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MARLESS (MARine Litter cross-border awarenESS and innovation actions)

Priority Axis: Environment and cultural heritage; Specific objective: 3.3 - Improve the environmental quality conditions of the sea and coastal area by use of sustainable and innovative technologies and approaches

D.6.5.1 – Report: Statistical analysis on quantity, dimensions and weight of marine litter

AT 6.5

WP 6

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PROJECT MARLESS

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1. Introduction

Plastics are one of the most widely used materials in the world; they are broadly integrated into today's lifestyle and make a major contribution to almost all product areas. Its large use inevitably results in wastes.

Plastic waste is largely recycled when it's correctly collected, but in many cases wastes escape from separate collection, form many and different reasons. A very major issue for the environment at the moment concerns artificial debris that gets into the water, in many ways: people often leave trash on beaches or throw it into the water from boats or offshore facilities; sometimes, litter makes its way into the ocean from land; this debris is carried by storm drains, canals, or rivers; the wind can even blow trash from landfills and other areas into the water; storms and accidents at sea can cause ships to sink or to lose cargo.

Plastic products can be very harmful to marine life. For instance, loggerhead sea turtles often mistake plastic bags for jellyfish, their favourite food. And many sea animals and birds have become strangled by the plastic rings used to hold six-packs of soda together. Some small plastic marine litter as "nurdles," the artificial pellets of raw material used in making plastic products, can collect in the stomachs of marine animals, interfering with digestion. When marine animals ingest nurdles, they can feel "full" although they are not getting nutrients. The animals are at risk of malnutrition and starvation. Another type of marine debris that is harmful to sea life comes from fishing gear. Discarded fishing lines and nets don't stop fishing once humans are done with them. They continue to trap fish, along with marine mammals, turtles, and birds. Finally, floating on the ocean's surface, nurdles and other small plastic pieces can block the sun's rays from reaching plants and algae that depend on the sun to create nutrients.

When these organisms are threatened, the entire marine food web may be disturbed. A reduction in the fish population can impact human activity in the area. Fisheries shrink, weakening the area's economy. Fish that are harvested may have a high amount of toxins or other marine debris in their system as a result of bioaccumulation. Some of these toxins, such as mercury or bisphenol A, may be harmful to people, putting consumers at risk.

Classification of plastics

Plastic litter comprises such diverse items with different shapes and sizes (ranging from meters to nanometres), which can vary according to their origin and use. Once dispersed in the marine environment, plastic items can float on the surface, drift in the water column, sink on the seafloor or settle on the beaches, depending on their size and their chemical-physical characteristics. Thus, interacting with different ecological niches and different species, both pelagic and benthic, and posing potential risks to marine biodiversity.
Marine debris can be categorized according to size and is defined for plastics as mega (>1 m diameter), macro (between 2.5 cm and <1 m), meso (between 5 mm and <2.5 cm), micro (between 0.1 µm and <5 mm) and nano (<0.1 µm).
Macro and mega debris relate to the larger parts of plastic debris. Large-sized plastic debris may comprise plastic chairs, shoes, car/plane/boat parts, buoys, footballs. An important, often found piece of macrodebris is the "ghost net." A ghost net is an abandoned or lost fishing net that roams the ocean. A ghost net travels with the currents and tides, continually catching animals and other macro debris in its maze and becomes filled primarily with other plastic objects. Ghost nets can grow to masses of 6 ton and are often too heavy and too large to be removed from the ocean.
Meso debris often consists of plastic resin pellets, the well-known nurdles. Nurdles are small granules that have the shape of a cylinder or disk, and have a maximum diameter of 5 mm. The pellets are made as raw industrial material and are sent to manufacturers for remelting and moulding into plastic products (Ogata et al. 2009). Because of their small size, nurdles are often accidentally expelled into the environment during transport and manufacturing. They then travel by surface run-off, rivers, and streams toward the ocean. Nurdles are highly persistent, and therefore are widely distributed in the ocean and are found on beaches and water surfaces all over the world. (Barnes et al. 2009 ; Derraik 2002 ; Edyvane et al. 2004 ; Ogata et al. 2009) .
Micro debris consists of small plastic fragments <5 mm in diameter. Meso- and macro-debris can fragmentize into smaller bits from the constant movement and collisions with other plastic debris, or from the influence of UV-radiation and photo-oxidative degradation (Ng and Obbard 2006 ; Shaw and Day 1994). These micro debris fragments can become as small as 2 mm. Other small plastic particles, also called "scrubbers," which originate from hand cleaners, cosmetic products, and airblast cleaning media, have also contaminated the marine environment. Scrubbers are often contaminated with other chemicals and can easily be ingested by filter-feeding organisms (Fendall and Sewell 2009 ; Gregory 1996).

2. Statistical analysis

Data shown in this report are based on the state of the art of literature concerning the plastic debris found in sediments, on the sea floor, floating on sea, through the Mediterranean Sea. (Fossi et al., 2017; Suaria et al., 2016; UNEP/MAP, 2015; van Sebille et al., 2015).
The marine litter problem in the Mediterranean is exacerbated by the basin's limited water exchanges with other oceans, a highly developed coastal tourism, densely populated coasts, busy

offshore waters (with 30% of the world's maritime traffic), waste disposal sites often located close to the coast, high temperatures accelerating litter degradation into difficult-to-collect secondary products, and litter inputs from large rivers.

Marine litter, in particular floating plastics have been found in the Mediterranean Sea in comparable quantities to those found in the five oceanic garbage patches (Fossi et al., 2019). In this respect, studies based on global models have proposed the Mediterranean Sea as the sixth greatest accumulation zone for marine litter worldwide (Baini et al., 2018; Fossi et al., 2017; Panti et al., 2015; Suaria et al., 2016; van Sebille et al., 2015). The abundance of microplastics in marine habitats increases and 115,000–1,050,000 particles/km 2 are estimated to float in the Mediterranean Sea (Fossi et al., 2012; Suaria et al., 2016; UNEP/MAP, 2015; Zeri et al., 2018).

In literature, most of the studies conducted to date, have been focusing on beach litter and on the accumulation of marine debris on the sea floor (Galgani et al., 1995, 1996, 2000; Güven et al., 2013; Mifsud et al., 2013; Sánchez et al., 2013). Floating debris has received less attention. Four studies dealt with the abundance of neustonic microplastics (Collignon et al., 2012; Fossi et al., 2012; Hagmann et al., 2013; Kornilios et al., 1998), and only a few studies have been published on the abundance of floating macro and mega debris in Mediterranean waters (Aliani et al., 2003; Morris, 1980; Topcu et al., 2010; UNEP/MAP/MEDPOL, 2009).

According to a study conducted by Fortibuoni et al., (2021), which investigates the occurrence of marine litter along Italian coasts (Adriatic Sea, Western Mediterranean Sea, Ionian Sea and Central Mediterranean Sea), subregional differences emerged both in terms of litter quantities and composition. In particular, the Adriatic Sea was the most polluted subregion (590 items/100 m), followed by the Western Mediterranean Sea (491 items/100 m) and the Ionian Sea and Central Mediterranean Sea subregion (274 items/100 m). The most common macro-category on Italian beaches was plastic and polystyrene (74%). Specifically, the numbers of cotton bud sticks were extremely high in some beaches of the Western Mediterranean Sea; while the aquaculture-related litter (mainly mussel nets) turned out to be the items more frequently observed during the samplings performed along the Adriatic coastline.

Figure 1 clearly represents a map of the central-western Mediterranean Sea and shows the study area selected by Suaria et al. (2014) which is divided in different sectors named by letters from "A" to "N". In particular, the Figure shows the distribution of both anthropogenic marine debris (AMD) represented by black bars and natural marine debris (NMD, e.g. wood: mainly logs, trunks, branches and canes; algae or others: egagropili of Posidonia oceanica L. Delile, cuttlebones, bird feathers, sponges or pumice) represented by white bars in all the 167 transects' locations. The marine debris' densities are expressed as number of items/km2 in all surveyed transects. From this figure is possible to deduce how the two Mediterranean sectors "A" and "B" which correspond to the Adriatic Sea, together with sector "M" (Algerian basin) reveal the maximum densities of AMD.

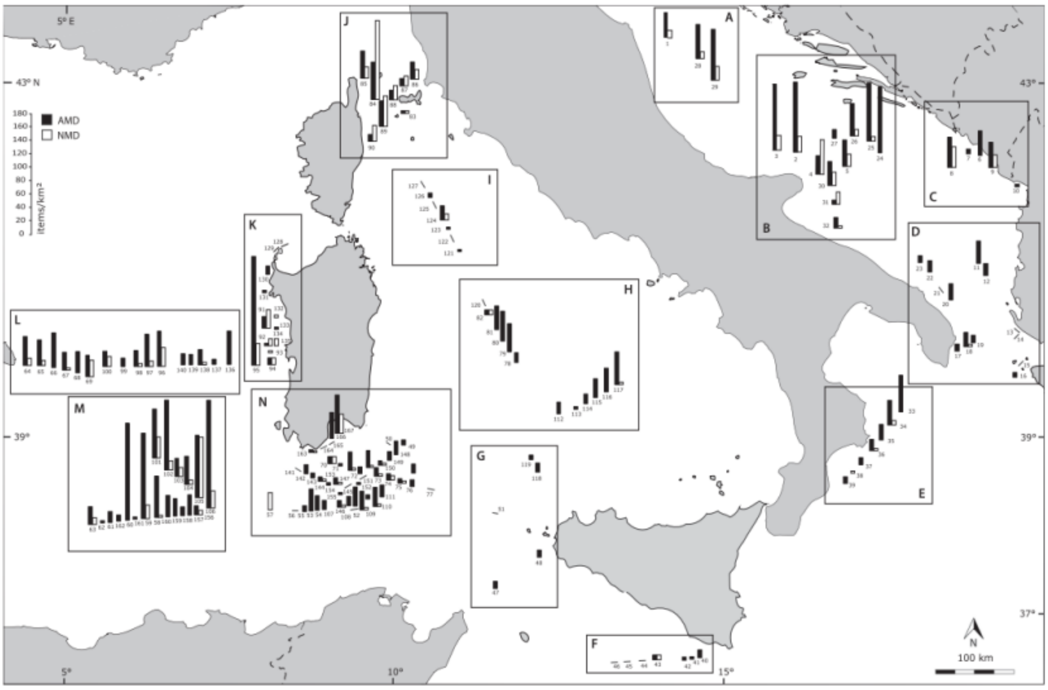

Figure 1: Map of the central-western Mediterranean Sea showing the location of transect and sectors and the distribution of anthropogenic marine debris (AMD, black bars) and natural marine debris (NMD, white bars) densities (items/km²).

Figure 2 shows in detail the mean densities of AMD and NMD (expressed as numbers of items per km^2 ± s.e.) in all surveyed sectors of the study area. The relative proportions of all AMD and NMD type categories are also shown in the pie charts.

As it is possible to see from this Figure, all the sectors of the Adratic basin show not only high level of AMD but also considerably high densities of NMD, that could be due to multiple interacting factors such as: the total river discharge (Po River in the northern basin, Albanian rivers in the southern basin) (UNEP/MAP, 2012), the high density of population of the shores (more than 3.5 million people) with fisheries and tourism acting as significant sources of income all along the Adriatic coast and the maritime traffic. In all the other sectors mean AMD densities ranged from 10.9 to 30.7 items/km^2.

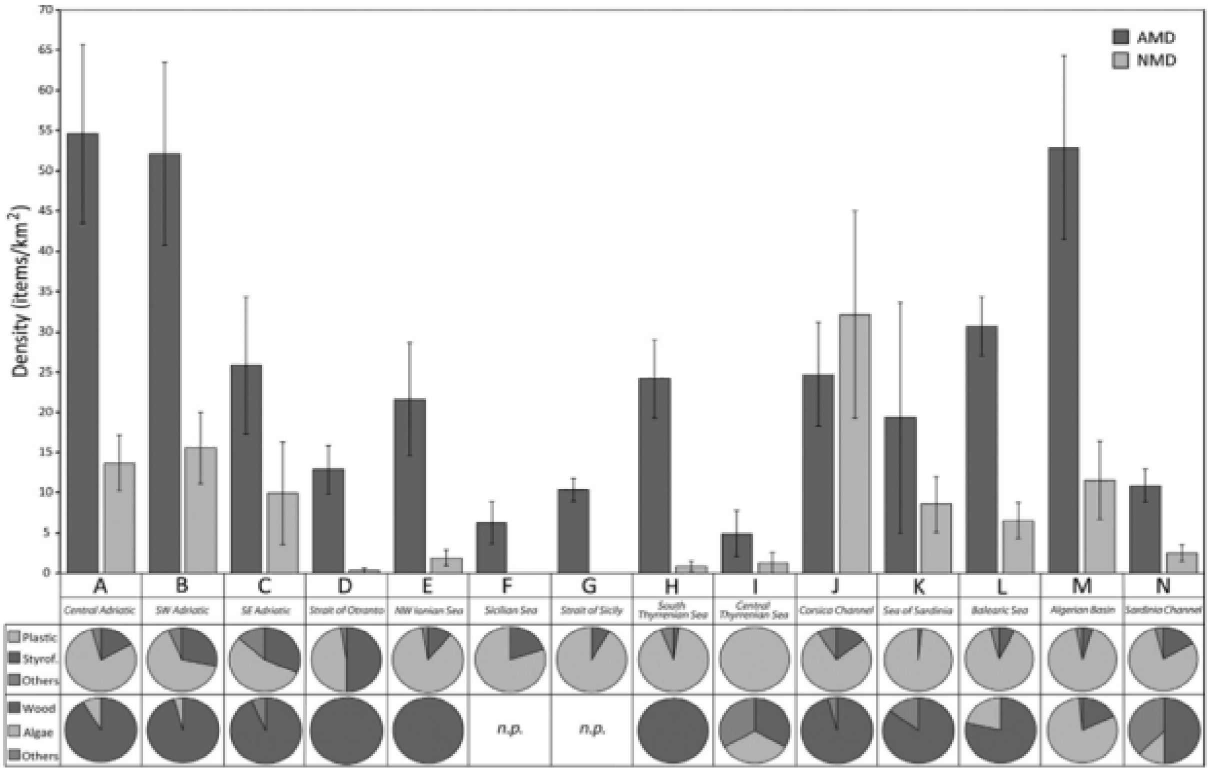

Figure 2: Mean densities of AMD (dark grey bars) and NMD (light grey bars) (n. of items per km[2]) in all the sectors studied. The pie charts show the relative proportion of AMD and NMD type categories.

Concerning with the composition of the sighted marine litter, plastic was the most abundant type of debris in all sampled locations, accounting for 82% of all man-made objects and confirming this way the overwhelming presence of plastic debris on the surface of the Mediterranean Sea (Suaria et al., 2014). On the whole, 95.6% of all man-made objects (74.7% of all sighted objects) were petrochemicals derivatives (i.e. plastic and expanded polystyrene). The highest abundances of expanded polystyrene (mean 10.2 items/km2) were observed in the Adriatic Sea (sectors A, B, C and D), with the highest values (peaking to a maximum of 34.75 items/km2) reported from sector B (Southwestern Adriatic. Even if the Adriatic basin seems to be, considering the already conducted investigations, a preferential area for marine litter accumulation, (due to the land inputs, impacting this basin such as: rivers runoff, industrialized area along the coasts, intense touristic activities during the summer and aquaculture, fishing, and port activities and also due to its geomorphological characteristics), there is a gap in the current scientific literature regarding the presence of marine litter in this part of the Mediterranean Sea.

Most of the existing studies concern the north-western part of the Adriatic Sea and, in particular, they investigate those areas which are close to the Po delta or to industrialized areas. In this sense, the southwestern area of the Adriatic Sea corresponds to the area where less scientific studies have been conducted.

Consulting the "Online Portal for Marine Litter" (https://litterbase.awi.de/litter), which summarize results from thousands of scientific studies about marine litter in understandable global maps and figures, it is possible to have a snapshot of the current investigations about the occurrence of marine litter and microplastics and their interactions with biota, in all over the world. One of the two global maps available on this website shows the distribution of litter and microplastics and their quantities, which were taken from 1426 publications. Marine litter quantity is expressed using the commonly used units: items / km²; items / km; items / m³.

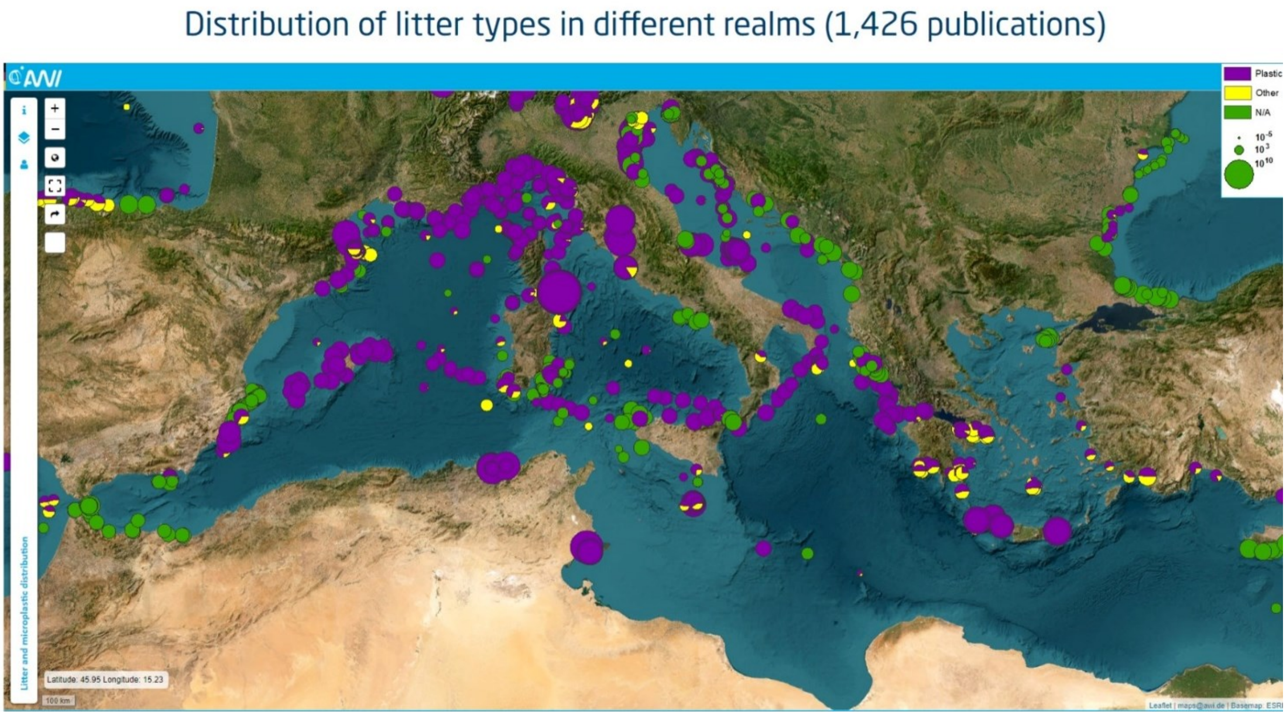

Figure 3: Map showing result from scientific publications on the quantity, location, density and composition of marine litter in the Mediterranean Sea. Purple circles represent plastic litter, yellow circles other type of litter and green circles not identified litter.

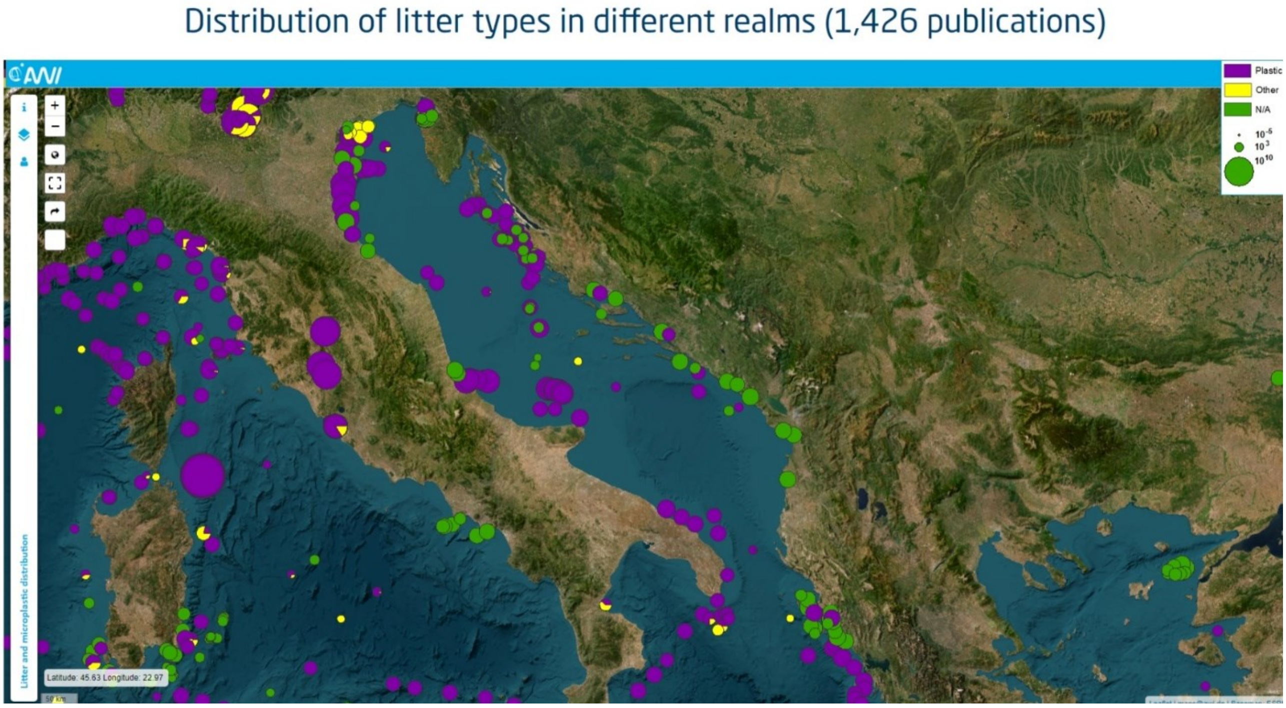

Figure 4: Map showing results more zoomed in Adriatic Sea, on the quantity, location, density and composition of marine litter.

Concerning with the Italian Region (Figure 4), it is possible to deduce from the map that: a) plastic is the major type of litter that occurs; b) most of the research are conducted in the Ligurian Sea, in the Northern Tyrrhenian Sea and in the in the North-Western Adriatic; c) the South-western part of the Adriatic Sea is less investigated.

3. Plastic collection's data from MARLESS pilot actions

This section describes the results of the collection of plastics made by the systems developed during the pilot actions of WP6. More in particular, are described data concerning the quantity, the location, the dimension and the type of litter recovered from sea, during some of the campaigns conducted.

Pilot Action 6.3

- *Fishing for litter*

Fondazione Cetacea Partner completed a pilot action on the recovery of marine litter from seabed, in collaboration with fishers.
Two boats were equipped with 4 special nets and 20 exits a year were done for each one of the 2 ports of the Emilia Romagna.
The collection detailed in table 1 and figure 5 shows data referring to only one of the last campaigns (March, 2023).

Table 1: Analysis of the collected seabed marine litter by category

category	weight of items (kg)	share (%)
Plastic	11	79%
Rubber	2	14%
Metal	1	7%
total	14	

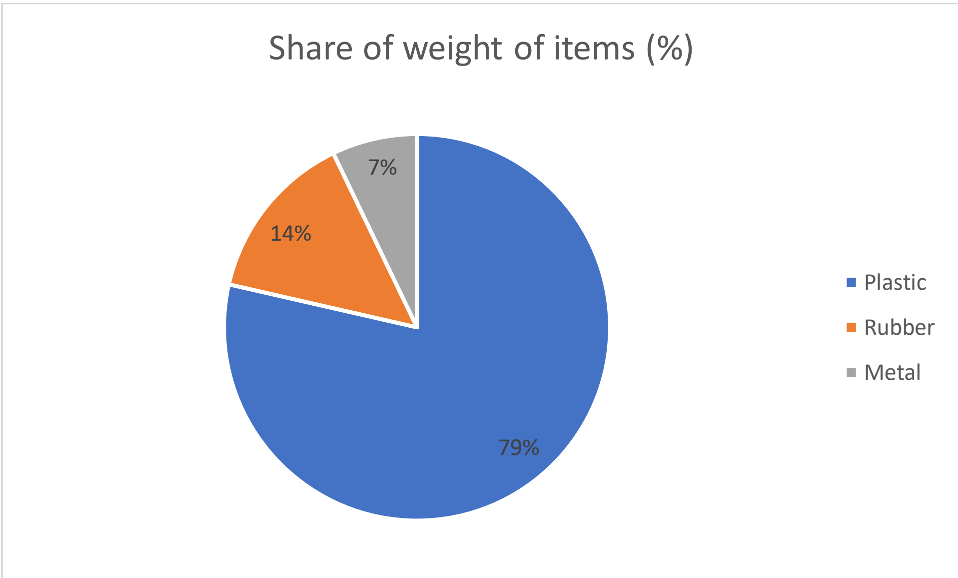

Figure 5: Share weight of items per category of collected seabed litter

- *Seabins*

Apulia Region Partner did a pilot action to collect plastic and microplastics in the harbours through a big collector, in order to recover a big amount of plastic. The action was made in collaboration with some Municipalities of the Region participating in the project.
Data shown in Table 2 and figure 6 are referred to the collector placed in Manfredonia harbour (north Apulia Region) in December 2022.
Material collected was classified as plastics, microplastics and metal materials (tin, cans, cigarette butts and sanitary napkin materials); contaminated wet organic mass (wood, leaves, branches, pieces of wood and algae) with respect to which it was possible to note several fragments of plastic and polystyrene that remained trapped, especially in the algal material; uncontaminated wet organic mass.

Table 2: Analysis of the collector's marine litter by category

category	weight of items (kg)	share (%)
Plastic and Microplastic and Metal	573	70%
Contaminated organic mass	164	20%
Uncontaminated organic mass	82	10%
total	819 (in 6 months)	

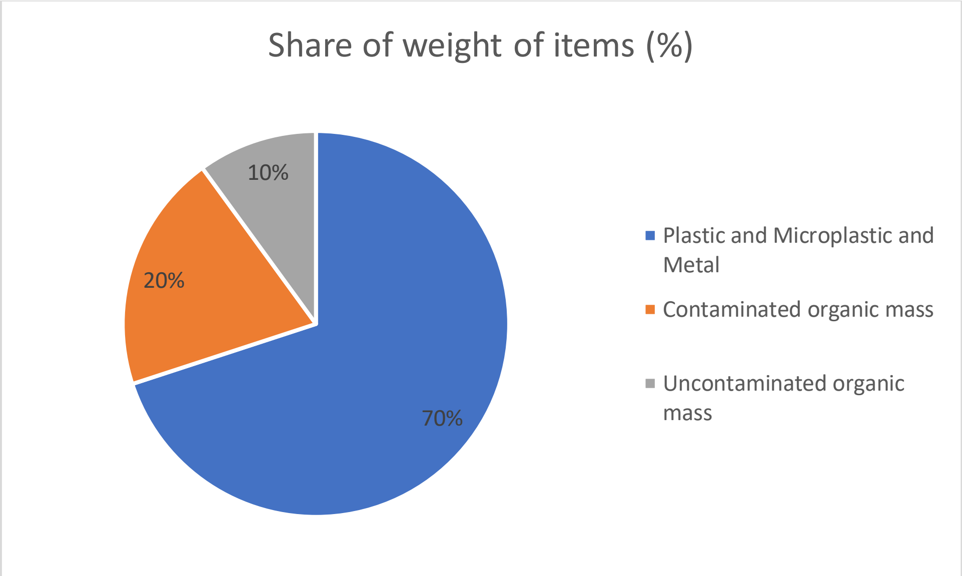

Figure 6: Share weight of items per category of collector's litter.

Pilot Action 6.4

Ruđer Bošković Institute was involved in the pilot action about the use of mussels as suitable tool for water column microplastic purification. They achieved and evaluated mussel micro plastic removal/purification efficiency by several lab experimental exposure, with different sized model microplastic Ruđer Bošković Institute was involved in the pilot action about the use of mussels as suitable tool for water column microplastic monitoring and purification. They achieved and evaluated mussel microplastic removal/purification efficiency by several laboratory experimental exposure, with different sized model microplastic particles derived from cigarette buts (CBs): mussel micro plastic ingestion, egestion and excretion, biological effects, including mussel filtration observation using valve gaping function as a proxy. Figure 7 demonstrate mussel filtration efficacy and show data retrieved in 24h-120h cleaning process after 1 – 6 h of MP exposure.

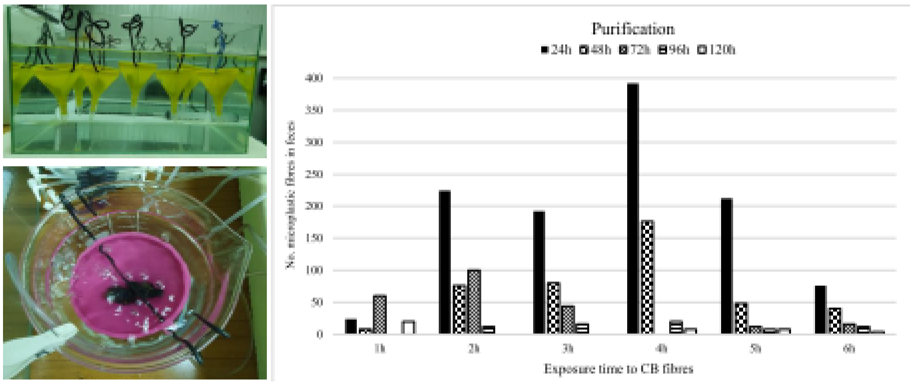

Figure 7: Cleaning process after 1h-6h mussel exposure to CBs microfibres

Mussels by filtration concentrate and remove suspended matter and microplastic from sea water column. Using sophisticated gill structures mussels further proceed, separate food (microalgae) from other particles. One part of filtered particles is ingested, digested and excreted as feces usually after > 24 h, and the rest is excreted as mucous pseudofeces (immediately or up to 6 h). Usually, only nanoplastic is passing intestinum barrier and spreading to other tissues (digestive gland, muscle etc.). Anyhow, collected mussel generated feces and pseudofeces represent concentrated content of microplastics in water column, while one singe mussels (*M. galloprovincialis*) can filtrate 1-5 L sea water per hour. After laboratory filtration (pseudo/feces) experiments: A) Mussel MicroPlastic Monitor (MMP-M) and B) Mussel MicroPlastic Purificator (MMP-P) installations were designed using mussel filtration power (Figure 8).

A) MMP-M

B) MMP-P

Figure 8: Installations used for A) MMP-M microplastic monitoring in water column and B) MMP-P environment purification.

By performed field activities our intention was assessment of microplastics pollution of Rovinj and Dubrovnik coastal area (5 + 2 locations) by using of mussels as a potential suitable innovative tool for monitoring and removing MP form water column including quality improvement (bioremediation) of the marine environment e.g. location in vicinity of Rovinj municipal waste water treatment plant outlet – Cuvi (October 2021 – May 2023).

FECES/PSEUDOFECES
MICROPLASTICS

K = collector
L = funnel

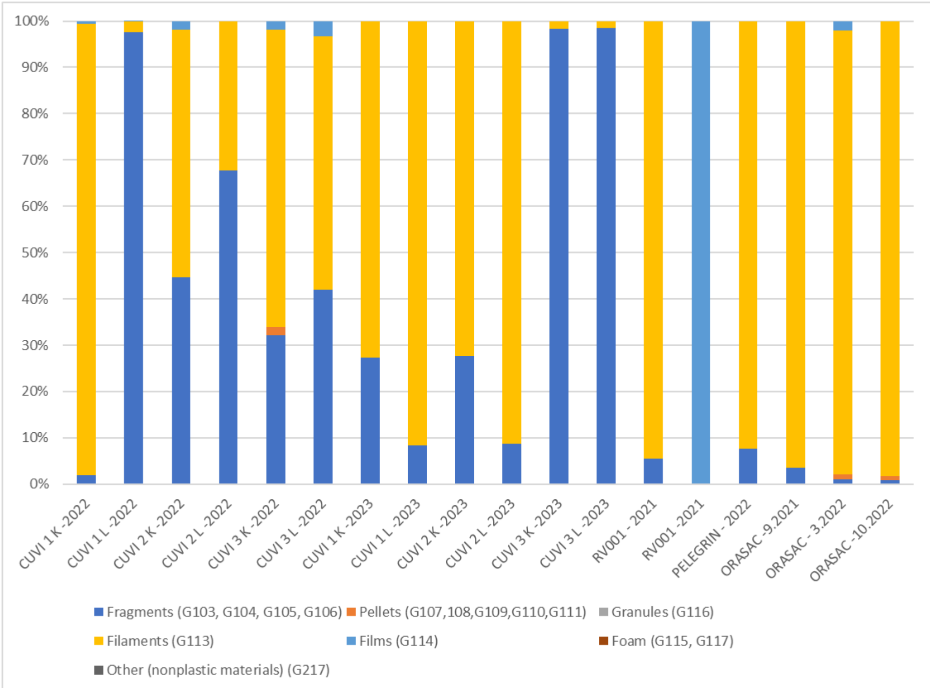

Figure 9: Size distribution of MP collected using MMP-M installations at investigated sites.

Table3: Analysis of the collected microplastics by category

category	number of items	share (%)
Plastic and Microplastic	NA	0.5 %
Organic (mostly send and seashells)	NA	83 %
Uncontaminated organic	NA	16 %
Other	NA	0.5 %
total	NA	100 %

By MMP-M installations, modified funnel construction with mussel (ca 1 kg) on top, hanging on aquaculture rope with buoy on surface and concrete anchor on bottom at investigated areas we succeeded to collect temporal data (2022, 12 months) about MP presence in water column. The MMP-P installations (3 x 100 km mussels) close to municipal waste water treatment plant outlet – Cuvi contributed to water column quality improvement by mussel filtration, preventing further spreading of effluents and MP to neighboring areas (October 2022 – May 2023).

Pilot Action 6.5

- *Marine drone for microplastic collection*

Researchers from the University of Bologna designed and prototyped a marine drone for the collection of microplastic at sea. First, a scalable filtering system for microplastic collection was designed and manufactured, able to filter sea water and to catch particles of 5mm dimension and less, then we designed, realized and tested the full prototype of a drone equipped with the filtering system, an autonomous guidance system and a collision avoidance sensor.
The collection of floating microplastics was performed in the Riccione Bay (North Adriatic).
The drone ran for an hour in the sea, near the coast, and collected item described in table 3 and figure 8.

Table 4: Analysis of the collected microplastics by category

category	number of items	share (%)
plastic	17	63%
Organic (mostly send and seashells)	7	26%
Other (mostly metal fragments)	3	11%
total	27	

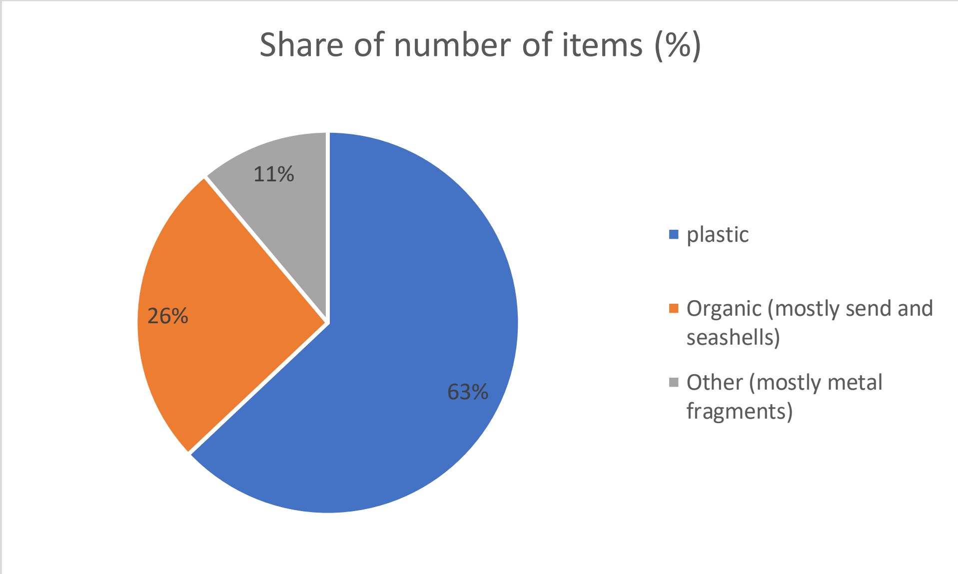

Figure 10: Share number of items per category of collected floating marine litter

Some images of the collection of microplastics by the drone filtering system are shown in Figure 11: the first image shows the first filter, which is larger than the others, allowing only elements of the size of the microplastic order to enter the filtering nets. The other images refer to the collection of microplastics.

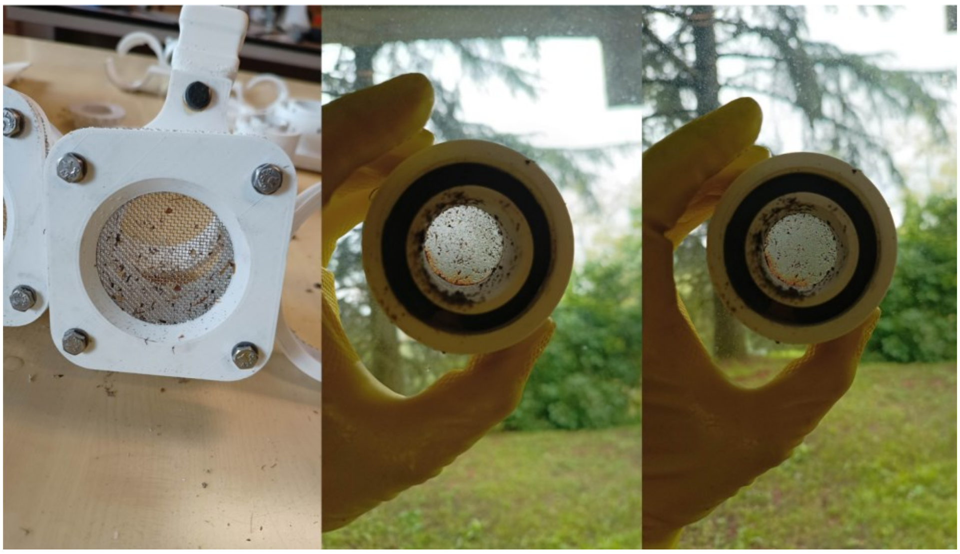

Figure11: Microplastics collected by the filter

- *Mobile net array for floating litter collection*

Researchers from the University of Dubrovnik designed and implemented the autonomous mobile net array for floating litter collection. Control algorithms for coordination and efficient litter collection were also developed and the prototype of the autonomous mobile net array was

custom made. The net array was successfully tested for collection of various types of common floating litter and it was presented at to different target groups (general public, local, regional and national public authorities, regional and local development agencies, education and training organizations as well as universities and research institutes).
The collection of floating marine litter was performed in the Bistrina Bay (Southern Adriatic), 55 km southern from Dubrovnik at the Laboratory for mariculture of the University of Dubrovnik. There, UNIDU has a research concession on sea area with floating longlines for suspended bivalve culture that was used to test the net array. The first version of the system was ready 17 months after the beginning of the activity and the first public demonstration including all the stakeholders was performed in May 2022. Until the end of the project the system was constantly updated, tested, and validated in real filed experiment, with the last demonstration performed in April 2023. In the following tables and graphs the floating marine litter collected my UNIDU mobile net array is presented.

Table 5: Analysis of the collected floating marine litter by code

code	name	number of items	weight of items (kg)
G7	Drink bottles <=0.5l	13	0,33
G8	Drink bottles >0.5l	4	0,13
G21	Plastic caps/lids from drinks	8	0,10
G79	Plastic pieces > 2.5 cm < 50cm	1	0,15
G81	Polystyrene pieces 0-2.5 cm	1	0,20
G82	Polystyrene pieces >2.5 cm <50cm	1	0,05
G83	Polystyrene pieces > 50 cm	1	0,25
G150	Processed timber	2	2,65

Table 6: Analysis of the collected floating marine litter by category

category	number of items	share (%)
plastic	29	94%
wood	2	6%
total	31	
category	**weight of items (kg)**	**share (%)**
plastic	1,19	31%

wood	2,65	69%
total	3,84	

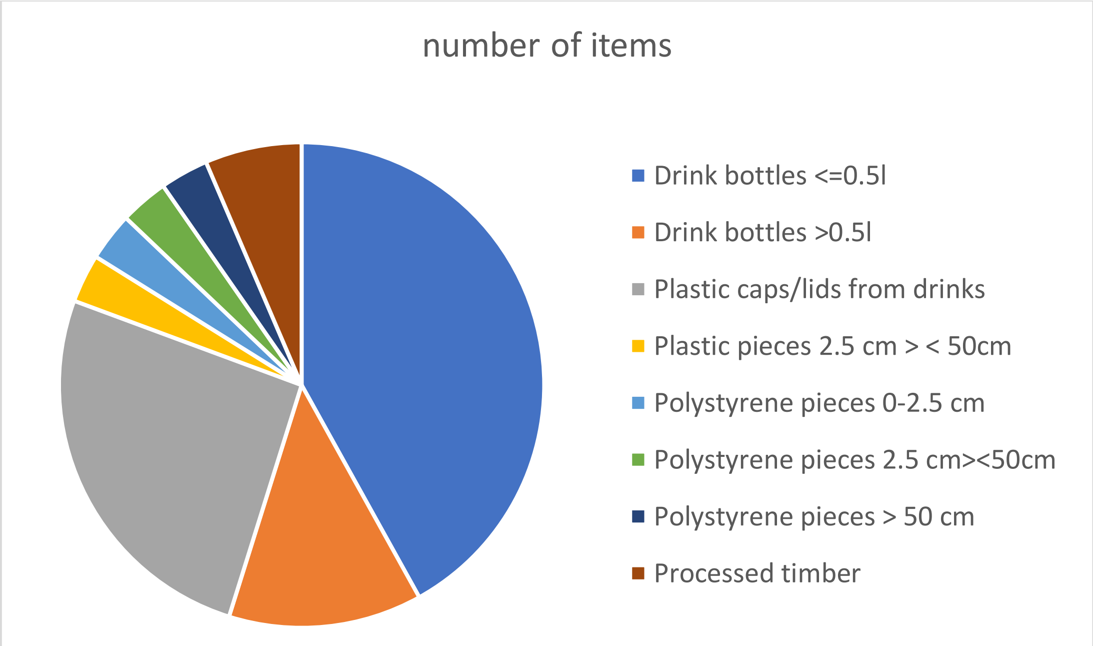

Figure 12: Analysis of the collected floating marine litter by code and number of items

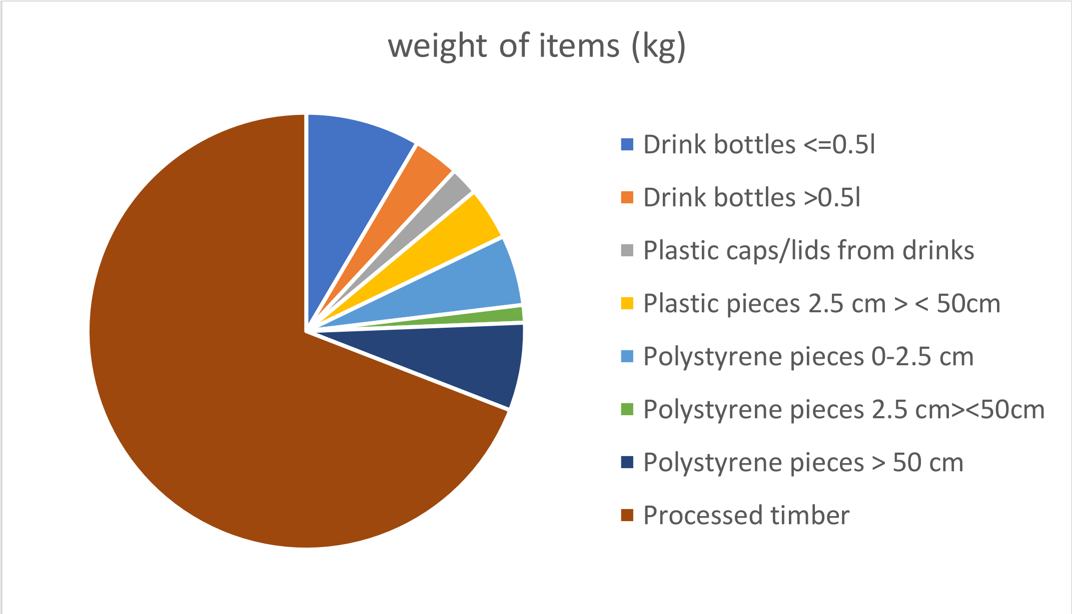

Figure 13: Analysis of the collected floating marine litter by code and weight of items

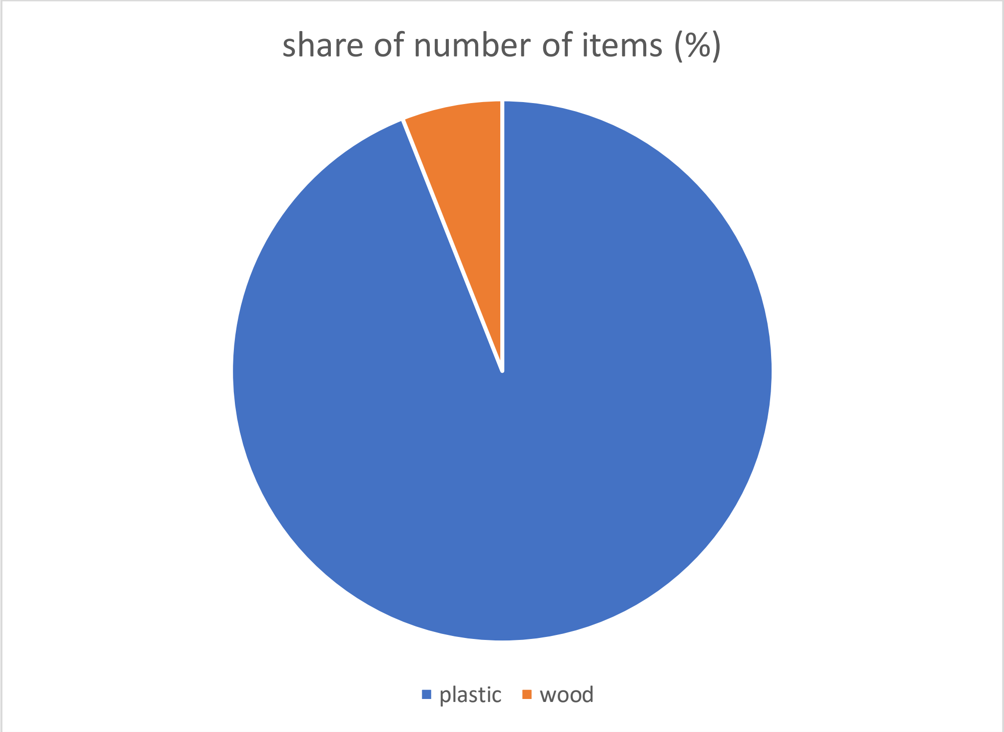

Figure 14: Share number of items per category of collected floating marine litter

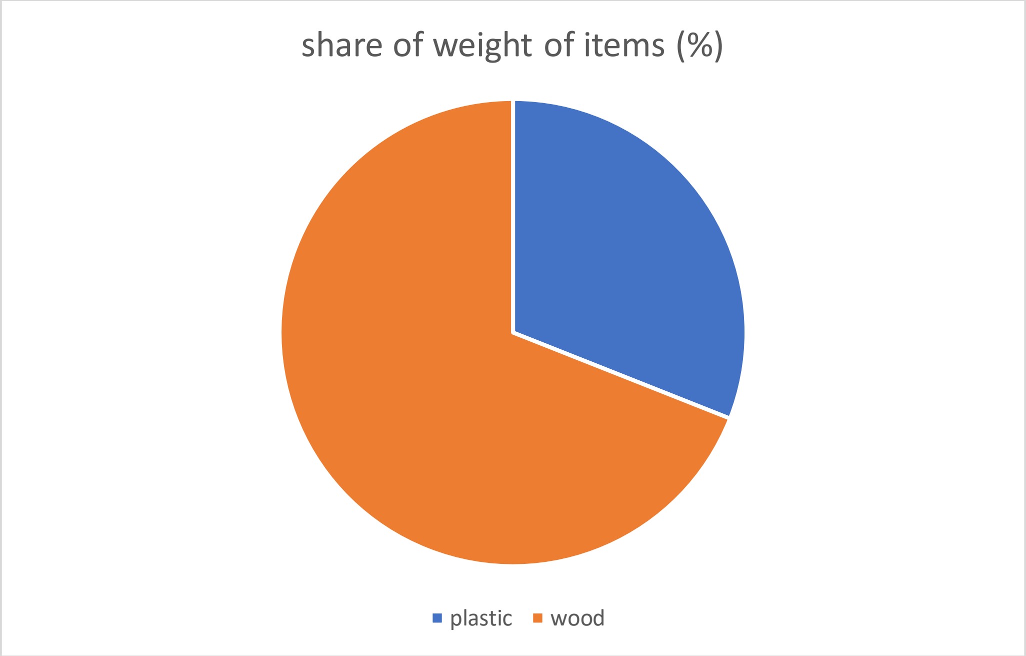

Figure 15: Share weight of items per category of collected floating marine litter

Conclusion

This report had the aim of taking a snapshot of the current situation regarding plastic waste at sea in the Mediterranean Sea.
It is important to notice that last section of the report has only the aim to give an overall idea of what each collection system developed in the MARLESS Project was able to do, in some limited condition, and to what kind of dimension of plastics it was addressed to. It can't have the purpose of giving results statistically feasible. In fact, in many cases, the tests done were only aimed to check the methodologies proposed or the prototypes realized. Furthermore, data collected can't cover all the season working conditions are not homogenous enough to have the consistency to provide a statistical analysis.
On the contrary, the first section of the report shares consistent data about the quantity, location, density and composition of marine litter in the Mediterranean Sea and can be considered a statistical analysis in the strict sense.

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