Oceanological and Hydrobiological Studies

International Journal of Oceanography and Hydrobiology

Volume 53, No. 4 December 2024
pages (435-446)

sciendo

ISSN 1730-413X
eISSN 1897-3191

Diversity of hydrozoans on artificial substrates in large commercial ports of the Sea of Marmara

by

Esin Yüksel[1,*], Melek Isinibilir[2], Luis Martell[3]

Abstract

Research on biofouling assemblages in large ports is crucial for economic, environmental and regulatory purposes, as it provides critical information for managing marine ecosystems, preventing the spread of invasive species and developing effective antifouling strategies. Hydrozoans are among the most common invertebrates found in marine biofouling communities, making them a priority taxon for monitoring and identification in large ports. In this study, we documented the diversity of benthic hydrozoans growing on three types of artificial panels (wood, plastic, and rope) submerged for three months in the major commercial ports of Ambarli, Haydarpasa, Kocaeli, and Bandirma, located in the Sea of Marmara. Seven species of hydrozoans (*Ectopleura crocea, Obelia dichotoma, Bougainvillia muscus, Clytia gracilis, Eudendrium capillare, Eudendrium merulum* and *Sertularella ellisii*) were observed throughout the study. Unique fouling hydrozoan assemblages were identified in each port, regardless of the type of panel used, suggesting that differences in the pool of species available for recruitment and port-specific conditions have a greater impact on the structure of local fouling assemblages than the type of substrate. *Ectopleura crocea*, a species typical of artificial substrates and characterized by high invasive potential, was recorded for the first time in the Sea of Marmara during this study.

Key words: hydroids, harbors, biofouling, experimental panels, Mediterranean Sea

DOI: **https://doi.org/10.26881/oahs-2024.4.10**
Category: **Original research paper**
Received: **October 6, 2022**
Accepted: **July 31, 2024**

[1]*Institute of Graduate Studies in Sciences, Istanbul University, Türkiye*

[2]*Department of Marine Biology, Faculty of Aquatic Sciences, Istanbul University, Türkiye*

[3]*University Museum of Bergen, Department of Natural History, University of Bergen, Norway*

* Corresponding author: *esin.yukseldurmaz@gmail.com*

online at www.oandhs.ug.edu.pl

©2024 Esin Yüksel et al. This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivs License (http://creativecommons.org/licenses/by-nc-nd/4.0/)

1. Introduction

Ports are marine ecosystems that play a crucial role in the spread and adaptation of non-native species (NIS) (Tempesti et al. 2022). Artificial habitats in these environments host a unique marine biological community dominated by benthic sessile invertebrates (e.g. bryozoans, ascidians, polychaetes, barnacles, hydroids) that attach themselves to submerged structures and hulls and contribute to biofouling (Hopkins et al. 2021). Biofouling has significant economic and environmental impacts on ports, including increased operational, maintenance, and cleaning costs, damage to infrastructure, and a high potential for introduction of invasive species (Schultz et al. 2011; Hopkins et al. 2021). For example, ships moving between ports serve as a significant vector for the translocation of fouling invertebrates as they connect diverse and distant habitats (Bressy, Lejars 2014; Lacoursière-Roussel et al. 2016), making ports a primary focus for biosecurity measures and regulations.

Hydrozoans are one of the invertebrate taxa most frequently relocated by human mediation due to their potential to be transported both by ship hulls in their benthic stages (Calder et al. 2019; Meloni et al. 2021) and by ballast water in their pelagic stages (Zaiko et al. 2015; Cabrini et al. 2019). Hydroid colonies are common and abundant on hard substrates of rocky coastal areas in and around ports (Megina et al. 2013; González-Duarte et al. 2014), and several species adapt well to artificial substrates such as commercial vessel hulls, buoys (Thompson 1977; Kirkendale, Calder 2003), foundation piles (Galea 2008), and fish cage nets (Martell et al. 2018; Bosch-Belmar et al. 2019). These organisms often cause a number of problems to a wide array of economic activities in the sea, negatively affecting the health of fish and shellfish in aquaculture facilities (Guenther et al. 2011; Fitridge, Keough 2013), playing a role as vectors for the introduction of associated non-indigenous fauna (Ros et al. 2013), or being responsible for economic losses in shipping (Edyvean 2010), industrial platforms (Page et al. 2010), power plants (Henderson 2010), and several other artificial substrates used in human activities (Terlizzi, Faimali 2010). Furthermore, some hydrozoan species have been recognized as “perfect invaders” because the presence of highly resistant stages and flexible life cycles facilitate survival in new and harsh environmental conditions (Boero, Bouillon 1993; Piraino et al. 2004). However, despite their significance and ubiquity, the dynamics and diversity of fouling hydrozoans in ports are still not fully understood, and the contribution of this taxon to biofouling is often overlooked or underestimated in the world’s seas (Morri, Boero 1986; Megina et al. 2013).

The Sea of Marmara has a strategic geographical location connecting the Black Sea and the Mediterranean Sea, while serving as a corridor for the distribution of some species and a barrier to the spread of others (Öztürk et al. 2001). In addition, the Sea of Marmara plays an important role as one of the main routes for commercial maritime trade in the Eastern Mediterranean region, as it, along with the Istanbul and Canakkale Straits, forms one of the busiest waterways in the world, with nearly 50,000 ships passing through it annually (DTO 2022). The high volume of maritime traffic in the Sea of Marmara leads to problems, such as the constant introduction of new species into the basin, which in turn results in harmful effects on native biota (e.g. Kideys 2002). Several hydrozoan species have been recognized as successful invaders in waters adjacent to the Sea of Marmara (Boero, Bouillon 1993; Piraino et al. 2004), but research on the diversity of hydrozoans growing on artificial substrates within the basin are still limited. The first studies dealing with hydrozoans in the area were related to taxonomy (e.g. Ostroumoff 1896), and although later works have focused on specific taxa and localities (e.g. Demir 1954; Tortonese 1959; Caspers 1968; Ünsal 1981; Albayrak, Balkis 2000; Isinibilir et al. 2010), the group has not been prioritized in ecological surveys conducted in the ports in recent years (Isinibilir et al. 2008, Isinibilir et al. 2010; Altuğ et al. 2011). The hydrozoan fauna on the coasts of the Marmara Sea has not been inventoried in detail, as evidenced by reports of further new records in every recent paper on these organisms (e.g. Isinibilir et al. 2015b; Topcu et al. 2018). Compiling a complete inventory of hydrozoans in the ports of the Sea of Marmara is necessary to assess the status of their populations, detect further introductions and manage the impact of fouling species on the ecosystems of the basin.

Large ports characterized by heavy traffic (e.g. cargo ships and tankers) at the national and international level have been suggested as particularly relevant areas for the introduction and establishment of NIS in the Mediterranean waters (Tempesti et al. 2022). There are 47 ports along the coast of the Sea of Marmara (Deniz, Kilic 2010), with Ambarli, Bandirma, Haydarpasa, and Kocaeli being the largest in terms of maritime traffic. Unlike small marinas, large commercial ports have restricted access and complex infrastructure, making it challenging for researchers to conduct fieldwork and collect samples. This has resulted in a poorer understanding of biofouling assemblages of these environments compared to smaller ports, and subsequently hindering our ability to detect new introductions in the localities where they are more likely to occur. The diversity of artificial substrates is also more extensive in large ports, including various structures made of a wide range of materials in which marine fouling can grow. Concrete, metal, wood, plastic, and organic fibers (such as rope and textiles) have all been shown to harbor a variety of biofouling communities (Giangrande et al. 2021; Bae et al. 2022), with all these types of substrates often found within the same port. Therefore, the objective of this study was to document the diversity of a major fouling taxon (Hydrozoa) growing on artificial plates strategically placed in large commercial ports of the Sea of Marmara, and to assess the substrate preferences of hydroid colonies in relation to three materials commonly encountered in these environments (wood, plastic, and rope).

2. Materials and methods

The abundance and diversity of benthic hydroids and associated fouling fauna were assessed on wood, rope, and PVC panels at four major cargo and commercial ports in the Sea of Marmara. These ports were selected based on their importance in the region in terms of traffic, cargo tonnage, and container volume: 1) Ambarli (40°57′56.8″N; 28°40′36.9″E; Istanbul), 2) Haydarpasa (41°00′23.2″N; 29°00′26.2″E; Istanbul), 3) Kocaeli (40°43′01.5″N; 29°52′18.7″E; Kocaeli), and 4) Bandirma (40°21′04.4″N; 27°57′46.0″E; Balikesir; Fig. 1).

The four selected ports share a strategic location in the same biogeographic province, relatively similar challenges due to their large size and complex infrastructure, and comparable transportation access and connectivity to other ports in the region:

Ambarli is the largest container port in Türkiye and one of the busiest container ports in the entire Mediterranean region, as well as one of the few Turkish ports that can berth vessels larger than 300 meters. It serves as a key hub for shipping cargo to ports in Black Sea countries, as well as to destinations in the Middle East, Europe, and North America (DTO 2022; Okşaş 2023).

Haydarpasa is the oldest container port in the Marmara region and the most important port located on the Anatolian side of the Istanbul Strait (Ünlü 2007). It serves millions of people in both public and commercial operations, facilitating passenger transfers

Figure 1

Map of the sampling locations: 1) Ambarli port (Istanbul), 2) Haydarpasa port (Istanbul), 3) Kocaeli port (Kocaeli) and 4) Bandirma port (Balikesir).

between Europe and Asia, as well as managing crucial cargo operations for the megacity of Istanbul. Its key components include passenger terminals, cargo and container storage areas, ro-ro handling operations, and the main railway station (Ülker et al. 2023).

Kocaeli is one of the fastest growing ports in the country, as well as the largest port serving the city of Kocaeli/Izmit, with a hinterland covering a large part of the Anatolian Peninsula. It handles approximately 5% of the total foreign trade, and about 16% of all goods in tonnage in Türkiye (DTO 2022).

Bandirma is the largest port on the southern coast of the Sea of Marmara, one of the largest hubs connecting the megacity of Istanbul with the Central Anatolia and Aegean regions in Türkiye, and the main port open to international traffic in the province of Balikesir (DTO 2022).

In each port, three sets of panels – one set of three wood panels, one set of three PVC panels and one set of three PVC panels covered with rope (henceforth rope panels) – were submerged 1 meter below the water surface in June 2017. Each panel measured 15 × 15 × 0.5 cm. The panels remained underwater for 3 months and were recovered in September 2017. Upon recovery, each panel was fixed immediately in 96% ethanol, and processed for subsequent analyses. All hydroids from all panels were sorted out under a stereomicroscope and identified to species level with the aid of specific literature (Bouillon et al. 2004; Bouillon et al. 2006; Schuchert 2008). All other non-target, sessile, accompanying biofouling specimens (i.e. belonging to taxa other than Hydrozoa) were identified to higher taxonomic ranks. The number of polyps (hydrozoans), the number of thalli (algae), the number of colonies (bryozoans), and the number of individuals (all other taxa) were recorded for each biofouling taxon. Two datasets were subsequently created: 1) a matrix containing data on the abundance for the entire fouling community at higher taxonomic levels (the 'all taxa dataset'), and 2) a matrix containing data on the abundance of fouling hydroid species (the 'hydrozoan dataset').

Cluster and multivariate analyses were used to visualize the underlying patterns in the structure of biofouling assemblages between different ports and types of panels. To achieve this, the raw abundance data were log (x + 1) transformed and a similarity matrix based on Bray–Curtis distances was created for each dataset. A non-metric multidimensional scaling (nMDS) plot and a cluster diagram (hierarchical grouping) were then generated for each similarity matrix. The SIMPROF (similarity profile) routine was run for each cluster diagram to test the null hypothesis of no meaningful structure within groups (Clarke et al. 2008). All cluster and nMDS plots were created with Primer v. 6.1.11 software (Clarke, Gorley 2006).

3. Results

We identified nine higher-level taxa of sessile invertebrates in the composition of the studied fouling assemblages (Table 1, Fig. 2). With the exception of algae, scyphozoans and ascidians, most of the taxa occurred on ≥ 75% of the panels, but only Hydrozoa and Bivalvia were present in every sample, regardless of the port or type of panel. Scyphozoan polyps, on the other hand, were observed only on three panels, all within the same port. All sessile fouling taxa were observed in each of the analyzed panel types, albeit in different ports, and none of the individual ports had the complete set of taxa.

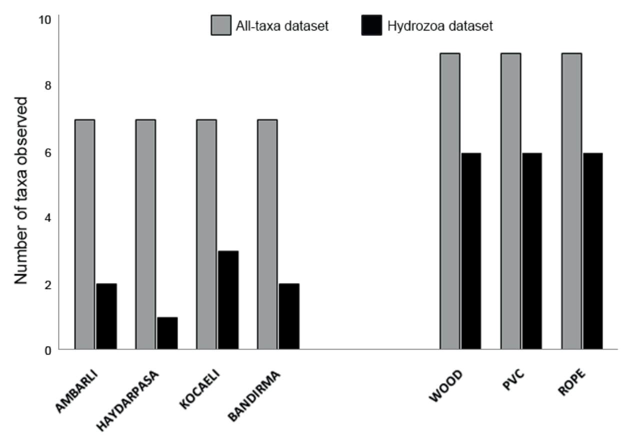

Figure 2

Number of higher-level taxa (all-taxa dataset) and species richness (Hydrozoa dataset) of sessile fouling organisms observed for each port and panel type.

Hydrozoans, bivalves, cirripedes, and actiniarians were the most abundant taxa, while Ascidiacea was the least abundant taxon recorded (Table 2, Fig. 3). In terms of differences between the ports, the highest total abundance of sessile biofouling was recorded in Haydarpasa, which was more than three times higher than the lowest recorded abundance (in Bandirma). The highest total and mean abundance of sessile biofouling was observed on rope panels, while the lowest on PVC panels.

A total of seven hydrozoan species were identified in the composition of the fouling community on the panels (Table 1). The most abundant fouling hydrozoan species was *Ectopleura crocea*, reported here for the first time from the Sea of Marmara, the abundance

Table 1

Abundance expressed as the number of polyps (Hydrozoa), thalli (algae), colonies (Bryozoa) or individuals (all other taxa) and frequency of occurrence (FO) of sessile biofouling taxa on recovered wood (W), PVC (P), and rope (R) panels from four major ports in the Sea of Marmara.

Taxon	Haydarpasa			Ambarli			Kocaeli			Bandirma			FO (%)
	W	P	R	W	P	R	W	P	R	W	P	R	
All-taxa dataset													
Algae	0	0	0	2	0	0	0	0	0	115	69	30	33.33
Cnidaria: Hydrozoa	260	253	500	193	161	200	132	177	267	24	30	54	100.00
Cnidaria: Scyphozoa	0	0	0	0	0	0	23	210	160	0	0	0	25.00
Cnidaria: Actiniaria	201	56	480	70	26	30	3	6	200	0	0	0	75.00
Annelida: Polychaeta	1	2	0	11	5	18	400	10	123	32	22	12	91.67
Mollusca: Bivalvia	13	152	640	78	50	67	430	120	280	26	15	17	100.00
Arthropoda: Cirripedia	313	29	4	122	35	17	18	7	0	287	95	73	91.67
Bryozoa: Cheilostomatida	8	4	0	6	3	2	27	43	44	3	2	3	91.67
Chordata: Ascidiacea	3	0	0	0	0	0	0	0	0	7	5	4	33.33
Hydrozoa dataset													
Ectopleura crocea (Agassiz, 1862)	260	253	500	0	0	0	0	0	0	0	0	0	25.00
Obelia dichotoma (Linnaeus, 1758)	0	0	0	130	70	110	50	40	90	0	0	0	50.00
Bougainvillia muscus (Allman, 1863)	0	0	0	0	0	0	54	81	135	0	0	0	25.00
Clytia gracilis (Sars, 1851)	0	0	0	0	0	0	0	0	0	24	0	0	8.33
Eudendrium capillare Alder, 1856	0	0	0	0	0	0	28	56	42	0	0	0	25.00
Eudendrium merulum Watson, 1985	0	0	0	0	0	0	0	0	0	0	30	54	16.67
Sertularella ellisii (Deshayes & Milne Edwards, 1836)	0	0	0	63	91	90	0	0	0	0	0	0	25.00

Table 2

Summary of total and mean (± standard deviation, SD) abundance of sessile biofouling taxa per port, type of panel, and taxon. Values are the number of individuals in the all-taxa dataset and the number of polyps in the Hydrozoa dataset.

Per port				
	All-taxa dataset		Hydrozoa dataset	
	Total	Mean ± SD	Total	Mean ± SD
Ambarli	1096	40.59 ± 60.49	554	26.38 ± 44.52
Haydarpasa	2919	108.11 ± 183.11	1013	48.24 ± 128.99
Kocaeli	2680	99.26 ± 127.42	576	27.43 ± 38.59
Bandirma	925	34.26 ± 59.25	108	5.14 ± 13.85
Per type of panel				
	All-taxa dataset		Hydrozoa dataset	
	Total	Mean ± SD	Total	Mean ± SD
wood	2808	78.00 ± 120.99	609	21.75 ± 55.11
PVC	1587	44.08 ± 67.36	621	22.18 ± 52.92
rope	3225	89.58 ± 159.38	1021	36.46 ± 98.88

Per taxon					
	All-taxa dataset		Hydrozoa dataset		
Higher-level taxon	Total	Mean ± SD	Species	Total	Mean ± SD
Algae	216	18.00 ± 36.93	*Ectopleura crocea*	1013	84.42 ± 164.07
Cnidaria: Hydrozoa	2251	187.58 ± 130.37	*Obelia dichotoma*	490	40.83 ± 48.7
Cnidaria: Scyphozoa	393	32.75 ± 72.21	*Bougainvillia muscus*	270	22.50 ± 44.34
Cnidaria: Actiniaria	1072	89.33 ± 142.92	*Clytia gracilis*	24	2.00 ± 6.93
Annelida: Polychaeta	636	53.00 ± 114.28	*Eudendrium capillare*	126	10.50 ± 19.91
Mollusca: Bivalvia	1888	157.33 ± 197.21	*Eudendrium merulum*	84	7.00 ± 17.13
Arthropoda: Cirripedia	1000	83.33 ± 108.29	*Sertularella ellisii*	244	20.33 ± 37.4
Bryozoa: Cheilostomatida	145	12.08 ± 16.27			
Chordata: Ascidiacea	19	01.58 ± 2.50			

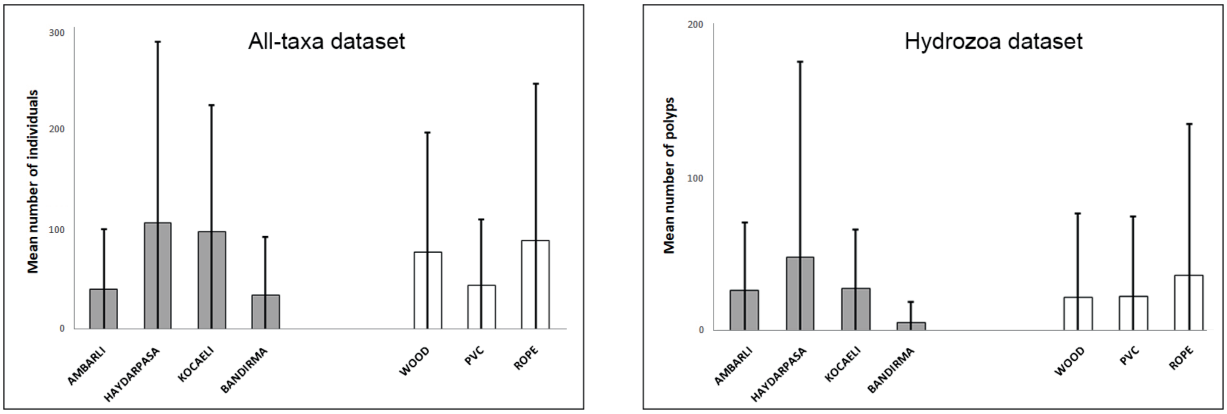

Figure 3

Average number of individuals (all-taxa dataset) and polyps (Hydrozoa dataset) of sessile fouling organisms observed for port and panel type.

of which was at least twice that of the second most abundant species, *Obelia dichotoma*. The least abundant hydrozoan species observed in this study was *Clytia gracilis*, which was recorded only once on a wood panel recovered from the port of Bandirma. In terms of frequency of occurrence, most of the fouling hydrozoan species (with the exception of *O. dichotoma*) were restricted to a single port, but when present, they occurred on all types of panels. *Obelia dichotoma* was the species with the widest distribution, recorded on all types of panels in the ports of Ambarli and Kocaeli. More hydrozoan polyps were collected on rope panels than on either of the other two types of panels (Table 2, Fig. 3). Similarly, hydroid colonies were more abundant in the port of Haydarpasa, where ca. 10 times more polyps were observed than in Bandirma, the port with the lowest abundance values (Table 2, Fig. 3).

In general, the nMDS plots and cluster diagrams for both the all-taxa dataset and the Hydrozoa dataset show relatively similar assemblages of sessile fouling organisms within the ports, regardless of the type of panel analyzed (Figs 4 & 5). When all taxa are considered, the biofouling assemblages on panels from Bandirma and Kocaeli appear to differ from each other and from those deployed in Ambarli and Haydarpasa. Biofouling assemblages from the latter two ports are loosely clustered, suggesting similar assemblage composition. In contrast, no clustering pattern related to the type of panel was observed in any of the surveyed ports (Fig. 4). This is evident again in the nMDS plot and cluster diagram for the Hydrozoa dataset, where each of the four ports form a well-defined group that includes assemblages from rope, wood, and PVC panels. Based on the species composition and the abundance of hydrozoans, the most dissimilar fouling assemblage occurred on wood in the port of Bandirma, which was the only case where a colony of *C. gracilis* was found (Fig. 5). The low stress value of the nMDS plots (< 0.04, below the commonly accepted threshold of 0.2) indicates a good representation of the data in the two dimensions shown in the plots.

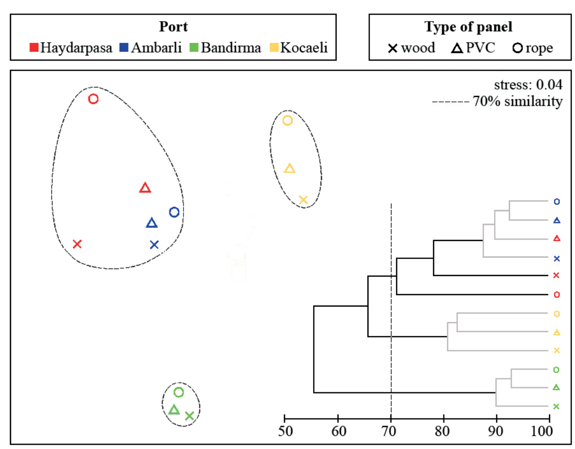

Figure 4

nMDS plot and cluster diagram based on the number of individuals for all sessile biofouling taxa found on recovered wood, PVC and rope panels in the ports of Ambarli, Haydarpasa, Kocaeli, and Bandirma. Well-supported clusters (as per the SIMPROF routine) are highlighted in light gray in the cluster diagram.

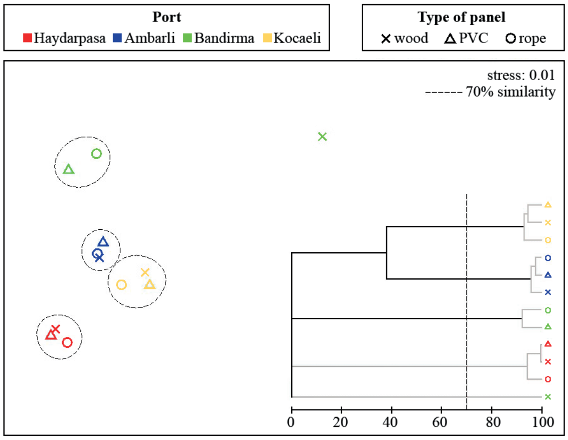

Figure 5

nMDS plot and cluster diagram based on the number of polyps for hydrozoan species on recovered wood, PVC, and rope panels in the ports of Ambarli, Haydarpasa, Kocaeli, and Bandirma. Well-supported clusters (as per the SIMPROF routine) are highlighted in light gray in the cluster diagram.

4. Discussion

The community of sessile fouling organisms observed in this study is typical of macrobenthic fouling assemblages growing on artificial substrates in Mediterranean ports, both with respect to high-level taxa and species level within Hydrozoa. Algae, hydroids, sea anemones, tube-building polychaetes, mussels, barnacles, bryozoans, and ascidians are all common biofouling taxa in Mediterranean harbors and marinas (Tempesti et al. 2022), and have constantly been reported as major structural biofouling agents in Turkish waters of the adjacent Aegean (Kocak, Kucuksezgin 2000) and Black seas (Snigirova et al. 2022), which was also confirmed by the results of our study. Macrofouling studies in the ports of the Sea of Marmara are scarce, but the set of taxa growing on panels used in our study nevertheless agrees with the overall picture of taxa composition of benthic hard-bottom communities found elsewhere in the basin, where the sessile structural component consists mainly of cnidarians, bivalves, bryozoans, and tunicates (e.g. Uysal et al. 2002).

The observed hydrozoan species represent a subset of the typical hard-bottom hydroid fauna in the Eastern Mediterranean (Isinibilir et al. 2015b; Yilmaz et al. 2020). Given the fact that benthic hydroids are among the first animals to colonize artificial marine substrates, as well as their ability to grow rapidly and settle repeatedly on a variety of surfaces, it is not surprising that they account for a large portion of the sessile macrobenthic biofouling on wood, PVC, and rope panels in large ports (Boero 1984; Martell et al. 2018). For the most part, the species observed in this study have already been reported as occurring in marinas and small ports in the Sea of Marmara (Topcu et al. 2018), but our discovery of large colonies of *Ectopleura crocea* on panels submerged in the port of Haydarpasa represents the first record for this species in the basin. The inventory of the hydrozoan fauna of the Sea of Marmara currently includes some 79 species, but new records are reported for the region in almost every recent publication on hydrozoans in the basin, highlighting the incompleteness of our knowledge on this relevant taxon at the regional level (Isinibilir et al. 2010; Isinibilir et al. 2015a; Isinibilir, Yilmaz 2016; Yilmaz et al. 2017; Albayrak, Balkis 2000; Topcu et al. 2018).

Ectopleura crocea is a well-documented fouling species frequently found on submerged artificial substrates in the western Mediterranean Sea (Morri, Boero 1986; Di Camillo et al. 2013). It was observed in large numbers in Eastern Mediterranean (Egyptian) ports in the 1980s (Abdel-Hamid et al. 1983; Shoukr, Abdel-Hamid 1987), but later studies did not find it in similar habitats in the Levant (Morri et al. 2009) and Aegean (Yilmaz et al. 2020) seas, nor did it occur in a study conducted in small marinas in the Sea of Marmara in 2015 (Topcu et al. 2018). Considered an invasive species in Australian and Korean waters (Fitridge, Keough 2013; Kim et al. 2020), it is suspected that *E. crocea* was introduced to the Pacific Ocean via ships (Kim et al. 2020; Choi, Kim 2023), since polyps of this species grow even on surfaces treated with antifouling compounds (Genzano 2001). In this sense, a similar explanation can be advanced for the presence of this species in the port of Haydarpasa. In our study, *E. crocea* showed no preference for any of the panel types tested, confirming previous observations that the species grows well on a wide range of artificial structures, including floating wood, ship hulls, plastic surfaces of boats and rafts, and barrels used for mussel cultivation (e.g. Brinckmann-Voss 1970; Morri 1981; Di Camillo et al. 2013; Fitridge, Keough 2013). The fact that a large number of *E. crocea* polyps were present in panels submerged for 3 months is also consistent with previous records of the species, indicating its role as a rapid colonizer in the early stages of fouling communities (e.g. Genzano et al. 2018).

Unlike *E. crocea*, which appears to grow poorly in natural habitats and appears to prefer artificial substrates (Di Camillo et al. 2013; Morri et al. 2017), other hydroid species observed on the panels are widespread taxa common on Mediterranean rocky substrates, where they are known to grow on a wide range of substrates (Bouillon et al. 2004). At least three of these taxa, *Bougainvillia muscus, Obelia dichotoma* and *Clytia gracilis*, belong to the most common and abundant hydrozoan species in small marinas of the Sea of Marmara (Topcu et al. 2018) and were frequently encountered during previous surveys in the region (Demir 1954; Ünsal 1981). In other parts of the Atlantic, *O. dichotoma* and *C. gracilis* were the most common hydrozoan species growing on artificial panels submerged for 3 months off the coast of South Carolina (Van Dolah et al. 1988) and, together with a *Bougainvillia* species, were identified as the main settlers in a study that analyzed the recruitment and succession of hydroids on experimental panels submerged for 3 months in the São Seabastião channel (Migotto et al. 2001). In a colonization and succession study conducted in the Ionian Sea (Western Mediterranean), *O. dichotoma*, *Eudendrium* spp., *Sertularella ellisii* and *B. muscus* were among the most abundant species growing on short-term (3 to 12 months) submerged panels (Martell et al. 2018). Based on these findings, the hydrozoan assemblages observed in this study can be characterized as typical of man-made substrates and habitats, demonstrating the rapid recruitment and early exploitation of available substrate space that is characteristic of opportunistic hydrozoans.

Differences in the local pool of species available for recruitment in each port, as well as port-specific environmental conditions, appear to impact the composition of fouling assemblages more than the type of panel. This is further supported by the fact that the two ports with the closest geographical proximity and supposedly the most similar environmental conditions (Ambarli and Haydarpasa, both within the limits of the city of Istanbul) shared a similar array of fouling organisms at higher taxonomic levels, while the port located farthest from the others (Bandirma) has the most dissimilar assemblage of fouling hydrozoans. The observed pattern of the highest abundance in the port of Haydarpasa (adjacent to the Istanbul Strait) and the lowest abundance in the port of Bandirma (located farthest from both the Istanbul Strait and the Canakkale Strait) confirms a previously documented trend in the area where higher values were observed for benthic invertebrate communities at locations closer to the straits, as opposed to other coastal sites within the Sea of Marmara (Uysal et al. 2002). This pattern could be attributed to the complex hydrodynamic processes that characterize the Istanbul Strait, which provide intensive nutrition for filter-feeding biofouling organisms due to an increased water exchange rate compared to other coastal areas (Uysal et al. 2002; Yalcin et al. 2017).

Similar biofouling assemblages developed on wood, PVC, and rope panels in each port. Several factors may have contributed to this pattern, including relatively homogeneous conditions within the ports in terms of water temperature, salinity, nutrient availability and flow, as well as high dispersal and recruitment rates of hydrozoans and other biofoulers (Boero, Bouillon 1993; Giangrande 1994), which given the proximity of different panels, may have facilitated rapid colonization of similar species across different types of substrates. In addition, human activities, such as internal boat traffic and maintenance, may have increased the spread of species within each port, thus making the observed biofouling assemblages uniform. Although the high similarity between assemblages of different types of panels seems to contradict previous research where the type of substrate greatly affected the species composition, diversity, and abundance of fouling organisms (e.g. Giangrande et al. 2021; Bae et al. 2022), a similar pattern has been observed previously for benthic hydroids in natural (Calder 1991) and artificial (Migotto et al. 2001) habitats, and it has been suggested that many benthic hydrozoan species are actually substrate generalists (Calder 1991).

The results of this study provide the first glance into the fouling hydrozoan assemblages currently occurring on some of the largest artificial environments in the Sea of Marmara. Our findings underscore the considerable variability of these assemblages, suggesting that their taxonomic composition and abundance is driven by site-specific dynamics. However, further research is needed to characterize the succession patterns of these communities, as well as to test the effects of seasonality on the colonization of artificial substrates in ports. Fouling hydrozoans act as structural elements that provide shelter for other organisms, facilitating the translocation of associated fauna (e.g. Ros et al. 2013). Understanding their diversity in large ports is therefore crucial to develop effective antifouling strategies that help prevent the spread of invasive species, especially in vulnerable systems such as the Sea of Marmara (Demirel et al. 2023).

Acknowledgements

Special thanks to the Ambarli Port Authority and their employee Samet İzgi for providing general statistical information. This work was supported by the Research Fund of Istanbul University (project No. 25369).

References

Abdel-Hamid, M. E., Mona, M. H., & Shoukr, F. A. (1983). Seasonal variations of growth and sexual maturity for *Tubularia crocea* (Cnidaria: Hydrozoa) in the eastern harbour of Alexandria. *Delta Journal of Science, 7*, 713–733.

Albayrak, S., & Balkis, N. (2000). Hydroid Polyps of the Bosphorus. *Turkish Journal of Marine Sciences, 6*(1), 41–53.

Altuğ, G., Aktan, Y., Oral, M., Topaloğlu, B., Dede, A., Keskin, Ç., Işinibilir, M., Çardak, M., & Çiftçi, P. S. (2011). Biodiversity of the northern Aegean Sea and southern part of the Sea of Marmara, Turkey. *Marine Biodiversity Records, 4*, e65, 1–17. https://doi.org/10.1017/S1755267211000662

Bae, S., Ubagan, M. D., Shin, S., & Kim, D. G. (2022). Comparison of recruitment patterns of sessile marine invertebrates according to substrate characteristics. *International Journal of Environmental Research and Public Health, 19*(3), 1083. https://doi.org/10.3390/ijerph19031083 PMID:35162107

Boero, F. (1984). The ecology of marine hydroids and effects of environmental factors: A review. *Marine Ecology (Berlin), 5*, 93–118. https://doi.org/10.1111/j.1439-0485.1984.tb00310.x

Boero, F., & Bouillon, J. (1993). Zoogeography and life cycle patterns of Mediterranean hydromedusae (Cnidaria). *Biological Journal of the Linnean Society. Linnean Society of London, 48*(3), 239–266. https://doi.org/10.1006/bijl.1993.1017

Bosch-Belmar, M., Escurriola, A., Milisenda, G., Fuentes, V. L., & Piraino, S. (2019). Harmful Fouling Communities on Fish Farms in the SW Mediterranean Sea: Composition, Growth and Reproductive Periods. *Journal of Marine Science and Engineering, 7*(9), 288–304. https://doi.org/10.3390/jmse7090288

Bouillon, J., Gravili, C., Pagès, F., Gili, J., & Boero, F. (Eds.) (2006). An introduction to Hydrozoa. Memoirs du Museum National d'Histoire Naturelle, Paris, 194, 591 pp.

Bouillon, J., Medel, M. D., Pagès, F., Gili, J. M., Boero, F., & Gravili, C. (2004). Fauna of the Mediterranean hydrozoa. *Scientia Marina, 68*(S2), 5-438. https://doi.org/10.3989/scimar.2004.68s25

Bressy, C., & Lejars, M. (2014). Marine Fouling: An overwiev. *Journal of Ocean Technology, 9*(4), 19–28.

Brinckmann-Voss, A. (1970). Anthomedusae-Athecatae (Hydrozoa, Cnidaria) of the Mediterranean: Capitata. *Stazione zoologica.*

Cabrini, M., Cerino, F., de Olazabal, A., Di Poi, E., Fabbro, C., Fornasaro, D., Goruppi, A., Flander-Putrle, V., Francé, J., Gollasch, S., Hure, M., Lipej, L., Lučić, D., Magaletti, E., Mozetič, P., Tinta, T., Tornambè, A., Turk, V., Uhan, J., & David, M. (2019). Potential transfer of aquatic organisms via ballast water with a particular focus on harmful and non-indigenous species: A survey from Adriatic ports. *Marine Pollution Bulletin, 147*, 16–35. https://doi.org/10.1016/j.marpolbul.2018.02.004 PMID:29454492

Calder, D. R. (1991). Associations between hydroid species assemblages and substrate types in the mangal at Twin Cays, Belize. *Canadian Journal of Zoology, 69*(8), 2067–2074. https://doi.org/10.1139/z91-288

Calder, D., Carlton, J. T., Larson, K., Mallinson, J. J., Choong, H. H., Keith, I., & Ruiz, G. (2019). Hydroids (Cnidaria, Hydrozoa) from marine fouling assemblages in the Galápagos Islands, Ecuador. *Aquatic Invasions, 14*(1), 21–58. https://doi.org/10.3391/ai.2019.14.1.02

Caspers, H. (1968). La macrophaune benthique du Bosphore et les problèmes de l'infiltration des éléments méditerranéens dans la mer Noire. [in French]. *Rapp Comm Int Mer Médit, 19*(2), 107–115.

Choi, H. Y., & Kim, S. (2023). *Ectopleura crocea* (Cnidaria: Hydrozoa) Identified as a Predator of Pelagic Fish Eggs through Cytochrome c Oxidase I Metabarcoding. *Journal of Marine Science and Engineering, 11*(11), 2178-2186. https://doi.org/10.3390/jmse11112178

Clarke, K. R., & Gorley, R. N. (2006). Primer. PRIMER-e.

Clarke, K. R., Somerfield, P. J., & Gorley, R. N. (2008). Testing of null hypotheses in exploratory community analyses: Similarity profiles and biota-environment linkage. *Journal of Experimental Marine Biology and Ecology, 366*(1-2), 56–69. https://doi.org/10.1016/j.jembe.2008.07.009

Demir, M. (1954). Boğaz ve Adalar sahillerinin omurgasız dip hayvanları. [in Turkish]. İstanbul Üniversitesi Fen Fakültesi Hidrobiyoloji Araştırma Enstitüsü Yayınları, *3*, 615 pp.

Demirel, N., Yildiz, T., Ulman, A., Zengin, M., Akoglu, E., Saygu, I., Ertor-Akyazi, P., Gül, G., Bedikoglu, D., & Yilmaz, I. N. (2023). Status of the Sea of Marmara ecosystem and its fishery resources: Mucilage episodes and recommendations for sustainable fisheries. *Istanbul University Press*, *5316*, 217–232 https://doi.org/10.26650/B/LS32.2023.003.10

Deniz, C., & Kilic, A. (2010). Estimation and assessment of shipping emissions in the region of Ambarli Port, Turkey. *Environmental Progress & Sustainable Energy, 29*(1), 107–115. https://doi.org/10.1002/ep.10373

Di Camillo, C. G., Boero, F., Gravili, C., Previati, M., Torsani, F., & Cerrano, C. (2013). Distribution, ecology and morphology of *Lytocarpia myriophyllum* (Cnidaria: Hydrozoa), a Mediterranean Sea habitat former to protect. *Biodiversity and Conservation, 22*, 773–787. https://doi.org/10.1007/s10531-013-0449-9

DTO (Turkish Chamber of Shipping). (2022). Annually Sector Reports, 2022. Turkish Chamber of Shipping.

Edyvean, R. (2010). Consequences of fouling on shipping. In S. Dürr & J. C. Thomason (Eds.), Biofouling, *10* (pp. 217–225). Wiley-Blackwell.

Fitridge, I., & Keough, M. J. (2013). Ruinous resident: The hydroid *Ectopleura crocea* negatively affects suspended culture of the mussel *Mytilus galloprovincialis*. *Biofouling, 29*, 119–131. https://doi.org/10.1080/08927014.2012.752465 PMID:23327223

Galea, H. R. (2008). On a collection of shallow-water hydroids

(Cnidaria: Hydrozoa) from Guadeloupe and Les Saintes, French Lesser Antilles. *Zootaxa, 1878*, 1–54. https://doi.org/10.11646/zootaxa.1878.1.1

Genzano, G. N. (2001). Associated fauna and sediment trappedby colonies of *Tubularia crocea* (Cnidaria, Hydrozoa) fromthe rocky intertidal of Mar del Plata, Argentina. *Biociencias, 9*(2), 105–119.

Genzano, G. N., Meretta, P. E., & Bremec, C. (2018). Macrobenthic colonization on the derelict fisheries vessel Khronometer, Cristo Rey submarine park, Argentina. *Marine Ecology (Berlin), 39*(2), e12491. https://doi.org/10.1111/maec.12491

Giangrande, A. (1994). The genus *Demonax* (Polychaeta, Sabellidae) in the Mediterranean Sea, with description of *D. tommasi n.* sp. *The Italian Journal of Zoology, 61*(3), 229–233. https://doi.org/10.1080/11250009409355890

Giangrande, A., Arduini, D., Borghese, J., Del Pasqua, M., Lezzi, M., Petrocelli, A., Cecere, E., Longo, C., & Pierri, C. (2021). Macrobenthic success of non-indigenous species related to substrate features in the Mar Grande of Taranto, Italy (Mediterranean Sea). *BioInvasions Records, 10*(2), 238–256. https://doi.org/10.3391/bir.2021.10.2.02

González-Duarte, M. M., Megina, C., & Piraino, S. (2014). Looking for longterm changes in hydroid assemblages (Cnidaria, Hydrozoa) in Alboran Sea (South-Western Mediterranean): A proposal of a monitoring point for the global warming. *Helgoland Marine Research, 68*, 511–521. https://doi.org/10.1007/s10152-014-0406-3

Guenther, J., Fitridge, I., & Misimi, E. (2011). Potential antifouling strategies for marine finfish aquaculture: The effects of physical and chemical treatments on the settlement and survival of the hydroid *Ectopleura larynx*. *Biofouling, 27*(9), 1033–1042. https://doi.org/10.1080/08927014.2011.627092 PMID:22017479

Henderson, P. (2010). Fouling and antifouling in other industries–power stations, desalination plants–drinking water supplies and sensors. In S. Dürr & J. C. Thomason (Eds.), Biofouling (pp. 288–305). Wiley-Blackwell.

Hopkins, G., Davidson, I., Georgiades, E., Floerl, O., Morrisey, D., & Cahill, P. (2021). Managing biofouling on submerged static artificial structures in the marine environment–assessment of current and emerging approaches. *Frontiers in Marine Science, 8*, 759194. https://doi.org/10.3389/fmars.2021.759194

Isinibilir, M., & Yilmaz, I. N. (2016). Jellyfish Species of the Sea of Marmara. In E. Özsoy, M. N. Çağatay, N. Balkıs, N. Balkıs, & B. Öztürk (Eds.), The Sea of Marmara; Marine Biodiversity, Fisheries, Conservation and Governance. Turkish Marine Research Foundation (pp. 390–400). TUDAV.

Isinibilir, M., Kideys, A. E., Tarkan, A. N., & Yilmaz, I. N. (2008). Annual cycle of zooplankton abundance and species composition in Izmit Bay (the northeastern Marmara Sea). *Estuarine, Coastal and Shelf Science, 78*(4), 739–747. https://doi.org/10.1016/j.ecss.2008.02.013

Isinibilir, M., Martell, L., Topçu, E. N., Yilmaz, I. N., & Piraino, S. (2015b). First inventory of the shallow-water benthic hydrozoan assemblages of Gökçeada Island (northern Aegean Sea). *The Italian Journal of Zoology, 82*(2), 281–290. https://doi.org/10.1080/11250003.2014.977970

Isinibilir, M., Yilmaz, I. N., & Demirel, N. (2015a). New records of jellyfish species in the Marmara Sea. *The Italian Journal of Zoology, 82*(3), 425–429. https://doi.org/10.1080/11250003.2015.1040858

Isinibilir, M., Yilmaz, I. N., & Piraino, S. (2010). New contributions to the jellyfish fauna of the Marmara Sea. *The Italian Journal of Zoology, 77*(2), 179–185. https://doi.org/10.1080/11250000902895766

Kideys, A. E. (2002). Ecology. Fall and rise of the Black Sea ecosystem. *Science, 297*(5586), 1482–1484. https://doi.org/10.1126/science.1073002 PMID:12202806

Kim, P., Yoon, T. J., & Shin, S. (2020). Environmental DNA and specific primers for detecting the invasive species *Ectopleura crocea* (Hydrozoa: Anthoathecata) in seawater samples. *Sustainability (Basel), 12*(6), 2360. https://doi.org/10.3390/su12062360

Kirkendale, L., & Calder, D. R. (2003). Hydroids (Cnidaria: Hydrozoa) from Guam and the Commonwealth of the Northern Marianas Islands (CNMI). *Micronesica, 35–36*, 159–188.

Kocak, F., & Kucuksezgin, F. (2000). Sessile fouling organisms and environmental parameters in the marinas of the Turkish Aegean coast. *Indian Journal of Marine Sciences, 29*(2), 149–157.

Lacoursière-Roussel, A., Bock, D. G., Cristescu, M. E., Guichard, F., & McKindsey, C. W. (2016). Effect of shipping traffic on biofouling invasion success at population and community levels. *Biological Invasions, 18*, 3681–3695. https://doi.org/10.1007/s10530-016-1258-3

Martell, L., Bracale, R., Carrion, S. A., Giangrande, A., Purcell, J. E., Lezzi, M., Gravili, C., Piraino, S., & Boero, F. (2018). Successional dynamics of marine fouling hydroids (Cnidaria: Hydrozoa) at a finfish aquaculture facility in the Mediterranean Sea. *PLoS One, 13*(4), e0195352. https://doi.org/10.1371/journal.pone.0195352 PMID:29608614

Megina, C., González-Duarte, M. M., López-González, P. J., & Piraino, S. (2013). Harbours as marine habitats: Hydroid assemblages on sea-walls compared with natural habitats. *Marine Biology, 160*(2), 371–381. https://doi.org/10.1007/s00227-012-2094-3

Meloni, M., Correa, N., Pitombo, F. B., Chiesa, I. L., Doti, B., Elías, R., Genzano, G., Giachetti, C. B., Giménez, D., López-Gappa, J., Pastor, C., Wandeness, A. P., Ramírez, F. C., Roccatagliata, D., Schulze-Sylvester, M., Tatián, M., Zelaya, D. G., & Sylvester, F. (2021). In-water and dry-dock hull fouling assessments reveal high risk for regional translocation of nonindigenous species in the southwestern Atlantic. *Hydrobiologia, 848*, 1981–1996. https://doi.org/10.1007/s10750-020-04345-4

Migotto, A. E., Marques, A. C., & Flynn, M. N. (2001). Seasonal recruitment of hydroids (Cnidaria) on experimental panels in the São Sebastião Channel, Southeastern Brazil. *Bulletin of Marine Science, 68*(2), 287–298.

Morri, C., & Boero, F. (1986). Marine fouling hydroids. In: Catalogue of the main marine fouling organisms, vol 7 hydroids. Catalogue of main marine fouling organisms, Bruxelles, pp 1–91.

Morri, C. (1981). Contributo alla conoscenza degli Idrozoi lagunari italiani: Idropolipi della Laguna Veneta settentrionale. [In Italian]. *Annali del Museo Civico di Storia Naturale di Venezia*, *31*(1980), 85-93.

Morri, C., Bianchi, C. N., Di Camillo, C. G., Ducarme, F., Allison, W. R., & Bavestrello, G. (2017). Global climate change and regional biotic responses: Two hydrozoan tales. *Marine Biology Research, 13*(5), 573–586. https://doi.org/10.1080/17451000.2017.1283419

Morri, C., Puce, S., Bianchi, C. N., Bitar, G., Zibrowius, H., & Bavestrello, G. (2009). Hydroids (Cnidaria: Hydrozoa) from the Levant Sea (mainly Lebanon), with emphasis on alien species. *Journal of the Marine Biological Association of the United Kingdom, 89*(1), 49–62. https://doi.org/10.1017/S0025315408002749

Okşaş, O. (2023). Carbon emission strategies for container handling equipment using the activity-based method: A case study of Ambarlı container port in Turkiye. *Marine Policy, 149*, 105480. https://doi.org/10.1016/j.marpol.2023.105480

Ostroumoff, A. (1896). Otchet o dragirovkax i planktonnyix ulovax ekspeditsii "Selyanika". [in Russian]. *Bulletin de l'Académie impériale des sciences de St.-Pétersbourg*, 5, 33-92.

Öztürk, B., Öztürk, A. A., & Algan, N. (2001). Ship originated pollution in the Turkish Straits System. In B. Öztürk & N. Algan (Eds.), In Proc. Int. Symp. on Regional Seas, Tudav Publication, Istanbul (pp. 86-94).

Page, H. M., Dugan, J. E., & Piltz, F. (2010). Fouling and antifouling in oil and other offshore industries. In S. Dürr & J. C. Thomason (Eds.), Biofouling (pp. 252–266). Wiley-Blackwell.

Piraino, S., De Vito, D., Schmich, J., Bouillon, J., & Boero, F. (2004). Reverse development in Cnidaria. *Canadian Journal of Zoology, 82*, 1748–1754. https://doi.org/10.1139/z04-174

Ros, M. J. M., Guerra-García, J. M., González-Macías, M., Saavedra, Á., & López-Fe, C. M. (2013). Influence of fouling communities on the establishment success of alien caprellids (Crustacea: Amphipoda) in Southern Spain. *Marine Biology Research, 9*(3), 261–273. https://doi.org/10.1080/17451000.2012.739695

Schuchert, P. (2008). The European athecate hydroids and their medusae (Hydrozoa, Cuidaria): Filifera Part 3. *Revue Suisse de Zoologie, 115*(2), 221–302. https://doi.org/10.5962/bhl.part.80426

Schultz, M. P., Bendick, J. A., Holm, E. R., & Hertel, W. M. (2011). Economic impact of biofouling on a naval surface ship. *Biofouling, 27*(1), 87–98. https://doi.org/10.1080/08927014.2010.542809 PMID:21161774

Shoukr, F. A., & Abdel-Hamid, M. E. (1987). Morphological variations of *Tubularia crocea* (Agassiz, 1862) (Hydrozoa: Tubulariidae) in Egyptian harbours. *Arab Gulf Journal of Scientific Research B-Agriculture and Biological Sciences, 5*(3), 455–462.

Snigirova, A. O., Uzun, O. Y., Bondarenko, O. S., Kapshyna, I. A., Synegub, I. A., Portianko, V. V., Kudrenko, S. A., Rybalko, O. A., Vorobyova, L. V., & Vynogradov, O. K. (2022). Biofouling growth on plastic substrates: Experimental studies in the Black Sea. *Biosystems Diversity, 30*(4), 397–405. https://doi.org/10.15421/012239

Tempesti, J., Langeneck, J., Romani, L., Garrido, M., Lardicci, C., Maltagliati, F., & Castelli, A. (2022). Harbour type and use destination shape fouling community and non-indigenous species assemblage: A study of three northern Tyrrhenian port systems (Mediterranean Sea). *Marine Pollution Bulletin, 174*, 113191. https://doi.org/10.1016/j.marpolbul.2021.113191 PMID:34864465

Terlizzi, A., & Faimali, M. (2010). Fouling on artificial substrata. In S. Dürr & J. C. Thomason (Eds.), Biofouling (pp. 170–184). Wiley-Blackwell.

Thompson, D. L. (1977). Biofouling organisms and their salinity tolerance on navigational buoys in Upper San Francisco Bay. Naval Postgraduate School. https://doi.org/10.5962/bhl.title.61336

Topcu, N. E., Martell, L. F., Yilmaz, I. N., & Isinibilir, M. (2018). Benthic hydrozoans as potential indicators of water masses and anthropogenic impact in the Sea of Marmara. *Mediterranean Marine Science*, *19* (2), 273-283. https://doi.org/10.12681/mms.15117

Tortonese, E. (1959). Osservazioni sul Bentos del mar di Marmara e del Bosforo. [in Italian]. *Rivista di Scienze Naturali, 50*, 18–26.

Ülker, D., Göksu, S., Yalçın, E., & Canbulat, Ö. (2023). Ship-generated waste management in Istanbul ports: An analytical methodology to evaluate waste reception performance. WRP. https://doi.org/10.4274/jems.2023.53244

Ünlü, S. (2007). Comparative analytical data in the source determination of unknown spilled oil in the Haydarpaşa Port (Marmara Sea), Turkey. *Bulletin of Environmental Contamination and Toxicology, 78*(5), 363–367. https://doi.org/10.1007/s00128-007-9199-2 PMID:17618381

Ünsal, I. (1981). Ege ve Marmara denizlerinin hidroid polipleri. (Doçentlik Tezi). [in Turkish]. İstanbul Üniversitesi Fen Fakültesi Biyoloji Bolümü. 70 pp.

Uysal, A., Yüksek, A., Okuş, E., & Yilmaz, N. (2002). Benthic community structure of the Bosphorus and surrounding area. *Water Science and Technology, 46*(8), 37–44. https://doi.org/10.2166/wst.2002.0140 PMID:12420963

Van Dolah, R. F., Wendt, P. H., Knott, D. M., & Wenner, E. L. (1988).

Recruitment and community development of sessile fouling assemblages on the continental shelf off South Carolina, USA. *Estuarine, Coastal and Shelf Science, 26*(6), 679–699. https://doi.org/10.1016/0272-7714(88)90043-1

Yalcin, B., Yılmaz, U. E., & Artüz, M. L. (2017). Nutrition profile of the Sea of Marmara between years 2010 and 2013. *Journal of the Turkish Chemical Society Section A: Chemistry, 4*(1), 197–226. https://doi.org/10.18596/jotcsa.287325

Yilmaz, I. N., Isinibilir, M., Vardar, D., & Dursun, F. (2017). First record of *Aequorea vitrina* Gosse, 1853 (Hydrozoa) from the Sea of Marmara: A potential invader for the Mediterranean Sea. *Zoology in the Middle East, 63*(2), 178–180. https://doi.org/10.1080/09397140.2017.1299334

Yilmaz, N., Martell, L., Topcu, N. E., & Isinibilir, M. (2020). Benthic hydrozoan assemblages as potential indicators of environmental health in a Mediterranean marine protected area. https://doi.org/10.12681/mms.20593

Zaiko, A., Martinez, J. L., Ardura, A., Clusa, L., Borrell, Y. J., Samuiloviene, A., Roca, A., & Garcia-Vazquez, E. (2015). Detecting nuisance species using NGST: Methodology shortcomings and possible application in ballast water monitoring. *Marine Environmental Research, 112*, 64–72. https://doi.org/10.1016/j.marenvres.2015.07.002 PMID:26174116