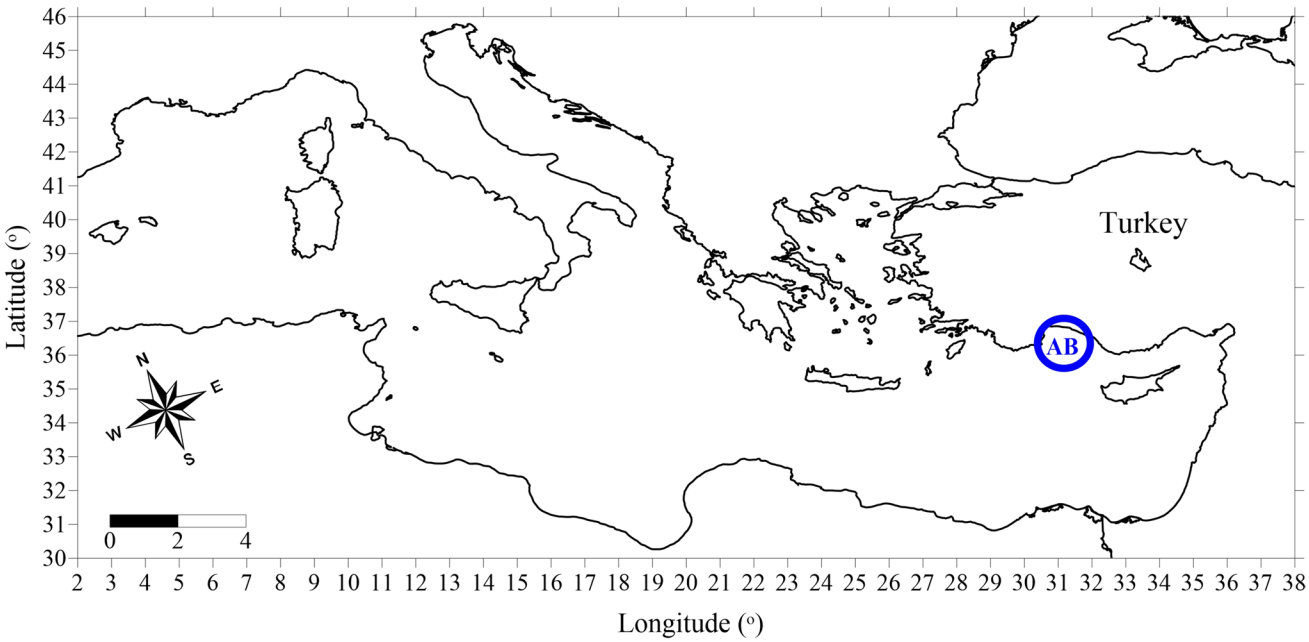


Fig. 1 Study area in Antalya Bay (AB), Turkey (blue circle indicates the study area, and the unit of the scale is the degree)

Table 1 Number of experimental bottom trawl hauls analysed by both survey and their depth stratums, the list of sampled Chondrichthyes species and spatial distributions of their pooled density (D_{TOT}, n/km^2) in the bathyal ground off Antalya Bay (*MaxL of JUV* approximately maximum length of juveniles, *MinL of MAT* approximately minimum length of matures, *N* number of individuals, *DO%* % of positive hauls of all hauls, *FO%* frequency of occurrence, *NO%* numerical occurrence, *ne* not estimated, *MRR* Mediterranean Regional Red List, *CR* critically endangered, *VU* vulnerable, *NT* near threatened, *LC* least concern, *DD* data deficient), * denotes that the fishing of the species is prohibited according to Turkish fisheries regulation)

	MRR	MaxL of JUV	MinL of MAT					D_{TOT}							
					Soyer's indexes			Upper slope			Middle slope				
Species				*N*	DO%	FO%	NO%	200	300	400	500	600	700	800	900
Dasyatis pastinaca (Linnaeus, 1758)	VU			2	0.8	0.2	0.01	1.5	-	-	-	-	-	-	
Raja miraletus Linnaeus, 1758	LC			7	5.8	1.6	0.01	5.2	-	-	-	-	-	-	
Torpedo marmorata Risso, 1810	LC			3	2.5	0.7	0.02	1.6	0.9	-	-	-	-	-	
Leucoraja circularis (Couch, 1838)	CR			1	0.8	0.2	0.01	-	-	0.1	-	-	-	-	
Raja clavata Linnaeus, 1758*	NT	≤30[11]	≥50[11]	1269	52.9	14.2	6.6	365	310	122	7.2	-	-	-	
Dipturus oxyrinchus (Linnaeus, 1758)	NT	≤30[2]	≥50[2]	129	35.5	9.9	0.7	26	33	18	3.7	0.5	-	-	
Mustelus mustelus (Linnaeus, 1758)	VU			2	0.8	0.2	0.01	2.0	-	-	-	-	-	-	
Squatina aculeata Cuvier, 1829*	CR			3	2.5	0.7	0.07	0.8	0.7	0.5	-	-	-	-	
Scyliorhinus canicula (Linnaeus, 1758)	LC	≤20[10]	≥34[3]	1985	59.2	16.3	10.4	423	453	260	38	9.2	-	-	
Centrophorus cf. uyato (Rafinesque, 1810)	CR	≤50[12]	≥70[1]	76	25.6	7.1	0.4	1	1.4	14	11	7.1	2.8	9.6	
Oxynotus centrina (Linnaeus, 1758)*	CR			8	5.8	1.1	0.04	-	1.3	1.0	-	1.4	-	-	
Etmopterus spinax (Linnaeus, 1758)	LC	≤17[9]	≥30[4]	12,747	54.2	14.9	66.5	-	154	1782	2475	167	43	48	
Galeus melastomus Rafinesque, 1810	LC	≤25[8]	≥45[5]	2598	66.7	18.4	13.6	-	197	722	159	85	135	253	
Squalus blainville (Risso, 1827)*	DD	≤30[7]	≥50[6]	317	35.0	9.7	1.7	3.0	27	92	15	3.0	-	-	
Dalatias licha (Bonnaterre, 1788)	VU			7	4.1	1.1	0.04	-	-	0.9	0.6	0.3	2.0	1.5	
Heptranchias perlo (Bonnaterre, 1788)	DD			18	6.6	1.8	0.1	-	-	6.6	1.4	-	-	-	
Chimaera monstrosa Linnaeus, 1758	NT			3	2.5	0.7	0.02	-	-	-	0.8	0.9	-	-	
Survey 1: 2010–2011					Hauls =			12	12	15	14	14	12	7	1
					Total time (min) =			875	755	1740	1415	1490	755	435	60
					Swept area (km^2) =			1.133	1.029	2.276	1.807	1.766	0.958	0.512	0.085
Survey 2: 2019–2021					Hauls =			4	6	14	4	4	1		
					Total time (min) =			220	310	770	225	345	60		
					Swept area (km^2) =			0.294	0.439	1.041	0.287	0.458	0.078		

[1]McLaughlin and Morrissey (2005), [2]Last et al. (2016), [3]Mnasri-Sioudi et al. (2014), [4]Porcu et al. (2015), [5]Ragonese et al. (2009), [6]Bonnici et al. (2018), [7]Kousteni and Megalofonou (2011), [8]Rey et al. (2004), [9]Gennari and Scacco (2007), [10]Carlucci et al. (2010), [11]Greenway et al. (2016), [12]Cotton et al. (2015)

were classified as juveniles and matures based on size limits (Table 1), and individuals between these size limits were considered as adults.

The sex ratio (SR) was calculated as $= F/(F+M)$. The χ^2 test was used to assess the dominance of females. To standardise the data from both surveys, total density indices (D_{TOT}, n/km^2) were calculated for each haul using ATrIS software (Gramolini et al. 2005). The preferred depth of juveniles (D_{JUV}, number of juveniles/km^2) and matures (D_{MAT}, number of adults/km^2) of these selected species was determined by calculating the density indices (n/km^2) of each haul and each depth stratum. The null hypothesis of no difference and significant correlation in density indices (D_{TOT}, D_{JUV}, D_{MAT}), SR, and TL values of seven species among depth strata was tested using one-way analysis of variance (ANOVA) and non-parametric Spearman's 'rho' correlation, respectively. Bray Curtis similarity-based three-way PERMANOVA (PERmutational Multivariate ANalaysis Of Variance) tests of log10-transformed density (D_{TOT}) of Chondrichthyes assemblage species for differences among the factors designed at an order of level with survey (fixed), season (fixed), and depth stratums (random) were performed using a method of permutation of residuals under a reduced model PRIMER 6 and PERMANOVA + software (Clarke and Gorley 2006). Number of permutations was set to 999 at the test. To describe the spatio-temporal distribution of fish assemblages, non-parametric multidimensional scaling (nMDS) was applied to the Bray–Curtis similarity matrix of $\log_{10}$-transformed density (D_{TOT}). Differences in fish densities for different sampling surveys, seasons, and bottom depths were then tested using one-way analysis of similarities (ANOSIM). Similarly, a percentage similarity analysis (SIMPER) was applied to the density in order to determine the contributor species within the factors and the discriminator species between the factors. nMDS ordination, Bray–Curtis similarity matrix, ANOSIM, and SIMPER analyses were also performed using PRIMER 6 & PERMANOVA + software.

Soyer's dominance index (DO%: < 25 is rare, 25–50 common, and > 50 constant species), frequency of occurrence (FO%), and numerical occurrence (NO%) were calculated to determine the consistency of the presence of Chondrichthyes species (Soyer 1970). The biodiversity characteristics (number of species: *S*, density: *N*, Margalef's richness index: *d*, Pielou's evenness index: *J′*, and Shannon-Weiner diversity index: *H′*) of the assemblages were determined using PRIMER software. The null hypothesis of no difference in biodiversity characteristics between strata, seasons, and surveys was tested by two-way multivariate analysis of variance (MANOVA) using SPSS 21.0 (Anderson et al. 2008).

The spatial distribution of the density indices of the species and the biodiversity characteristics of the Chondrichthyes assemblage were mapped using ordinary kriging as the geostatistical gridding method of Surfer 13.0 (Golden Software, Inc.).

Results

A total of 17 species from 14 families composed of 10 sharks, 6 batoids, and one chimaera was collected in the 121 hauls (Table 1). During both surveys, 14 and 15 species were caught, respectively. Chondrichthyans were found in 93.3% of the 121 hauls, totalling 19,170 individuals. Four species (*Dasyatis pastinaca*, *Dalatias licha*, *Mustelus mustelus*, and *Torpedo marmorata*) are listed as vulnerable (VU) and another four (*Centrophorus cf. uyato*, *Leucoraja circularis*, *Oxynotus centrina* and *Squatina aculeata*) as critically endangered (CR) according to the Mediterranean Regional Red List (MRR). Table 1 provides a taxonomic list, bathymetric range, and number of hauls in which each species was found, as well as the total number of individuals caught and their total density. The 3-way PERMANOVA test showed a significant difference in density of Chondrichthyes between depth strata ($p < 0.05$), while the test showed no significant effect of season, survey or interaction of season, depth and survey (Table 2).

Biodiversity characteristics

The distribution of the number of species (*S*) and diversity indices (*d*, *J′*, and *H′*) per individual haul is shown in Fig. 2, and two-way MANOVA showed that only depth had a significant effect ($p < 0.05$) on these indices (except for Pielou's evenness) (Table 3). A clearly defined hotspot of species richness was found around the centre of the study area (Fig. 2a). The maximum number of species (*S*) per haul was 7 in a few hauls at depths of 400 and 500 m. The faunistic

Table 2 Results of PERMANOVA test of $\log_{10}$-transformed density (D_{TOT}) of individual hauls for the Chondrichthyes species for the differences among survey (model; fixed), season (fixed), and bottom depths (random). Bold *p* values denote significant difference in sources at $p < 0.05$

Source	*df*	SS	MS	Pseudo-*F*	*p*
Survey	1	1985.8	1985.8	1.412	0.230
Season	3	6246.5	2082.2	1.481	0.109
Stratum	7	80,948	11,564.0	8.225	**0.001**
Survey × season	3	4025.9	1342.0	0.954	0.490
Survey × stratum	5	5707.1	1141.4	0.812	0.678
Season × stratum	18	27,149	1508.3	1.073	0.344
Survey × season × stratum	8	12,272	1534.1	1.091	0.357
Res	75	1.0545^5	1406.0		
Total	120	3.0032^5			

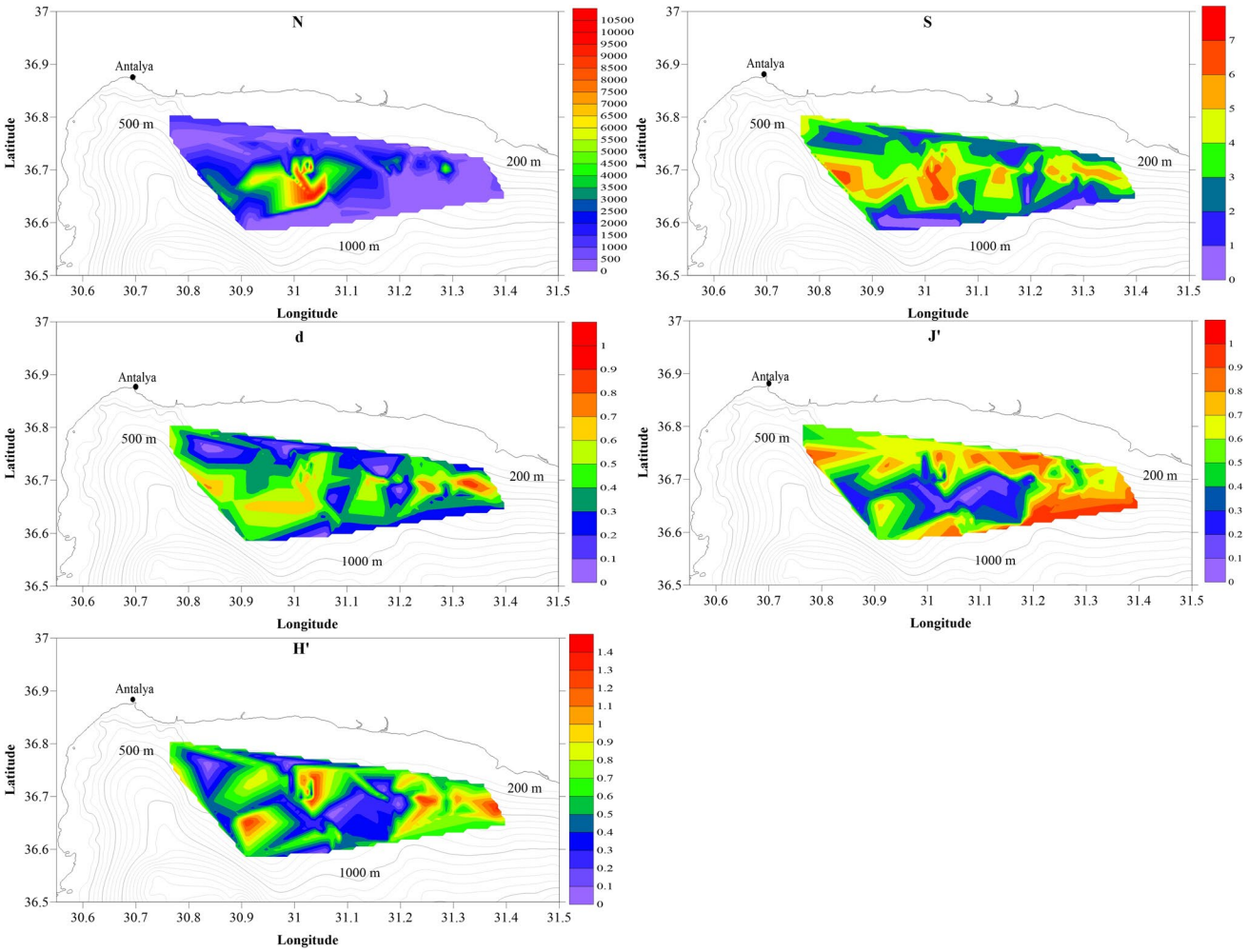


Fig. 2 The spatial modelling of the indicator's values of Chondrichthyes species according to distribution of individual haul in the Antalya Bay; **S** number of species; **d** Margalef's richness index; **H′** Shannon-Weiner diversity index; **J′** Pielou's evenness index

Table 3 Results of the significance level of the three-way MANOVA test of the faunistic characteristics of the Chondrichthyes assemblage structure in the whole study area (200–900 m) per depth stratum, season, and survey. Bold *p* values denote significant difference in sources at $p < 0.05$ (*S*, total species; *d*, species richness; *J′*, evenness; *H′*, diversity)

Source	*df*		*N*	*S*	*d*	*J′*	*H′*
Stratum	6	*F*	13.747	11.627	9.062	1.939	11.086
		p	**0.000**	**0.000**	**0.000**	0.088	**0.000**
Season	3	*F*	0.196	0.154	0.336	0.127	0.259
		p	0.899	0.927	0.799	0.944	0.855
Survey	1	*F*	1.916	3.065	2.967	1.000	2.375
		p	0.171	0.085	0.090	0.321	0.128
Stratum × season	18	*F*	0.810	0.865	0.975	1.411	1.123
		p	0.682	0.620	0.498	0.158	0.353
Stratum × survey	5	*F*	0.399	0.640	0.693	0.769	0.360
		p	0.848	0.670	0.631	0.575	0.874
Season × survey	3	*F*	1.356	1.793	1.600	0.244	1.715
		p	0.265	0.158	0.199	0.866	0.173
Stratum × season × survey	7	*F*	1.436	1.767	1.754	0.442	2.170
		p	0.207	0.110	0.113	0.872	0.049

Table 4 Faunistic characters (*N*, number of individuals; *S*, total species; *d*, species richness; *J′*, evenness; *H′*, diversity) of Chondrichthyes species according to depth stratums in the Antalya Bay (bold *p* value (Spearman's correlation) denotes significant difference among depth stratums at $p < 0.05$; *r*, correlation coefficient)

Stratum (m)	N/km^2	*S*	*d*	*J′*	*H′*
200	12,546	10	0.9537	0.4038	0.9298
300	18,445	10	0.9163	0.6253	1.4400
400	93,296	12	0.9612	0.4505	1.1190
500	45,091	10	0.8398	0.1780	0.4098
600	5265	9	0.9336	0.4497	0.9881
700	2401	5	0.5139	0.4389	0.7064
800	2105	4	0.3921	0.3870	0.5365
900	-	0	-	-	-
p =	0.442	**0.040**	0.052	0.432	0.215
r =	−0.679	−0.815	−0.750	−0.357	−0.536

characters according to depth strata were recalculated and presented in Table 4. While no Chondrichthyes species were caught in a single haul in the 900 m depth stratum, the highest number of species (12 species) were sampled in the 400 m stratum. Although all diversity indices showed negative correlations with depth, only the trend between species number and depth was statistically significant ($r = -0.265$, $p < 0.01$). Similar to species number, the highest richness (0.961) was recorded at 400 depth strata. Maximum values for both Pielou's evenness (0.625) and Shannon-Weiner diversity (1.440) were estimated at 300 m depth strata.

Composition of the chondrichthyan assemblage

Ecologically, the cluster (Fig. 3a) and MDS (Fig. 3b) analyses revealed the presence of two distinct bathymetric assemblages in the area: overall, (1) shallower than 500 m (upper slope) and (2) depths greater than to 500 m (middle slope).

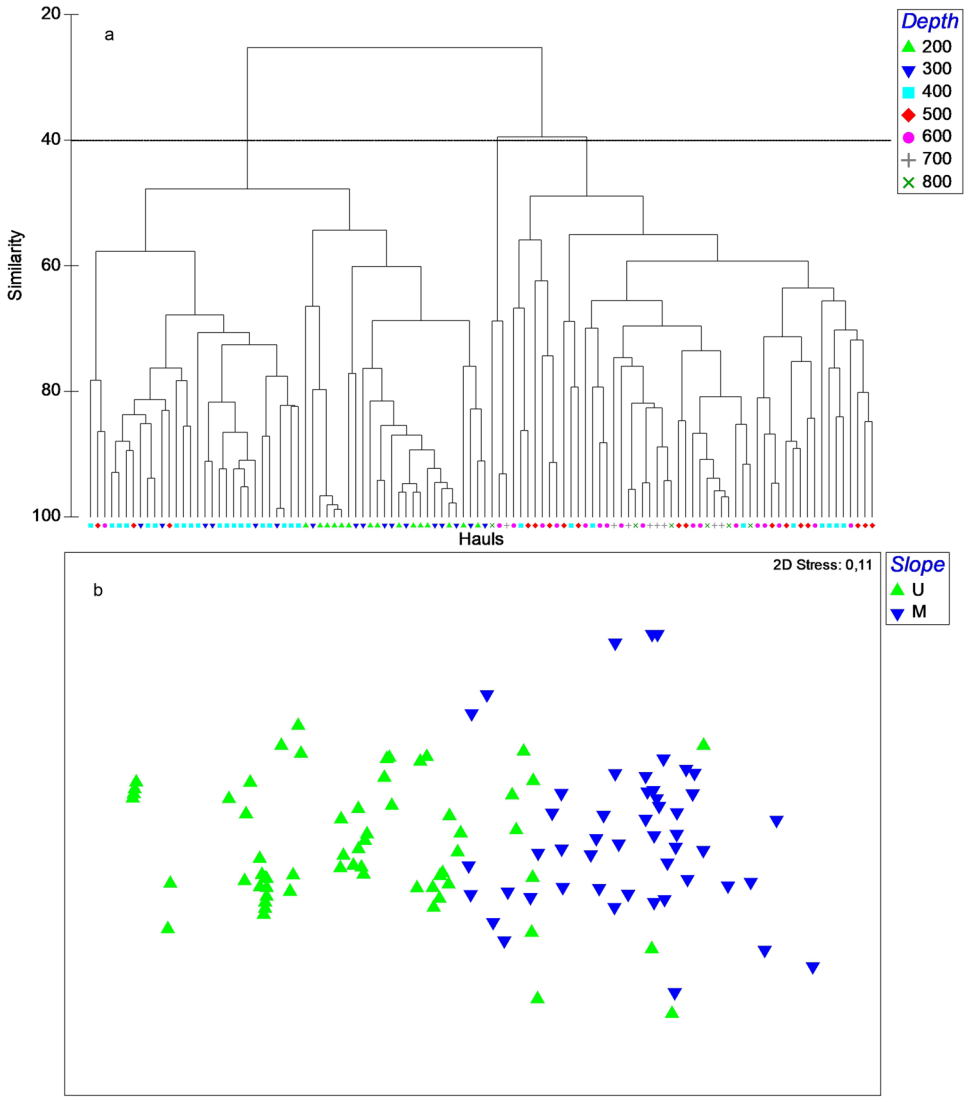


Fig. 3 **a** The cluster analyses among the sampling hauls (log10-transformed abundances) truncated at a similarity of 40% and classified by bottom depths; **b** non-metric multidimensional scaling ordination (nMDS) according to slopes

The ANOSIM test showed a significant dissimilarity in density only between the depth strata (ANOSIM test: Global $R = 0.473$; $p < 0.01$).

However, it was somehow observed that some hauls in the 300–400 m strata were grouped with the middle slope, while some hauls in the 500–600 m strata were grouped with the upper slope (Fig. 3a). Although season had no statistically significant effect on the density of the chondrichthyan assemblage (Supplementary Table S1), a two-way ANOVA test showed a statistically significant depth *x* season interaction ($F = 1.907$; $p = 0.027$) for the density of the most abundant species *E. spinax* (NO% = 66.5). The vertical and seasonal movement of this most abundant species has caused density oscillations between the upper and middle slopes (especially in the 300–500 m strata) (Fig. 4), which may have disturbed the homogeneity of the hauls and caused clusters on different slopes. The SIMPER analysis showed that *R. clavata*, *S. canicula*, and *G. melastomus* were the main contributing species, accounting for 79% of the similarity in the upper slope. *G. melastomus* was also present as a transitional species in the middle slope and, together with *E. spinax*, contributed 88% of the similarity, characterising the assemblage (Table 5).

Distributions and biological parameters

As the results of the analyses (PERMANOVA, MANOVA, and ANOSIM) presented above confirmed that only depth was a statistically significant factor for biodiversity characteristics and Chondrichthyan assemblages, only the spatial factor (depth stratum) was used in the analysis for each of the seven-contributing species.

Sharks

The highest numerical occurrence (NO%) was recorded for *E. spinax* (66.5%), followed by *G. melastomus* (13.6%) and *S. canicula* (10.4%), and these three species constitute 90.5% of the total numerical occurrence of ten shark species which were identified in the study area. Followed other two species, *S. blainville* and *C. cf. uyato* had a numerical occurrence of 1.7% and 0.4%, respectively, and for *C. cf. uyato*, only D_{TOT} and TL could be calculated for each stratum. The relationships between density indices (D_{TOT}, D_{JUV}, and D_{MAT}) and dept strata for each of five shark species are shown in Figs. 5 and 6 and Table 6.

Velvet belly lantern shark—Etmopterus spinax

The most sampled species, *E. spinax* (12,410 indv.) was distributed between the 300 and 800 m strata (Fig. 5a), and about 90% of its density was found in only two strata (between 400 and 599 m) (Table 6). Almost all mature individuals (97.8%) whose proportion in the population is extremely low (1.2%) inhabiting the meso-bathyal zone (≥ 600 m depth) whereas almost all juvenile individuals (97%) comprising more than half (53%) of the population were found only in the epi-bathyal zone (between 400 and 599 m) (Fig. 5b). The TL range was 10–40 cm (mean, 15.9 ± 0.1 cm) for females and 10–31 cm (mean, 15.9 ± 0.1 cm) for males and was not statistically significant between the sex ($p > 0.05$). The SR (0.52) was not significantly different from 1:1 ($\chi^2 = 0.323$, $p > 0.05$), and there was no significant difference between depths ($p > 0.05$). A strong positive trend was observed between depth and both D_{MAT} and TL ($p < 0.05$) (Table 6).

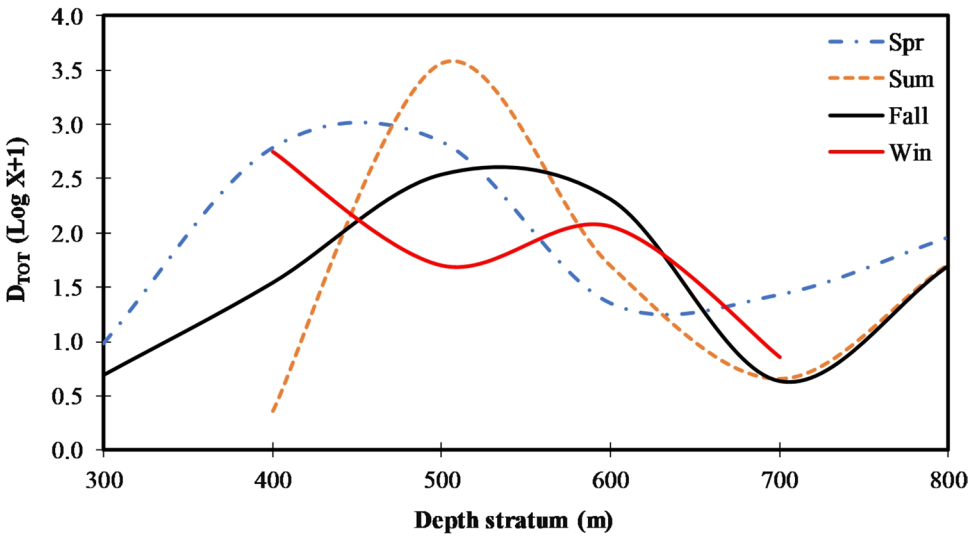


Fig. 4 The oscillation of total density (D_{TOT}, n/km^2) of *Etmopterus spinax* between depth strata and seasons

Table 5 Results of one-factor SIMPER analyses based on Bray–Curtis similarity (cut-off at 95%; *AA*, average abundance; *AS*, average similarity; *C%*, percentage contribution to the similarity; *CC%*, cumulative percentage contribution to the similarity (average similarity values are in brackets)

Species	AA	AS	C%	CC%		AA	AS	C%	CC%
200 m: 64.7					Upper slope (200–499 m): 49.5				
R. clavata	4.2	47.6	72.7	72.7	*R. clavata*	4.5	19.1	38.5	38.5
S. canicula	2.9	13.0	19.8	92.6	*S. canicula*	4.3	14.5	29.3	67.8
300 m: 67.9					*G. melastomus*	3.0	5.5	11.2	79.0
R. clavata	4.1	30.3	44.6	44.6	*D. oxyrinchus*	2.0	4.9	9.9	88.8
S. canicula	4.1	24.8	36.5	81.1	*S. blainville*	1.8	2.7	5.5	94.3
D. oxyrinchus	1.9	9.2	13.6	94.7					
400 m: 57.7					Middle slope (500–899 m): 42.9				
G. melastomus	4.1	15.5	27.0	27.0	*E. spinax*	4.0	19.8	47.1	47.1
S. canicula	3.3	12.4	21.5	48.5	*G. melastomus*	3.5	17.3	41.1	88.1
E. spinax	4.0	9.7	16.8	65.4	*C. granulosus*	1.0	2.5	6.0	94.1
R. clavata	2.6	9.0	15.6	81.3					
S. blainville	2.2	7.1	12.3	93.4					
500 m: 57.3									
E. spinax	5.9	29.3	47.3	47.3					
G. melastomus	3.1	15.4	24.1	72.3					
S. canicula	2.0	9.7	15.7	87.9					
S. blainville	1.2	2.9	4.7	92.7					
600 m: 58.2									
E. spinax	3.2	33.6	55.3	55.3					
G. melastomus	2.6	22.1	36.3	91.6					
700 m: 77.2									
G. melastomus	3.6	40.4	52.4	52.4					
E. spinax	2.9	35.7	46.2	98.7					
800 m: 79.4									
G. melastomus	3.7	39.0	49.1	49.1					
E. spinax	2.6	33.3	42.0	91.5					

Blackmouth catshark—Galeus melastomus

G. melastomus was the second most abundant species (NO% = 13.6) with a total of 2598 individuals, and its bathymetric distribution pattern (Fig. 5c, d) was similar to that of *E. spinax*. The distribution depth ranges of total, mature, and juvenile individuals of both species overlapped. Furthermore, highly significant positive correlations (D_{TOT}: $r = 0.371$, $p = 0.000$; D_{JUV}: $r = 0.386$, $p = 0.000$; D_{MAT}: $r = 0.395$, $p = 0.000$) were found between the density indices of both species (*G. melastomus* and *E. spinax*). The population consisted of 38% juveniles and 7% matures. Significant spatial differences were found in all density indices and TL ($p < 0.05$) (Table 6). TL ranged from 11.5 to 56.7 cm with no significant difference between the sexes ($F = 2.659$, $p > 0.05$). The SR (0.49) was not significantly different from 1:1 ($\chi^2 = 0.050$, $p > 0.05$). The female fraction, which was 0.25 at 300 m, increased significantly to 0.62 at 700 m ($p < 0.05$) (Table 6).

Small-spotted catshark—Scyliorhinus canicula

S. canicula (2055 indv.) is a typical upper slope species with a 59% dominance constituting of more than ≥ 96% of the population (D_{TOT}, D_{JUV}, and D_{MAT}) and was distributed at depths shallower than 500 m (Fig. 5e and Table 6). Juveniles represented 18% of the population, while 21% were mature individuals (Fig. 5f). The TL of males (28.2 ± 0.22 cm) was statistically different from that of females (27.3 ± 0.22 cm) ($F = 5.410$, $p < 0.01$). Total SR was not significantly different from 1:1 ($\chi^2 = 0.583$, $p > 0.05$). Depth stratum had a statistically significant effect on all five parameters (D_{TOT}, D_{JUV} and D_{MAT}, SR, and TL) ($p < 0.05$). While TL showed a positive correlation with increasing depth ($p < 0.01$), the density indices (D_{TOT}, D_{JUV}, and D_{MAT}) were decreased ($p < 0.01$) (Table 6).

Longnose spiny dogfish Squalus blainville

S. blainville ($n = 317$) showed a dominance of 35% and the bathymetric distribution range was similar to that of *S. canicula* (Fig. 5g). Twenty-four percent and 31% of the total density consisted of juvenile and mature individuals, respectively. Eighty-five percent of the D_{TOT} and almost all of the juveniles were found in the 300–400 m depth stratum, while 86% of the D_{MAT} was accumulated in the 400–500 m depth stratum (Fig. 4h and Table 6). TL ranged from 16.0 to 75.4 cm and no significant difference was found between

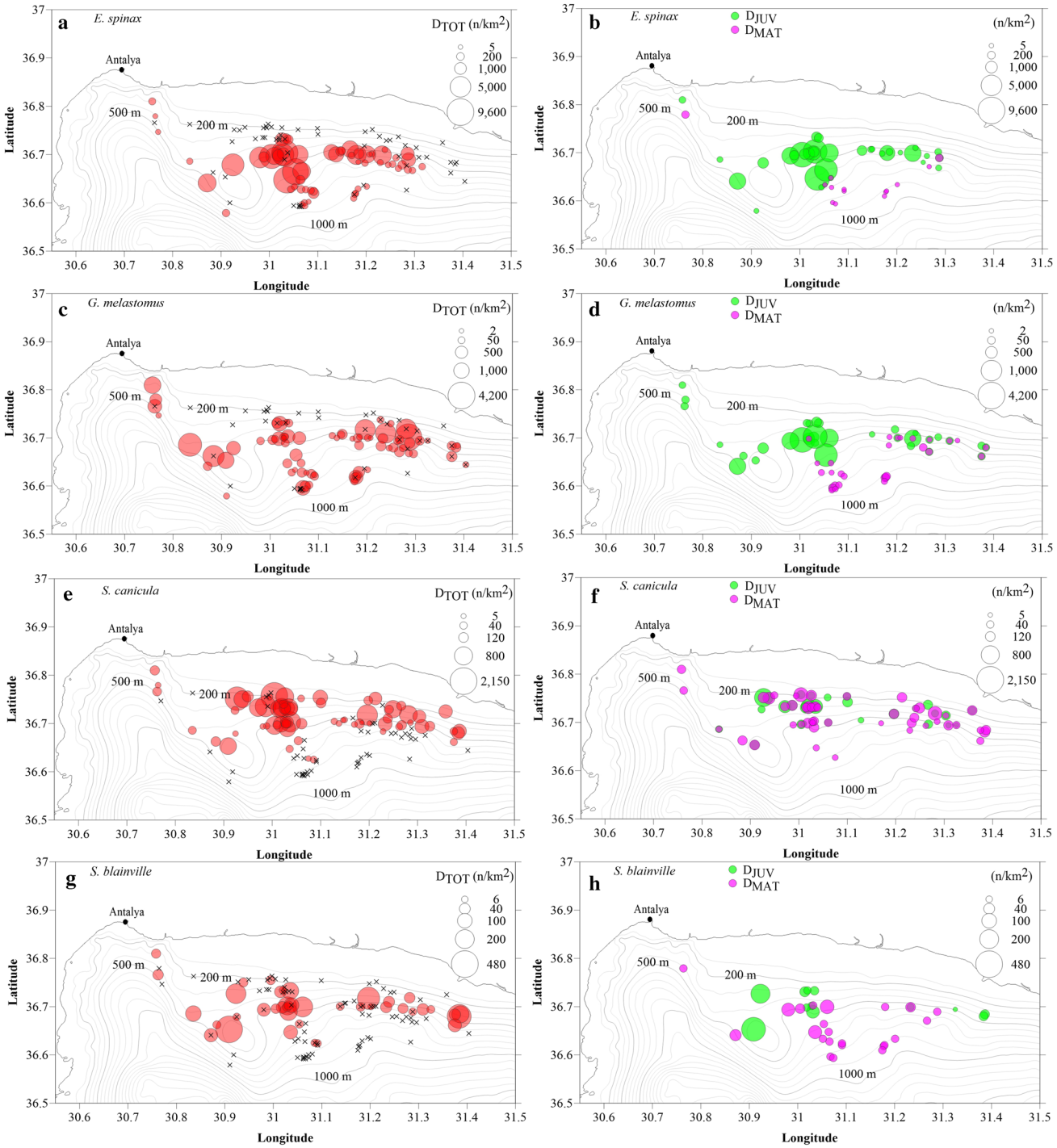


Fig. 5 Spatial distribution of overall (D_{TOT}, n/km^2), juvenile (D_{JUV}), and mature (D_{MAT}) densities estimated in the slope stratum (200–899 m) in the Antalya Bay; **a**, **b** *Etmopterus spinax*; **c**, **d** *Galeus melastomus*; **e**, **f** *Scyliorhinus canicula*; **g**, **h** *Squalus blainville*; + the empty hauls

the sexes ($F = 0.214$, $p > 0.05$) and was positively correlated with depth ($p < 0.05$). The overall SR was 0.42 and the departure from the 1:1 ratio was statistically significant in favour of males ($\chi^2 = 12.861$, $p < 0.05$) (Table 6).

Gulper shark Centrophorus cf. uyato

Although only 76 individuals of *C. cf. uyato* were captured during the study, the surveys revealed a wide spatial distribution

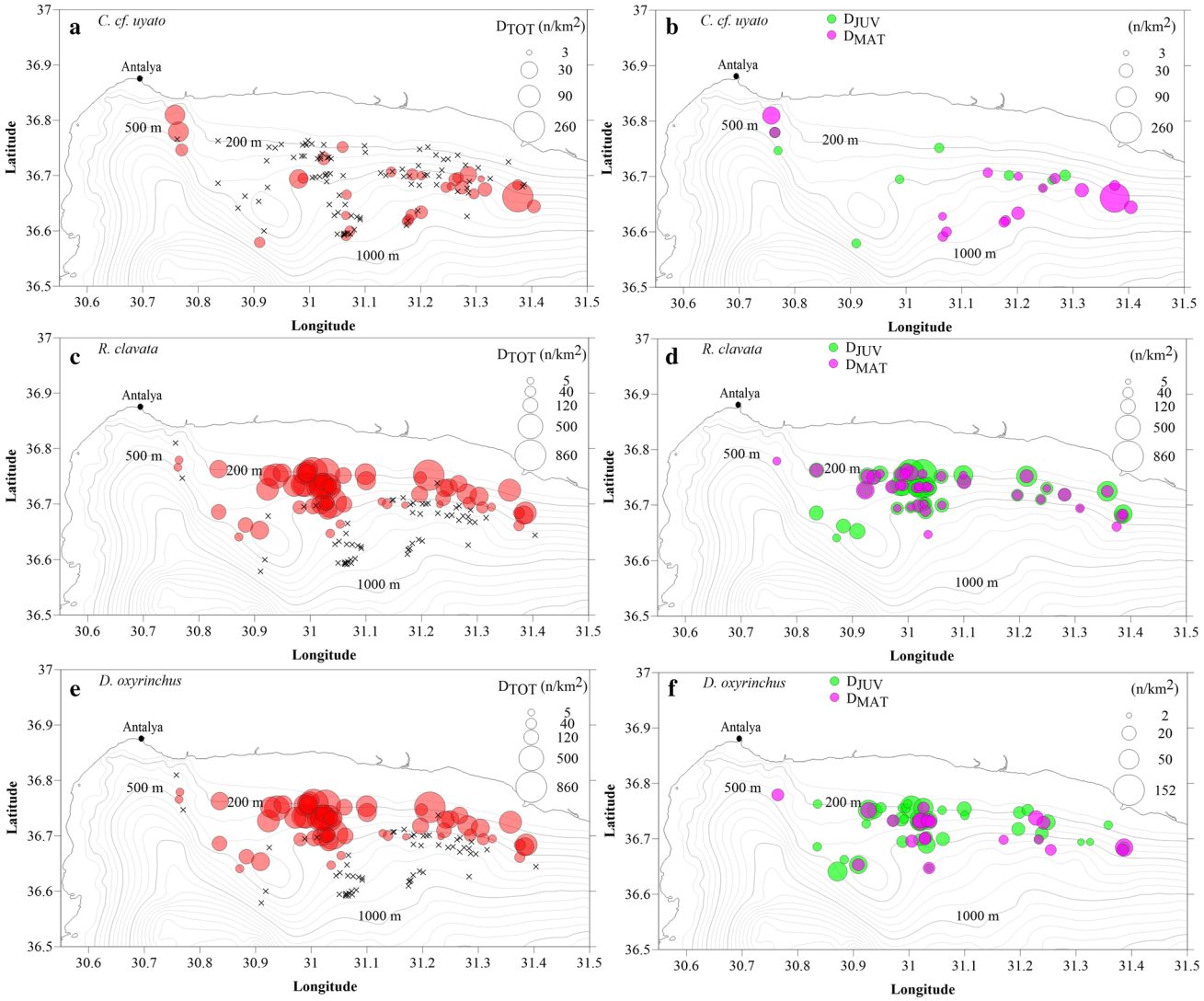


Fig. 6 Spatial distribution (n/km^2) of overall (D_{TOT}), juvenile (D_{JUV}), and mature (D_{MAT}) densities estimated in the slope stratum (200–899 m) in the Antalya Bay; **a**, **b** *Centrophorus cf. uyato*; **c**, **d** *Raja clavata*; **e**, **f** *Dipturus oxyrinchus*; + the empty hauls

of this species between 200 and 800 m strata (Fig. 6a, b). TL ranged from 40.5 to 98.5 cm, and no significant difference was found between the sexes ($F = 3.583$, $p > 0.05$). Depth was a significant factor in variation of TL ($p < 0.05$), and a positive correlation was observed between them ($p < 0.05$). The proportion of females (0.44) in the samples was not significantly different from that of males ($\chi^2 = 1.487$, $p > 0.05$). Forty-six percent of the total density consisted of adult individuals, while only 12% were juveniles (Fig. 6b). Neither depth nor season affected the D_{TOT}, D_{JUV}, and D_{MAT} indices ($p > 0.05$) (Table 6 and Supplementary Table S1).

Batoids

The thornback ray *R. clavata* (DO% = 53.3) and the long-nose skate *D. oxyrinchus* (DO% = 35.8) were the two most abundant of the six batoid species caught in the bathyal zone. Almost all individuals of both species (except only two specimens of *D. oxyrinchus* in the 600 m stratum) were distributed in the shallower than 600 m.

The thornback ray Raja clavata

Ninety-nine percent of *R. clavata* individuals were sampled only on the upper slope (< 500 m depth) (Fig. 6c). While half of the species density was consisted of juveniles, approximately 14% were constituted of mature individuals (Fig. 6d and Table 6). There was no difference in TL between females (32.5 ± 14 cm) and males (31.1 ± 12 cm) ($F = 2.540$, $p > 0.05$), and the SR was neither different from 1:1 ($\chi^2 = 0.190$; $p > 0.05$) nor statistically changed with depth ($p > 0.05$). Depth was a significant factor in fish size

Table 6 Spatial distributions of density (D_{TOT}, D_{JUV}, D_{MAT}) indices of individuals, sex ratio (SR), and total length (TL, cm) of seven contributor species during surveys. Bold p_1 values (one-way ANOVA) and p_2 values (Spearman's correlation) denote significant difference in variables ($\log_{10} X+1$) among depth stratums at $p<0.05$ (D_{TOT} total density, D_{JUV} density of juveniles, D_{MAT} density of mates, r = correlation coefficient)

Species	Str	N		D_{TOT}	D_{JUV}	D_{MAT}	SR	TL (cm)
E. spinax	300	210		154 ± 419	59 ± 170		0.47	15.7 ± 0.8
	400	5859		1782 ± 2664	1110 ± 2100	0.5 ± 2.4	0.56 ± 0.03	15.8 ± 0.3
	500	5897		2475 ± 3104	1277 ± 2526	0.9 ± 3.6	0.49 ± 0.07	15.3 ± 0.5
	600	378		167 ± 189	4.4 ± 8.3	3.5 ± 5.6	0.48 ± 0.19	24.4 ± 2.5
	700	43		43 ± 53	4.6 ± 15.9	10 ± 21	0.68 ± 0.33	27.7 ± 6.2
	800	23		48 ± 41		43 ± 45	0.68 ± 0.20	32.6 ± 5.9
			$\bar{x}$ =	778 ± 2170	409 ± 1609	9.7 ± 17	0.52 ± 0.19	16.1 ± 3.1
			p_1 =	**0.000**	**0.000**	**0.000**	0.254	**0.000**
			p_2 =	0.355	0.093	**0.000**	0.184	**0.042**
			r =	0.092	−0.166	**0.401**[b]	0.234	**0.829**[a]
G. melastomus	300	280		197 ± 514	75 ± 214		0.25 ± 0.25	20.9 ± 2.6
	400	1589		722 ± 1041	460 ± 729	1.9 ± 5.5	0.48 ± 0.21	27.3 ± 5.6
	500	279		159 ± 208	26 ± 52	3.8 ± 7.2	0.44 ± 0.29	30.9 ± 5.5
	600	205		85 ± 83	4.1 ± 7.5	12 ± 23	0.57 ± 0.32	38.1 ± 5.6
	700	128		135 ± 248	7.6 ± 22	29 ± 44	0.62 ± 0.19	36.8 ± 6.3
	800	117		253 ± 279	9.7 ± 13	59 ± 56	0.56 ± 0.29	39.5 ± 5.9
			$\bar{x}$ =	259 ± 649	97 ± 435	18 ± 27	0.49 ± 0.28	28.9 ± 3.6
			p_1 =	**0.001**	**0.000**	**0.000**	0.210	**0.000**
			p_2 =	0.914	**0.003**	**0.000**	**0.026**	**0.000**
			r =	0.011	**−0.292**[b]	**0.445**[b]	**0.311**[a]	**0.704**[a]
S. canicula	200	499		423 ± 623	79 ± 199	82 ± 115	0.51 ± 0.23	26.8 ± 2.6
	300	675		453 ± 367	111 ± 143	93 ± 98	0.38 ± 0.20	27.7 ± 2.5
	400	760		260 ± 320	15 ± 33	57 ± 51	0.41 ± 0.16	28.9 ± 2.0
	500	99		38 ± 88	0.7 ± 2.9	10 ± 25	0.52 ± 0.32	29.7 ± 2.6
	600	22		9.2 ± 27	3.7 ± 17	1.4 ± 4.1	0.89 ± 0.19	30.6 ± 3.2
			$\bar{x}$ =	237 ± 379	42 ± 77	49 ± 63	0.54 ± 28	27.8 ± 1.5
			p_1 =	**0.000**	**0.000**	**0.000**	**0.019**	**0.000**
			p_2 =	**0.000**	**0.000**	**0.000**	0.136	**0.004**
			r =	**−0.549**[b]	**−0.483**[b]	**−0.464**[b]	0.256	0.072
S. blainville	200	4		3.0 ± 8.0			1.0 ± 0.71	40 ± 2.8
	300	37		27 ± 63	15 ± 49	4.2 ± 12	0.17 ± 0.14	32.4 ± 14
	400	226		92 ± 121	18 ± 69	29 ± 42	0.47 ± 0.28	42.5 ± 12
	500	42		15 ± 27	0.7 ± 3.0	9.0 ± 21	0.51 ± 0.35	49.2 ± 10
	600	4		3.0 ± 8.4		1.8 ± 7.8	0.0	61.6 ± 13
			$\bar{x}$ =	28 ± 82	6.7 ± 45	8.8 ± 28	0.42 ± 0.33	41.6 ± 13
			p_1 =	**0.000**	**0.031**	**0.000**	0.098	**0.000**
			p_2 =	0.999	0.324	0.673	0.882	**0.000**
			r =	0.000	−0.100	0.043	−0.034	**0.381**[b]
C. cf. uyato	200	1		1.0 ± 4.0	1.0 ± 4.0		-	48.0
	300	2		1.4 ± 5.9	0.0	0.0	-	ne
	400	33		12 ± 27	2.6 ± 7.2	3.1 ± 11.9	0.50 ± 0.71	63.1 ± 11.1
	500	18		18 ± 59	1.6 ±	14 ± 54	0.64 ± 0.37	80.3 ± 17.9
	600	14		7.2 ± 11	0.9 ±	4.7 ± 9.5	0.28 ± 0.25	77.3 ± 16.5
	700	3		2.8 ± 5.3	0.0	2.0 ± 4.7	0.0	81.1 ± 2.7
	800	5		9.6 ± 9.9	0.0	8.3 ± 10	0.33 ± 0.58	76.1 ± 3.3
			$\bar{x}$ =	7.4 ± 27	1.0 ± 4.5	4.0 ± 22	0.44 ± 0.43	72.4 ± 16.7
			p_1 =	0.097	0.590	0.103	0.429	**0.000**
			p_2 =	**0.006**	0.835	**0.001**	0.158	**0.000**
			r =	**0.249**[b]	−0.019	0.287	−0.370	**0.506**[b]
R. clavata	200	493		365 ± 246	221 ± 216	56 ± 42	0.59 ± 0.13	30.7 ± 13.7
	300	470		310 ± 154	146 ± 124	42 ± 52	0.46 ± 0.13	29.7 ± 13.6

Table 6 (continued)

Species	Str	*N*		D_{TOT}	D_{JUV}	D_{MAT}	SR	TL (cm)
	400	290		122 ± 167	53 ± 59	11 ± 17	0.45 ± 0.14	33.5 ± 12.3
	500	15		7.2 ± 12		2.3 ± 6.9	0.69 ± 0.43	49.9 ± 7.0
			$\bar{x}$ =	201 ± 171	105 ± 90	28 ± 33	0.52 ± 0.21	30.9 ± 13.5
			p_1 =	**0.000**	**0.000**	**0.000**	0.105	**0.000**
			p_2 =	**0.000**	**0.000**	**0.000**	0.367	**0.010**
			r =	**−0.740b**	**−0.634[b]**	**−0.571[b]**	0.177	0.083
D. oxyrinchus	200	30		26 ± 46	16 ± 23	2.5 ± 7.4	0.32 ± 0.30	29.2 ± 13.3
	300	47		33 ± 31	13 ± 18	8.4 ± 9.9	0.59 ± 0.34	40.0 ± 20.8
	400	44		18 ± 21	7.9 ± 13	4.1 ± 8.4	0.55 ± 0.30	42.5 ± 17.4
	500	10		3.7 ± 6.6	0.6 ± 1.7	1.1 ± 3.3	0.36 ± 0.38	59.2 ± 18.8
	600	2		0.5 ± 2.3		0.5 ± 2.3	1.00	90.4 ± 0.2
			$\bar{x}$ =	16 ± 22	9.4 ± 12	3.3 ± 7.2	0.51 ± 0.34	38.3 ± 20.2
			p_1 =	**0.000**	**0.000**	**0.000**	0.409	**0.000**
			p_2 =	**0.000**	**0.000**	0.058	0.888	**0.000**
			r =	**−0.434b**	**−0.419[b]**	−0.190	−0.029	**0.415[b]**

($p < 0.05$), and mean TL was increased from 30.7 to 49.7 cm in parallel with depth ($p < 0.05$). A statistically significant difference ($p < 0.05$) and strong negative trends were found between abundance indices (D_{TOT}, D_{JUV}, and D_{MAT}) and depth ($p < 0.05$) (Table 6).

Longnose skate Dipturus oxyrinchus

Despite their low NO% (0.7%) and FO% (9.9%) values, 133 individuals of *D. oxyrinchus* were distributed over a wide depth stratum (200–600 m) (Fig. 6e). Juveniles which constituted of more than half of the population were mostly found in the 200–300 m strata while mature individuals which constitute only 5% of the density were found in all strata between 200 and 600 m (Fig. 6f). SR was not different from an expected ratio of 0.5 ($\chi^2 = 0.248$; $p > 0.05$), and mean fish size was increased from 29.2 (at 200 m) to 90.4 cm (at 600 m) at $p < 0.05$ and was not significantly different between sexes (female = 40.7 ± 20 cm, male = 39.4 ± 21 cm) ($F = 0.107$, $p = 0.745$). Except for SR, depth was found to be a significant factor in TL and in three density indices (D_{TOT}, D_{JUV}, and D_{MAT}) ($p < 0.05$), and density indices showed negative trends with increasing depth (Table 6).

Discussion

The Adriatic Sea and the Gulf of Antalya are the poorest areas in Elasmobranches' species diversity which decreased from the westernmost to easternmost of the Mediterranean Sea (Coll et al. 2010). The FAO's geographical classification divides the Mediterranean Sea into three sub-areas (western, central, and eastern), while the GFCM divides into four sub-regions (plus the Adriatic Sea) and englobes 27 Geographical Sub-Areas (GSAs). Together with these, the Mediterranean Sea can be roughly divided into two main sub-basins, the western and the eastern Mediterranean, separated by the Sicily-Tunisia Ridge, also according to oceanographic variability. The eastern basin is characterised by a higher variability of SSTs (sea surface temperatures), ranging from 17.8 °C in winter to 29.7 °C in the warmest months (Poulos et al. 1997; Abboud-Abi Saab et al. 2013), and also by a higher average salinity (39‰). In contrast, the western basin is generally cooler and relatively less saline, with an average SST of 12 °C in winter and 23 °C in summer, and an average salinity of about 36‰ (Mansuci et al. 2020).

Present study provides information on the composition of the chondrichthyan assemblage on the slope of Antalya Bay (Northern Levant Sea, GSA24), and contributes to a deeper understanding of its structure and spatial distribution. A total of 17 species were recorded on the slope, including 10 sharks, 6 batoids, and one chimaera. Together with 7 batoid (*Aetomylaeus bovinus*, *Dasyatis centroura*, *Gymnura altavela*, *Raja asterias*, *Raja radula*, *Rhinobatos rhinobatos*, and *Torpedo marmorata*) and 2 shark species (*Squatina squatina* and *Carcharhinus plumbeus*) found on the continental shelf (Mutlu et al. 2022a, b), the total number of demersal cartilaginous species distributed in the Antalya Bay reaches 26 which was more than threshold of < 20 cartilaginous species previously recognised for the Antalya Bay by Coll et al. (2010). In the Antalya Bay, most of the batoids were found on the continental shelf (Mutlu et al. 2022a, b). In contrast, most sharks preferred the slope. These results are consistent with the results of GSAs in the central and western Mediterranean (Table 7).

Demersal chondrichthyan species show distinct patterns of distribution and abundance patterns in different GSAs of the Mediterranean Sea. These patterns may be influenced by

several factors, including habitat preferences, environmental conditions, fishing pressure, and ecological interactions. Various previous results provide an overview of the distribution and density of demersal chondrichthyan assemblages on the slope with 24 sites relating for 17 different GSAs (Table 7). While 14 of these results belong to the western, 7 to the central, there are only 3 results for the eastern Mediterranean (including our study). Our study provides standardised information which is lacking for the easternmost sub-area (GSA24), and contributes to a better assessment of the demersal chondrichthyan assemblages on the slopes of the entire Mediterranean basin. Thirty chondrichthyans were recorded from the slopes in 17 different GSAs, including 14 sharks, 15 batoids, and 1 chimaera. The number of species reported in the GSAs; (i) between 6 in GSA6 and 19 in GSA11 with a total of 26 in the western Mediterranean, (ii), between 7 in GSA17 and 20 in GSAs 16 and 20 with a total of 22 in the central Mediterranean, and (iii) between 7 in GSA23 and 17 in GSA24 (this study) with a total of 22 in the eastern Mediterranean. The correlation between GSAs and species numbers from west to east was not significant ($r=0.105$, $p=0.624$), and sub-areas had no statistically effect on species numbers ($F=0.346$, $p=0.712$). Rare species with mean densities ≤ 1 n/km^2 accounted for about 70% of the chondrichthyan species found on the slopes of these three sub-areas. In our study, the number of species with mean densities above 1 n/km^2 and 5 n/km^2 was 8 and 7, respectively.

Few species showed a wide distribution on the slopes in all GSAs: the sharks *S. canicula* and *G. melastomus* occurred in all studies. Another shark, *E. spinax*, was found in all GSAs excepting GSA 23, and two important batoids, *R. clavata* and *R. oxyrinchus*, were found in all GSAs excepting GSA19 and GSA17, respectively. Although the densities of G. *melastumus* ($r=-0.346$, $p=0.098$) and *S. canicula* ($r=-0.393$, $p=0.057$) decreased from the western to the eastern basin, these decreases did not show a statistically significant trend. In contrast to these shark species, there was a positive increase for batoids of *R. clavata* ($r=0.219$, $p=0.304$) and *R. oxyrinchus* ($r=0.285$, $p=0.178$), but these increases were not statistically significant. However, there was significant trend increasing from west to east basin for both *E. spinax* ($r=0.410$, $p=0.047$) and *S. blainville* ($r=0.599$, $p=0.002$).

The top 3 GSAs with the highest density of cartilaginous fish are GSA19 (Western Ionian Sea) with 3739 n/km^2, GSA1 (Northern Alboran Sea) with 3114 n/km^2, and GSA8 (Corsica) with 3025 n/km^2. The Antalya Bay in GSA24 is the 5th highest sub-area with a total value of 1532 n/km^2. A negative insignificant correlation ($r=-0.247$, $p=0.245$) was found between GSAs and D_{TOT} values from east to west, and the sub-areas also had no significant effect on total density ($F=1.032$, $p=0.377$).

One of the most important factors stressing the Chondrichthyes assemblage is the bottom trawl fishery (Tiralongo et al. 2018; Mutlu et al. 2022b). The bottom trawl fishery in Antalya Bay was concentrated in two different groups of fishing operations targeting a specific assemblage of species and these two métiers do not overlap bathymetrically: (i) The 'first métier' targets *Mullus* spp., porgies, *Farfantepnaus aztecus*, and *Penaus pulchricaudatus* (Deval et al. 2023) and occurred mainly on the continental shelf (approximately 50–150 m depth) (Deval 2020b; Deval and Koçancı 2021), (ii) the 'second métier' targets two red shrimp species, with the main by-catch species *Merluccius merluccius*, *Helicolenus dactylopterus*, and *Parapenaus longirostris* occurring in the slope (approximately 350–650 m deep) (Deval et al. 2016; Deval 2020a) (Supplementary Fig. 1). Although there is only one trawler registered in Antalya port, the number of bottom trawl vessels signalled in the Gulf of Antalya between 2018 and 2022 was 55. Strength of the operations varied significantly with years, months, and days (unpublished data). Considering that only one vessel was actively trawling for 460 h in 2019 (in February, March, October, and December) (unpublished data), and an average CPEU value of 120 n/h was estimated during our study, it can be concluded that the discarded cartilaginous species in the Antalya Bay fishery is very high. Areas of high fishing pressure, such as the Adriatic Sea and the Spanish coast (excluding the Balearic Islands), show a low abundance of chondrichthyans, but other areas with a high level of fishing pressure, such as southwestern Sicily, show a high abundance, suggesting that other environmental drivers work together with fishing pressure to shape their distribution (Follesa et al. 2019).

Depthwise distribution of Chondrichthyes assemblage in the present study area suggested that a bottom depth of around 500 m which was highly variable in terms of Chondrichthyes diversity and abundance in year was considered a critical depth which discriminated the study area from the upper slope to lower slope of the bathyal. The depth, seafloor morphology, and water temperature were the main factors for elasmobranchs choosing suitable habitats, which occurred in late spring–early summer in the central Mediterranean (Lauria et al. 2015). Besides seasonal and ontogenic migration of the species along the bottom depth gradient as abruptly observed for *E. spinax* (Fig. 3), deep-water species were impacted by the North Atlantic Oscillation index (Ligas et al. 2010). *E. spinax* was responded unimodally to the bottom depth but the modal depth was shallower in Algerian water than the Balearic waters (Ordines et al. 2011). Therefore, the species had unimodal distribution in the eastern Mediterranean Sea as occurred along the depth gradient in Antalya Gulf during the present study.

Table 7 Mean values of density indices (D, n/km^2) for chondrichthyan species sampled in the slope (200–899 m) in different Mediterranean sub-areas and GFCM geographical sub-areas (GSA) are reported in the literature (S number of species, *WM* western Mediterranean, *CM* central Mediterranean, *EM* eastern Mediterranean) (the species codes are given in Supplementary Table S2)

	GSA	CMO	CPU	SCK	ETX	GAG	GAG	SHO	SBL	HXT	SMD	OXY
WM	1		4.6	13	131	180		2663				0.5
	1	34	0.2	1.5		188	2	1815				89
	5			3	40			705				
	5	0.2			7.8			370				
	5		0.1	< 0.1	2.9			179				
	6			1.1	3.7			228				
	6	0.6		0.3	2.7			163				
	6	0.1	0.1	0.1	7.8			88	0.1			0.1
	7	80		0.2	34			1573				0.4
	8		0.4	2	222			2319				0.3
	9	4	0.4	0.6	77			439	0.1			
	10	0.8		0.9	34			207				
	11		0.1	0.6	108			542				0.1
	11	1.7	0.3	0.2	87			786	0.1	0.1	0.1	0.1
CM	16	7	2.1	3	35		0.04	244	0.1	0.4	0.1	0.1
	17	0.5			5			51				
	18	17	0.1	2	157			305		0.2		
	19	4	0.1	1	77			193		0.06		
	19	41	0.3	18	1253			2379			13.2	0.3
	20		4		30			126		2		2
	22	38	2	0.5	74			289	0.1	8	1	1
EM	23							85		1.2		
	25				420			188	2	8		0.7
	24	**0.2**	**7.4**	**0.7**	**778**			**259**		**1.8**	**0.3**	**0.6**
Avg	WM	8.7	0.4	1.7	54	26	0.1	863	< 0.1	< 0.1	< 0.1	6.5
	CM	15	1.2	3.5	233		< 0.1	512	< 0.1	1.5	2	0.5
	EM	< 0.1	2.5	0.2	399			177	1	4	< 0.1	< 0.1
	SYC	DGS	QUB	SUA	JDP	RJA	JRS	RJI	RJC	RJF	JAM	JAI
WM	84							4				
	232							0.2	0.3			
	316		3					8	88			
	904							2.2	50			
	56		0.3			0.01		0.1	6.4			
	59	0.3							2			
	509						4.6					
	240								4.1			
	90	0.6	0.5						20			
	322		99					0.3	21			
	102		20					0.1	13			
	7		1.9						2			
	471		7.4					2	31			
	402		6.6					0.6	37			1.4

Table 7 (continued)

	SYC	DGS	QUB	SUA	JDP	RJA	JRS	RJI	RJC	RJF	JAM	JAI
CM	41		28					0.1	10		7	
	13	0.1							3			
	61		3					1	2.8			
	14							1				
	26		0.3									
	24		55						27			
	420	73	133	1.5				0.3	84		2	
EM	39		21						18			
	21	28	19						10	1		
	237		**28**	**0.3**	**0.2**			**0.1**	**201**			**0.7**
Avg	271	0.1	9.9			< 0.1	0.3	1.2	20			0.1
	86	10	31	0.2				0.3	18		1.3	
	99	9	23	< 0.1	< 0.1			< 0.1	76	0.3		0.2

	RJM	RJN	JDP	RJO	JAY	TTR	TTO	$\sum D$	S	$S > 1$ n/km^2	$S > 5$ n/km^2	Reference
WM		31		1.1			2	3114	11	10	6	4
		7.8				4.7	1.4	2376	13	10	6	1
		13		26	11			1213	10	10	8	4
		8.7		2.7	20		0.8	1366	10	8	6	2
		0.4		2.4	0.1		0.1	248	13	5	3	7
		0.4						295	7	5	2	4
								680	6	4	2	1
				0.6		3.3		344	11	5	3	6
		7.1		0.2	6.3			1812	12	7	7	4
	0.2			37	2			3025	12	8	6	4
				1	2			659	12	7	5	4
				0.3			0.1	254	9	5	3	4
				14	7			1183	11	8	7	4
			0. 1	20	10	0.1	0.1	1354	19	9	7	3
CM	0.3			5	0.1		0.5	384	19	10	7	4
					0.1			73	7	4	2	4
				0.3				549	11	7	4	4
				0.2			0.1	290	10	4	3	4
				2.4			6	3739	11	8	7	5
				4				274	9	9	5	4
	16	2		6	31			1182	20	15	11	4
EM	10			5				179	7	7	5	4
	3			3	12		1	717	14	11	8	4
				16			**0.3**	**1532**	**17**	**8**	**7**	**8**
Avg	< 0.1	4.9	< 0.1	7.5	4.2	0.6	0.3		26	13	9	
	2.3	0.3		2.6	4.5		0.9		23	15	7	
	4.3		< 0.1	8	4		0.4		22	11	7	

1: Ramírez-Amaro et al. (2015), 2: Ramírez-Amaro et al. (2015), 3: Marongui et al. (2017), 4: Follesa et al. (2019), 5: Ricci et al. (2021), 6: Ruiz-García et al. (2023), 7: Serrat et al. (2023), 8: this study

In conclusion, the slope in Antalya Bay serves as an important feeding and reproductive grounds for chondrichthyan species. It is important to note that the demersal chondrichthyan assemblages on the slope are influenced by a combination of factors, including depth, substrate type, prey availability, anthropogenic pressures, and environmental factors (Mutlu et al. 2022b). However, as in other areas of the Mediterranean, overfishing remains a concern

for the conservation of chondrichthyan populations. Conservation measures, such as the establishment of marine protected areas and sustainable fishing practices, are crucial for the preservation of these important habitats and the long-term sustainability of demersal chondrichthyan populations in the Mediterranean. Totally, 22 chondrichthyan species with 4 (*Oxynotus centrina*, *Squalus blainville*, *Squatina aculeate*, and *Raja clavata*) obtained from our study have been included to the list of prohibited species since 2018. Although fishing for these species has been banned, it is not possible to prevent them from entering in bottom trawl nets and dying during the hauls. Therefore, in order to reduce incidental catching of batoid species, and increase survival as a result, trials of a modified turtle excluder device (TED) net should be conducted in bottom trawl fisheries.

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Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval No animal testing was performed during this study.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Author contribution M.C.D.: conceptualization, design, funding acquisition, supervision, field work, writing first draft, review, analysis, and writing revision. E.M.: analyses, statistics, and review.

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