Final report will describe the status of the selected N2000 sites in relation to the presence of ADLFG and ML

WP4 – Activity 4.3

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ML-Repair Reducing and preventing, an integrated Approach to Marine Litter Management in the Adriatic Sea – Axis 3 – SO 3.3

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1 INTRODUCTION

1.1 Overview of marine litter issue

Marine litter refers to any solid material or items that have been made or used by people and (i) deliberately discarded into the sea or rivers or on beaches (ii) brought indirectly to the sea with rivers, sewage, stormwater or winds (iii) or accidentally lost, including material lost at sea in bad weather. Marine litter originates from many sources and can cause a wide spectrum of environmental, economic, safety, health and cultural impacts.

Our unsustainable consumption patterns and behaviours, coupled with a very slow rate of degradation of most marine litter items, especially plastics, are leading to an ever-increasing quantity of litter and debris found at sea and on the shores, making this an emergent global problem.

At European level, growing concern over marine litter issue is also reflected in its recent incorporation to a number of EU strategic policy documents (e.g. Marine Strategy Framework Directive and the related Directives such as Waste Framework Directive, the Packaging and Packaging Waste Directive, the Landfill Directive, the Port Reception Facilities Directive, etc.), UNEP/MAP Regional Plan for Marine litter Management in the Mediterranean (UNEP/MAP IG.21/9), the Barcelona Convention Regional Plan for Marine Litter in the Mediterranean, and the Convention for the Prevention of Pollution from Ships (MARPOL), which now at least recognize the scale and magnitude of the problem.

Concurrently, also research efforts have been put into increasing the knowledge of the topic of marine litter. Gathering marine litter information for the Adriatic and wider Mediterranean region is particularly important as it is widely accepted that this region is one of the most affected seas by marine litter worldwide owing to the combination of high anthropogenic pressures (e.g. densely populated coastline, intensive shipping, massive tourism, fishing and aquaculture) and specific geomorphological and oceanographic features (semi-enclosed basin with a limited water exchange, negligible tidal flow and massive river flow inputs) (Cózar et al., 2015). Proper evaluation and assessment of marine litter are needed to achieve effective waste management and sustainable use of the marine and coastal environment.

The challenge to address the need for accurate, coherent and comparable scientific data on marine litter in the Adriatic-Ionian region was first tackled by the DeFishGear project. Within the framework of the project, standardized monitoring procedures for conducting rapid assessments of the debris material type and quantity present in a monitored location were developed. Standard methodology and reporting are necessary in order to compare marine litter sources, abundance, distribution, movement, and impact on regional, national, and global scales. Monitoring guidelines

were then applied in pilot surveys conducted in seven countries sharing the Adriatic and Ionian Seas (Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Montenegro, Slovenia) obtaining field marine litter data for all marine compartments (beaches, Vlachogianni et al., 2018; sea surface, Zeri et al., 2018; seafloor, Fortibuoni et al., 2019; biota, Anastasopoulou et al., 2018). The DeFishGear results provided initial insight on the amounts, composition, sources ad impacts of marine litter in the Adriatic-Ionian macroregion. The assumptions of high loads of marine litter were confirmed and sufficient evidence provided to support immediate actions towards implementing concrete actions (e.g. Fishing for Litter, Ronchi et al., 2019) and the relevant legislative frameworks.

Another clear conclusion emerging from the DeFishGear pilot actions was that in the studied region, similar to elsewhere in the world (Backhurst and Cole, 2000; Donohue et al., 2001; Nagelkerken et al., 2001; Chiappone et al., 2002; Katsanevakis and Katsarou, 2004), seafloor represents one of the main sinks for litter in the marine environment. However, the accumulation and impacts of submerged marine litter are particularly demanding to study and represent one of the main remaining knowledge gaps (Abu-Hilal and Al-Najjar, 2009).

The methodologies commonly used in litter investigation on the seafloor are visual surveys with scuba diving/snorkelling in shallow waters (< 20 m depth) and bottom trawling (both on continental shelves and in deep-sea) with fishing or research vessels (Spengler and Costa, 2008). Trawling is an efficient method for large-scale evaluation and monitoring of the seafloor litter that can be incorporated within the on-going monitoring schemes already implemented at European level, e.g. existing fisheries stock assessment programmes which are covering most European Regional Seas (Spedicato et al., 2019). Therefore, a recommendation was given within the framework of the DeFishGear project to make the collection of seafloor litter data mandatory for ongoing trawl survey programs (e.g. MEDITS) and make this data available to National Institutions for the implementation of the MSFD.

Trawling activities are not permitted, nor feasible, in shallow waters, or over-complex rocky habitats. In such environments, visual surveys, either by divers, submersibles or remotely operated vehicles (ROVs), provide the opportunity to investigate the abundance of litter items, albeit over smaller areas of seafloor compared to trawling. Another advantage of visual investigations is that they are not intrusive (nothing but litter is removed, the environment is not damaged in any way) and as such, they are appropriate for application in areas with high ecological value, e.g. protected or sensitive areas (Melli et al., 2017).

The need to enhance the monitoring on the shallow seafloor motivated a continuation of part of the DeFishGear activities within the framework of the ML-REPAIR project. Considering that protected areas, due to their attractiveness for tourism, might be affected by waste accumulation, the focus was put on Natura 2000 Sites of Community Importance (SIC).

1.2 Natura 2000 in a nutshell

Natura 2000 is the largest coordinated network of protected areas in the world and is composed of areas important for the conservation of endangered species and habitat types of the European Union. It stretches across all 28 EU countries covering about 18% of land area and 9.5% of its marine territory. The aim of Natura 2000 network is to preserve or re-establish the suitable status of more than a thousand endangered and rare species and about 230 natural and semi-natural habitat types listed under both, the Birds Directive and the Habitats Directive. The conservation goals and measures should be implemented in management plans, which do not exist yet for a lot of Natura 2000 sites. Management plans are adopted mostly for areas that are already protected under higher protection categories (e.g. national parks, nature parks, nature reserves, etc.) and are managed by competent public institutions.

The ecological network Natura 2000 of the Republic of Croatia encompasses 36.7% of the land territory and 15.4% of the coastal sea (NN 124/13 and 105/15). In 2017 in Italy, 249,513 ha of the sea were included in SIC, of which approximately the 8% in terms of surface were located in the Adriatic Sea.

2 MATERIAL AND METHODS

2.1 Geomorphologic and oceanographic features of Adriatic

The Adriatic Sea is an elongated semi-enclosed basin of the northernmost part of the Mediterranean Sea that is connected with the Ionian Sea with 72 km wide Strait of Otranto (Cushman-Roisin et al., 2001). Its present form is a consequence of the elevation of the sea level by around 100 m after the last Ice Age in the Pleistocene. Northern Adriatic, being a flooded Po River valley, is very shallow with an average depth of about 35 m, while the central and the southern parts are much deeper with the most prominent 260 m deep Pomo Pit, and South Adriatic Pit reaching 1,233 m. The majority of the seabed is located on the continental shelf that is covered with sandy and muddy sediment with different grain size and composition. The northern part is greatly influenced by the number of rivers discharging into it, of which Po is most relevant, while Buna-Bojana shed has a huge impact on its south-eastern part. The geomorphology of the western part of the Adriatic is characterized by low, mostly sandy, sediment-loaded coasts, while the eastern coast is karstic, generally high, rugged and rocky with only 5% covered with coastal silt, sands and gravels. The Croatian coast, with 1.246 islands, islets, and rocks, is one of the most indented in the Mediterranean.

The circulation of Adriatic surface water is driven by the inflow of freshwater from the Po River, the inflow of Mediterranean water through the Otranto Strait and secondary rivers (McKinney, 2007), and variability is related also to winds effects. Accordingly, the prevailing cyclonic surface currents flow from the Strait of Otranto along the eastern coast (EAC-East Adriatic Current) and back to the

strait along the western coast (WAC-West Adriatic Current) (Artegiani et al., 1997). Three cyclonic gyres occur, one in the northern part, one in the middle and one that is permanently located over the southern basin. Bora (from North-East) and Sirocco (from South-East) are the major winds blowing over the Adriatic Sea.

2.2 Sources of marine litter

As marine litter is globally recognized as one of the greatest pressures on the marine environment, it is of utmost importance to identify the main causes and threats. Potential litter inputs in the Adriatic refer to river discharge, urban and industrial areas, maritime transport, touristic activities, fisheries and aquaculture (Table 1).

Table 1. Top 10 marine litter inputs into the Adriatic Basin (from Liubartseva et al., 2016).

	Input	Intensity (ton year $^{-1}$)	% of total inputs
1	Shipping lanes	2000	20.0
2	Po River	1349	13.5
3	Buna/Bojana River	575	5.8
4	Bari	351	3.5
5	Venice	291	2.9
6	Neretva River	283	2.8
7	Trieste	229	2.3
8	Split	198	2.0
9	Adige River	191	1.9
10	Ravenna	183	1.8
	Other rivers (58) and cities (41)	4350	43.5

The rivers are the key transport mechanisms which move litter from various land-based sources into and within the marine environment. Most important rivers in terms of water and sediment transport in the Adriatic Sea are situated along the north-western coast (e.g. Po, Adige, Isonzo, etc.), while on its south-eastern part, Buna-Bojana shed and Neretva river play a significant role in the discharge of water and are important due to its transboundary flow.

High population densities along the Adriatic coasts (3.5 million inhabitants), additionally increasing by several dozen times in the summer months, pose a great threat to the marine environment. Maritime transport in the Adriatic Sea has been growing continuously with both commercial and recreational activities increasing yearly. Besides the huge number of vessels registered in Croatia (more than 4,000 fishing vessels, 2,500 yachts, 118,000 boats), it is worth mentioning around 60,000 foreign recreational vessels that visit the Croatian part of the Adriatic Sea each year.

Regarding Italy, the port of Chioggia, located in the southern part of the Venice Lagoon, hosts the most important fishing fleet in the basin, with all the different métiers well represented and a total of 213 active fishing boats in 2016, according to the EU Fleet Register. Moreover, the area hosts 37 mussel farms with an annual production of approximately 11,096 tons, nearly 15% of the national mussel culture production (Prioli, 2008).

In Cattolica, there are two fishing vessels that practice bottom trawling, 7 vessels used in the mussel farms and about 41 vessels for the artisanal and small-scale fisheries.

2.3 Natura 2000 sites

The assessment of the marine litter presence and its active removal encompassed 5 Natura 2000 sites (3 in Croatia, 2 in Italy).

Pakleni islands (HR3000095) with an area of around 20 km^2 refers to the marine area up to 500 m from the coastline of the Pakleni islands (Fig. 1.A). It is a group of 20 islands and reefs located in front of the town of Hvar, on the southeast side of the island of Hvar. It's an area important for the preservation of Posidonia beds (1120) and reef settlements (1170), but also an important site for sandbanks which are slightly covered by seawater all the time (1110) and submerged or partially submerged sea caves (8330). The Natura 2000 ecological network borders with the significant landscape of the Pakleni islands that protects the mainland of the islands.

The area of Vis island with its associated waters includes eight separate Natura 2000 sites, of which two are included for the purposes of the project; SE part of Vis island (HR3000096) (Fig. 1.B1) and the island of Vis – marine area (HR3000097) (Fig. 1.B2). Those marine sites include the marine area up to 500 m distance from the coast of the island of Vis and associated islets, reefs and rocks. The maximum depth reaches 80-90 m. With the total area of around 40 km^2, those are important sites for Posidonia beds (1120), sandbanks which are slightly covered by seawater all the time (1110) and for mudflats and sandflats not covered by seawater at low tide (1140). Additionally, the island of Vis – marine area is one of the most representative site for reefs (coralligenous biocenosis) (1170) and submerged or partially submerged sea caves (8330).

According to the Croatian Nature Protection Act, Lokrum island was proclaimed as a special reserve of forest vegetation in 1948. Today the island and the sea-belt up to approximately 150 m from the shore are Natura 2000 site (HR4000017). Within its 1.2 km^2 the site includes eight terrestrial, coastal and marine Natura 2000 habitat types. Just over 40% is a marine area important for its Posidonia beds (1120), reefs (1170) and submerged or partially submerged sea caves (8330) (Fig. 1.C).

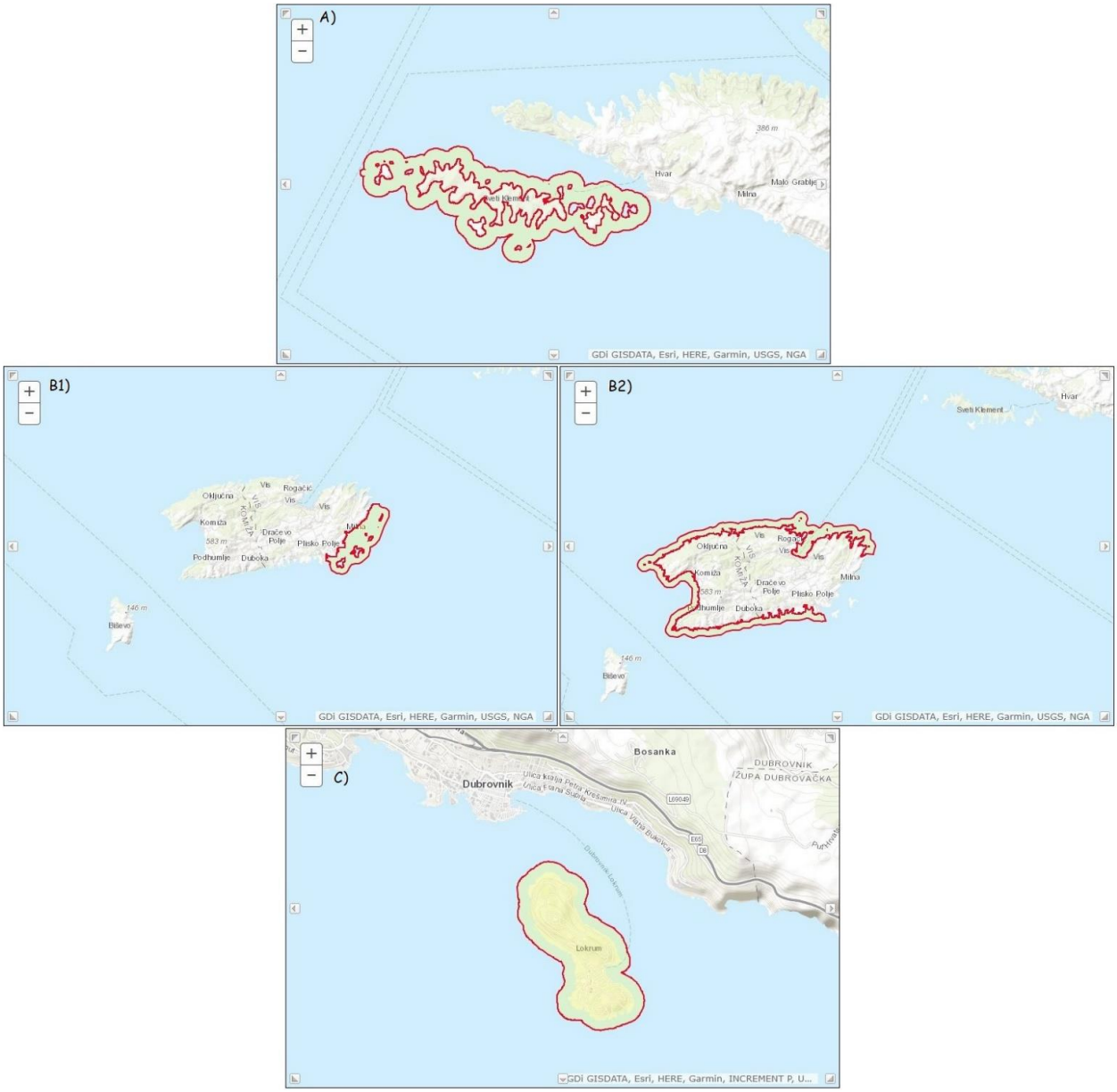

Fig. 1. Selected Natura 2000 sites in Croatia; A) Pakleni islands, B1) SE part of Vis island, B2) Island of Vis – marine area, C) Lokrum island.

The SIC “Tegnùe di Chioggia” (IT3250047) is a marine environment consisting of an extended system of outcrops located off the coast of Chioggia (Fig. 2.A). The area has been protected since 2002, first as a No-Take Zone (NTZ) and then, in 2011, as a SCI (Habitats Directive 92/43/EEC) protecting those important reefs (1170). The protected area includes four sub-areas: a wider one located between 6 and 10 km from the coast, with a surface of 22 km2, and three small areas

between 13 and 15 km offshore, accounting in total for 4.5 km2. In the protection area, both professional and sport fishing are prohibited and recreational diving is regulated, allowing anchoring exclusively to special buoys. The site is also important for the conservation of loggerhead *Caretta caretta* (1224) and bottle-nosed dolphin *Tursiops truncatus* (1349).

Colle S. Bartolo (IT5310006) encompasses an area of 1193 ha of which around 57.55% is a marine area important for its reefs (1170) and for the presence of some species of marine phanerogams (Bagli et al. 2002). On the beaches along the coast, the site is also characterized by annual vegetation of drift lines (1210) (Fig. 2.B).

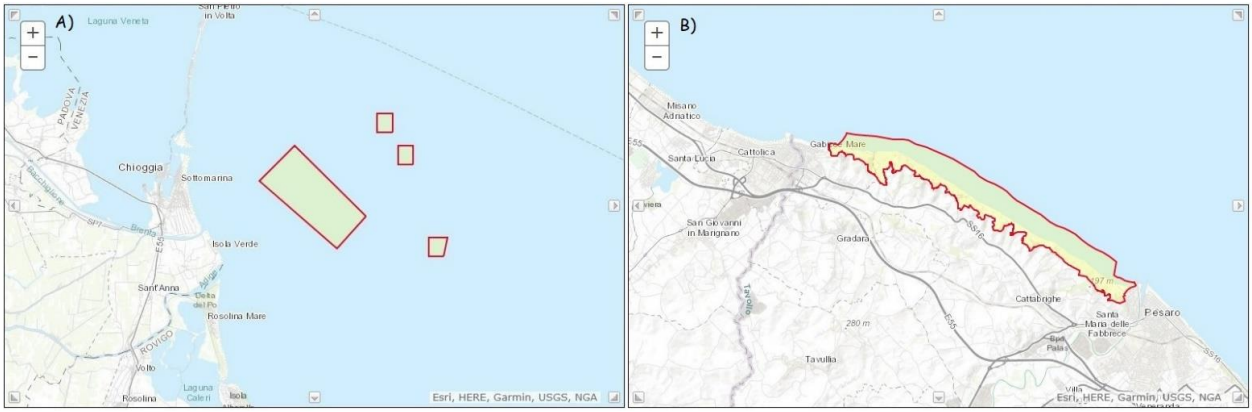

Fig. 2. Selected Natura 2000 sites in Italy; A) Tegnùe di Chioggia, B) Colle S. Bartolo.

2.4 Methodology

The purpose of seafloor monitoring activities in Natura 2000 sites was to improve the available data on quantities, composition, distribution and possible source of marine litter and abandoned, lost or discarded fishing gears (ALDFG) of chosen vulnerable sites suspected to be significantly loaded with marine litter due to touristic activities, maritime transport, fishery, aquaculture, coastal outputs and transboundary litter. Depending on the preferences and equipment of the project partner in charge, different non-invasive sampling methods were used in different areas.

Monitoring activities in Croatia were conducted at two locations Split-Dalmatia county, in Pakleni islands (HR3000095) and Vis island (HR3000096; HR3000097) in June 2018 and in Lokrum island (HR4000017) in Dubrovnik-Neretva county in September 2018. The contribution of nautical tourism and exposure to prevailing current for the input of marine litter was explored by choosing two locations (coves) for each combination of factors (tourism: high/low; exposure: exposed/sheltered). The exception was Lokrum island where, due to the space limitation, half of the aforementioned design was conducted (Table 2, Fig. 3). At each of the locations, sampling was done by SCUBA diving along 25x4 m linear transects, two divers swimming side-by-side and

collecting marine litter items from each side of the transect. These transect dimensions were chosen as optimal due to highly indented coastline and habitat complexity. Four transects at each location and a total of 20 locations were monitored (Fig. 3). Transects were performed at a depth ranging between 2 and 15 m. Collected marine litter items were analysed onboard by being divided into 7 categories (artificial polymer materials, cloth/textile, glass/ceramics, metal, paper/cardboard, processed/worked wood, and rubber) and classified into 53 subcategories following the Master List described by the EU MSFD TG10 "Guidance on Monitoring of Marine Litter in European Seas" (Galgani et al., 2013; Vlachogianni et al., 2017).

Table 2. List of Natura 2000 sites and locations surveyed, associated with factors (nautical tourism, exposure to dominant winds and currents), station label and depth range.

Natura 2000 site	Location (cove)	Nautical tourism	Exposure	Station label	Depth range (m)
Pakleni islands (HR3000095)	Palmižana	High	Sheltered	PZN1	5-6
	Ždrilca	High	Sheltered	PZN2	3-9
	Duboka	Low	Sheltered	PZbN1	6-10
	Čarnjeni bok	Low	Sheltered	PZbN2	4-8
	Stipanska	High	Exposed	PIN1	4-10
	Taršće	High	Exposed	PIN2	5-7
	Kardovan	Low	Exposed	PIbN1	5-8
	Perna	Low	Exposed	PIbN2	5-8
Vis island (HR3000096; HR3000097)	Stonca	High	Sheltered	VZN1	4-12
	Stončica	High	Sheltered	VZN2	4-12
	Ruda	Low	Sheltered	VZbN1	2-7
	Travna	Low	Sheltered	VZbN2	2-10
	Rukavac	High	Exposed	VIN1	5-10
	Stiniva	High	Exposed	VIN2	7-15
	Brgujac	Low	Exposed	VIbN1	3-5
	Mala Smokova	Low	Exposed	VIbN2	3-5
Lokrum island (HR4000017)	Portoč	High	Sheltered	LZN	6-10
	Bočina	Low	Sheltered	LZbN	6-8
	Vela i Mala Spilja	High	Exposed	LIN	2-8
	Pod Manastijerom	Low	Exposed	LIbN	6-7

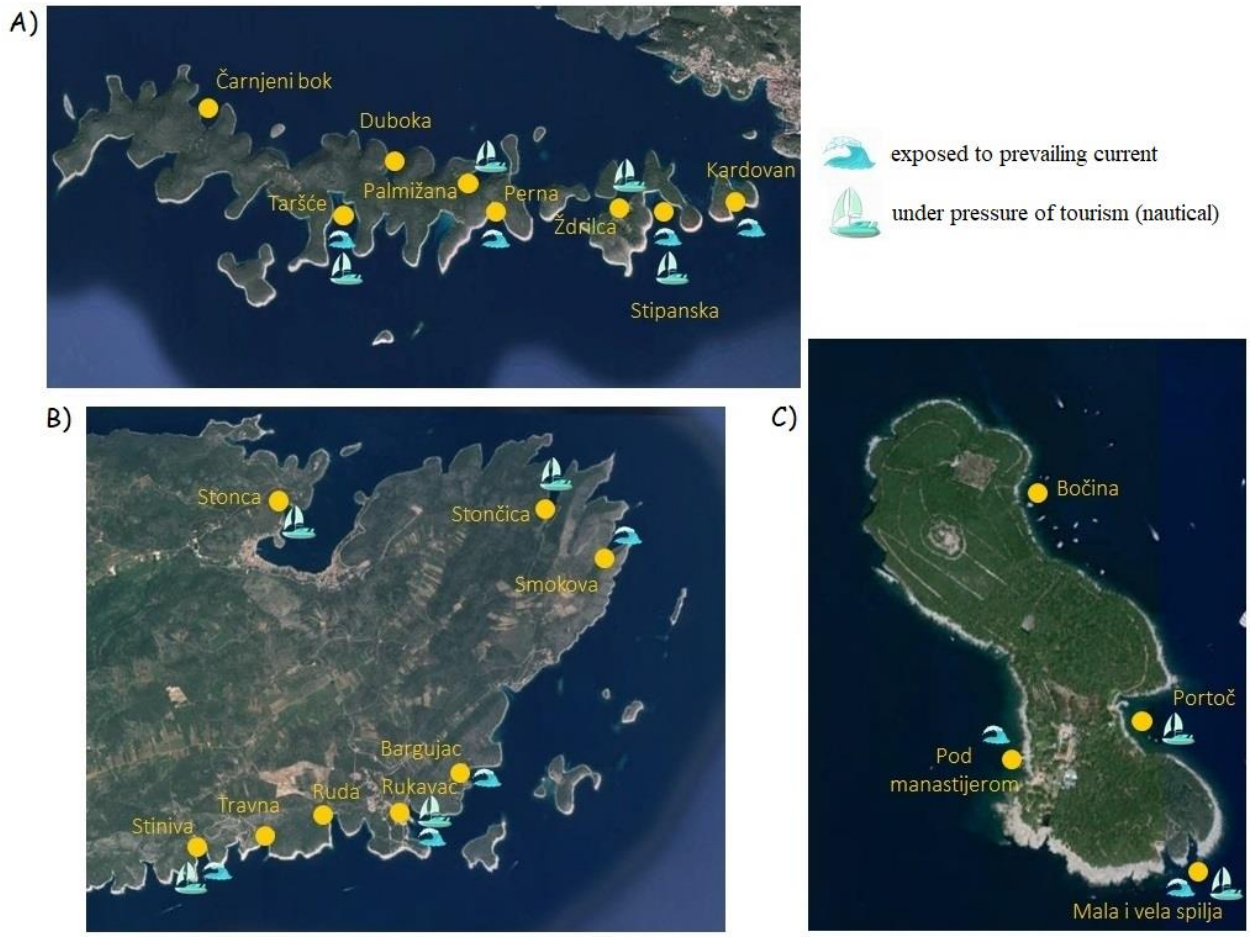

Fig. 3. Map of surveyed locations at Natura 2000 sites A) Pakleni islands, B) Vis island and C) Lokrum island.

In Italy, the monitoring performed during the DeFishGear project in the "Tegnue di Chioggia" SCI (IT3250047) (Melli et al., 2017) was complemented in November 2018 using a Remotely Operating Vehicle (ROV) with the aim of covering areas not previously monitored, and focussing on the interactions of litter with sensitive species (i.e. the sea sponge *Geodia cydonium*). Six zones were monitored for a total surface of 9.66 km^2 at a depth ranging between 18 and 22 m (Table 3 and Fig. 4).

Table 3. List of locations surveyed in the “Tegnue di Chioggia” SIC, total area surface and depth.

Natura 2000 site	Location	Area (km^2)	Depth (m)
Tegnue di Chioggia (IT3250047)	Cittadella	0.01071	19.5
	Club Sommozzatori Rovigo	0.01516	19.9
	Serenissima Sub	0.01518	21.0
	Sub Mestre	0.01692	19.0
	Transetto1	0.01777	18.3
	Transetto12	0.02086	21.7

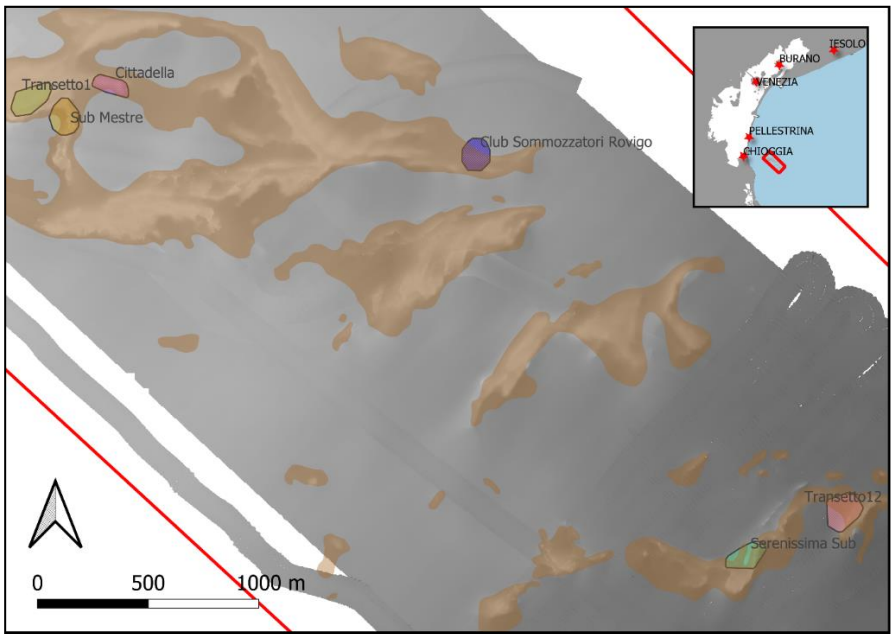

Fig. 4. The study area with the 6 locations monitored in the SIC “Tegnue di Chioggia” in November 2018.

In Colle S. Bartolo (IT5310006) SCUBA diving visual census and beach litter investigations were performed. Two divers dived in 3 different points of the Natura 2000 site, analysing, for each point, 100 m of the seabed (two different 50 m line transects for each point, 2 m on each side of the extended rope). A fifty meters rope with two weights and a net bag to collect marine litter were used. Point A was selected because of exposure to anthropogenic influences, with the presence of a small marina and many pleasure boats passing or anchoring. Point B was chosen due to the vicinity of the artificial reef that is probably acting like a barrier stopping and retaining marine litter, preventing it to end up on the beaches. Point C did not present any of the previous characteristics;

it was located in the less anthropogenically influenced area of the San Bartolo site where boats do not usually anchor, and there are no artificial reefs.

Table 4. List of locations surveyed in Colle San Bartolo site, total area surface and depth.

Natura 2000 site	Location	Nautical tourism	Breakwater cliffs presence	Exposure	Transect dimension (m)	Depth (m)	Station name
Colle San Bartolo	Vallugola Port	High	No	Exposed	4x50 4x50	3	Point A
	Breakwater cliffs	Medium	Yes	Sheltered	4x50 4x50	2.5	Point B
	No cliffs / no Nautical tourism	Low	No	Exposed	4x50 4x50	3	Point C

Fig. 5. A) Point A and beach cleaning transept, B) Point B, C) Point C, D) Beach cleaning transect.

3 RESULTS AND DISCUSSION

3.1 Croatia

3.1.1 Pakleni islands (HR3000095)

With monitoring activities at eight locations around Pakleni islands, we covered an area of 3,200 m^2 that was predominantly composed of rocky bottoms, occasionally interspersed with Posidonia and sandy patches.

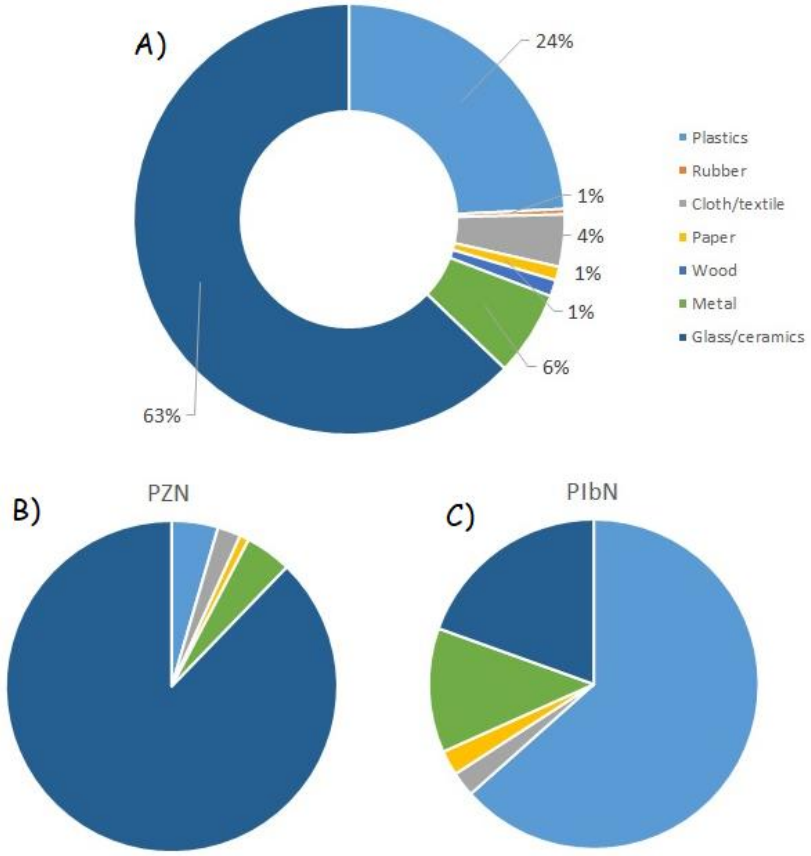

Fig. 6. Proportion of the number of marine litter items per category for: (A) all the locations in Pakleni islands, (B) only for locations that are under high nautical pressure but not exposed to dominant winds and currents and (C) for those under low nautical pressure and exposed.

Overall, 487 litter items weighing 183.8 kg were collected and identified. Litter was present at all locations ranging from 4 to 51.25 items/100 m^2. There is an apparent difference in litter

composition, as well as quantities, between the locations with regard to the pressure of nautical tourism and exposure to dominant currents and winds (Fig. 6.B, C). The glass and ceramic items were the most abundant (63%), followed by plastics (24%) and metals (6%) (Fig. 6.A). The dominance of glass/ceramic items was especially pronounced in locations with high pressure of nautical tourism, with the highest amount recorded in Palmižana (46.25 items/100 m^2) where they represented 90% of the total number. Palmižana bay is located near the City of Hvar, one of the most visited summer destinations in Croatia. As in the port of Hvar, there is not enough capacity for mooring, thus the yacht marina in Palmižana is swarming with nautical tourists all throughout April until October when it is open for business. The rest of the Pakleni islands aquatorium is also popular and most coves record a high number of visitation.

The 5 most abundant subcategories represented the large majority of litter found (80%), where again the glass sub-category "bottles (incl. pieces)" was the most abundant (38%), followed by "glass or ceramic fragments > 2.5 cm" (19%).

3.1.2 Vis island (HR3000096; HR3000097)

At eight locations on E, SE and S side of Vis island we covered an area of 3,200 m^2 of mainly rocky bottoms, with the exception of Stončica where the bottom is sandy and Mala Smokova which is covered by Posidonia beds at depths of the survey.

A total of 772 litter items were identified, for a total weight of 195.8 kg excludes the weight of four large metal objects found in Stonca that were too heavy to remove. The concentration of litter varied drastically between the locations, from 0.5 items/100 m^2 in Ruda to 95.5 items/100 m^2 in Mala Smokova. A very high concentration of litter in the coves on the south side of the island of Vis is not surprising and have been noticed during earlier studies. The dominant category was artificial polymer materials (plastics) (72%), especially in the locations exposed to prevailing current and winds with low pressure of nautical tourism (82%) (Fig. 7.B). Three important facts can explain these results; geographical position and geomorphology of the Croatian coastline and properties of plastics e.g. low specific weight and hence a high probability of prolonged floating. General surface circulation in the Adriatic consists of northerly flow along the eastern coast and a southerly return flow along the western coast (Orlić et al., 1992). In the period with higher precipitation (winter and spring), the rivers outflow increases, and in this area the Buna-Bojana watershed is especially significant (Marini et al., 2010). In addition to the existing circulation regime and due to the long period of strong southern winds, there is an increased accumulation of transboundary litter on southern shores of the exposed islands (Vis, Mljet, Korčula and Lastovo) and peninsula Pelješac. Furthermore, Croatian coastline is mostly made of limestone with deep coves with rocky shores, acting like a funnel that accumulates the marine litter as it bounces until it reaches the bottom of the coves. The non-existence of other sources of litter on Vis island additionally confirms the prevailing long-distance input.

Among the litter found in locations under high pressure of nautical tourism, especially in Stonca and Stiniva, a greater variety of metal, glass and textile items have been recorded (Fig. 7.C). These items were lost or intentionally thrown overboard due to the irresponsible behaviour of nautical tourists. This is confirmed by the five most common subcategories found around the Vis island; plastic "bottles" were the most abundant (43%), "other plastic/polystyrene items (identifiable)" (11%), "food containers inc. fast food containers" (7%), "clothing/rags (clothing, hats, towels)" (5%) and "cans (beverage)" (5%).

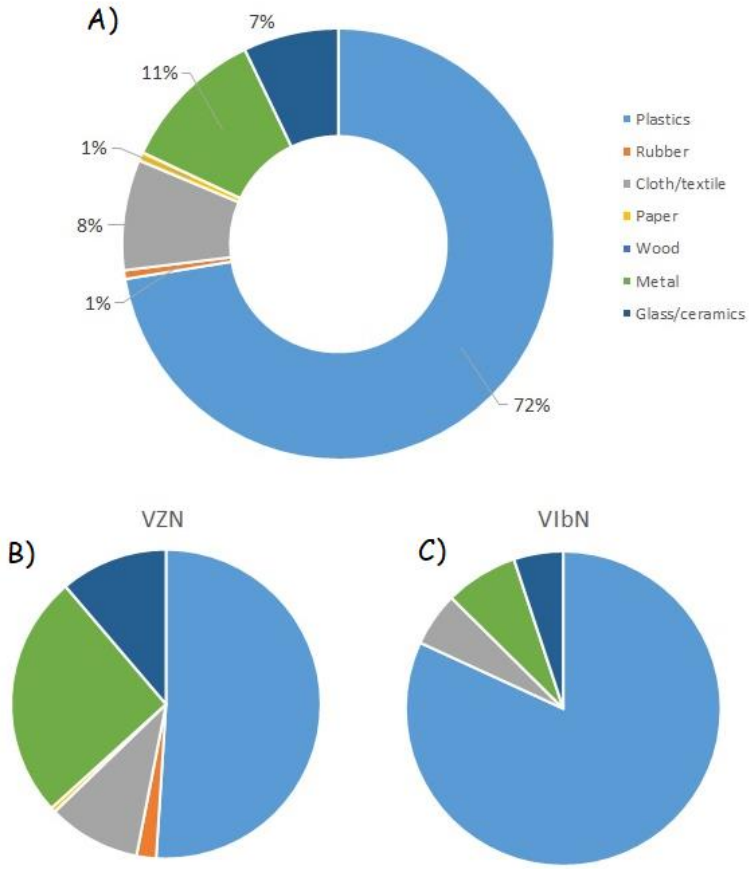

Fig. 7. Proportion of the number of marine litter items per category for: (A) all the locations in Vis Island, (B) only for locations that are under high nautical pressure but not exposed to dominant winds and currents and (C) for those under low nautical pressure and exposed.

3.1.3 Lokrum island (HR4000017)

Monitoring activities at four locations around Lokrum island covered an area of 1,600 m^2 that was predominantly composed of rocky bottoms, occasionally interspersed with Posidonia and in Portoč bay with sandy patches.

At the locations around Lokrum Island, 77 items weighing 27 kg were identified, of which three lost anchors weighing 13.5 kg. The number of items ranged from 2.25 to 6 items/100 m^2, and only at one transect in Portoč bay, more than 10 items were recorded. Items made of artificial polymer materials were dominant (53%), followed by metal (13%), paper (12%) and glass/ceramics (11%) (Fig. 8). Although it is included in the litter accumulation hotspot, the Lokrum island, due to its small area and position in the direction of prevailing current and winds, does not act as a barrier to the litter and this is probably the reason for the low litter concentrations recorded on the seafloor. Extremely strong southern winds, reinforced by waves, the floating litter is partly washed ashore on the island but the rest bypasses the island and accumulates in the city port.

Most items belong to the plastic subcategories "bottles" (24.5%) and "other plastic/polystyrene items (identifiable)" (20%), than "paper" (11%), glass "bottles" (10%) and "other (metal)" (7%).

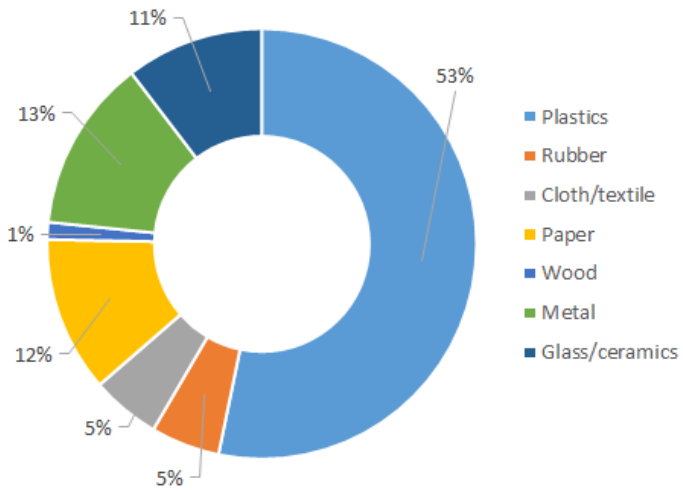

Fig. 8. Proportion of the number of marine litter items per category at all the locations in Lokrum Island.

3.2 Italy

3.2.1 Tegnùe di Chioggia (IT3250047)

At six locations we covered an area of 96,600 m^2 of rocky outcrops. Four locations were located in the northern part of the area (Cittadella, Club Sommozzatori Rovigo, Sub Mestre and Transetto 1), where a surface of 60,557 m^2 was monitored. The other 2 locations (Serenissima Sub and Transetto 12) were located in the southern part of the area, covering a surface of 36,043 m^2.

A total of 687 litter items were identified. The density of litter did not differ substantially between areas, with 0.09 ± 0.17 items/100 m^2 in the northern area and 0.07 ± 0.09 items/100 m^2 in the southern area. Conversely, the composition of litter slightly changed between the north and the south (Fig. 9).

The dominant category was artificial polymer materials (plastics) (> 90%) in all the locations monitored, followed by metal that ranged between 5% in the north and 3% in the south (Fig. 10). In particular, in the north, the contribution of mussel nets was higher due to the vicinity to mussel farms and the hydrological conditions. Indeed, Melli et al. (2017) hypothesized that mussel nets are transported by the main current (northern branch of the WAC) that flows southward along the Italian coast, accumulating on the closest outcrop. The rocky concretions act as physical barriers, limiting mussel nets from reaching other parts of the area. Indeed, the current regime is very stable, with a narrow distribution of current directions, which are almost all oriented southward throughout the whole water column.

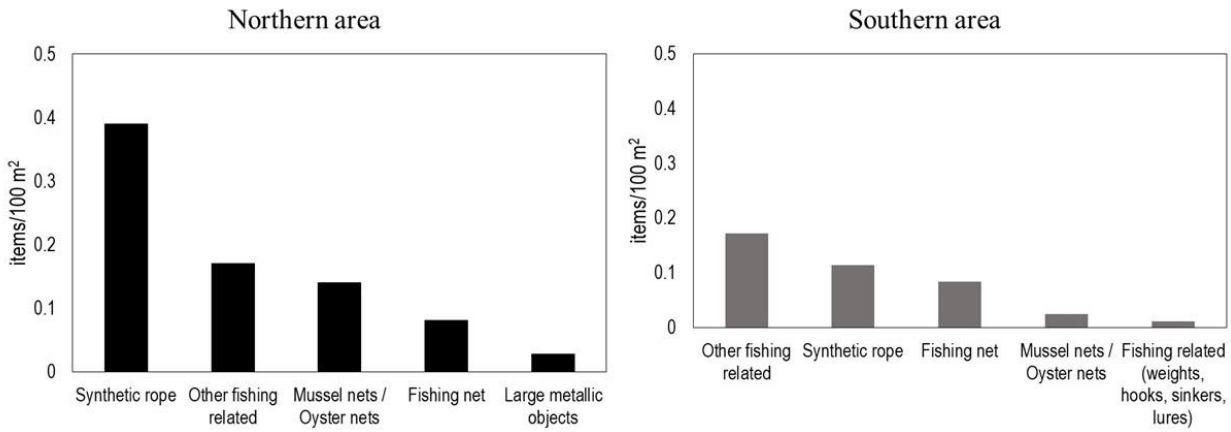

Fig. 9. Top 5 items found in the northern and southern areas of the SIC “Tegnue di Chioggia”.

In the northern area, “synthetic ropes” (44%), “other fishing related” (19%), “mussel nets/oyster nets” (16%) and “fishing nets” (9%) accounted for almost the 90% of litter found. In the south, “other fishing related” (41%), “synthetic ropes” (27%) and “fishing nets” (20%) accounted for almost the 90% of litter found.

During the monitoring, 474 specimens of the sea-sponge *G. cydonium* were identified, with a higher number in the southern area (317). Among these sea-sponges, 40 were clearly impacted by marine litter (entanglement, contact, colonization; Fig. 11), 25 of which in the southern area.

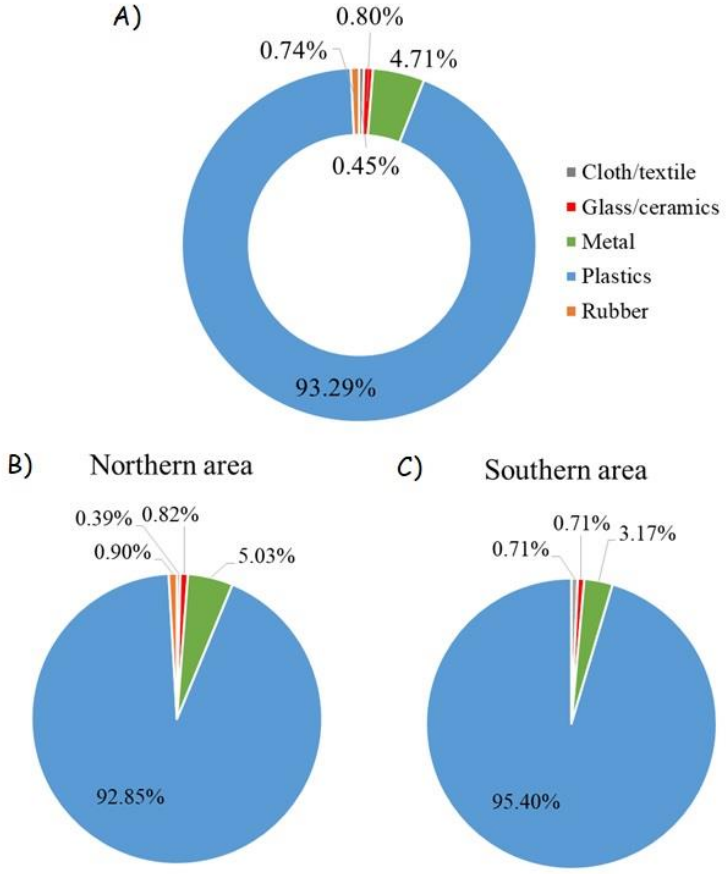

Fig. 10. Proportion of the number of marine litter items per category for: (A) all the locations in the SIC "Tegnue di Chioggia", (B) for the locations in the north (C) for those in the south.

Fig. 11. A specimen of the sea-sponge *G. cydonium* entangled by a fishing net in the SIC "Tegnue di Chioggia".

3.2.2 *Colle San Bartolo (IT5310006)*

300 meters of coastline divided into 6 different areas were monitored by SCUBA diving and no marine litter was found. We assumed that strong sea storms washed all the marine litter on the coastline. Additionally, we performed beach clean-up activities to confirm that hypothesis. 700 meters of the beach were analysed and 35 kg of unsorted waste, 31 kg of mussel nets and 45 kg of plastics were collected. In order to have more precise data on beach litter, a second beach clean-up activity in the Natura 2000 site "Colle San Bartolo" was performed according to monitoring protocol "Methodology for Monitoring Marine Litter on Beaches Macro-Debris (> 2.5 cm)" developed during the DeFishGear project (Vlachogianni et al., 2014). In this case, 400 m² (100x4 m) of the beach were analysed and the results are reported in Fig. 12.

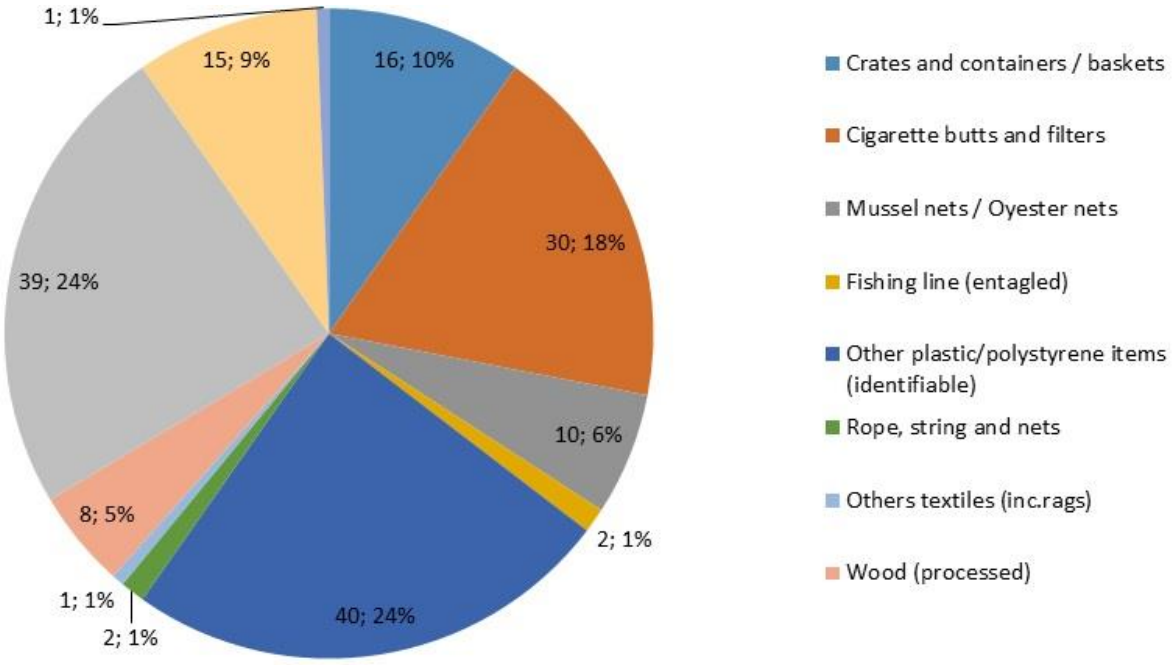

Fig. 12. Proportion of marine litter items found on the beach in Colle San Bartolo Natura 2000 site.

In conclusion, we can suppose that, since the whole marine area of the Natura 2000 site "Colle San Bartolo" is characterized by low depths reaching maximally 3 meters, and by high hydrodynamics, all the marine litter is pushed ashore by strong sea storms.

3.3 *Source of litter*

In order to determine the source of pollution of investigated Natura 2000 sites, litter items were classified according to 11 economic sectors (i.e. aquaculture, automotive, commercial & industrial, construction, disposable goods, domestic goods, electronic goods, fisheries, food & drink packaging, packaging, and sanitary items; UNEP, 2016) and according to their use (long-term & multiple-use VS short-term & single-use).

The SIC "Tegnue di Chioggia", according to the present monitoring, was almost exclusively loaded with litter derived from maritime activities – fishing and aquaculture. Around 90% of items were synthetic ropes, nets and other fishing-related items.

Croatian Natura 2000 sites were mainly loaded with litter derived from food & drink packaging (Pakleni islands 60%, Lokrum island 61%, Vis island 75%) while only 1% litter came from fishery sector. Regarding usage durability, 69% were short-term and single-use items.

4 CONCLUSIONS AND RECOMMENDATIONS

Monitoring activities conducted in five selected Natura 2000 sites in Italy and Croatia confirmed that marine litter pose a significant threat, not only to habitat and species preservation although crucial, but also causes visual landscape contamination.

Natura 2000 sites in the Croatian part of the Adriatic Sea are located in the coastal shallow waters and are affected by various sources of marine litter, including nautical tourism and floating transboundary litter above all. It is important to point out that in the vicinity of selected Natura 2000 sites there are no land-based sources of pollution e.g. landfills, sewage discharges, industries, wastewaters or river inputs, neither sea-based sources like oil/gas platforms or fish and shellfish farms. Therefore, the main impact on the amount and distribution of litter in this area is maritime transport (merchant shipping, ferries and cruise liners, pleasure crafts (yacht, boats), fishing vessels) and generated litter from distant areas.

In the Pakleni islands, where there are almost no permanent residents, the only activity is based on the exploitation of natural beauties for tourism purposes, especially in the summer season when a large number of luxury yacht tourists swamp the coves around the islands. The most commonly found item were glass bottles and cups, which indicate nautical tourism as the main source of litter. Conversely, at Vis and Lokrum Islands plastic items predominated. Both islands are located in an area with a strong impact of prevailing currents and winds and tendency to accumulate plastic litter with good floating capability transported usually away from the source of the pollution. Once floating, litter is partly washed ashore when reaching the islands. The rest eventually settle on the seafloor in the energy-low parts of the coves.

Despite the broad range of policy and legislation contributing to the management of marine litter in Croatian waters, this study highlights that the quantity of marine litter continues to increase. Key challenges in managing marine litter in the Natura 2000 marine areas in Croatian waters generally arises from:

- limited knowledge on the sources and types of marine litter, and the hotspots which generate pressures from marine litter;
- limited understanding of the sensitivity of marine Natura 2000 features to different forms of marine litter and its impacts;
- the need for joined-up activity of different agencies and authority approach, given the significant value of Natura 2000 sites and marine litter pressure.

Compared with global data that identified marine litter as mainly land-sourced, the SIC "Tegnue di Chioggia" is affected by an unusually high percentage of fishing-related debris, including debris from aquaculture (mussel nets). High densities of mussel nets have already been documented in the northern and central Adriatic Sea (Strafella et al., 2015; 2019; Vlachogianni et al., 2018; Fortibuoni et al., 2019), suggesting the mismanagement of the waste produced by mussel culture in the area (Pasquini et al., 2016). Indeed, although full-size mussel nets might have been lost accidentally during storms, the net fragments were likely cut and lost/abandoned at sea during the collection and preparation of the product. The correct handling and management of mussel nets should be implemented to reduce further inputs into the environment.

It is not possible to determine whether the fishing-related debris are recent or precede the establishment of the SCI. Modern fishing gear is made of highly durable synthetic materials, and thus they persist in the environment for decades (Laist, 1997). The fishing-related debris may have already existed when commercial and recreational fisheries were banned in the area in 2002. However, as the rocky outcrops are not compatible with trawling activities, the high abundance of trawl nets and trawl gear components (i.e., net linen and wires) is unlikely to be derived from accidental losses. Indeed, the SCI is used by part of the fishing community as an illegal dumping area for ALDFG (personal observations). This phenomenon is imputable to the lack of a ALDFG management system at both the regional and national levels.

According to the Habitats Directive, Member States must take the necessary management or restoration measures to ensure the favourable conservation status of the SCI. Moreover, within six years of its designation as SCI (thus within 2017), Italy should have designated the "Tegnue di Chioggia" as a Special Area of Conservation (SAC) and adopted conservation measures involving appropriate management plans. Thus, it is urgent that a management plan is adopted for the SCI "Tegnùe of Chioggia", including possible restoration measures. According to the results of the previous (Melli et al., 2017) and the present study, the SCI "Tegnùe of Chioggia", which is supposed to be a "sanctuary" of marine biodiversity, is heavily polluted by marine litter.

The long-term effects of nets, lines and ropes constantly rasping the sea-bottom and the biota may eventually lead to breakage or ramifications, skin abrasion, open wounds and infection in habitat constructors (e.g., sponges and ascidians). Because of their morphology, erect sponges, the main habitat constructors of these peculiar outcrops, are more susceptible to this type of damage (Anastasopoulou and Fortibuoni, 2019). In particular, the sea sponge *G. cydonium*, an endangered species protected by the Barcelona Convention (1995), abundant in the SCI, is very prone to damage and coverage due to its dimensions. As shown by our data, 8% of the Geodia surveyed were affected by debris. Even if the natural processes of the colonization of hard substrates may reduce the marine litter impact on the seafloor, this process may lead to a further alteration of the benthic community, favouring fast-growing organisms instead of slow-growing habitat constructors. Rocky bottoms are important habitats for maintaining marine biodiversity, and thus modifying these habitats is contradictory to biodiversity conservation and sustainability purposes.

In conclusion, the present study provides fit-for-purpose data and baseline information on the amounts, composition and sources of marine litter in selected Natura 2000 sites of Italy and Croatia. It provides a useful tool for appropriate authorities managers to gear up their efforts in the combat against the marine litter threat and identify targeted measures to tackle this issue.

Recommendations Croatia

1) Considering the importance of Natura 2000 sites in the overall natural diversity and their exposure to marine litter, it is necessary to determine the jurisdiction for protection and combating this issue.
2) Raising awareness by organising clean-up campaigns.
3) Since no seafloor litter monitoring programme has so far been included in the marine Natura 2000 sites, it is important and cost-effective to include litter monitoring into clean-up actions. The main purpose of monitoring marine litter is to collect data and draw conclusions on trends over seasons and years as well as to identify differences between geographical areas and beach types. From that information conclusions can be drawn on sources and mitigation actions can be identified and evaluated.
4) Raising awareness among nautical tourists that is not acceptable to dispose of both, intentionally or unintentionally, any kind of litter in the mooring/anchoring area.
5) To promote and improve a separate collection of litter (especially glass bottles) in the mooring area.

Recommendations Italy

1) It is urgent that a management plan is adopted for the SCI “Tegnùe of Chioggia”, including possible restoration measures.

2) Correct handling and management of mussel nets should be implemented in the areas nearby the SCI "Tegnue of Chioggia" to reduce further inputs into the environment.
3) A proper ALDFG management system at both the regional and national levels is needed in Italy in order to avoid intentional release at sea and promote a circular-economy.
4) Raising awareness among fishermen and mussel farmers that is not acceptable to dispose of both, intentionally or unintentionally, ALDFG and mussel nets in the SCI.
5) More studies are needed to assess the impacts of marine litter and ALFDG on the sea-sponge *Geodia cydonium* and other vulnerable or protected species (e.g. *Pinna nobilis*).

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