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Benthic hydrozoan assemblages as potential indicators of environmental health in a mediterranean marine protected area

Izzet Noyan YILMAZ¹, Luis MARTELL^{1,2}, Nur Eda TOPÇU³ and Melek ISINIBILIR

¹Institute of Marine Sciences and Management, Istanbul University, Turkey

²University Museum of Bergen, Department of Natural History, University of Bergen, Norway

³Department of Marine Biology, Faculty of Aquatic Sciences, Istanbul University, Turkey

Corresponding author: luisfmartell@gmail.com

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Abstract

The comparative study of marine benthic hydrozoan assemblages can improve our understanding of environmental and ecological conditions in marine protected areas (MPAs) such as the large Mediterranean MPA of Datça-Bozburun, where important prospects for future intensive tourism development exist. The analysis of such assemblages may help managers detect changes in important parameters of ecosystem health within this MPA. In this study we compared the hydrozoan assemblages occurring on hard (rocky) and soft (*Posidonia* meadows) bottoms from stations belonging to three different conditions: i) small marinas (medium anthropogenic impact), ii) yacht stopovers (low impact), and iii) unspoiled sites (no impact) in the southern part of the Datça Peninsula during summer and winter 2015 and 2016. Significant differences in the structure, species composition and richness of benthic hydrozoans among the sampling sites were detected. In both seasons, hydroid assemblages in medium-impact sites significantly differed from little-impact and no-impact sites in terms of qualitative composition. Large structural species were widely represented in all hard-bottomed sampling sites, but small inconspicuous taxa with diverse life histories were much less abundant at the medium impacted sites. Species richness and diversity in *Posidonia* meadows was much higher in little- and no-impact sites, where highly specific hydroid epibionts were abundant.

Keywords: Hydroids; bioindicators; Datça-Bozburun; *Posidonia oceanica*; Eastern Mediterranean Sea; Southeastern Aegean Sea.

Introduction

Monitoring plans for marine protected areas often benefit from the use of a suite of indicator taxa that offer reliable information on the health of habitats and ecosystems. Variations in the abundance of indicator species denote the condition of a particular community or habitat, and as such these taxa form the basis of biological monitoring of environmental change in many marine protected areas (MPAs). It has been suggested that the use of indicator taxa may be more effective than other methods of monitoring (such as relying on species richness) in marine ecosystems (Zacharias & Roff, 2001), and as a result the use of indicator taxa for conservation and management purposes has been increasing steadily in the last decades (e.g. Webb, 1989; Bayle-Sempere & Ramos Esplà, 1993; Thomas, 1993; Boening, 1999; Pelletier *et al.*, 2005). This approach, however, has not been fully implemented in important Mediterranean MPAs such as the Special Environmental Protection Area (SEPA) of Datça-Bozburun, the largest SEPA of the Mediterranean

basin (Optimar, 2010) and one of the most pristine areas in the Mediterranean Sea (Okuş *et al.*, 2007), for which little is still known in terms of biodiversity and environmental pressures (Okuş *et al.*, 2007; Bann & Başak, 2013). Previous studies (e.g. Okuş *et al.*, 2007; Oz *et al.*, 2007; Taş, 2013) have produced relatively complete inventories for selected taxa in the area, but our knowledge on other groups, among which benthic and planktonic hydrozoans, is still far from complete.

Being common components of bottom communities in temperate and tropical waters, benthic hydrozoans are often advocated as having a high potential as monitor and indicator species of environmental conditions in the marine realm (e.g. Mergner, 1977; Gili & Hughes, 1995; Megina *et al.*, 2013, 2016). They form distinct and often characteristic assemblages in different marine habitats, and present a set of life-history traits (sessile colonies unable to migrate from changing conditions, ubiquity in benthic communities, key actors in marine food webs, rather rapid population responses to stress and disturbances, etc.) (Boero, 1984; Gili & Hughes, 1995) that make

them good candidates for environmental monitoring. At the species level, the morphological changes suffered by individual colonies of some species may be indicative of turbulent conditions (e.g. da Silveira & Migotto, 1991) or increased concentrations of heavy metals (e.g. Karbe, 1972; Theede *et al.*, 1979), while at the community level local changes in abundance and distribution of hydrozoan species have been shown to indicate variations in intensity and speed of water flow (Riedl, 1966), other particular hydrodynamic conditions (Mergner 1972, 1977, 1987; Wedler, 1975), climate change effects (Puce *et al.*, 2009; González-Duarte *et al.*, 2014), and anthropogenic impact in harbours (Megina *et al.*, 2013, 2016).

In this study, the potential use of benthic hydrozoans as indicators of environmental conditions is investigated by two independent surveys (one conducted in summer, the other in winter) comparing the hydroid assemblages occurring in two substrate types (hard-rocky *versus* soft-*Posidonia oceanica* meadows) from localities subjected to one of three levels of anthropogenic impact: i) small marinas (medium impact), ii) yacht stopovers (low impact), and iii) natural sites (no impact) within the SEPA of Datça-Bozburun. We specifically addressed the questions of whether the multivariate structure of the assemblages differed in relation to the anthropogenic impact and whether the observed assemblages are characteristic enough as to allow for their spatial variations in abundance to be used as indicators of environmental health inside the SEPA.

Materials and Methods

Study site

The Datça (Reşadiye) Peninsula, situated in the Turkish sector of the southern Aegean Sea, has a rough topography that results in a high diversity of underwater habitats (Fig. 1). Together with the adjacent Bozburun Peninsula, it was declared a Special Environmental Protection Area (SEPA) in 1990 covering a total area of 1,443.89 km² (Optimar, 2010). Widely considered as one of the cleanest areas of the Mediterranean Sea (Bann & Başak, 2013), this SEPA is also one of the most important conservation areas within the borders of Turkey due to both its rich biodiversity and its archaeological richness (Okuş *et al.*, 2007). Marine environmental quality has been reported as ‘relatively good’ within the SEPA (Bann & Başak, 2013), as the region is not densely populated and it has not yet fallen under intense tourism pressures (Yerli, 2003). The area faces however some environmental problems such as increasing yacht tourism and anchoring, potential alien species, overfishing, unplanned recreational use of the coasts, coastal fillings and rubble dumping (Okuş *et al.*, 2007). The duality of relatively unspoiled nature and the growing local industry of tourism and recreation creates a clear gradient of anthropogenic pressures within the peninsula of Datça, ranging from medium impacted sites in and at the vicinities of the largest towns, low (seasonal) impacted sites at yacht

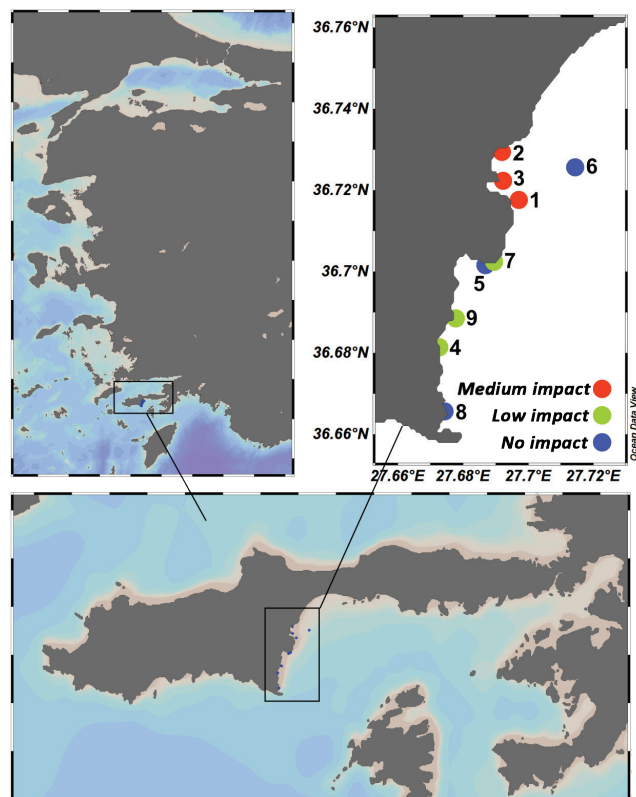


Fig. 1: Sampling stations and associated level of impact in the study area.

stopovers, and relatively unimpacted sites at protected / isolated bays and coves. Most of these pressures are highly seasonal in the region, with higher levels of impact during the warm (April to September) season.

Bedrock commonly outcrops at the sampling area, leaving bare rock without any sedimentary drape (Kaşer, 2010) that enables the settlement of sessile fauna along a wide gradient of depth. Additionally, there are vast areas of low-angle slopes with dense *Posidonia oceanica* meadows extending to 40 m depth (Okuş *et al.*, 2007). The oceanography of the region is highly associated with wind and Ekman transport due to strong and highly consistent North-Northeastern winds and during winter southern gales have significant physical impact on the coast.

Sampling design and data analysis

Two samplings events were conducted, one in August 2015 (summer sampling for warm-water assemblages) and the other in February 2016 (winter sampling for cold-water assemblages). The fieldwork, sampling and laboratory methodologies were identical for both events.

To allow for a meaningful comparison, all the sampling stations were selected based on two criteria: their representativeness of exclusively one category of anthropogenic impact (medium, low and no impact) in the area, and their inclusion of the two targeted habitats (rocky bottoms and *Posidonia* meadows). A qualitative assessment of the habitat types, anthropogenic pressures and

impacts of each locality was drafted from previous published reports (Bann & Başak, 2013), personal communication with local touristic operators and direct observation (I.N. Yılmaz). Thus, nine stations were selected and sampled in August 2015, each representative of one of the tree levels of anthropogenic impact observed in the area: i) small marinas (medium impact, 3 stations), ii) seasonal yacht stopovers (low impact, 3 stations), and iii) natural sites (no impact, 3 stations). In each station, two replicate random transects were sampled, each subdivided into five depth zones (if not limited by the bottom depth): 0-5 m, 5-10 m, 10-15 m, 15-20 m, and 20-25 m, following the methodology described by Boero & Fresi (1986). The two deepest zones were not present in the shallowest stations (St2 and St3). Each sampled zone was dominated by one of two substrate types: hard (e.g. rocks, artificial hard materials, etc.) or soft (e.g. sand, *Posidonia oceanica* meadows), and it was assigned to the corresponding substrate type for all further analysis. Due to climatic constraints, station St8 was not sampled in February 2016 (Fig. 1).

Samples were collected by SCUBA diving through visual collection techniques (e.g. Megina *et al.*, 2013; González-Duarte *et al.*, 2014; İşinibilir *et al.*, 2015; Topçu *et al.*, 2018) in order to obtain an efficient representation of the diversity of benthic hydrozoans in shallow coastal benthic habitats of the study area (as stated by Piraino *et al.*, 2013). In each station, one diver picked up all hydroid colonies or their potential substrates along 0.5 m each side of two randomly placed 3 m transects. A second diver conducted a visually-oriented collection around the perimeter for 5 minutes per transect, selectively collecting hydroid colonies and their potential substrates from a single, larger homogeneous bottom belt (~50 m²).

Samples were fixed immediately after collection in a 10% formalin-seawater solution. All hydrozoans were sorted and identified in the laboratory to the lowest taxonomic level with the aid of specialized scientific literature (Bouillon *et al.*, 2004, 2006). Abundances were estimated by assigning an abundance value to each species following the methodology of Boero & Fresi (1986) also used in other studies focused in hydrozoan assemblages (e.g. Di Camillo *et al.*, 2008; González-Duarte *et al.*, 2016). The abundance categories employed for each species in each sampling site were: 0 (absent), 1 (only one specimen present), 2 (scarce), 3 (common), 4 (abundant) or 5 (extremely abundant). Species richness (number of hydrozoan species per station and depth), the substrate on which each hydroid colony was growing, and the reproductive status of each species in each site were also recorded.

Data analysis

Multivariate analyses were used to compare the assemblages of benthic hydrozoans in relation to the tested factors. Seasonality cannot be explicitly tested with our current sampling design because only one sampling event was conducted in each season (no replicates), and thus we decided to analyse each data set independently and

subsequently search for congruent patterns. Non-Metric multidimensional scaling (nMDS) analyses based on Bray-Curtis distances on untransformed abundance data were performed to visualize changes in the assemblages, while distance-based permutational multivariate analysis of variance (PERMANOVA; Anderson, 2001) was used to test the differences in the composition of the assemblages in relation to factors “substrate” (fixed, two levels: hard-rocky, soft-*Posidonia* meadows) and “anthropogenic impact” (fixed, three levels: medium-, low-, and no impact) in both sets of data. Homogeneity of multivariate dispersion was tested using PERMDISP (Anderson, 2006). Significant terms revealed by the PERMANOVA were subsequently investigated using *a posteriori* pairwise comparisons. Finally, the similarity percentage procedure SIMPER was employed to calculate the contribution of each species to the observed patterns. All multivariate analyses were performed using the PRIMER v6.1.11 & PERMANOVA +v1.0.1 software package (Clarke & Gorley, 2006).

Results

In all, 47 hydrozoan taxa were recorded in the assemblages in Datça (Table 1). Species richness was similar in summer (34 species) and in winter (35 species), with 21 species shared by both seasons. Higher values of richness were observed in the low and no impact stations, while fewer species were recorded in the medium impacted sites (Fig. 2). No clear pattern of species richness was observed in relation to depth, but a general overview of substrate types suggest that both in hard bottoms and *Posidonia* meadows there were more species of benthic hydrozoans in low and no impact stations, in comparison with medium impacted sites. The first 10 meters in each sampling station roughly corresponded to zones with a predominance of hard, rocky bottoms; while deeper strata were usually dominated by soft bottoms and *Posidonia* meadows. In 6 cases (*Eudendrium* sp., *Halecium* sp., Campanulinidae sp., Corynidae sp. 1 and sp. 2, Hebellidae sp.), identification to species level was prevented by either the small amount of material available or the lack of characters essential for identification. To our knowledge, there are no previous observations of *Stylactis inermis*, *Amphinema dinema*, and *Zanclaea giancarloii* in the Aegean Sea, neither of *Coryne pintneri*, *Eudendrium moulouyensis*, *Halecium petrosum*, *Halocoryne epizoica*, and genus *Sphaerocoryne* in both the Aegean Sea or any Turkish coast.

The nMDS plots (Fig. 3) show the different distribution of the hydroid assemblages in the summer samples according to the tested factors. The corresponding PERMANOVA analysis revealed significant differences between the two substrate types and also among the levels of anthropogenic impact (Table 2), while the pair-wise comparison clearly showed that the sites with medium anthropogenic impact were significantly different from the sites with low- and no impact (Table 3).

The interactions between these two factors (“sub-

Table 1. Species found in the present study. Species collected exclusively in summer are marked with (a). Species collected exclusively in winter are marked with (b). Species in bold are new records for the Aegean Sea. Species marked with * are new records for the Turkish coasts.

Family Aglaopheniidae Marktanner-Turneretscher, 1890	Family Halopterididae Millard, 1962
<i>Aglaophenia harpago</i> Schenck, 1965	<i>Antennella secundaria</i> (Gmelin, 1791)
(a) <i>Aglaophenia octodonta</i> Heller, 1868	(b) <i>Halopteris diaphana</i> (Heller, 1868)
(b) <i>Aglaophenia picardi</i> Svoboda, 1979	Family Hebellidae Fraser, 1912
Family Bougainvilliidae Lütken, 1850	(a) Hebellidae sp.
(b) <i>Bougainvillia muscus</i> (Allman, 1863)	Family Hydractiniidae L. Agassiz, 1862
Family Campanulariidae Johnston, 1836	(b) <i>Stylactis inermis</i> Allman, 1872
<i>Campanularia volubilis</i> (Linnaeus, 1758)	Family Kirchenpaueriidae Stechow, 1921
(a) <i>Clytia gracilis</i> (Sars, 1850)	(b) <i>Kirchenpaueria pinnata</i> (Linnaeus, 1758)
<i>Clytia hemisphaerica</i> (Linnaeus, 1767)	Family Lafoeidae Hincks, 1868
<i>Clytia linearis</i> (Thorneley, 1900)	<i>Filellum</i> cf. <i>serpens</i> (Hassall, 1848)
<i>Clytia paulensis</i> (Vanhöffen, 1910)	Family Oceaniidae Eschscholtz, 1829
(a) <i>Laomedea angulata</i> Hincks, 1861	<i>Turritopsis dohrnii</i> (Weismann, 1883)
(b) <i>Laomedea flexuosa</i> Alder, 1857	Family Pandeidae Haeckel, 1879
<i>Obelia bidentata</i> Clark, 1875	(b) <i>Amphinema dinema</i> (Péron & Lesueur, 1810)
<i>Obelia dichotoma</i> (Linnaeus, 1758)	<i>Amphinema rugosum</i> (Mayer, 1900)
(a) <i>Orthopyxis crenata</i> (Hartlaub, 1901)	Family Pennariidae McCrady, 1859
Family Campanulinidae Hincks, 1868	<i>Pennaria disticha</i> Goldfuss, 1820
<i>Lafoeina tenuis</i> Sars, 1874	Family Plumulariidae Agassiz, 1862
(a) Campanulinidae sp.	<i>Plumularia obliqua</i> (Johnston, 1847)
Family Corynidae Johnston, 1836	Family Sertulariidae Lamouroux, 1812
(b) <i>Coryne pintneri</i> Schneider, 1897*	<i>Sertularella polyzonias</i> (Linnaeus, 1758)
Corynidae sp. 1	<i>Sertularia perpusilla</i> Stechow, 1919
(a) Corynidae sp. 2	Family Sphaerocorynidae Prévot, 1959
Family Eudendriidae L. Agassiz, 1862	(a) <i>Sphaerocoryne</i> sp*
(b) <i>Eudendrium armatum</i> Tichomiroff, 1890	Family Zancleidae Russell, 1953
<i>Eudendrium racemosum</i> (Cavolini, 1785)	(b) <i>Halocoryne epizoica</i> Hadzi, 1917*
<i>Eudendrium glomeratum</i> Picard, 1952	(b) <i>Zanclaea giancarloii</i> Boero, Bouillon & Gravili, 2000
(b) <i>Eudendrium moulouyensis</i> Marques, Peña Cantero & Vervoort, 2000*	(a) <i>Zanclaea sessilis</i> (Gosse, 1853)
<i>Eudendrium</i> sp.	
Family Haleciidae Hincks, 1868	
<i>Halecium lankesterii</i> (Bourne, 1890)	
<i>Halecium mediterraneum</i> Weismann, 1883	
(a) <i>Halecium nanum</i> Alder, 1859	
(a) <i>Halecium petrosum</i> Stechow, 1919*	
(b) <i>Halecium pusillum</i> Sars, 1856	
<i>Halecium</i> sp.	

strate” and “anthropogenic impact”) were not significant, thus suggesting that the differences with substrate did not change significantly between differently impacted sampling sites. In winter, the same tendency was observed in the nMDS plots (Fig. 4) and similar significant differences were detected by the PERMANOVA and pairwise comparison analyses (Tables 3 and 4).

Table 5 shows the contribution that each species made

to the similarity within each level of anthropogenic impact, as well as to the dissimilarity between differently impacted sites, according to the SIMPER analysis of the summer and winter samples. The results of the corresponding analysis for the different substrate types is shown in Table 6. These analyses showed that *Pennaria disticha*, *Halecium mediterraneum* (in summer), and *Halecium pusillum* (in winter) characterized the medi-

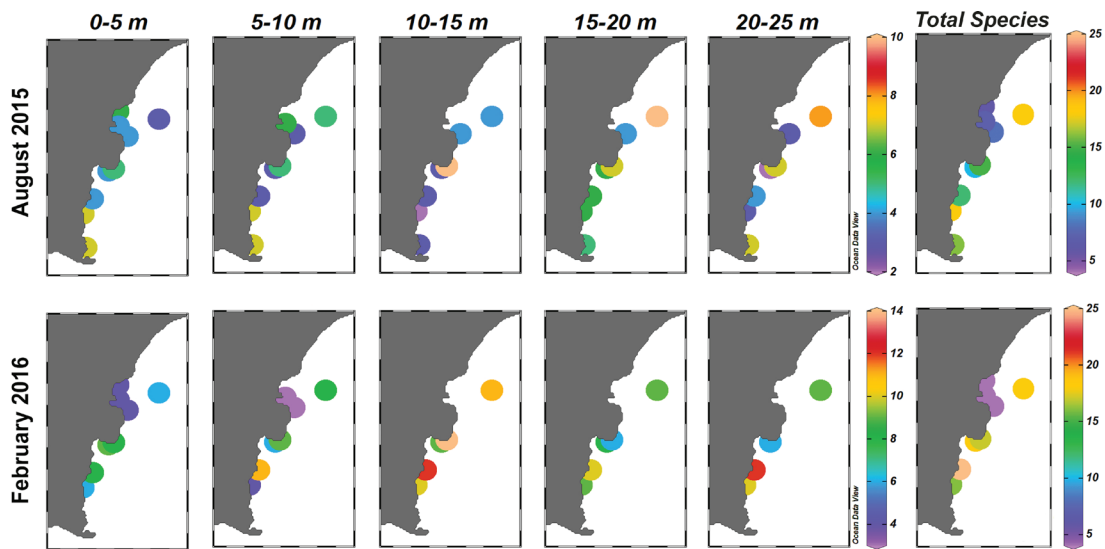


Fig. 2: Species numbers according to depth strata and total depth integrated species numbers in the study area.

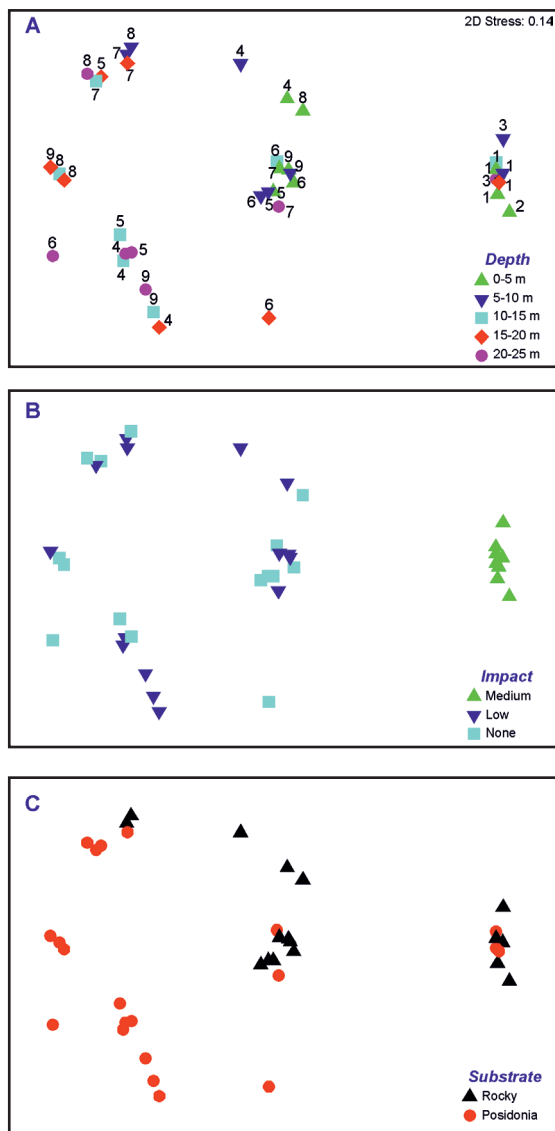


Fig. 3: Two-dimensional nMDS representation of the similarity (Bray-Curtis) of hydrozoan assemblages among samples in the summer campaign. Samples displayed according to stations (numbers) and sampling depth (a), anthropogenic impact (b) and substrate type (c).

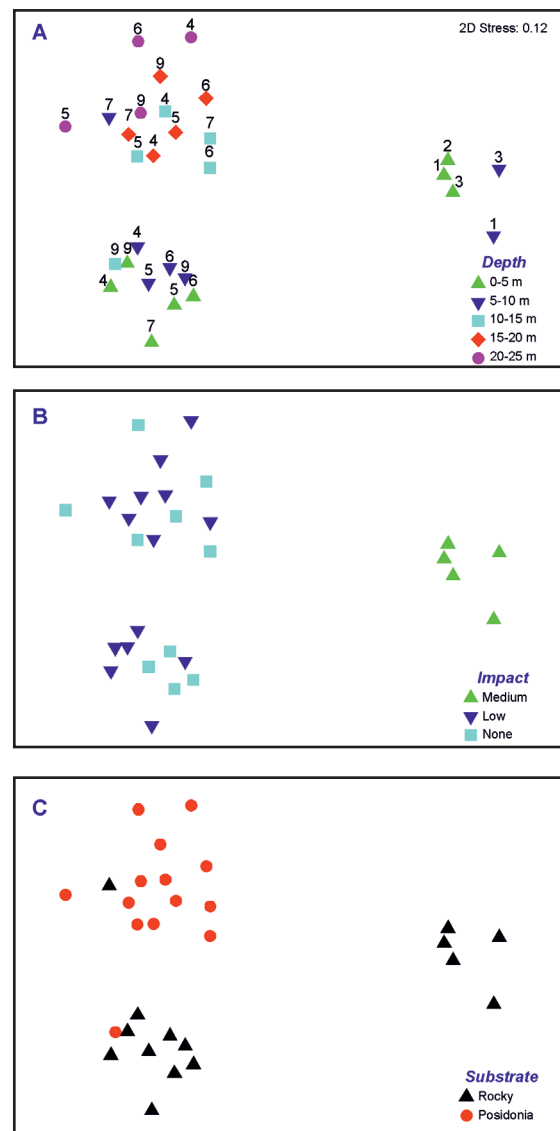


Fig. 4: Two-dimensional nMDS representation of the similarity (Bray-Curtis) of hydrozoan assemblages among samples in the winter campaign. Samples displayed according to stations (numbers) and sampling depth (a), anthropogenic impact (b) and substrate type (c).

Table 2. Summary of the PERMANOVA (permutational multivariate analysis of variance) results for the effect of factors “anthropogenic impact” and “substrate” on the assemblages of benthic hydrozoans in the summer campaign. Statistically significant results ($P < 0.05$) are highlighted in grey. DF = degrees of freedom; SS = sum of squares; MS = mean squares; Pseudo-F = Pseudo-F statistic; P (perm) = probability after the permutations; U perms = permutations performed.

Source	Df	SS	MS	Pseudo-F	P(perm)	U perms
Impact (Im)	2	31200	15600	14.456	0.001	996
Substrate (Su)	1	4698.6	4698.6	4.3541	0.002	999
Im x Su	2	4274.5	2137.2	1.9805	0.333	999
Res	32	34532	1079.1			
Total	37	80652				

Table 3. Results of the *a posteriori* pair-wise comparisons for the fixed factor “anthropogenic impact” in the summer (right columns) and winter (left columns) samples. Statistically significant results ($P < 0.05$) are highlighted in grey. t = t statistic; P (perm) = probability after the permutations.

Groups	Summer samples		Winter samples	
	t	P(perm)	t	P(perm)
Medium vs low impact	9.333	0.001	4.562	0.001
Medium vs no impact	8.100	0.001	4.099	0.009
Low vs no impact	0.046	0.952	0.258	0.791

Table 4. Summary of the PERMANOVA (permutational multivariate analysis of variance) results for the effect of factors “anthropogenic impact” and “substrate” on the assemblages of benthic hydrozoans in the winter campaign. Statistically significant results ($P < 0.05$) are highlighted in grey. DF = degrees of freedom; SS = sum of squares; MS = mean squares; Pseudo-F = Pseudo-F statistic; P (perm) = probability after the permutations; U perms = permutations performed.

Source	Df	SS	MS	Pseudo-F	P(perm)	U perms
Impact (Im)	2	21321	10661	11.297	0.001	999
Substrate (Su)	1	11105	11105	11.767	0.001	997
Im x Su	1	1171.2	1171.2	1.2411	0.307	999
Res	24	22648	943.68			
Total	28	58733				

um-impact sites, distinguishing them from low and not impacted localities. Regarding the substrate, strict *Posidonia oceanica* epibionts such as *Aglaophenia harpago* and *Sertularia perpusilla* characterized the assemblages of soft substrate-*Posidonia* meadows, while large, structural species *Pennaria disticha* and the couple of *Eudendrium* species *Eudendrium racemosum* (in summer) and *Eudendrium glomeratum* (in winter) were characteristic of hard, rocky bottoms, contributing to differentiate between the two substrate types (Table 7).

Discussion

In terms of their specific composition, the hydrozoan assemblages observed in Datça are typical of rocky bottoms and *Posidonia oceanica* meadows in the Mediterranean Sea (e.g. Boero, 1981; Boero *et al.*, 1985; Boero & Fresi, 1986; Piraino & Morri, 1990). The general status of the hydrozoan communities and the structure and extent of the sampled *Posidonia* meadows (even in the medium impact sites) seem to confirm previous hypotheses

(Okuş *et al.*, 2007; Bann & Başak, 2013) about the relatively good environmental health in the region. In fact, the species richness of hydrozoans in Datça falls within the range of other relatively unimpacted sites in central and eastern Mediterranean (e.g. Morri & Bianchi, 1999; Frascchetti *et al.*, 2006; İşinibilir *et al.*, 2015), and several conspicuous, non-indigenous hydrozoan species (such as *Eudendrium carneum* Clarke, 1882, *Dynamena quadridentata* (Ellis & Solander, 1786), and *Macrorhynchia phillipina* Kirchenpauer, 1872) that have been regularly observed in neighbouring regions (Morri *et al.*, 2009; Gravili *et al.*, 2013) are still absent from Datça despite the vicinity of the area to the trafficked ports of Kos and Bodrum and to the Levantine Sea.

Most of the new records observed in our study fill up distributional gaps or represent range extensions for well-known species already present in the Mediterranean Sea. This is the case, for example, of *Coryne pintneri* and *Halocoryne epizoica*, previously recorded in the western and central Mediterranean as far as the Adriatic Sea (Schuchert, 2001, 2010; Piazzini *et al.*, 2016), or of *Halecium petrosum*, known from the western and east-

Table 5. SIMPER results. Breakdown of the species contribution to the average similarity and dissimilarity among levels of anthropogenic impact in the summer and winter benthic hydrozoan assemblages. Only species with significant contributions (Sim/SD \geq 1.4 and Diss/SD \geq 1.4; González-Duarte *et al.*, 2014; 2016) are shown. Sim/SD = similarity to standard deviation ratio; Diss/SD = dissimilarity to standard deviation ratio.

	Average similarity (Av. Sim)						Average dissimilarity (Av. Diss)					
	Medium impact		Low impact		No impact		Medium- versus low impact		Medium- versus no impact		Low- versus no impact	
	Av. Sim	Sim/SD	A. Sim	Sim/SD	Av. Sim	Sim/SD	Av. Diss	Diss/SD	Av. Diss	Diss/SD	Av. Diss	Diss/SD
SUMMER SAMPLES												
<i>Pennaria disticha</i>	34.44	7.57	-	-	-	-	-	-	-	-	-	-
<i>Halecium mediterraneum</i>	34.44	7.57	-	-	-	-	17.18	4.88	16.73	3.76	-	-
<i>Eudendrium racemosum</i>	-	-	34.88	3.7	35.14	4.44	17.18	4.88	17.36	5.66	-	-
WINTER SAMPLES												
<i>Halecium pusillum</i>	20.13	1.54	-	-	-	-	3.77	4.81	8.36	1.67	-	-
<i>Halecium sp.</i>	18.16	3.9	-	-	-	-	-	-	-	-	-	-
<i>Pennaria disticha</i>	18.16	3.9	-	-	-	-	4.53	2.66	4.32	2.68	-	-
<i>Clytia linearis</i>	14.07	1.52	-	-	-	-	-	-	-	-	-	-
<i>Eudendrium glomeratum</i>	-	-	12.45	2.54	12.79	3.06	15.7	3.6	13.85	6.04	-	-
<i>Eudendrium racemosum</i>	-	-	11.46	1.56	13.79	1.76	17.37	2.78	19.91	7.45	-	-
<i>Sertularia perpusilla</i>	-	-	6.72	1.58	7.52	1.52	6.15	1.55	9.91	2.77	-	-
<i>Aglaophenia harpago</i>	-	-	-	-	6.48	1.58	-	-	-	-	-	-

Table 6. SIMPER results. Breakdown of the species contribution to the average similarity and dissimilarity between substrate types in the summer and winter benthic hydrozoan assemblages. Only species with significant contributions (Sim/SD \geq 1.4 and Diss/SD \geq 1.4; González-Duarte *et al.*, 2014; 2016) are shown. Sim/SD = similarity to standard deviation ratio; Diss/SD = dissimilarity to standard deviation ratio.

	Average similarity (Av. Sim)				Average dissimilarity (Av. Diss)	
	Hard-rocky		Soft-Posidonia		Hard-rocky versus soft-Posidonia substrate	
	Av. Sim	Sim/SD	Av. Sim	Sim/SD	Av. Diss	Diss/SD
SUMMER						
<i>Pennaria disticha</i>	23.46	1.63			11.19	1.52
<i>Eudendrium racemosum</i>	22.67	1.64				
<i>Aglaophenia harpago</i>			35.52	3.07	5.12	1.52
WINTER						
<i>Eudendrium racemosum</i>	14.26	1.52	7.91	3.34	5.47	2.12
<i>Eudendrium glomeratum</i>	11.55	1.55	10.37	2.98		
<i>Sertularia perpusilla</i>			8.64	1.94	5.21	2.05
<i>Aglaophenia harpago</i>			7	1.76	4.54	1.91
<i>Plumularia obliqua</i>					5.55	1.5

ern Mediterranean basins (Schuchert, 2005; Morri *et al.*, 2009) but not reported previously from the Aegean Sea. In particular, the first Aegean records of *Stylactis inermis*, *Amphinema dinema*, and *Zanclaea giancarloii* are

not surprising given that these species are also present in the central Mediterranean and the Sea of Marmara (Schuchert, 2007, 2008a, 2010; Topçu *et al.*, 2018). Perhaps only the unexpected presence of *Eudendrium mou-*

Table 7. Summary of the results and patterns observed.

Depth / dominant substrate	Hydrozoan assemblages	
	Medium impact sites	Low- and no impact sites
0-10 m / hard substrates, mainly rocks (in harbours also artificial concrete blocks and pillars)	Large colonies of <i>Pennaria disticha</i> , monopolizing space and resources. Almost no epibiont hydroids.	Large colonies of <i>Eudendrium racemosum</i> (in summer) and <i>Eudendrium glomeratum</i> (in winter), some colonies of <i>Pennaria disticha</i> . Rich community of hydrozoan epibionts and small-size species.
10-25 m / <i>Posidonia oceanica</i> meadows, patches of rock and other hard substrates	Hydrozoan epibionts on <i>P. oceanica</i> scarce. <i>Posidonia</i> in relatively bad condition. Low diversity and abundance of hydroids, mainly small species of <i>Halecium</i> .	Hydrozoan epibionts on <i>P. oceanica</i> abundant. <i>Posidonia</i> in good condition. High diversity and abundance of hydroids, several families and genera, including species of <i>Aglaophenia</i> , <i>Plumularia</i> , <i>Halecium</i> , <i>Sertularella</i> , <i>Sphaerocoryne</i> , <i>Turritopsis</i> , <i>Zanclaea</i> , and <i>Halocoryne</i> .

louyensis and *Sphaerocoryne* sp. could be related to environmental changes at a regional scale, although even in these cases any assumption must be taken with caution, given the confusing taxonomic history of both taxa in Mediterranean waters (Schuchert 2008b, 2010). *Eudendrium moulouyensis* has been considered by Puce *et al.* (2009) as an indicator of ocean warming in the Mediterranean, and the latter authors suggest that this species has only recently expanded its distribution eastwards to the Ligurian and Adriatic Seas (De Vito *et al.*, 2008; Puce *et al.*, 2009). Similarly, the presence of *Sphaerocoryne* in the Eastern Mediterranean has been attributed to the introduction of individuals from the warmer Red Sea (Zenetos *et al.*, 2012). If such trends are confirmed, the presence of both taxa in the Aegean Sea could represent further evidence of the increase in temperatures suffered by the Mediterranean, a phenomenon already observed in hydrozoan assemblages from the Alborán and Ligurian seas (Puce *et al.*, 2009; González-Duarte *et al.*, 2014).

The differences between medium impacted and low and not impacted stations were clearly indicated by the composition of the hydrozoan assemblages in the area. Regardless of the season and substrate type, medium impacted stations were characterized by few, large dominant species and overall lower diversity of hydrozoan epibionts, while low and not impacted localities had a more diverse set of both structural and epibiont hydrozoans. Our results also confirmed the well-known pivotal role of substrate type in the determination of the hydrozoan assemblages, as shown by the significant differences between assemblages from hard/rocky bottoms and *Posidonia* meadows, although the anthropogenic impact was evident in the hydrozoans assemblages regardless of the analyzed substrate type. Substrate type is a key factor in the structuring of hydrozoan communities (Calder, 1991; Genzano & Rodríguez, 1998), but other environmental factors affect the distribution in time and space of benthic hydrozoans over a wide geographical scale in spite of the substrate in rocky shores, *Posidonia* meadows, and littoral algal belts (Boero *et al.*, 1985; Boero & Fresi, 1986; Frascchetti *et al.*, 2002). The main species responsible for

the differences between the medium impact sites and the rest of the stations were either species characteristic of impacted localities or species that grew much better in less-impacted sites. Many of the latter are known to grow preferably on natural substrates and are common components of natural rocky locations elsewhere in the Mediterranean waters or are strict epibionts of *Posidonia* leaves. In our study, species composition was a more important parameter than species richness in detecting the differences between medium impact stations and low- and no-impacted sites, a conclusion similar to that of Megina *et al.* (2013) for hydrozoan assemblages in the western Mediterranean basin.

High numbers of colonies of *Pennaria disticha* and an almost complete absence of hydrozoan epibionts were characteristic of hard/rocky substrates in medium impacted sites. *Pennaria disticha* is a widespread and abundant species common in fouling communities (Carlton & Eldredge, 2009; Mead *et al.*, 2011), and it was one of the hydroids occurring exclusively in harbours in a recent study that evaluated the differences on species composition of hydrozoan assemblages on natural rock cliffs versus commercial harbours in western Mediterranean waters (Megina *et al.*, 2013). In turn, hard/rocky substrates at low and not impacted localities were characterized by large colonies of *Eudendrium* spp. (*E. racemosum* in summer and *E. glomeratum* in winter), and these colonies were often used as substrate by small hydrozoan epibionts such as *Clytia* spp. and *Halecium* spp., thus greatly contributing to the higher species richness observed in these stations. Both *E. racemosum* and *E. glomeratum* are common components of shallow hard bottoms in western and central Mediterranean waters (Boero *et al.*, 1986; Di Camillo *et al.*, 2012), where they are used as substrate by up to 32 species of hydrozoans (e.g. Peña Cantero & García Carrascosa, 2002). The potential use of *Eudendrium* as a bioindicator group in the Mediterranean Sea has been previously investigated by Megina *et al.* (2016), who concluded that the genus is a suitable indicator of natural rocky habitats, in a way analogous to our observations from the peninsula of Datça. The multivariate struc-

ture of the assemblages on *Posidonia* meadows also diverged significantly between medium impacted stations, characterized by only a few colonies of a limited set of species of *Halecium*; and low- and not impacted sites, characterized by thriving populations of a diverse array of hydroid species. In particular, the high abundance of colonies from exclusive epibionts *Sertularia perpusilla* and *Aglaophenia harpago* at low- and no impact sites is congruent with the patterns reported for hydrozoans assemblages on *Posidonia* leaves at natural, unimpacted localities elsewhere in the Mediterranean (Boero 1981; Boero *et al.*, 1985).

Although small in a Mediterranean scale, the anthropogenic pressures and habitat modification suffered by the harbours and marinas in Datça are not negligible, as suggested by the clear difference between assemblages in medium impact sites and low- and no- impact stations. The observed differences in species composition and species richness confirm that the effect of the human activities in the small local harbor is determinant in structuring the analyzed hydrozoan communities. Conversely, the low impact related to seasonal yacht stopovers do not seem to put a significant pressure on the hydrozoan assemblages of the study area, with similar results observed in summer and winter. The fact that stations that were subjected to seasonal (summer) pressure in the form of yacht stopovers and recreational diving were not significantly different from unimpacted areas, and that the latter were relatively similar to unimpacted areas elsewhere in the Mediterranean, suggests that the hydrozoans assemblages of the SEPA of Datça-Bozborun can cope with the low pressure generated by seasonal recreational boating and diving without showing alarming signs of destruction or modification.

In general, considering both the different levels of impact and the distinct substrate types included in our analysis, the hydroid assemblages constituted useful indicators of environmental conditions in the study area. The multivariate structure of the assemblages diverged significantly and the differences seem to be determined by the qualitative (specific) composition. The benthic hydrozoans assemblages developing in impacted and natural areas exhibit some particular and interesting characteristics that would make them a good bioindicator group, helping to reduce the effort needed for the comparison of different levels of impact in the area and providing a useful tool for both scientists and policy-makers regarding the SEPA of Datça-Bozborun.

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