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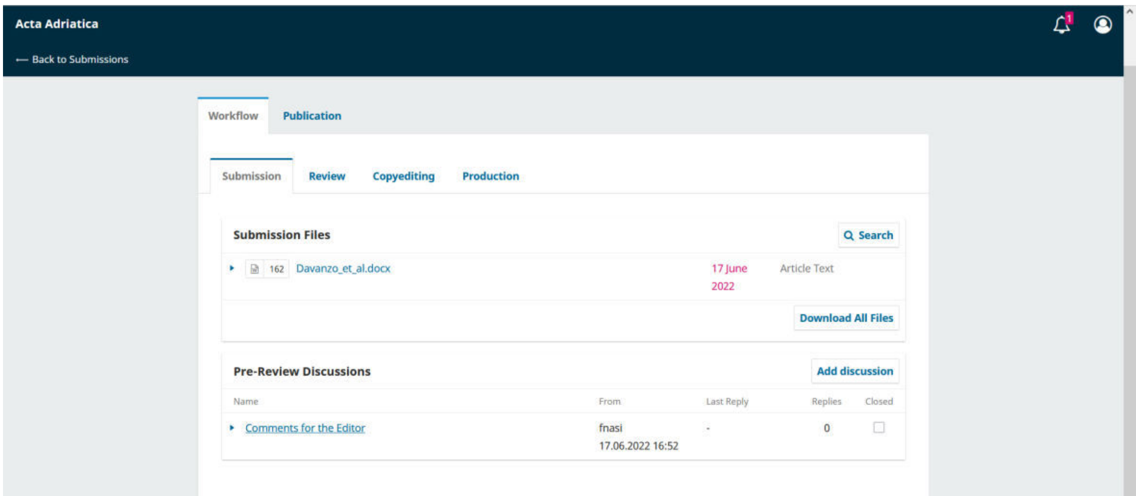
Foreword

The Deliverable 4.2.6 consists of a scientific paper in which some of the biological results, gained over the project Ecomap, are presented. The biodiversity of the macrozoobenthic community and its functional features were investigated in Špinut and Strožanac marinas, two project study areas. The main results were gathered in the paper "Diversity and spatial distribution patterns of soft-bottom macrofaunal communities inhabiting two Croatian recreational marinas" by Davanzo et al. The manuscript has been submitted to the international journal Acta Adriatica (see screenshots below) and is enclosed to this Deliverable as an attachment.



Diversity and spatial distribution patterns of soft-bottom macrofaunal communities inhabiting two Croatian recreational marinas

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ABSTRACT

In semi-enclosed basins, such as ports, the effects of point source and synergistic forms of contaminations are emphasized. The effects of human pressure on benthic macrofaunal assemblages inhabiting touristic marinas have been seldom studied, especially in the eastern part of the Adriatic Sea. In July 2019, we investigated the macrofaunal communities in two Croatian marinas located nearby the city of Split (Špinut and Strožanac). The influence of the morphology of the basins and the lasting anthropogenic activities, such as boat careening and painting, on macrofaunal diversity and feeding structure, was evaluated. We observed higher macrofaunal densities and species richness at the main entrances than at the inner sites in both marinas. In Špinut, a clear confinement gradient pattern was mirrored in the number of species. In Strožanac marina the macrofaunal community was not directly influenced by the confinement gradient, probably because of the morphology of the basin, which is more open compared to Špinut. In addition, the macrofaunal community observed in Strožanac at the station nearby the boathouse, where boat careening and painting take place, did not seem to be influenced by these activities. This station was located toward the outer part of the basin, thus the sediments were directly influenced by high water renewal, improving the quality of the sea bottom. On the contrary, in Špinut, we observed an impoverished community with a sharp reduction in species numbers near the boathouse area. In both marinas, the variation of the feeding structure and the species composition were likely driven by the grain-size. Subsurface deposit feeders characterized the finer sediments of both marinas, whereas the suspension feeders dominated the sandy-bottom stations. Well-balanced feeding guilds characterized the station near the boathouse in Špinut. However, only a few species represented each trophic guild at this site, which could indicate higher community vulnerability.

KEYWORD: Feeding habits, Beta-diversity, Macrofauna, Marina, Eastern Adriatic Sea

INTRODUCTION

Coastal tourism plays a major role in the economic development of many countries. Its recreational value is estimated to be the highest along the densely populated coastal areas (GHERMANDI & NUNES, 2013). However, this increased recreational use of coastal waters has led to greater demands for boat-mooring facilities over the last decades. To meet this demand, the number of marinas has rapidly increased, and concern about their environmental impacts is growing (GUERRA-GARCÍA & GARCIA-GÓMEZ, 2005; DAVENPORT & DAVENPORT, 2006). Artificial constructions in coastal areas, as marinas and touristic ports, can cause substantial habitat destruction and local environmental change (BUGNOT et al., 2020). The building of such infrastructure requires a lot of modifications to the natural environment (i.e., seabed dredging, land reclamation, installation of seawalls, pilings, and pontoons) that change the physical-chemical characteristics of the nearby and adjacent marine areas. These alterations potentially influence the diversity and distribution of the resident biological communities (RIVERO et al., 2013; CORDELL et al., 2017). Ports can be the recipient and the source of considerable anthropogenic disturbance, both for marine and adjacent land habitats, since they centralize a range of environmental problems, such as emission of air pollutants, noise, sediment dredging and transport, industrial installations, jetties construction, wastewater discharges, oil spill accidents, leaks of petroleum derivatives and antifouling coatings, storage and spillage of hazardous materials, as well as the introduction of invasive species (DARBRA et al., 2005; CHATZINIKOLAOU et al., 2018).

Furthermore, marina structures (e.g., piles and pontoons) may also alter water circulation, decrease the current flow, increasing natural sedimentation rates (TURNER et al., 1997). They are designed for smaller boats and are frequently semi-enclosed, with their innermost parts experiencing lower water renewal and thus anoxia with detrimental effects on the benthic communities (GUERRA-GARCÍA & GARCIA-GÓMEZ, 2005).

The benthic macroinvertebrates are the most traditionally used biological indicators of ecosystem health in marine environments, especially infaunal assemblages associated with soft-bottom habitats (BORJA et al., 2003). Most of them are sessile, semi-sessile, or confined to restricted bottom areas, and they spend a complete life cycle or its greater part in direct contact with bottom sediments. Moreover, macrofaunal invertebrates have different feeding habits (e.g., suspension feeder, deposit feeders, and carnivores), representing the higher trophic levels of the benthic food web (GRAY & ELLIOTT, 2009). Thus, benthic communities' structure can be directly linked to disturbance exposure. Changes in macrofaunal diversity (species composition and feeding structures) can be mirrored in variations of the ecosystem functioning in marinas.

Overall, few information is available on soft-bottom benthic communities' diversity and species composition in small marinas (MCGEE et al., 1995; TURNER et al., 1997; CHATZINIKOLAOU et al., 2018), and the feeding structures of the macrofaunal community inside the marinas are even less explored.

In order to support small local ports to design and apply better environmental strategies aimed at a sustainable management of their maritime space, some initiatives have recently been set up such as the international European project ECOMAP (ECOsustainable management of MArine and tourist Ports). ECOMAP aims at improving the environmental quality conditions of nautical ports by promoting a coordinated development and implementation of environmentally friendly solutions and the exchange of knowledge and good practices between Italian and Croatian recreational ports. In this context, one of the project goals is to improve the environmental quality conditions of small marinas and touristic ports, influenced by anthropogenic activities.

In this study, we investigated the variation in diversity, species composition and feeding habits of macrofaunal communities inhabiting two Croatian marinas, namely Špinut and Strožanac, characterized by different morphology and anthropogenic impacts. To this end, we considered the macrofaunal α- and β- diversity: the α-diversity refers to the biodiversity and its components (richness, diversity, and evenness) at each site, whereas the β-diversity focuses on two distinct processes: the replacement, and the loss or gain of a subset of species at a spatial scale. This study is one of the ECOMAP project outcomes as it represents a first insight into the actual conditions of the soft-bottom macrozoobenthic community in Špinut and Strožanac marinas. More precisely, we hypothesized that i) the morphology of the basin and the long-lasting anthropogenic activities strongly affect the species composition and biodiversity of benthic invertebrates; (ii) the environmental features of the marinas shape the feeding structures of macrofaunal communities.

MATERIAL AND METHODS

Špinut is a relatively large marina (hosting 780 boats), and it was established in 1973. This marina is located in the north of the city of Split, under the Marjan hill and next to its protected wood park. Špinut faces Kastela Bay, which is characterized by several freshwater springs that influence the seawater temperature and salinity during the winter and spring seasons (FRITZ & BAHUN, 1983). Strožanac marina has been operational since 1975, and it hosts 330 boats belonging to local people. The marina is located west of a 500-meter-long gravel beach along the coast (south of Podstrana municipality) and south-east of the mouth of a small river named Žrnovnica.

Sampling was carried out in July 2019 at five stations in each marina (Fig. 1). The sampling stations were chosen considering the confinement gradient (i.e., the distance from the main port entrance and the time required for the renewal of marine water) and the presence of anthropogenic activities like boat careening and painting (hereafter, named boathouse area) (Fig. 1a, b). Depths and geographical coordinates of all stations are presented in Table 1.

At each sampling station, salinity and temperature of bottom seawater were registered by a multiparameter probe YSI ECO2 EXP7 20014.

Sediments for grain-size and macrofauna analyses were sampled using a stainless steel van Veen grab (0.1 m^2). For macrofauna detection three replicates per station were taken.

Sediment samples for the grain-size analyses were sieved at 2 mm and pre-treated with 10% hydrogen peroxide before being analysed with a BECKMAN COULTER LS 13 320 Laser Diffraction Particle Size Analyzer. Data are expressed as percentages of sand, silt, and clay following the Udden-Wentworth grain-size classification (WENTWORTH, 1922).

The collected sediments for macrofauna were sieved through a 500 μm mesh to retain the invertebrates and immediately fixed with 70% ethanol for further determination. In the laboratory, organisms were separated from the sediment remains, sorted, and identified to the species level whenever possible. Species determination was done using traditional identification keys listed in MORRI et al. (2004). The abundance was expressed as individuals per m^2.

To investigate the functional structure of the community, we considered the feeding habits as the functional trait of paramount importance. Six different feeding habits were assigned to all individuals: suspension feeders (SF), deposit feeders (DF) divided into surface deposit (SDF) and subsurface deposit (SSDF) feeders, carnivores (C), omnivores (OMN), and herbivores (H). These functional traits were assigned to each species based on the database by FAULWETTER et al. (2014) and the literature (JUMARS et al., 2015). The values of feeding guilds for each sampling station and area were expressed as their relative abundance (RA %).

We assessed the benthic community α-diversity and its components across space, calculating the (i) species richness; (ii) Shannon–Weaver biodiversity- H' (Log_2) and (iii) Pielou evenness (J'). The H' diversity was coupled to the analyses of β-diversity. This diversity portioning framework (VELLÉGER et al., 2013) was based on Jaccard's dissimilarity index (BASELGA et al., 2012). β-diversity equals 0 when communities are identical and equals 1 when communities are maximally dissimilar along spatial scales (e.g., no species shared for taxonomic β-diversity; BASELGA, 2010). We investigated whether the β-diversity among stations of each marina was mostly due to turnover (i.e., differences in species between stations were due to a replacement) or to nestedness resultant processes (i.e., species between two stations represented a subset of those found at the other stations). Furthermore, multivariate analyses were performed to assess the variation in species composition along spatial scales (one-way PERMANOVA with an unrestricted permutation of raw data and 9999 permutations). The following fixed factors were applied for each test: (i) 'marina'; (ii) 'confinement gradient'. The latter factor was tested for each marina separately. In order to visualize any spatial patterns of macrofaunal species composition in the two marinas, a non-metric multidimensional scaling ordination (nMDS) was performed. The vectors of temperature, salinity, grain-size (sand, silt, and clay) were overlaid. Additionally, vectors of heavy metals collected concomitantly at the same sampling stations (unpublished data) were overlaid. We selected contaminants strictly linked to careening and boat painting activities (i.e., Cu, Cd, Cr, Ni, Pb, Zn; SINGH & TURNER, 2009).

The biotic matrix for the multivariate analyses was previously square root transformed, and then the Bray-Curtis similarity was applied. Furthermore, to highlight differences between the two marinas, the macrofaunal community biodiversity and relative abundance of feeding habits indices were tested by the Mann-Whitney U test, applying the factor 'marina'. This analysis was carried out using STATISTICA 7 software.

The univariate (i.e., H' and J') and the multivariate analyses (PERMANOVA and nMDS) were performed using PRIMER 7 (PRIMER-E Ltd. Plymouth, UK) (CLARKE et al., 2014).

RESULTS

The physical features of the water column (temperature and salinity) at the moment of sampling are reported in Table 1.

Špinut marina was characterized by muddy sediments in the inner part, and higher sand percentage at the port entrance (SP3, Table 2). A similar grain-size distribution pattern was noticed in Strožanac, where the highest percentage of sand was observed at the main entrance (PD2, Table 2).

In Špinut marina, abundances varied from 76.6±124.2 ind. m^{-2} (SP4) to 2760.0±1459.3 (SP2) ind. m^{-2}. Higher densities were noticed at stations nearby the main entrance (SP3 and SP2), whereas lower values were observed in the inner sites (SP1 and SP5). In Strožanac marina, the lowest macrofaunal abundance was observed at PD3 (150±141.8 ind m^{-2}), whereas the highest value was recorded at PD2 (2710±874.7 ind. m^{-2}). Polychaetes generally dominated in Špinut, with values ranging from 61.3% at SP2 to 93.5% at SP1, except for SP3 and SP4, where molluscs accounted for the highest values (54.5% and 82.6%, respectively). We observed the same pattern in Strožanac, where polychaetes dominated at most stations, varying from 82.0% (PD5) to 85.5% (PD2, PD4), except for PD1 and PD3 where molluscs represented 78.1% and 68.9% of the total macrofaunal community, respectively.
Overall, 223 species were identified in both marinas. In Špinut marina, the highest species number (S=85) was obtained at the station nearby the main entrance (SP3), whereas decreasing numbers were noticed inside the marina (Fig. 2a). The high species richness at SP3 was mirrored in the H' (Shannon-Wiener biodiversity) index (H'=4.75). Although only 9 species were observed at SP4, the lowest value was obtained at SP1 (H'=2.12; Fig. 2a). This was probably due to the highest dominance of a single species, i.e., the polychaete *Pseudoleiocapitella fauveli* (65.0 % of total abundance). This was mirrored in the lowest value of J' observed at this station (J'=0.41) Similarly, in Strožanac, the highest species number (S=79) was observed at the station nearby the main entrance (PD2; Fig. 2b). Despite only 13 species were observed at PD3, the lowest values of H' and J' were obtained at PD1 (H'=3.00 and J'=0.59). This was due to the highest dominance of a single species, e.g., the bivalve *Loripes orbiculatus* (43.3% of total abundance). The Mann-Whitney test did not evidence significant differences in macrofaunal densities and diversity values between the two marinas.
The spatial β-diversity analysis underlined that a great variation in the assemblage composition was observed along the confinement gradient from the main entrance toward the inner stations of Špinut (Table 3). Despite the major contribution of turnover to the total β-diversity, the nestedness-resultant components among stations were quite higher. In addition, the community in front of the boathouse was composed of species' subsets also observed at the station nearby the entrance (nestedness-resultant SP3 vs. SP4: 0.56). On the contrary, the β-diversity analysed in Strožanac was characterized by lower nestedness-resultant components and was mainly ascribable to the turnover. The highest values of turnover were noticed between PD1 vs. PD5 (0.86; Table 3). We did not observe any variation in species composition between Špinut and Strožanac (by PERMANOVA test). This result was mirrored in the species composition. Both marinas were characterized by the same dominant species, like the polychaete *P. fauveli* and the molluscs *Abra alba* and *L. orbiculatus* (Table 4). Moreover, in Špinut marina, an alien species, the polychaete *Neopseudocapitella brasiliensis*, was identified at stations SP2 and SP3, with low abundance values of 6.6±11.5 and 20.0±17.3 ind. m^{-2}, respectively.
The nMDS analysis (Fig. 3) gathered those stations placed near the open part of the marinas (i.e., SP3, PD2, PD4 and PD5) on the left side of the plot, as the vectors of salinity and sand. On the contrary, the inner stations of Strožanac were plotted on the lower and right side of the graph, as the silt, clay, temperature and Ni and Cr vectors. In addition, the station nearby the boathouse (SP4) in Špinut marina was plotted separately from the others in the nMDS graph, driven by the higher concentrations of Pb, Zn, Cd, and Cu in the sediments. The feeding habits taken into account in this study confirmed the nMDS outputs. The variation of feeding guilds could be directly linked to the position of stations inside the basin (Fig. 4). In Špinut marina, SSDF dominated the community at the inner stations (i.e., SP1, SP2), with values ranging from 82.7% to 84.5%, respectively. SDF reached high values at the outer ones (i.e., SP3 and SP4) with 49.1% and 45.5%, respectively, followed by carnivores (24.5% at SP3 and 27.3% at SP4). An intermediate situation was displayed at SP5, with a high percentage of both SSDF (60.4%) and SDF (27.8%). As for Špinut, the position of stations inside the marina of Strožanac reflected a clear difference in the macrofaunal feeding structure. The inner stations (PD1 and PD3) were dominated by SF (50.4% and 26.2%, respectively) and SDF, with values ranging from 24.7% (PD1) to 33.3 % (PD3). The outer stations (PD2, PD4 and PD5) showed a community dominated by SSDF (29.3%, 58.5% and 44.5%, respectively), followed by SDF (38.4%, 15.3%, 21.3 %, respectively).

DISCUSSION

The species and diversity variation patterns indicated that the macrofaunal diversity was highly influenced by the renewal time of marine water, showing low biodiversity and strong dominance of few species (GUELORGET & PERTHUISOT, 1983) in areas where the renewal time was high (see Fig. 2). In fact, we can state that small marinas can be considered like brackish environments, where high diversity is commonly observed toward the open part of the basin, whereas lower species numbers with few dominant taxa are present in its innermost part (TAGLIAPIETRA et al., 2009).

However, we did not observe species typical of paralic environments (as lagoons or basins with freshwater inputs). This could be ascribable to the lower variation in the salinity gradient compared to a lagoonal system (BLASUTTO et al., 2005). We can infer that the confinement was higher toward the inner part of the basin (i.e., SP1, SP4, PD1, and PD3). Moreover, the grain-size distribution could be due to the intrinsic nature of the marinas that, like any other area sheltered from waves and marine currents, are prone to siltation (WINTERWEP, 2005). In fact, we observed a higher percentage of sand at stations placed nearby the main port entrance, whereas finer sediments were noticed at the inner stations.

Overall, regarding the different morphology of Strožanac and Špinut marinas, Strožanac is undoubtably a more open system than Špinut. This aspect was mirrored in higher nestendess-resultant values of β-diversity in Špinut that evidenced the presence of a community characterized by species that were a subset of those inhabiting the nearby stations (BASELGA et al., 2012). On the contrary, the higher turnover values observed at sampling stations in Strožanac marina indicated that a higher variation in species composition among stations was present. The presence of seagrass coverage (*Zostera* spp., Nasi pers. comm.) enhanced this species difference among stations, particularly at PD1 and PD3. In Špinut marina, the differences among stations were mainly due to the grain-size distribution and anthropogenic influence in the basin (i.e., boathouse area) (see Fig. 3). The highest diversity observed at SP3 was due to mixed environmental conditions (i.e., major seawater renewal and high sand content). In fact, at the latter station, common marine species, rare species (the polychaete *Paragoniadides* sp.), and alien taxa (the polychaete *Neopseudocapitella brasiliensis*) were all co-occurring. Despite the differences among stations for each marina, we did not observe significant variations in species composition between Strožanac and Špinut (by PERMANOVA test). A few dominant species, like the polychaete *Pseudoleiocapitella fauveli* and the mollusc *Abra alba,* have probably masked the variation of less abundant species in both marina; thus, the statistical permutation did not evidence significant differences. However, these two macrofaunal invertebrates could be considered ubiquity species of costal environments that reach the highest dominance in the muddy fine sands, as those present at the inner stations of both marina (DAUVIN, 2000 and D'ALESSANDRO et al., 2016).

The presence of anthropogenic activities seemed to strongly affect the species' composition at that station, where the lowest number of species was observed (see Fig.2 and Fig.3). In fact, we observed an impoverished community nearby the boathouse area in Špinut (SP4) which sediments were characterized by a higher concentration of heavy metals ascribable mainly to boat-painting activity (i.e., Cd, Cu, Pb and Zn; SINGH & TURNER, 2009). Even if careening and boat painting activities were located in Strožanac too, we did not observe such a sharp reduction in the number of species at the nearby station (PD2). At this station, placed also toward the open side of the marina, the macrofaunal community was not so strongly affected by the presence of the boathouse. The higher depth (see Table 1) and a more open system likely increased the dilution of the contaminants deriving from this activity. Our results agree with those of CHATZINIKOLAOU et al. (2018). They observed a reduction of macrofaunal density and species in the area directly influenced by human activity in tourist ports of the Mediterranean Sea (i.e., Cagliari-Italy, Heraklion-Greece and El Kantaoui-Tunisia). In addition, at the inner stations of Strožanac, characterized by high percentages of silt and clay.

In both marinas, the variation of the feeding structure, as well as the species composition, could be driven by the grain-size pattern. Sediment composition is a key element in structuring the macrofaunal community and the distribution of dominant species, also when related to organic enrichment (HERMAND et al., 2008). Deposit-feeding invertebrates were reported to be numerically dominant in sandy-mud or muddy sediments (NASI et al., 2017 and reference therein). Much of the detrital food for these invertebrates is associated with a high proportion of particles within the silt-clay range. The high surface-area-to-volume ratio of small particles provide a large expanse for the attachment and growth of microbial populations that produce mucopolysaccharide exudates, which are very palatable for these invertebrates (DONALD & LARRY, 1982).

Many SSDF are considered able bioturbators (KRISTENSEN et al., 2012). Bioturbator invertebrates are organisms whose activity produces constant and random local sediment biomixing over a short distance resulting in particle transport (QUEIRÓS et al., 2013). According to these authors, the high bioturbation activity at stations characterized by higher percentage of SSDF, by intensifying the oxygen fluxes into the sediments, plays a major role in the re-oxidation and detoxification of highly reduced sediments. This could occur also at our stations, in particular toward the inner part of the marinas. Furthermore, the presence of SDF and SF nearby the main entrance could be linked to the higher amount of sand. Similarly, VESAL et al. (2021), reported the high dominance of suspension feeders related to high contents of sand. Many bivalves (27.9 % of the total individuals) were observed at SP3 while higher percentages of SF in Strožanac were noticed at PD1 and PD3 (Fig. 4). The presence of SF at the latter stations was mostly due to the increased dominance of *L. orbiculatus.* The occurrence of this species was reported in strict association with the seagrass *Zostera spp.* (EL-HACEN et

al., 2018 and reference therein). Indeed, this bivalve was observed solely at PD1 and PD2, the only stations in Stro*ž*anac marina characterized by finer sediments and the presence of seagrass.
Finally, SP4, the station nearby the boathouse in Špinut, was characterized by well-balanced feeding guilds. Despite low species richness, the community was constituted by different feeding habits. This result was not surprising, since the macrofaunal community is able to adapt their structure in presence of long-lasting pressure, like the boat cleaning activity. However, the occurrence of few species for each trophic guild (e.g., carnivorous) could indicate higher vulnerability of the community. In turn, the vulnerability induces the reduction of long term-resilience of biological communities to cope with other environmental stressors, both of natural and anthropogenic origin (NAEEM et al., 2012).

CONCLUSION

This study confirmed the importance of the renewal time of marine water (confinement) for the dilution and dispersion rates of contaminants related to the nautical world. Strožanac is characterized by seagrass coverage at the bottom, and the anthropogenic activities did not seem to influence the structure of the investigated macrofaunal community. This does not hold true for Špinut, where long-lasting anthropic activities deeply modified the sediment characteristics and evidenced higher macrofaunal adaptation to contamination at the main impacted site. Furthermore, these results indicate that including the macrofaunal community features in monitoring plans could help local managers of ports and marinas design site-specific environmental interventions to mitigate anthropic disturbances.

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Table 1: Depth, coordinates, and bottom seawater temperature and salinity recorded at the sampling stations in each marina.

Marina	**Station**	**Depth (m)**	**Coordinates**		**Temperature (C°)**	**Salinity**
Špinut	SP1	5.3	43° 30.950'N	16°24'.942 E	19.9	35.60
	SP2	6.0	43° 30.951'N	16° 25.072'E	17.8	36.06
	SP3	5.0	43° 30.950'N	16° 25.218'E	17.6	36.22
	SP4	3.5	43° 30.899'N	16° 25.176'E	19.9	35.42
	SP5	4.5	43° 30.940'N	16° 24.988'E	18.5	36.01
Strožanac	PD1	3.0	43° 30.009'N	16° 32.041'E	20.7	35.48
	PD2	6.0	43° 30.033'N	16° 31.990'E	16.0	37.29
	PD3	3.5	43° 30.107'N	16° 32.000'E	20.4	35.67
	PD4	3.1	43° 30.081'N	16° 31.997'E	16.7	36.91
	PD5	4.2	43° 30.118'N	16° 31.944'E	19.7	35.81

Table 2: Sand, silt and clay percentages at each sampling station and in each marina.

Marina	Station	Sand	Silt	Clay
		%		
Špinut	SP1	14.0	61.8	24.2
	SP2	38.2	46.0	15.8
	SP3	98.8	0.7	0.5
	SP4	47.2	36.4	16.4
	SP5	12.0	57.6	30.4
Strožanac	PD1	12.3	63.2	24.5
	PD2	38.5	52.0	9.5
	PD3	10.3	68.0	21.7
	PD4	16.6	56.2	27.2
	PD5	21.3	59.0	19.7

Table 3: Taxonomic β-diversity comparisons among stations in each marina. Values show β-diversity, its two components (turnover and nestedness-resultant), and relative contribution of turnover to β-diversity (%). The asterisks indicate stations nearby anthropogenic activities.

Špinut					**Strožanac**				
Turnover	**SP1**	**SP2**	**SP3**	**SP4***	***Turnover***	**PD1**	**PD2***	**PD3**	**PD4**
SP2	0.48				**PD2***	0.71			
SP3	0.60	0.62			**PD3**	0.56	0.70		
SP4*	0.62	0.36	0.36		**PD4**	0.80	0.71	0.70	
SP5	0.68	0.26	0.56	0.71	**PD5**	0.86	0.36	0.82	0.70
Nestedness-resultant	**SP1**	**SP2**	**SP3**	**SP4***	***Nestedness-resultant***	**PD1**	**PD2***	**PD3**	**PD4**
SP2	0.25				**PD2***	0.14			
SP3	0.20	0.02			**PD3**	0.23	0.23		
SP4*	0.26	0.55	0.56		**PD4**	0.08	0.03	0.22	
SP5	0.03	0.33	0.19	0.20	**PD5**	0.03	0.21	0.11	0.05
β-diversity	**SP1**	**SP2**	**SP3**	**SP4***	***β-diversity***	**PD1**	**PD2***	**PD3**	**PD4**
SP2	0.73				**PD2***	0.85			
SP3	0.80	0.64			**PD3**	0.79	0.93		
SP4*	0.87	0.91	0.92		**PD4**	0.88	0.74	0.92	
SP5	0.71	0.58	0.75	0.91	**PD5**	0.89	0.57	0.93	0.75
Turnover/ β-diversity (%)	**SP1**	**SP2**	**SP3**	**SP4***	***Turnover/ β-diversity (%)***	**PD1**	**PD2***	**PD3**	**PD4**
SP2	65.48				**PD2***	83.50			
SP3	75.00	96.54			**PD3**	70.37	75.25		
SP4*	70.59	39.85	39.55		**PD4**	91.43	95.50	76.27	
SP5	95.42	43.77	74.61	78.23	**PD5**	96.50	63.65	87.77	93.17

Table 4: Relative abundance, expressed as percentage, of macrofaunal community in Špinut and Strožanac marinas (cut-off <0.3%).

Špinut	**SP1**	**SP2**	**SP3**	**SP4**	**SP5**
Abra alba	0.00	11.28	0.00	34.78	0.00
Antalis inaequicostata	0.00	0.00	0.00	4.35	0.00
Aricidea (Strelzovia) claudiae	0.00	0.00	0.00	4.35	0.00
Caecum trachea	0.00	0.00	30.68	0.00	0.00
Caprella rapax	0.00	0.00	0.00	4.35	0.00
Cirrophorus branchiatus	0.00	4.30	0.00	0.00	0.00
Cirrophorus nikebianchii	14.24	21.96	0.00	0.00	20.59
Fustiaria rubescens	0.00	0.00	0.00	8.70	0.00
Kirkegaardia dorsobranchialis	3.16	0.00	0.00	0.00	0.00
Loripes orbiculatus	0.00	0.00	3.88	0.00	0.00
Lucinella divaricate	0.00	0.00	5.73	0.00	0.00
Nemertea	0.00	0.00	0.00	4.35	0.00
Nucula nucleus	0.00	0.00	0.00	8.70	0.00
Oestergrenia digitata	0.00	0.00	0.00	4.35	0.00
Papillicardium papillosum	0.00	0.00	4.44	4.35	0.00
Polititapes aureus	0.00	0.00	3.88	0.00	0.00
Protodorvillea kefersteini	0.00	0.00	10.72	0.00	0.00
Pseudoleiocapitella fauveli	65.03	22.85	3.70	0.00	33.90
Pseudolirius kroyeri	0.00	3.26	0.00	0.00	20.90
Syllis hyaline	0.00	0.00	8.87	0.00	0.00
Varicorbula gibba	0.00	9.94	9.43	21.74	4.18
Strožanac	**PD1**	**PD2**	**PD3**	**PD4**	**PD5**
Abra alba	19.14	0.00	24.44	0.00	0.00
Aonides oxycephala	0.00	0.00	0.00	5.00	0.00
Aricidea cfr. suecica meridionalis	0.00	0.00	0.00	0.00	4.12
Bivalvia	0.00	0.00	6.67	0.00	0.00
Cirrophorus nikebianchii	8.82	0.00	0.00	0.00	0.00
Cossura soyeri	0.00	11.32	0.00	0.00	14.23
Diogenes pugilator	0.00	0.00	4.44	0.00	0.00
Heteromastus filiformis	3.27	0.00	4.44	0.00	4.12
Paraleptopentacta elongate	0.00	0.00	6.67	0.00	0.00
Levinsenia gracilis	0.00	22.26	0.00	0.00	9.36
Loripes orbiculatus	43.32	0.00	15.56	0.00	0.00
Lumbrineris longipodiata	0.00	0.00	0.00	0.00	7.49
Monticellina sp.	0.00	11.69	0.00	0.00	5.24
Nemertea	0.00	0.00	4.44	0.00	0.00
Notomastus latericeus	4.79	0.00	0.00	0.00	0.00
Pseudoleiocapitella fauveli	0.00	6.15	0.00	42.67	9.74
Spisula subtruncata	0.00	0.00	6.67	0.00	0.00
Tritia reticulata	0.00	0.00	11.11	0.00	0.00

Figure captions

Fig. 1: Sampling stations within Špinut (SP) and Strožanac (PD) marinas. Stars indicate the stations nearby anthropogenic activities like careening and boat painting.

Fig. 2: Number of species and diversity values (Shannon-Wiener-H, $\log_2$) of macrofaunal communities at sampling stations in Špinut (a) and Strožanac (b) marinas.

Fig 3: Non-metric multidimensional scaling (nMDS) ordination plot of the macrofaunal community in the study areas. The vectors of salinity, temperature, sand, silt, clay percentages, and heavy metals (Cu, Cd, Cr, Ni, Pb, Zn Zn) are overlaid. Zn, Pb and Cu are overlapped in the graph.

Fig.4: Relative abundance, expressed as percentage, of the macrofauna feeding habits at sampling sites. The asterisks indicate stations nearby anthropogenic activities SF: suspension feeders; DF: deposit feeders; SDF: surface deposit feeder; SSDF: subsurface deposit feeders; C: carnivores; OMN: omnivores; H: herbivores.

Figure 1

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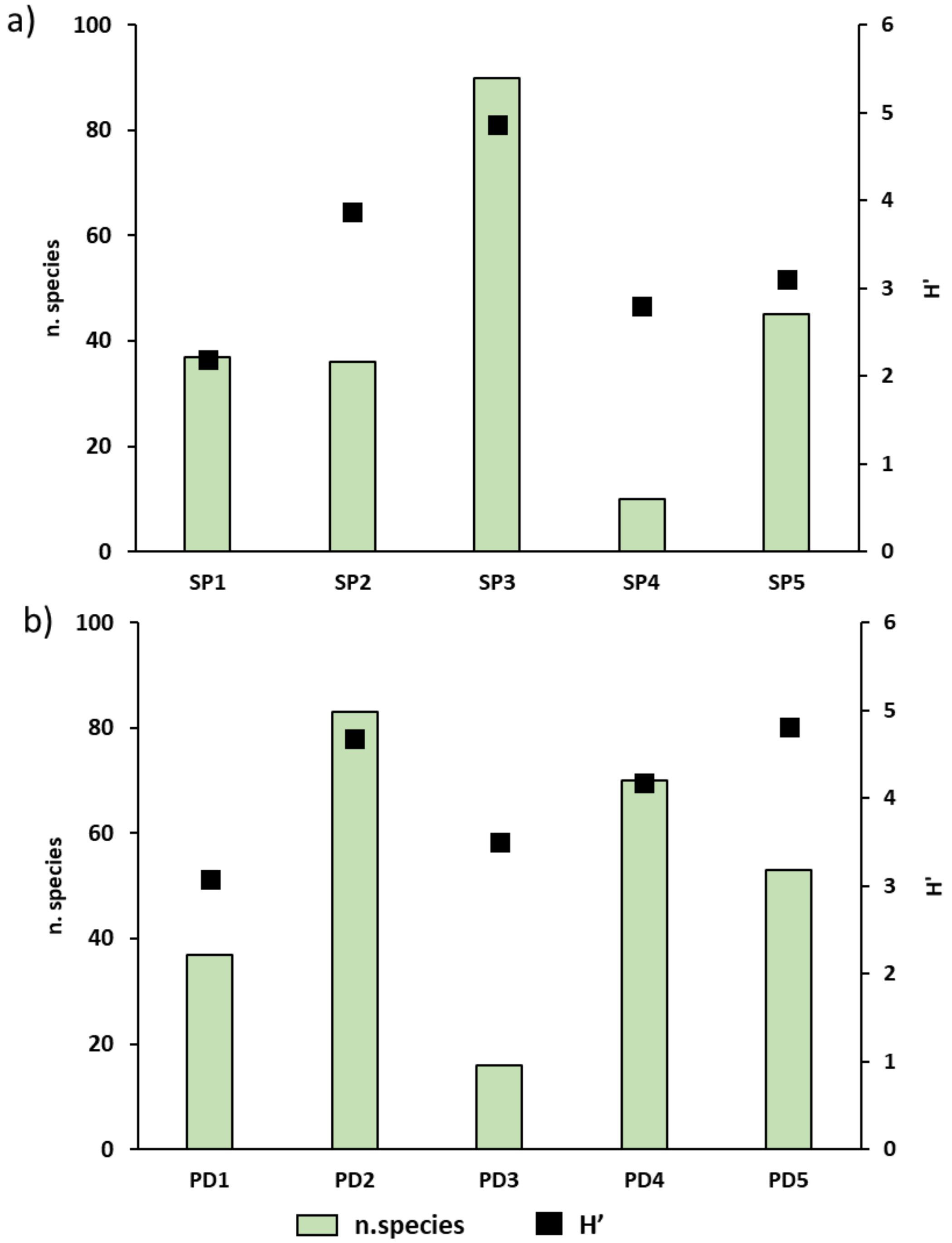
Figure 2


a)
b)
n. species
H'
SP1
SP2
SP3
SP4
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PD2
PD3
PD4
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0
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40
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80
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0
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2
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5
6
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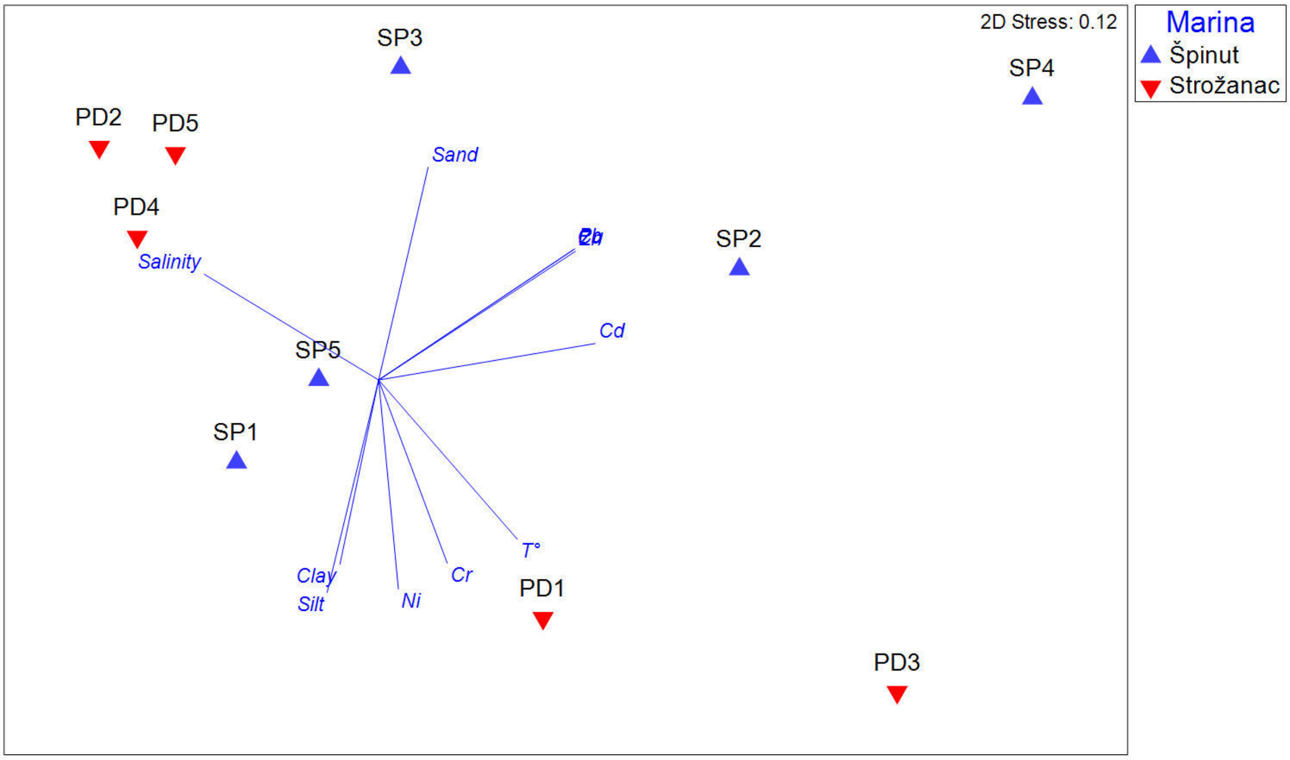
Figure 3


2D Stress: 0.12
Marina
Špinut
Strožanac
SP3
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PD2
PD5
PD4
Sand
Salinity
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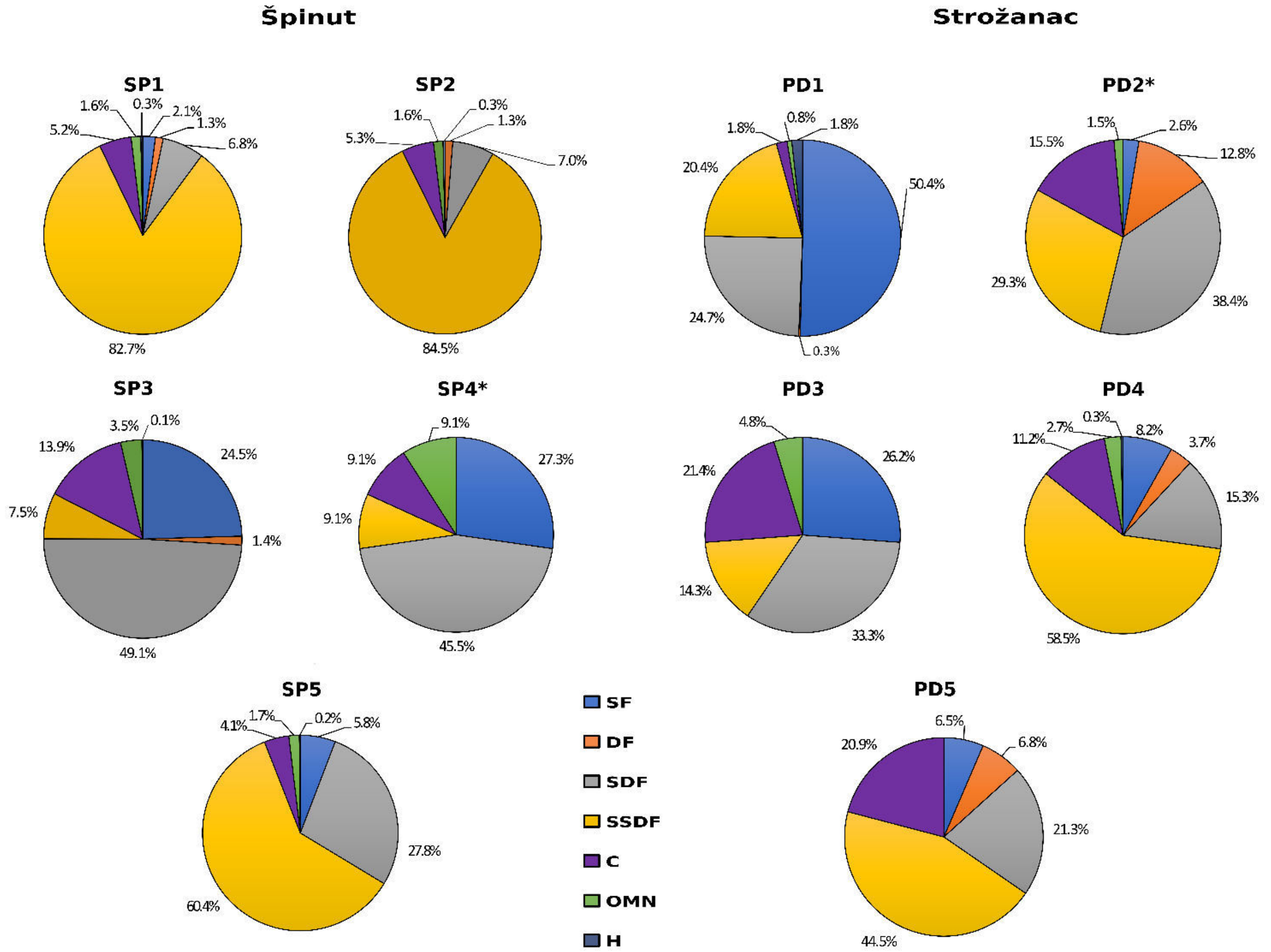
Cr
Clay
Silt
Ni
PD1
PD3

Figure 4


Špinut
Strožanac
SP1
SP2
SP3
SP4*
SP5
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PD3
PD4
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SF
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C
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H