MONITORING AND ASSESSMENT GUIDELINES FOR MARINE

LITTER IN MEDITERRANEAN MPAS

INTERREG/ MED, project AMARE

Galgani F., A. Deidun, S. Liubartseva, A. Gauci, B. Doronzo, C.Brandini, O.Gerigny

Title : Monitoring and assessment guidelines for marine litter in Mediterranean MPAs	
Reference : https://archimer.ifremer.fr/doc/00487/59840/ **Diffusion :** Free (online)	**Date :** 2019/April/15 **Version :** Final **Cover picture :** F. Galgani , A corsican beach, 2018 **language :** English
Authors : F Galgani (IFREMER, Bastia, France), A. Deidun (University of Malta, La valette, Malta), S. Liubartseva (CMCC, Bologna, Italy), A. Gauci (University of Malta, La valette, Malta), B. Doronzo (Lamma, Livorno, Italy), C. Brandini (Lamma, Livorno, Italy), O.Gerigny (IFREMER, toulon, France)	
Key words : Marine Litter , Mediterranean Sea, Marine protected areas, Monitoring	
Citation: Galgani F., A. Deidun, S. Liubartseva, A. Gauci, B. Doronzo, C.Brandini, O.Gerigny (2019) Monitoring and assessment guidelines for marine litter in Mediterranean MPAs. Technical report of the Interreg/ MED/AMARE project. IFREMER/AMARE editor, 57 pages, (https://archimer.ifremer.fr/doc/00487/59840/)	
Data availability: AMARE partners	
DOI : DOI (10.13155/59840)	
Supporting project : INTERREG /MED/ AMARE (amare.interreg-med.eu/)	

Preface

As part of the AMARE project, the main purpose of this report is to provide advice and practical guidance, for establishing programmes to monitor and assess the distribution and abundance of marine litter in MPAs. The present document build on relevant existing monitoring and assessment practices in the Mediterranean, such as the existing monitoring practices in UNEP/MAP and within the Marine Strategy Framework Directive. The proposed strategy (defining the sampling scheme, the environmental compartment to monitor and the protocols to be used) is also following the recommendations of the UN GESAMP report on monitoring marine litter (GESAMP, 2019). In addition, it is based on the experience of ongoing monitoring and assessment activities under various scientific projects in the Mediterranean Sea (CleanSea, Marelitt, Perseus, Marlisco, Ac4forlitter, INDICIT, MEDseaLitter, Plastic Buster MPA, PANACEA, Life projects, etc.), and also considers the available scientific literature.

SUMMARY

1. INTRODUCING THE MONITORING AND ASSESSMENT GUIDELINES FOR MARINE LITTER IN THE MEDITERRANEAN MARINE PROTECTED AREAS

1.1 The context

Marine litter, covering an extremely wide variety of materials and sizes and originating from many unspecified sources, is one of the most serious, rapidly developing and worsening global environmental problems. The annual global production of waste has reached 4 billion tons and this figure is expected to double by 2025, while about half of this amount concerns non-biodegradable material (i.e. plastics and metals). Plastics are ubiquitous in the marine environment, in vast quantities and are present even on the most remote areas of the planet. This is evident in certain areas of the globe for which plastics can be found in excess, constituting more than 80% of the recorded marine litter items. Periodic assessments of the state of the marine environment, monitoring and the formulation of environmental targets are perceived as part of the adaptive management process within MSFD and within Regional Sea Convention (RSC) Action Plans, and has become a major concern for Marine Protected Areas (MPAs).

In the Mediterranean Sea, the intensive use of maritime space calls for integrated management to avoid cumulative impacts and user conflicts. Maritime Spatial Planning (MSP) – the harmonization of human activities in marine areas - is advocated as a powerful approach to reach these goals. However, most Mediterranean countries have not yet even embarked on this process. The objectives of the project AMARE are (i) to develop shared methodologies and geospatial tools for multiple stressors assessment, coordinated environmental monitoring, Multi Criterion Analyses (MCA) and stakeholders' engagements and (ii) to translate these guidelines into concrete pilot actions and coordinated strategies in selected Marine Protected Areas (MPAs) to solve hot spots of conflicts affecting marine biodiversity and the services it provides. Transnational cooperation and regulations, development of coordinated best practices to deal with present and future drivers of changes in biodiversity and ecosystem services, coordinated monitoring, data access to share information and concrete stakeholder and users' involvement are the expected results. The final aim is to scale up strategies and recommendations, adopting an ecosystem-based approach to MSP considering the goals of the Marine Strategy Framework Directive (MSFD) across MPAs. MPA managers, public institutions, and key stakeholders working within the MPAs will benefit from the results of the project.

As part of the project, the principle purpose of this report is to provide advice and practical guidance, for establishing programmes to monitor and assess the distribution and abundance of marine litter in MPAs. The intention is to promote a more harmonised approach to the design of sampling programmes and the selection of appropriate monitoring strategies. The Guidelines cover all types of marine litter on shorelines, floating on the sea surface, deposited on the seabed or associated with biota (ingested/encrusted/entangled). They may be used for the monitoring of items originating from specific sources (e.g. Abandoned or Lost Derelict Fishing Gear, ALDFG) or specific items to evaluate the efficiency of dedicated reduction measures (e.g. for single-use consumer plastics, sanitary-related items, etc).

The present monitoring guidelines for marine litter in MPAs strongly build on relevant existing monitoring and assessment practices in the Mediterranean, such as the existing monitoring practices in UNEP/MAP and within the Marine Strategy Framework Directive. The proposed strategy (defining the sampling scheme, the environmental compartment to monitor and the protocols to be used) is also based on recommendations of the UN GESAMP report on monitoring marine litter (GESAMP, 2019). In addition, it is based on the experience of ongoing monitoring and assessment activities under various scientific projects, including in the Mediterranean Sea (CleanSea, Marelitt, Perseus, Marlisco, Ac4forlitter, INDICIT, MEDseaLitter, Plastic Buster MPA, PANACEA, Life projects, etc.), and also considers the available scientific literature.

1.2 Marine litter in the Mediterranean Sea (after UNEP, 2015 and RAC SPA, 2017)

The Mediterranean Sea is a closed basin and has been described as one of the most affected areas by marine litter in the world. This has been possible because of large cities distributed around the basin, large rivers and shore uses (including tourism), some of the largest volumes of Municipal Solid Waste (MSW) that are generated per inhabitant, more than 700 tons of plastics entering the basin every day (Jambeck et al., 2015), 20% of the world's maritime traffic and, lastly, insufficient infrastructure to process the waste.

Current knowledge on the quantities of litter in the Mediterranean Sea, the degradation and fate of litter in the marine environment and its potentially harmful biological, physical and chemical impacts remains limited (CIESM, 2014; UNEP, 2015 ; Galgani et al., 2015; ioakeimidis et al., 2017; Galgani et al., 2017). Research recently demonstrated (i) the importance of hydrodynamics, (ii) the impact of plastic at sea that include entanglement, physical damage and ingestion, the release of chemicals, the transport of species and the alteration of benthic community structures, and (iii) social and economic harm caused by the accumulation of marine litter in the marine environment.

As described recently in RAC SPA (2017), sources of marine litter are traditionally classified as either land-based or sea-based, depending on where the litter enters the water. Other factors, such as ocean current patterns, climate, tides, and proximity to urban centers, waste disposal sites, industrial and recreational areas, shipping lanes, and commercial fishing grounds, influence the type and amount of marine litter found in open ocean areas or collected along beaches and ocean, including underwater areas. Studies on land-based source pollution estimated the input of the Po River alone at a level of 50 billion particles every year (Vianello et al., 2015). Uncontrolled discharges also act as main sources of litter in the Mediterranean Sea since, in some countries, a low percentage of coastal cities implement wastewater treament systems prior to discharge. Ocean-based sources for marine litter include merchant shipping, liners, fishing vessels, military fleets, and offshore installations. It is estimated that garbage originating directly from ships to the Mediterranean may be in the range of 0.5 million tons.

The overall outcome of this unique context is that, in the Mediterranean, one finds a density of litter that is among the greatest in the world (Table 1), and that can reach over 100,000 bits of waste per square kilometer of seabed (UNEP/MAP, 2015a) and over 64 million particles per square kilometer in the case of surface micro-plastics (Van der Hal, 2017).

Table 1: Summary of observations of litter in the Mediterranean (source RAC SPA, 2017)

	MIN	MAX	NUNBER of STUDIES	LOCATION	REFERENCES
Beaches	30/km	36000/km	13	Western, eastern, central and Adriatic basins	UNEP, 2015 ;
Floating	1,98/km2	45/km2	10	Whole basin	UNEP, 2015
Sea floor	24/km2	120 000/km2	37	Western, eastern, central basins	Ioakeimidis et al., 2014; Angiolillo et al., 2015
Floating Microplastics (mean /study)	115000/km2	1,518,340/km2*	9	Whole basin	UNEP, 2015 ; Van den Hal et al. 2017*
Microplastics on beaches	10/m2	2920/m2	3	Spain, Greece, France	UNEP, 2015

*Maximum per sample at 64,800,000 particles per sq.km in the eastern Mediterranean

Mesoscale circulation is the main driver of marine waste accumulation in the Mediterranean. The role of currents, however, can be very complex, for it also acts on the distribution of the species that can be affected by litter. It is observed that the main sites for biota aggregation also coincide with areas having a high density of marine litter, whilst evidence is also emerging that the the phenomena of stranding and the surface transport or accumulation of litter at sea are also linked (Pham et al., 2014).

Marine litter in the Mediterranean can take a great variety of shapes, colours and composition. The most common marine litter in the Mediterranean are cigarette butts on beaches, plastic packaging, bottles and caps, and, to a lesser extent, metal cans and glass bottles. The litter items recorded indicate a predominance of land-originated waste, resulting mainly from leisure/tourist activities, which increase markedly during and after the tourist season. However, out at sea and on the seabed, certain parts of the Mediterranean are much affected by litter from fishing, constituting a major risk of entanglement/strangling for marine fauna.

Only few studies have focused on debris located on the sea floor in the Mediterranean (review in Ioakemides et al., 2017). Surveys concluded that submarine canyons might act as a conduit for the transport of marine debris into the deep sea. Higher benthic litter densities are also found in high sedimentation zones, denoting the importance of vertical transport processes. A wide variety of human activities, such as fishing, urban development and tourism, contribute to these patterns of deep seabed debris distribution. Fishing debris, including ghost nets, prevails in commercial fishing zones and can constitute high percentages of total litter (Ioakeimides et al., 2017). A mean density of 179 plastic items/ km2 has been recorded for all compartments, including shelves, slopes, canyons and deep-sea plains, with an important plastic component, registering 62.7 % +/- 5.47 of the total debris recorded. On slopes, the dominant litter items recovered consisted of fishing gear, responsible for a fraction of 59-89% (Angiolillo et al., 2015). Fishing gear (mesh nets, trammel nets, ghost nets, pots and traps), when damaged or old, can be discarded and abandoned by fishermen, or is broken up and dispersed by storms. Some of this gear may continue to catch and kill marine organisms (fishes and crustaceans, whether for the market or not, birds, mammals and marine turtles) for months, even years, until they degrade (UNEP, 2015). In the Mediterranean, static gear is an important part of ghost fishing. Estimated ghost catches are generally believed to be well under 1% of landed catches and was estimated annually, for hake, between 0.27% and 0.54% of the total commercial landings.

Marine litter can persist for long periods in the environment due to the slow decomposition rate, based on processes of abrasion (mechanical), heat, chemical and biological photo-degradation that can slow down at sea in the dark, and where there are low levels of oxygen. One of the more common phenomena of degradation is fragmentation, leading to the presence of micro-plastics, smaller than 5mm, even potentially of nano-plastics less than a micron in size.

Most of the micro- and nanoplastics are of secondary origin, resulting from the breakdown of larger plastic materials into increasingly small fragments, rather than from precursors (virgin resin pellets) used for the production of polymer consumer products. Mean sea surface plastic was found in concentrations up to 100,000-200 000 particles / km^2 in the NW Mediterranean Sea (maximum at 64 000000 particles per km2, Hal et al., 2017), giving an estimated weight of over 1000 tons for the whole basin. Micro plastics have been also found on beaches and sediments, including the deep sea (Van cauwenberghe et al., 2013).

Little is known about the impacts of plastic on marine organisms. Marine litter affects marine organisms at different levels of biological organization, via entanglement/strangling, ingestion, contamination, as a vector of non-indigenous species and by harming assemblages of different species (Werner et al., 2017). Both entanglement of marine species and ingestion are the source of more substantial effects that should be taken into account when monitoring. So far, there is a lack of validated research methodologies and data on litter concentration levels and its real environmental impacts, particularly as regards the smaller particles.

So far, over 80 studies have dealt with interactions between marine organisms and marine litter (mainly plastics) in the Mediterranean basin (reviewed in Deudero & Alomar, in CIESM, 2014; Deudero and Alomar, 2015; UNEP, 2015). These studies cover a wide range of depths (0 to 850 meters), an extended timescale (1986-2017), and identify a vast range of species affected by litter, from invertebrates (polychaeta, ascidians, bryozoan, sponges, etc.) to fishes, reptiles and cetaceans. The effects identified in these studies concern entanglement, ingestion, and, to a lesser extent, colonization by and transport of species.

A summary of the literature published between 1986 and 2014 on interactions between plastic waste and marine organisms, shows that 134 species from different taxa could be affected (Deudero and Alomar, 2015). In the context of monitoring, only a few species are potentially interesting, particularly those that of high conservation importance are (migratory species, such asmarine sea turtles, for example).

Litter in the marine environment gives rise to a wide range of economic and social impacts. Value for the closed Mediterranean Sea may be more important due to the high-density population settlement in the region, fishing, maritime traffic, and tourism. In this basin, there is little or no reliable data on what the exact economic cost of the putative impact is. While the impact on tourism has been well documented, economic impacts are most often described at sea almost exclusively as the impacts “from fishing” and “on fishing”, whilst marine eecosystems degradation is an extremely complex cost to evaluate.

Management, mitigation and reduction protocols still need to be developed, implemented and coordinated, especially within MPAs. However, a number of key questions will have to be considered in order to provide a scientific and technical background for a consistent monitoring, a better management system, and science-based reduction measures. UNEP (2015), MSFD, (2013), the

European project STAGES (http://www.stagesproject.eu), CIESM (2014) and recent reports from the GES TG (Veiga et al., 2016; Werner et al., 2017, Osterban et al., 2017) recently reviewed the gaps in and the needs for knowledge, monitoring, and management of marine litter, considering a list of actions and research to be initiated in order to improve basic knowledge and to support both monitoring and management of the deep sea environment. Typically, valuable and comparable monitoring data could be obtained by standardizing approaches adopted in different countries and the following points were listed in these various assessments as critical for the near future:

1- Identify pathways / transport of marine litter to and in the Mediterranean.

2- Map the hot spots (accumulation areas, areas at risk) of marine litter (stranding, floating, if any, and deep sea), with a focus on lost fishing gears.

3- Determine the sinks for marine litter and better understand its degradation at sea

4- Define a GIS platform to support the integration and the analysis of all monitoring data.

5- List the species settled on litter at sea, better explain the risk of dispersion and the possible colonization of new areas

6- Evaluate fluctuations in the distribution of micro plastics (stranding, floating, seafloor and ingested).

7- Support the rationalization of monitoring (i.e. common and comparable monitoring approaches, standards/baselines, inter-calibration, data management system and analysis/quality insurance).

8- Define specific baselines and targets for important litter categories, that may individually targeted by reduction plans or measures by Mediterranean countries (plastic bags, fishing gears)

9- Identify new indicator species for impact (entanglement, ingestion, microplastics, and rafted species), and define thresholds for harm

10- Evaluate the potential loss of fish stocks due to the main types of abandoned/lost fishing gears. Locate ghost nets to support collection.

For the Mediterranean MPAs, Points 2, 4, 7, 8 and 9 are critical and must be addressed before any comprehensive implementation of marine litter monitoring programmes.

1.3 The common MSFD indicators

Monitoring and assessment are essential steps to characterise the baseline and to provide objective information on the design of mitigation measures as well as to evaluate implementation measure effectiveness through the promotion of adaptive management. It is also critical to understand the overarching policy frameworks as this will help to determine the nature and extent of the approach. For the monitoring of marine litter in European countries, including areas confined within MPAs, the Marine Strategy Framework Directive (MSFD) emerges as the main policy framework. Of the 11 descriptors listed in Annex I of the MSFD for determining Good Environmental Status, Descriptor 10 has been defined, as “Properties and quantities of marine litter do not cause harm to the coastal and marine environment”. The Revised Commission Decision identified in 2017 the following criteria and associated four indicators for Descriptor 10, to be considered for regular monitoring purposes :

Table 2: Descriptor 10 – Properties and quantities of marine litter do not cause harm to the coastal and marine environment (Relevant pressure is Input of litter)

Criteria elements	Criteria	Methodological standards
Litter (excluding micro-litter), classified in 9 main categories) Member States may define further subcategories.	D10C1 – Primary: The composition, amount and spatial distribution of litter on the coastline, in the surface layer of the water column, and on the seabed, are at levels that do not cause harm to the coastal and marine environment.	Scale of assessment: Subdivisions of the region or sub region, divided where needed by national boundaries. Use of criteria: The extent to which good environmental status has been achieved shall be expressed for each criterion separately for each area assessed as follows: (a) the outcomes for each criterion (amount of litter or micro-litter per category) and its distribution per matrix used under D10C1 and D10C2 and whether the threshold values set have been achieved. (b) the outcomes for D10C3 (amount of litter and micro-litter per category per species) and whether the threshold values set have been achieved. The use of criteria D10C1, D10C2 and D10C3 in the overall assessment of good environmental status for Descriptor 10 shall be agreed at Union level. The outcomes of criterion D10C3 shall also contribute to assessments under Descriptor 1, where appropriate
Micro-litter (particles < 5mm), classified in the categories 'artificial polymer materials' and 'other'.	D10C2 – Primary: The composition, amount and spatial distribution of micro litter on the coastline, in the surface layer of the water column, and in seabed sediment, are at levels that do not cause harm to the coastal and marine environment. Member States shall establish threshold values for these levels through cooperation at Union level, taking into account regional or sub regional specificities.	
Litter and micro-litter classified in the categories 'artificial polymer materials' and 'other', assessed in any species from the following groups: birds, mammals, reptiles, fish or invertebrates. Member States shall establish that list of species to be assessed through regional or sub regional cooperation	D10C3 – Secondary: The amount of litter and micro-litter ingested by marine animals is at a level that does not adversely affect the health of the species concerned. Member States shall establish threshold values for these levels through regional or sub regional cooperation.	
Species of birds, mammals, reptiles, fish or invertebrates which are at risk from litter. Member States shall establish that list of species to be assessed through regional or sub regional cooperation.	D10C4 – Secondary: The number of individuals of each species which are adversely affected due to litter, such as by entanglement, other types of injury or mortality, or health effects. Member States shall establish threshold values for the adverse effects of litter, through regional or sub regional cooperation	Scale of assessment: As used for assessment of the species group under Descriptor 1.Use of criteria: The extent to which good environmental status has been achieved shall be expressed for each area assessed as follows: – for each species assessed under criterion D10C4, an estimate of the number of individuals in the assessment area that have been adversely affected. The use of criterion D10C4 in the overall assessment of good environmental status for Descriptor 10 shall be agreed at Union level. The outcomes of this criterion shall also contribute to assessments under Descriptor 1, where appropriate.

Besides, the following specific guidance and standardized monitoring and assessment methods were detailed:

1. For D10C1: litter shall be monitored along the coastline and may additionally be monitored in the surface layer of the water column and on the seabed. Information on the source and pathway of the litter shall be collected, where feasible;

2. For D10C2: micro-litter shall be monitored in the surface layer of the water column and in the seabed sediment and may additionally be monitored along the coastline. Micro-litter shall be monitored in a manner that can be related to point sources for inputs (such as harbours, marinas, wastewater treatment plants, storm-water effluents), where feasible.

3. For D10C3 and D10C4: the monitoring may be based on incidental occurrences (e.g. stranding of dead animals, entangled animals in breeding colonies, and affected individuals per survey).

Finally, the units for reporting litter quantities were agreed as follows:

– D10C1: amount of litter per category in number of items: – per 100 meters (m) along the coastline, – per square kilometer (km2) for surface layer of the water column and for seabed, D10C2: amount of micro-litter per category in number of items and weight in grams (g): – per square meter (m2) for surface layer of the water column, – per kilogram (dry weight) (kg) of sediment for the coastline and for seabed,

– D10C3: amount of litter/micro-litter in grams (g) and number of items per individual for each species in relation to size (weight or length, as appropriate) of the individual sampled,

– D10C4: number of individuals affected (lethal; sub-lethal) per species.

2. MONITORING AND ASSESSMENT METHODOLOGICAL GUIDANCE FOR MARINE LITTER IN MARINE PROTECTED AREAS (MPAs)

2.1 Introduction

MPAs in the Mediterranean Sea are most often coastal areas, including shallow waters, and may be affected by a higher human frequentation due to their attractiveness and sites promotion. They are exposed to vigorous hydrodynamic activity and are thus subject to accumulation of litter originating outside the MPA confines. In terms of monitoring, methodological standards are currently available for the assessment of litter along coastlines, with protocols for beach litter surveys, developed specifically for the Mediterranean region, and litter at sea, with some experiments and protocols available for floating and sea floor litter. These approaches also concern the amount, distribution and composition of microparticles, which can be assessed at the surface of the sea by concentrating the particles from water or by washing low-density particles from sediment samples. Implementing these protocols may indirectly enable the measurement of inputs, impacts on aesthetic values, litter dynamics and of potential interactions with marine life. Accumulation areas will have to be also located and identified, in support of identified implementation measures.

For impacts of marine litter, marine species stomach content analyses is already operational in some countries, but may not fit with the requested standards of monitoring an MPA, since the identification of spatial differences is only possible at a far larger scale than that normally encountered within a regular MPA, i.e. basin or sub-regional scale. At best, results from an individual MPA may contribute to a monitoring network, providing both an indication of the state of environment in the MPA and contributing to a larger monitoring network by providing data.

In some MPAs, such an approach will require additional experimental/pilot monitoring experiments, to first define the suitable sentinel species and secondly to optimise a monitoring protocol adapted to the local conditions. The choice of a monitoring strategy (standing networks of dead animals, use of rescue centers, etc.) will be the first step before the implementation of monitoring that may need capacity building. New indicators of impact on biota, such as the density of ingested microplastics by fish, collected on a regular basis may be also be considered, but for future monitoring only, as related protocols are still not endorsed and are still subject for discussion t (e.g. aspects related to the presence of natural materials that may interfere with measurements, problems of contamination during sample processes and analysis and the impossibility of characterizing particles in the micrometer range).

The MSFD and UNEP MAP Regional Action Plans provide a framework for coordinated monitoring programmess, which will deliver data to assessing whether GES (Good Environmental Status), and associated environmental targets, are being achieved. The monitoring requirements are dependent upon measuring techniques of demonstrated accuracy and must deliver reliable data at affordable costs. There are different aims for monitoring including: assessing (i) the environmental status, (ii) the temporal and spatial trends in a phenomenon, (iii) environmental target achievement levels, (iv) source identification, and (v) the effectiveness of measures.

Key relevant documents on marine litter monitoring that may be applied for Mediterranean MPAs already exist, namely the UNEP Operational Guidelines for Comprehensive Beach Litter Assessment (Cheshire et al. 2009), the Guidance on Monitoring of Marine Litter in European Seas document produced between 2012 and 2013 by the European Union Task Group on Marine Litter (TSG ML), the UNEP MAP IMAP (http://www.unep.org/unepmap/publications_) and the GESAMP recommendations for monitoring marine litter (Gesamp, 2019).

The recent overviews by UNEP (Cheshire et al, 2009), and by NOAA (Opfer et al. (2012) are useful overviews for monitoring methods along the coast. The UNEP overview includes a comprehensive comparison of existing marine litter survey and monitoring methods and protocols in which beach surveys were assessed. Much of the information included in the TSG ML report for the monitoring of beach litter is taken from the UNEP Operational Guidelines for Comprehensive Beach Litter Assessment (Cheshire et al., 2009) and the NOAA Marine Debris Shoreline Survey Field Guide (Opfer et al., 2012).

The Guidance on Monitoring of Marine Litter in European Seas provides EU Member States with recommendations and information needed to implement harmonized monitoring programs for marine litter. The report describes specific protocols and considerations to collect, report and assess data on marine litter, in particular beach litter, floating litter, seafloor litter, litter in biota and micro-litter. This guidance document was developed through a collaborative program involving the European Commission, all EU Member States, and Four Regional sea conventions, including UNEP/MAP for the Mediterranean Sea, and other stakeholders and Non-Governmental Organizations. The document should be regarded as a consensus position on marine litter monitoring best practice agreed by all partners.

The UNEP/MAP Regional Plan on Marine Litter Management in the Mediterranean is based on an ecosystem approach, ecological objectives and integrated monitoring program. It prepared the Regional Marine Litter Monitoring Program, as part of the integrated regional monitoring program, establishing a Regional Data Bank on Marine Litter, which should be compatible with other regional or overarching database, also taking into account the need for harmonization. This Plan prepared in 2014 the Guidelines to support the implementation of the National Marine Litter Monitoring Programs.

Finally, the Gesamp report (Gesamp, 2019) provide recommendations, advice and practical guidance, for establishing programs to monitor and assess the distribution and abundance of plastic litter. The intention is to promote a more harmonized approach to the design of sampling programs, the selection of appropriate indicators (i.e. type of sample), the collection of samples or observations, and the characterization of sampled material, dealing with uncertainties, data analysis and reporting the results.

Most of the protocols proposed can be applied across an MPA, although some of them cannot be perfectly replicated, for the simple reason that constraints, locations, sentinel species, biotopes, etc. are not identical. Alternatively, a risk-based approach can be adopted, whereby the assessment focuses on where the amounts of litter are likely to be highest or on the type of litter which has the largest impact on biota. For example, it is proposed to measure litter on the sea surface rather than in the whole water column, because pilot studies indicate that litter quantities are higher on the sea surface. Similarly, the protocols for monitoring on the sea floor propose to assess where litter tends to accumulate (e.g. through pilot studies or oceanographic modelling), and then to direct monitoring towards such areas. While there may be problems to generalize the results from this kind of monitoring to other areas, such strategies are in line with a risk-based approach.

2.2 Setting priorities

It is proposed to ensure the state and pressure-based assessments are compatible within MPAs, in terms of scales of assessment. When possible, it is thus critical that each MPA address these issues during the initial phase of monitoring, in a coordinated manner, under the auspices of an institution such as, for example, UNEP/ MAP, RAC/SPA or MEDPAN. Before addressing possible options, some principle requirements need to be outlined and further developed, in particular (I) Defining scales and areas for assessment of environmental status , also considering finer scales if needed (as required for the different assessment elements – species, habitats, pressures), (ii) Developing suitable mapping/dissemination tools to show the environmental status of the different indicators across MPA waters, and (iii) Linking the scales of assessment to management issues (pressures/ measures, for example).

The first years of monitoring of Marine litter will focus on its implementation, considering investigations, data gathering, capacity building and further experiments to ensure that all MPAs are able to adjust to the new elements of the program. After the initial phase of the implementation of the monitoring programme, based on the experience and capacity acquired within the MPA in question and on further expert input, the full monitoring programme implementation is foreseen, with possible adjustments, and the inclusion of specific indicators.

Implementing the monitoring of the impact in Mediterranean MPAs must enable workers to assess temporal trends, local differences, and compliance with a set target. Such monitoring may also include entanglement rates of representative species and a strategy to measure the impact of "ghost" nets. These have to be considered especially in or around MPAs where fishing occurs.

The reference levels (baseline, GES boundary between GES, and not in GES), the aggregation rules, methods for spatial and temporal data, as well as the assessment scale need further expert work, especially during the initial phase. In principal GES should be defined as an acceptable/agreed degree of deviation from reference state (which accommodates sustainable uses at specified scales of assessment). For this, baselines must be defined as reference condition or state (background levels, free from adverse effects) or a specified/known state of the environment. Both can be defined using a variety of methods, including past state at a specified time, past state based on time-series data, or current state. The baseline is primarily used in connection with targets (i.e. to improve status in relation to a current/past poor status).

It is necessary to update the assessments of the environmental status at least once every six years to fit with the reporting requirements of both UNEP/MAP Regional Plan and MSFD to show progress against set targets and established measures. It is still possible to update the assessments at more frequent intervals. When feasible and if desirable, this can be done every year. For instance, the assessment can be updated after the outcomes of the initial phase of the monitoring program, on additional new scientific knowledge, or when monitoring is carried out on an annual basis and processing of the data is routine (consideration of marine litter during benthic surveys for instance). Undertaking the assessment implies the need to (i) consider data over the longest possible period so as to help understand changes in the data including natural variability as well as anthropogenic influences, (ii) use the latest available data from monitoring programs, (iii) update all data used in the assessment at least once every six years , (iv) use data from the same time period when combining datasets as much as possible, and (v) compare the latest six-year assessment period with the previous six-year assessment period in order to report progress in achieving GES and targets.

To have a more integrated approach for the determination of GES and consequently, to assess whether GES has been achieved, one should focus on mapping the distribution and quantities of marine litter (10DC1, litter on beaches, at the surface, and on the sea floor; and 10DC2, microplastics). It is also important to assess the impacts (possibly on a trial basis, the 10DC4). This information will provide an overview of the status which in turn will be useful to specify a standard methodology to carry out the assessment.

Coherent monitoring programmes will ensure that the assessment of the environmental state is consistent across MPAs. This will support the management and will allow for consistent reduction measures to improve the status and achieve the same quality standards. Ideally, differences in the monitoring strategies would be justified through the demonstration of significant differences in the biological and physicochemical characteristic (e.g. impact of litter on species that are not common to all Mediterranean MPAs).

The identification of marine litter items which require priority action due to their high abundance in the marine environment and/or their high potential to cause harm, is a matter of concern which will be addressed in the upcoming mitigation processes. Specific measures are needed to prevent further inputs and reduce the abundance of litter items. It is necessary to identify the items that require most attention. There is a need to identify and rank the top marine litter items, to know how to monitor them as well as to identify additional information regarding the risks related to such item categories. There are still some questions about the comparability of such top item lists. These include for instance, the scale at which the top items should be identified, how to consider fragments, the specific risk posed by the individual litter categories, and the importance of specific measures. These concerns are being addressed by the TGML. Information on the possible scheme to prioritize litter categories as well as the corresponding consequences on monitoring, will be available. For MPAs, these issues have become critical to support specific management and reduction measures.

In order to achieve common datasets and interoperability of information, data sources need to make sure that they are capable to deliver standardised data with the same format. Work done in AMARE that focused on developing mapping tools to support MPA management, should be considered.

While it is important to ensure that the monitoring is cost-effective, it is also important (i) prioritize (scientific credibility, practical monitoring, and data requirements, policy/social relevance) the monitoring program to address the most significant risks and associated indicators, (ii) find innovative and efficient ways of doing the monitoring, as tested within the AMARE project, (iii) encourage MPAs for cooperation as a potential cost-efficient execution of the monitoring programs (common strategies, common tools, data bases, etc.), (iv) build on existing monitoring activities (existing monitoring stations, cruises, etc.) carried out on the use of existing resources (e.g. ship time), and finally (v) encourage monitoring through participative sciences. A number of citizen communities

(NGOs, civil society initiatives) and environmental protection associations, as well as institutes, are already organizing and participating in activities to tackle marine litter in MPAs. The goal would be to enable them to participate in activities that address marine litter issues as envisaged within the MPA monitoring and reduction plans, to reach the main objectives.

2.3 A monitoring framework for marine litter in Mediterranean MPAs

Fulfilling the marine litter monitoring requirements within a MPAs is a major undertaking especially if the resources are limited. Our present understanding of litter in the marine environment is based on information from a small subset of parameters. Conclusions cannot be solely based on the trends of the amounts within the various size categories of marine litter. The parameters selected for monitoring should provide information to help identify source as well as the pathway through which the item entered the marine environment. Therefore, it is recommended to consider all parameters of the marine environment in the Monitoring plan.

2.3.1 Considerations on strategies

The strategy used to select a site to monitor, apart from partly being a statistical/technical issue, should first and foremost be related to the purpose of monitoring. Such a decision should be taken when a monitoring strategy is defined.

Individual sites may be chosen because they have certain characteristics and they represent what is needed for the MPA manager (such as maritime pollution, characterization of sources, etc.). However, sites can also be chosen randomly from a large number of possible locations that meet certain criteria based upon the method and the monitoring purpose.

The work performed within the AMARE project (see Chapter IV) has created a lot of interest and serves as an initial coastline survey that maps areas where litter accumulates. This also demonstrates how hot spots can be identified, and provides a definition of sites that should be monitored. In practice, these two strategies are not used directly. Instead a combined approach that is sometimes referred to as “stratified randomized sampling strategy”, is adopted. Sites meeting certain criteria are (more or less) randomly chosen. In this case, priority should be given to monitoring programs that measure environmental status and trends, in sites where the risk of harm is greatest. One way to make best use of the limited resources, is to take advantage of other studies and programs that supports the integration of litter monitoring (what is called “opportunities to reduce costs”). An example is to combine monitoring for litter on the sea floor with dive observations for biodiversity. In such cases, it is important to analyze the sampling strategy to assess whether this is suitable for litter monitoring as well. For marine litter, a stratified, randomized sampling strategy is preferred. The criteria for site selection are normally defined by the purpose of the monitoring program. When resources are limited, simplification and concentration of monitoring effort is critical.

The design of a monitoring program needs to take into account the magnitude of change we wish to detect. It is of course easier to detect a large trend than a small one. The smaller the magnitude we want to detect, the more comprehensive the monitoring program needs to be. If the aim of the action is to reduce the amounts of marine litter significantly, then monitoring programs can detect real changes. Given sufficient resources, it is easy to change the number of replicates. In this case litter trends, replicates refer to the combination of monitoring sites and monitoring occasions. Using the same number of sites, the ability to detect a significant trend increases with time. In monitoring programs, which often are complex with multiple temporal and spatial layers, the actual number of replicates is less easy to define. More importantly is the ability to decrease the sampling variation among the sites that are monitored. As described in the section on site selection strategies above, this is achieved by introducing criteria for the sampling. However, it is important to realize that the possibility to extrapolate to un-sampled sites decreases.

Starting a monitoring program is very important even if the initial resources are limited. The collected data can nevertheless be used for subsequent trend analysis (albeit with reduced statistical power). More importantly, such data can also be used to refine the design of the program.

2.3.2 Considerations regarding Quality Assessment/Quality Control

Important decisions will be taken based on the results obtained by monitoring programs. Therefore, it is important that the data generated is of acceptable quality. In order to ensure the quality and integrity of marine litter monitoring data, it is important to carry out capacity-building activities within local survey coordination and management groups. Quality assurance (QA) and quality control (QC) measures ensure that high quality monitoring is carried out across MPAs at all times. Monitoring activities should result in data which is representative of the location and time of sampling. In particular, for temporal trend monitoring, it is extremely important to perform reliable and reproducible high-quality analyses over decades. Such analyses require well-documented procedures and experienced analysts. QA/QC seems to be limited to methods and technical specifications. However, these are still important for the whole monitoring chain. QA and QC also apply to data storage and exchange. This includes common data management standards, as well as technical and semantic interoperability between data management systems. The use of quality control and assurance measures such as inter-calibrations, use of reference material (where appropriate), and training for operators, should accompany the implementation of the adopted monitoring protocols. These approaches should be developed in the context of dedicated research. Finally, to ensure highest quality of data, the MPA managers shall harmonize the monitoring methodology, compare the resulting data, ensure compliance with quality assurance prescriptions, participate in intercalibration exercises, develop and use duly validated scientific assessment tools (such as modeling and risk assessment strategies), carry out necessary research, and take into account scientific progress which is considered useful for assessment purposes.

The quality of monitoring programs can be improved by compiling a standard list of litter items which in turn can be used for preparing assessment protocols. A master-list of categories with litter items has already been prepared by TSG-ML. The use of appropriate field guides with examples of each litter type will assist survey team members (particularly volunteers) to be consistent in litter characterization. Such field guides should be coupled with the master list of litter items, and be made available over the web to increase consistency between survey teams working at remote locations. The use of standard lists and item definitions will enable the comparison of results between regions and environmental compartments. Items can be attributed to a given source e.g. fisheries, shipping, etc. or be given a form of harm e.g. entanglement, ingestion, etc. The value of the monitoring results can be further increased by the identification of the main sources of marine litter pollution, and the potential level of harm that this litter may inflict.

2.3.3 Consideration of Costs

Monitoring programs must be cost-effective to make best use of the often limited resources. This also maximizes the chances of the programs to be maintained. As stated in the MSFD (Galgani et al., 2013) and GESAMP (2019), there are a number of key factors are key and the following approaches are recommended:

- Prioritize the monitoring program to address the most significant risks and associated indicators (i.e. scientific, technical, policy/social relevance, data requirements)
- Favour innovative and opportunistic approaches
- Encourage cooperation (common services; common cruises)
- Build on existing monitoring activities
- Encourage monitoring by structures responsible of the environmental effects (industry, municipalities)

The table 3 provides a summary of estimated costs based on the experience in a European setting (Galgani 2013). It is appreciated that staff costs may vary considerably between countries.

Table 3 : Estimated Costs and Level of Expertise for the different protocols (adapted from Galgani et al., 2013 and GESAMP, 2019). L: Low (< 10K USD); M Medium (<50K USD); H High (<100K USD); VH Very High (>100K USD). *ROV: Remote Operated Vehicles

Component	Beach	Sea floor			Surface		Biota		Microlitter		
Protocol	Visual	Diving <20m	Trawling <800 m	ROV*	Trawl	Ship surveys	Ingested	Entanglement	Beach	Sediment	Biota
Sampling	L	M	M	VH	L	M	M/H	M/H	L	M/H	M/H
Processing	L	L	L	M	L	M	H	M	M	M	H
Analysis	M	M	M	M	M	M	H	M	H	H	H
Equipement	L	M	H	H	M	L/H	M	L/M	M	M	M
Expertise	M	M/H	M	H	L	M	M/H	M/H	M	M	M
Overall	L/M	M	M	H	L/M	M	M/H	M	M	M/H	M/H

2.3.4 The role of Citizen Science (After GESAMP, 2019)

There is a long tradition of citizen science volunteers in MPAs and marine litter research. Most citizen science studies have been conducted in accessible areas that interest the general public. Citizen scientists participate in a wide range of activities, ranging from the reporting of incidental findings to collection of specific samples with some active participation in data evaluation and publication of results. Many of the common marine litter sampling protocols can benefit from the participation of motivated and well-trained citizen scientists. The use of mobile phone applications can improve the output, as this provides a harmonised approach and uses an existing data framework. Furthermore, the collected data can be submitted and used by a dedicated project or initiative. Depending on the complexity of the sampling methodology, volunteers may autonomously conduct surveys, or they can support professional scientists in their sampling efforts. However, quality control and assurance are important for comparability between observers. When possible, interested volunteers should participate in existing programs within their regions, or extend existing citizen science protocols to their home MPAs.

Samples or data gathered by citizen science projects can include: (i) observational data of litter impacts, (ii) collection of specific litter items, (iii) bulk estimates of gross amounts of litter, (iv) frequency data on litter types, and (v) quantitative data on litter densities. A rigorous citizen science program still requires intensive coordination and communication with the volunteer participants. The resulting data must be controlled, reviewed, and validated by experts in order to remove errors, and spot unlikely results resulting from mistakes or misunderstandings in data acquisition. Given the complex habitats and inherent difficulties with marine litter sampling in some habitats, the supervision of professional scientists is crucial.

2.4 Strategies for MPAs

In line with the recommendations of the Mediterranean Integrated Monitoring and Assessment Program (IMAP), and from TGML, the assessment of marine litter must be based on indicators that summarizes data into simple, standardized, and communicable figures. Ideally, a common indicator can deliver valuable information on the effectiveness of reduction measures taken by policy makers. For monitoring MPAs, different indicators are available but they must be adequately chosen in order to optimize both the strategy and operations. The common indicators, which are at the core of the Programme are presented in the following paragraphs.

Beach Litter (10DC1) monitoring has become an effective process for combating anthropological influence on the sea coast. This has proven to be an easily applicable tool even during intensive touristic activities for both estimation of litter density and discrimination of in-situ vs marine sources of litter. Various approaches have been proposed and strategies have been mostly based on regular sampling to evaluate trends and/or efficiency of reduction measures. Critical constraints such as accumulation areas and hot spots, specific and local categories of litter, as well as the importance of tourism or fishing, have already been identified and will need to be better considered before implementing monitoring in MPAs.

When considering Sea floor litter monitoring (10DC1) in MPAs, shallow waters must be considered first. Litter in such areas can be harmful to a lot of marine organisms that live in this component of the marine environment, and because the pressure of fishing is more important. Moreover, deep sea monitoring may require specific means such as ROVs which will be used only in specific areas when sampling opportunities arise. Generally, shallow water monitoring is cheaper and may use ongoing monitoring schemes and sampling strategy as dedicated to benthic species. Modelling for this indicator is very important and support should be provided to locate hot spots of accumulation.

It may be important to measure floating litter (10DC1) especially when coastlines are exposed. The relevance of this approach depends on the local situation. Floating debris may be transported by currents and monitoring activity may have to rely on background knowledge about the hydrodynamics of the area. Ideally, floating litter will be measured when massive stranding occurs, when trans-boundaries circulation may bring some litter, or when a specific source must be monitored (fishing grounds, highly frequented beaches and large cities in the vicinity of a MPA).

Microplastics (10DC2 in the revised version of the commission decision) is of importance for two aspects related to (i) the contamination of a MPA, indicating the level and distribution of Microplastics in the different compartments of the environment, and (ii) the importance of microplastics in rafting species that may be at risk, such as toxic dinoflagellates, pathogens to marine organisms, invasive or non-native species. In a lesser extent, the release of adsorbed contaminants may be important in some areas. In such cases, when compared to other sources, plastic will act as a minor pathway through aggregates, live cells, or silts. When considering the distribution and quantities of microplastics, the assessment of microparticules will have to mainly focus on sediments because floating microplastics and species that ingest them, are moving at sea. Therefore, sediment measurements will support better trend evaluations as well as the mapping of persistent pollution within a MPA. Floating microplastics or microplastics in biota may, as a counterpart, provide some information about the possible sources of microplastics and their impact. However, interpretation of these results remains difficult due to the possible elimination of pollution after transport of both particles and species, outside of a MPA. Moreover, protocols remain under discussion for ingested microplastics, because of possible contamination by polymers during samples treatment, by the presence of natural fibers, or because of the absence of simple method to characterize small sized particles.

The indicator related to harm (MSFD indicator 10DC3) is often measured on a large scale (sub regional, large basin). Measurements in a MPA related to migrations and/or the duration of stomach transit, must be part of a larger scale monitoring programme. Since discrimination between various MPA sites is not possible in most case, this indicator must be considered when a specific and well understood harm, in relation with the presence of sensitive sentinel species, exists. For example, priority should be given to beaches where sea turtles are nesting, and MAP waters around where affected species (sea turtles, seals, cetaceans, etc.) are living. Capacity building and pilot studies are strongly recommended during the initial phase of monitoring. These should take into consideration the possibility to select species as indicator and the local practices (type of fishing, iconic species, etc.).

Observations of the entrapment/entanglement of marine species (indicator 10DC4), have so far been poorly described. This restricts the development of corresponding monitoring networks. Carrying out coordinated pilot experiments based on a strategy of improved data collection seems to be the most suitable preliminary step before envisaging developing MPA monitoring. Work should focus on the prevalence of entrapment/entanglement of local/resident species, the identification and mapping of risk areas (presence of active or ghost fishing gear, distribution of susceptible species, probability of encounters between susceptible species and marine litter, etc.), and the rationalization of observation procedures on the basis of existing arrangements. If stranding seems to be rare, the use of regular monitoring of benthic species by diving or ROV (Remotely Operated Vehicles) will provide the best platform to collect data related to the entanglement in MPAs. In such cases, the focus should be set on specific pressures such as fishing (fishing grounds around a MPA, specific type of fishing or fishing gears in use, etc.).

Overall, the optimal strategy will involve the application of the most relevant protocols for monitoring, feasibility, significance, and management. One should also consider the necessary steps before implementation. Initial assessment, definition of priority areas to be monitored, selection of the most relevant indicators, implementation at a pilot scale, as well as optimization to ensure a regular and efficient monitoring of the MPA coastlines and waters, are critical steps to consider. Table 4 provides a summary of best strategies for monitoring marine litter in MPAs

2.5 Referenced protocols

Monitoring the marine environment for the presence of marine litter is a necessary part of assessing the extent and possible impact. This also allows one to plan possible mitigation methods to reduce inputs, and assessing the effectiveness of such measures (Gesamp, 2019). However, it is important to use consistent and reliable methods of sampling and sample characterisation (e.g. number, size, shape, mass and type of material to gain greatest benefit). It is common to adopt a hierarchical approach that describes: i) the composition (e.g. plastic, glass, metal, etc…), ii) the overall form (e.g. bottle, film, rope, net, bag, etc., and iii) the size. The category lists used by Regional Seas and the EU-MSFD monitoring programmes, tend to have a common root based on the UNEP/IOC guidelines (UNEP/IOC 2009). However, these can be adapted to meet the specific requirements of each monitoring programme.

General guidelines have been already described in documents from UNEP Operational Guidelines for Comprehensive Beach Litter Assessment (Cheshire et al., 2009), the MSFD TGML Guidance (Galgani et al., 2013), and the Unep /MAP IMAP document (http://www.unep.org/unepmap/publications_).

The type of survey selected depends on the objectives of the assessment as well as on the magnitude of the pollution on the coastline. As demonstrated by Table 5, various protocols are available to be used under the framework of UNERP MAP and MSFD. These protocols are all MSFD/ UNEP MAP compatible and may be used for regular monitoring in MPAs supporting harmonized approaches. Note that detailed supporting strategies were described and published recently in a dedicated UN related report. In particular, AMARE experts (GESAMP, 2019) were involved. Proposed templates for logging data that are compatible with MSFD and UNEP MAP, are provided in the annex section of this report.

Table 4 : Recommended (green) and possible (orange) approaches for monitoring Marine litter in MPAs, based on scientific relevance, resource sampling, processing requirements and common policy concerns addressed. The policy relevance index is the sum of the policy concerns addressed by the sampling approach. Compartments: ING- Ingestion, ENT- Entanglement (* interactions with invertebrates), RAFT- Rafting of organisms, CONT-release of contaminants, Plastic sizes: MA – macro-plastic, MI – micro-plastic. Table adapted from GESAMP (2019)

	Compartments & plastic size			Resource sampling and processing requirements (costs increase from left to right)						Examples of policy concerns									
												Impacts on							
Feasibility	Compartment	Sub-compartment / tool	Litter size	People	Basic field equipment	Sieves	Nets	Dissecting microscope	Ship	Distribution & Abundance	Source identification	Tourism	Seafood safety	Human health and injuries	Navigational hazards	Fisheries & aquaculture	Animal welfare	Biodiversity	Policy relevance index
1	SHORE	BEACH	MA MI	X	X					X	X	XX		X				X	5
3	SEABED	TRAWL	MA	X			X		Xa	X	X				X	X		X	5
2	SEABED	DIVING	MA MI	X	X			X*		X	X	X			X	XX	XX	X	7
4	SEABED	ROV	MA MI	X	X			X*	X	X	X	X			X	XX	XX	X	7
3	BIOTA	ING	ME MI	X	X			X		X			X				XX	X	4
2	BIOTA	ENT*	MA	X						X			X				XX	X	4
4	BIOTA	RAFT	MA MI	X		X		X		X	X						X	XX	4
4	CONT	CHEM	MA MI	X				X		X	X		X		X	X	X		3
2	SURFACE	VISUAL	MA	X		X			Xd	X						X		X	3
3	SURFACE	NET	MI	X	X	X	X	X	X	X			X				X		3

(a) Opportunistic sampling using fishing vessel, (b) Opportunistic observations using recreational divers, (c) Stranded organisms, (d) research vessel, € ship of opportunity, visual observation

Table 5: Summary of existing monitoring programmes and protocols, used by national and regional organisations

Protocol		Compartment								Links
name	date	shoreline		seafloor		biota		Sea surface		
		Mi	Ma	Mi	Ma	Mi	Ma	Mi	Ma	
EU-MSFD*	2013	x	x	x	x		x	x	x	http://mcc.jrc.ec.europa.eu/documents/201702074014.pdf
FAO**	2016		X		x				x	http://www.fao.org/3/a-i5051e.pdf
FAO	2016					x				http://www.fao.org/3/a-i7677e.pdf
UNEP	2009		x		x		x		x	http://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y
DeFishGear	2016	x	x		x		x	x	x	http://www.defishgear.net/media-items/publications
INDICIT	2017						X***			https://indicit-europa.eu/protocols/

*Update planned in 2019, ** focusing on Abandoned or Lost Derelict Fishing Gear (ALDFG), *** Sea turtles

3. NEW TOOLS FOR MONITORING MARINE LITTER IN MPAS

Monitoring of marine debris has been undertaken around the world for several years. Monitoring is a series of measures made to detect change in the state of a system. It is goal dependent, so the protocols used need to be tailored to the questions being asked. For all questions, targets may be linked to specific mitigation measures and may operate at a range of spatial and temporal scales. For example, at a local scale, monitoring may assess whether the implementation of a leisure reduces litter loads to target levels. As described in Ryan et al. (2009), Its purposes are to provide (i) information on the types, quantities and distribution of marine debris, (ii) insights into problems and threats associated with an area, (iii) assess the effectiveness of reduction measures, (iv) identify source of marine debris, (v) explore public health issues, if any, relating to marine debris and (vi) increase public awareness of the condition of the marine environment.

While some protocols are dedicated to monitoring, there are also approaches with potential for monitoring of litter especially when surveys face considerably different observation conditions and therefore different observation protocols. There should be methodological research on how to cover the various gaps but original approaches have been proposed recently and some of them appears of interest for the monitoring of marine litter within MPAs. These approaches include aerial surveys, modelling based predictions, drones based observation, and the implementation of existing approaches or the search for fast and efficient methods, to better fit with MPAs requirements. Within the project AMARE and searching for relevant methods to support a better management of marine litter at the MPA scale, some of these approaches were tested and are summarized in the following chapters

3.1 A protocol for mapping litter accumulation along the coastlines (after GESAMP, 2019)

Much of what we know about the abundance, distribution and origin of plastic debris in the marine environment comes from surveys of litter stranded on beaches, initially as baseline in various regions, with difficulty in comparing data among studies due to the differences in sampling protocols and the type of data recorded (numbers or mass of items). Litter is often categorized by the type of material, function or both. Finally, most studies report standing stocks of litter, whereas others assess the rate of accumulation following removal of existing debris. Standing-stock surveys, a balance between inputs and removal, can show gross changes in the abundance and distribution of plastic litter but the amount of litter is determined by several other factors. Then, although standing-stock surveys can track changes in the composition of beach litter, they are not sufficiently sensitive to monitor changes in macro-litter abundance (Ryan et al., 2009). On the other hand, accumulation and loading rates records the rate at which litter accumulates on beaches. This requires an initial cleanup to remove all existing debris, followed by regular surveys that record and remove all newly arrived debris. Such surveys form the basis of major monitoring programs but requires much more efforts.

Additional issues need to be considered when planning accumulation surveys. The initial cleanup is unlikely to locate all debris, so several collections may be necessary before the data reflect actual accumulation rates. In addition, there remain the problems of lateral drift from adjacent, uncleaned areas and exhumation of buried debris. A less demanding alternative is to sample accumulation rates sporadically, with consideration, however, to be given to the variability since long intervals between surveys buffer some of the short-term variability in accumulation rates linked to local conditions (e.g. wind direction and sea state).

For MPAs, the main questions regarding plastic litter are about the sources, abundance, distribution, composition, what are the local impacts of litter (environmental and economic) and how are they changing over time? A stated in previous paragraphs, Monitoring within MSFD is under implementation with various goals, constraints and approaches, but also some limits.

In any case, the location of accumulation areas is a major concern that has not been considered until now. Knowledge about where litter accumulate will support a better location of monitoring sites and where cleaning must occurs to support reduction measures. MPAs don’t generally have long coastlines and it appears technically and easily possible to list and maps all places where litter strand.

This strategy was adopted within the project AMARE with several objectives such as elaborating a simple protocol to first locate hot spots, provide data to support in deep analysis, provide scientific basis for further detailed monitoring using more sophisticated protocols such as within MSFD and finally better locate areas to clean, a key information that has not always considered in MPAs.

Surveys were performed in 2016/2018 for Corsica, September 2017 for La Magdalena and NE Malta and 2018 for Formentera and the two MPA from the Salento peninsula Data were obtained from field surveys, using small 4-6.5 meters length boat (operated by MPAs or IFREMER), performed at low speed (1-12 knots) along the coastlines at a distance of 20 -100m, depending on the presence of rocks and/or shallow waters. The presence of litter was recorded usually along sites onshore of 10-30 m distance for low accumulation zones (2-10 debris on each differentiated areas), and high accumulation rates (more than 10 debris/ site). Individual debris were not recorded since possibly stranded at random. Cleaned areas were dotted as highly polluted (or specifically in Formentera), after visual evidence, questionnaires and information taken from MPA managers. On board, positions of accumulations areas were dotted on navigation charts (1/50 000), translated into GPS positions using google earth and then extracted as CSV/excel file before further processing. Pictures were taken for specific situation (very high accumulation areas, special type of litter, etc.) using a camera with incrusted GPS positions. Data were then transformed in shape/shp files, enabling the number of accumulation areas to be calculated in relation to the length of coastline.

Various scenario were evaluated in order to find the best calculation scheme in term of sampling. Number of accumulation areas per 2 km did provide consistent results to support modeling studies when number of hot spots per 1 km was providing a very local scheme of accumulation, of interest for the local management of MPAs

Results clearly indicate a high variability in the stranding of litter in AMARE MPA. When some MPA could be intensively affected with densities up to 15 sites / km ((Bonifacio/ La Magdalena, Torre Guaceto), other such as NE Malta were not with far lower number of sites. Within each MAP, the variability was also high with large differences depending on local situation.

Figure 1 : Accumulation areas of stranded litter along the coastlines in MPAs (AMARE project Partners) from the Strait of Bonifacio(A&B), Formentera (C), Malta (D), Porto cesareo (E) and Torreguaceto (F). Data were obtained through boating (5-6 meters boat) at low speed (1-12 knots) along the coastline at a distance of 20 -100m, depending on the presence of rocks and/or shallow waters. Individual debris was not recorded since possibly stranded at random. On board, positions of accumulations areas onshore were recorded (GPS). Low (2-10 debris/site white dots), High (> 10 debris/site, red dots) accumulation zones were recorded. Purple dot (Formentera) indicate extensive cleaning. G & H: Examples of accumulation areas (Bonifacio strait)

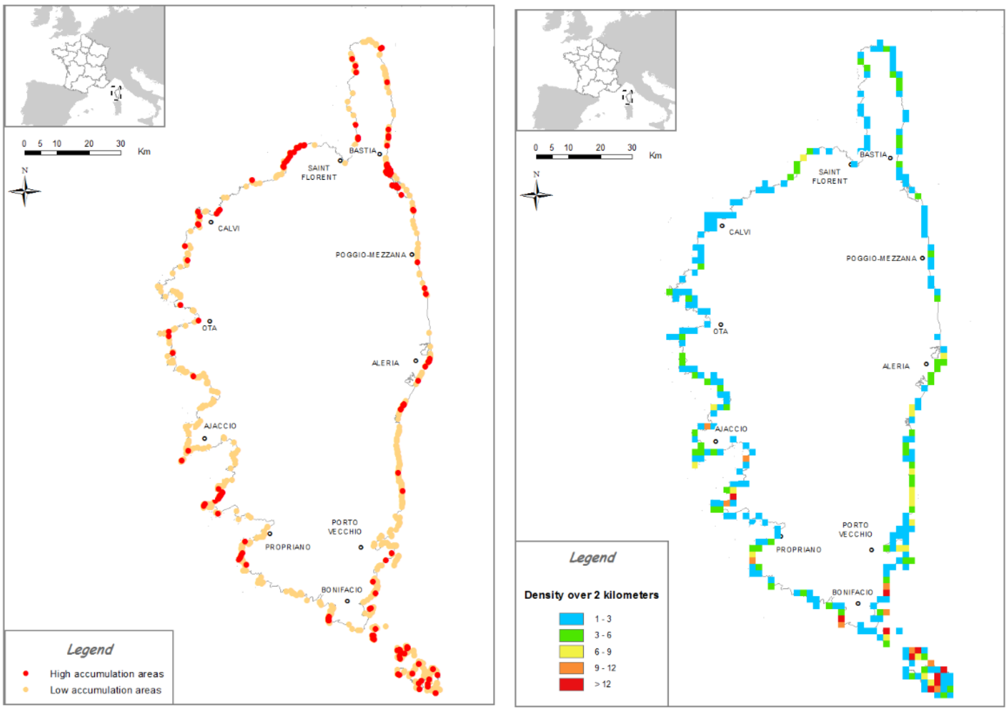


Figure 2: An assessment of stranding areas in Corsica and North East Sardinia. Number of accumulation areas per 2 km coastline shown to provide consistent results to support both the location of monitoring sites and associated modelling predictions. (A) Low (2-10 debris/site yellow dots) or High (> 10 debris/site, red dots) accumulation zones. (B) GIS (*.shp) files mapping the number of accumulation areas of beached debris found on 2 km distances of coastline

The approach is not based on detailed assessment of debris type, providing original information on place of interest rather than on specific types of items. The fate of most items is unknown and persistent accumulations occur at some locations as determined by several factors in addition to the abundance of litter in adjacent coastal waters. These include currents and circulation patterns, coastline structure, weather conditions and associated beach morphodynamics, local land-based sources and, in some cases, clean-up efforts. Accumulation then reflects the long-term balance between inputs (both local, land-based sources and stranding) and removal (through export, burial, degradation and clean-ups). Except episodic storms events that may affect the number of items rather that the location of stranding, most of the factors affecting litter inputs and removal are fairly constant, with little influence on where the litter strands

3.2 modelling the transport of marine litter in MPAs

3.2.1 Predicting the stranding of litter in MPAs (After Liubartseva, S., G. Coppini, R. Lecci (2019) Are Mediterranean Marine Protected Areas sheltered from plastic pollution. Marine Pollution Bulletin, in press)

In the absence of systematic monitoring of plastic litter over all the Mediterranean MPAs, numerical modeling offers a holistic approach that can shed light on the potential impact of plastic pollution at basin and regional scales (review in Liubartseva et al., 2018). A wide variety of useful applications can be identified and implemented by cross mapping marine biodiversity and calculated plastic distributions or their derivatives. Such methodologies were developed and applied successfully to marine turtles, seabirds and whales (review in Fossi et al., 2017). An original fusion between field sampling and modeling was implemented by Aliani and Molcard (2003) to investigate the phenomenon of species hitch-hiking on floating marine debris. The use of Lagrangian modeling helped these researchers interpret the data on dispersal of rafted macrobenthic species in the Ligurian Basin (NW Mediterranean). A recently obtained 2D Lagrangian model output for floating plastic debris in the Mediterranean (Liubartseva et al., 2018) was post processed to conduct a comparative analysis among the following six selected MPAs (1) the National Park of SES Salines d'Eivissa i Formentera, (2) Nature Reserve of Bouches de Bonifacio, (3) North-East Malta MPA, (4) Specially Protected Area of Porto Cesareo, (5) Community Importance Site of Torre Guaceto, and (6) Ethniko Thalassio Parko Alonnisou Voreion Sporadon.

Two-dimensional Lagrangian modeling was implemented to track the transport and fate of plastic marine debris at the Mediterranean basin scale (Liubartseva et al., 2018). The model embraced three environmental destinations: (i) the sea surface, (ii) coastlines, and (iii) the seabed. Having a limited knowledge about actual marine plastic sources (place, time, duration, and volume of marine litter loads), virtual particles that imitated the plastic were released from the largest coastal Mediterranean cities and rivers, and the most congested shipping lanes. Postulated plastic input of 100,000 metric ton/year was distributed as follows: 50% from the large coastal cities in proportion to population, 30% from large rivers in proportion to annual discharge, and 20% from shipping lanes in accordance with an annual marine transport Probability Density Function (PDF) built on the Automatic Identification System (Marine Traffic, 2015) vessel information. Transport of plastic was forced by the high-resolution sea surface kinematics provided by the Copernicus Marine Environment Monitoring Service (http://marine.copernicus.eu/services-portfolio/access-to-products). Daily analyses of ocean currents and waves at a horizontal resolution of 1/16° (ca., 6.5 km) were used to force the drift of particles. The Monte Carlo technique developed for the beaching and sedimentation of plastic debris allowed taking into consideration the probabilistic nature of these processes. As outputs, the model provided daily distributions of plastic concentrations at the sea surface and fluxes of plastic onto the coastline and seabed.

Table 6: Basic features of the Mediterranean MPAs studied in the AMARE project

#	MPA (location)	Designation (type of designation), year designated	Area (km^{-2})	Threatened species (total species)	Near-site socioeconomic drivers of plastic pollution
1	Ses Salines d'Eivissa i Formentera (Balearic Islands, W Mediterranean)	Natural Park (National), 2001	167.9	30 (189)	Growth in coastal population, tourism, heavy maritime traffic, inadequate wastewater treatment, near-site oil and gas exploration
2	Bouches de Bonifacio (Strait of Bonifacio, NW Mediterranean)	Corsican Nature Reserve (National), 1999	797.8	37 (249)	Intensive navigation, tourism
3	North-East Malta MPA (Malta Channel)	Special Area of Conservation (International and National), 2010	155.1	29 (112)	Rapid increase in navigation including ship bunkering, tourism, aquaculture
4	Porto Cesareo MPA (Taranto Gulf, N Ionian Sea)	Specially Protected Area of Mediterranean Importance (Regional), 1997	165	32 (182)	Commercial navigation, tourism
5	Torre Guaceto MPA (S Adriatic)	Site of Community Importance (Regional), 1995	79.7	34 (216)	Densely populated urban, industrial, and agricultural areas, maritime traffic
6	Ethniko Thalassio Parko Alonnisou Voreion Sporadon (NW Aegean Sea)	National Marine Park (National), 1992	2303.9	26 (151)	Navigation

The model results revealed that any long-term accumulation of plastic at the sea surface would be unlikely in the Mediterranean, in contrast to the global ocean. Our computations showed a substantial accumulation of plastic on the coastlines and sea bottom and that the former sink greatly exceeded the latter one.

Backtracking (inverse problem) set up was to determine and rank the relative contributions of each source of plastic to the MPAs studied. For each released particle, specifications were stored, including (1) geographic coordinates (longitude and latitude) of the source or the "birth" place of the particle, (2) date of the release of the particle or date of "birth", (3) type of "birth" (i.e., whether the particle originated in a city, river, or along shipping lanes), (4) geographic coordinates (longitude and latitude) of where the particle changed state (from "floating at the sea surface" to "beached onto the coastline," or from "floating at the sea surface" to "sedimented," or the "death" place of the particle), (5) date of "death"; and (6) type of "death," if the particle eventually attaches to the coastline or sinks to the sea bottom.

Examining the data about the "birth" of particles that "died" on a specific MPA's coastline, the particles that originated from each source were counted and the relative contribution from each source was estimated as a ratio before ranking each contributions.

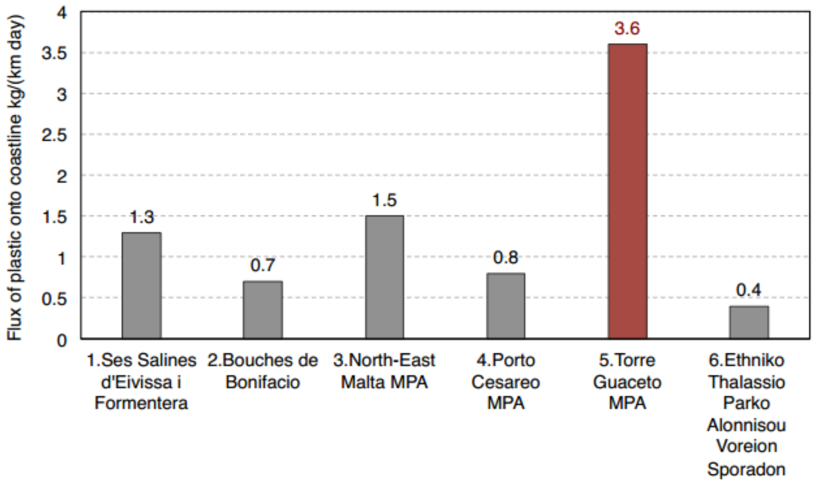


Figure 3: Bar diagram of model plastic fluxes (kg/(km day)) onto the coastlines of the studied MPAs.

Fluxes of plastic that arrived at each MPA's coastlines (Fig. 3) were relatively low in comparison with an average flux of 6.2±0.8 kg/ (km day)) calculated with the same method over the whole Mediterranean 2013-2017 (Liubartseva et al., 2018). The coastline of the Torre Guaceto MPA has a plastic flux of 3.6 kg/ (km day)) and is the most polluted among the studied MPAs. The plastic flux for the North-East Malta MPA is 1.5 kg/ (km day), which is very similar to that of the SES Salines d'Eivissa i Formentera MPA (1.3 kg/ (km day)). The Porto Cesareo MPA receives a flux of 0.8 kg/(km day), followed by Bouches de Bonifacio with 0.7 kg/(km day) when the Ethniko Thalassio Parko Alonnisou Voreion Sporadon is found to be the least polluted site, with a plastic flux of 0.4 kg/(km day).

To understand similarities and site-specifc differences in plastic fluxes received by different MPAs, the identification of the five main plastic sources was performed for each MPA using the backtracking (inverse approach, figure 3). Shipping was identified as a major source of plastic litter in all MPAs studied, contributing 55%-88% of total plastic. Site-specific rankings of the top 5 land-based plastic sources revealed that sea surface kinematics control plastic drift.

In the National Park of Ses Salines d'Eivissa i Formentera, there is plastic discarded from ships (54.5%), followed by the Spanish cities of Alicante (5.5%), Valencia (4.9%), Barcelona (4.7%), and Torrevieja (2.1%). Interestingly, the contributions of the land-based sources from North Africa tend to be minor. In fact, the most influential African source, the Chelif River in Algeria, contributes 0.7% and ranks 14th in the list of sources. Transport of plastic in this area is controlled by a highly variable current system characterized by a convergence between the southwestward Northern Current (NC) carrying the old Atlantic waters along the continental slope from the Gulf of Genoa to the Gulf of Valencia, and the northward intrusions of the Recent Atlantic Waters (RAW) through the Ibiza Channel. Some parts of plastic drift back to the northeast, eventually following the Balearic Current (BC). Additional dispersal of plastic is linked with mesoscale phenomena of different intensities.

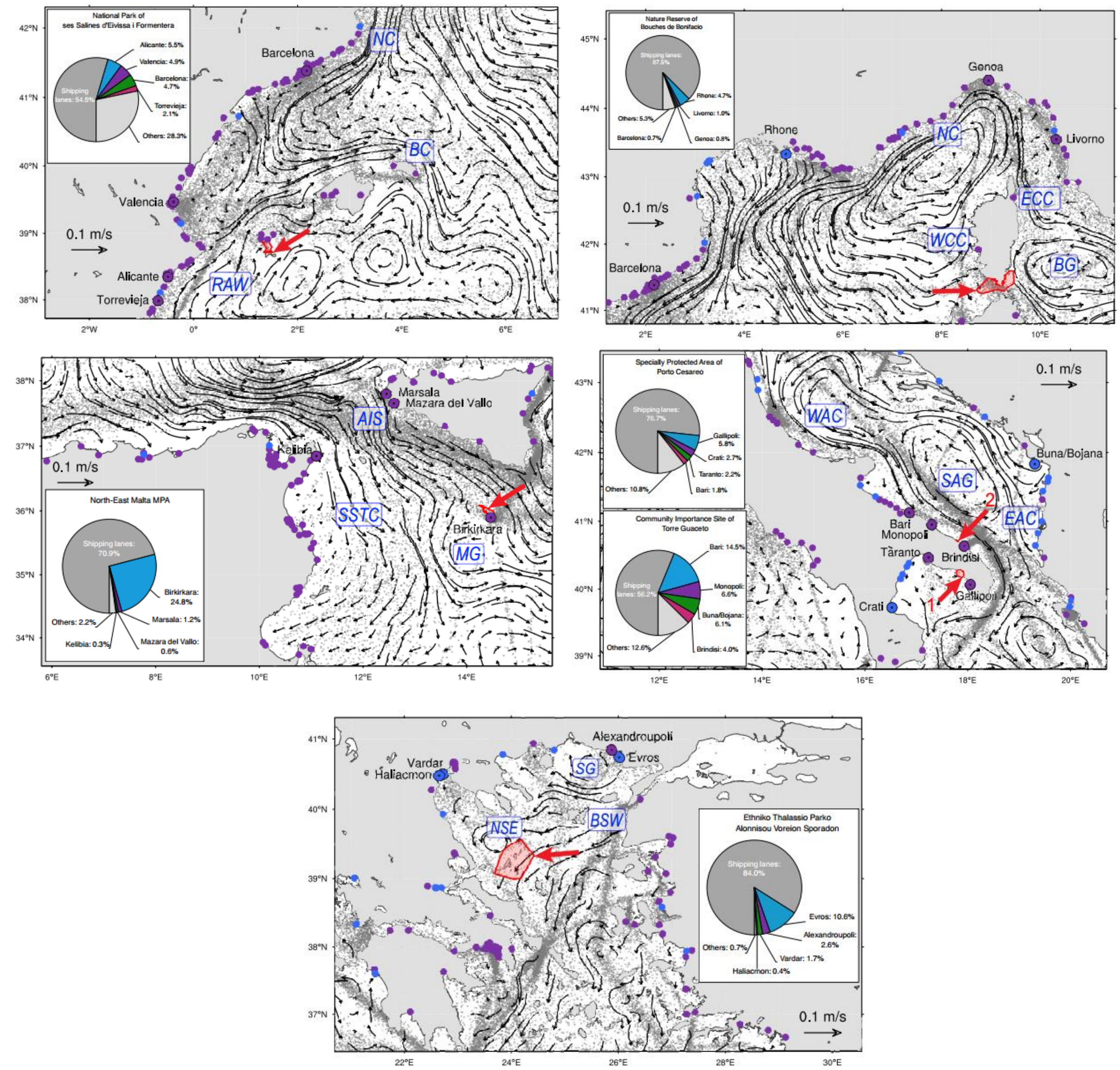


Figure 4 : Predicted transport and stranding of marine litter in 6 Mediterranean MPAs. MPAs are indicated by red arrows. Model plastic sources are shipping lanes (gray dots), cities (purple circles), and rivers (blue circles). Pie diagram illustrates relative contributions from the top 5 sources. Locations of cities and rivers ranked in the top 5 are highlighted by circled dots. Transport of plastic is illustrated by average sea surface kinematics 2013–2017. The main circulation patterns are Northern Current (NC), the Recent Atlantic Waters (RAW), and Balearic Current (BC), Western Corsican Current (WCC), Eastern Corsican Current (ECC), Bonifacio Gyre (BG), Atlantic-Ionian Stream (AIS), Sicily Strait Tunisian Current (SSTC), and Medina Gyre (MG), Northern Current (NC), Western Adriatic Current (WAC), Eastern Adriatic Current (EAC), and South Adriatic Gyre (SAG), Black Sea Waters (BSW), Samothraki Gyre (SG), and North Sporades Eddy (NSE).

The Natural Reserve of Bouches de Bonifacio receives the highest percentage (87.5%) of plastic from shipping lanes. The other sources of plastic are the Rhone River (4.7%), the Italian cities of Livorno (1.0%) and Genoa (0.8%), and Barcelona (0.7%) in Spain. The transport of plastic to the site is linked with two northward owing currents, ascending along opposite coastlines of Corsica. The first, referred to as the Western Corsican Current (WCC) is part of the basin-scale cyclonic circulation. The second is the Eastern Corsican Current (ECC), which brings Tyrrhenian water into the Ligurian Basin. Although both currents constitute a part of wind-driven circulation, previous studies found that the WCC tends to be more stable over the year, while the ECC may reverse direction in summer. The confluence of the WCC and ECC north of Corsica forms the previously mentioned Northern Current (NC), which flows along the continental slope towards the southwest reaching a maximum velocity of 0.9 m/s. In the vicinity of the Nature Reserve of "Bouches de Bonifacio", the circulation is mainly wind-driven and extremely variable but governed by the eastward wind blowing from the Bonifacio Strait (Artale et al., 1994).

In the North-East Malta MPA, the plastic discarded along shipping lanes also dominates the top 5 sources with a contribution of 70.9%. The city of Birkirkara is the next highest contributor (24.8%), followed by the Sicilian cities of Marsala (1.2%) and Mazara Del Vallo (0.6%). The Tunisian city of Kelibia ranks 5th with a contribution of 0.3%. Transport of plastic in this area is driven by the Atlantic-Ionian Stream (AIS), a strong free-jet current mainly flowing eastward along the southern coast of Sicily, and the Sicily Strait Tunisian Current (SSTC) that flows southeastward along the Tunisian and Libyan continental shelf break (Pinardi et al., 2015). Both basin-scale current systems are governed primarily by density gradients and winds. Mesoscale variability is driven by the cyclonic Medina Gyre (MG) in the area south of Malta.

Shipping is the main contributor (76.7%) to plastic pollution of the Specially Protected Area of Porto Cesareo. This source is followed by the city of Gallipoli (5.8%), the River of Crati (2.7%), and the city of Taranto (2.2%), which is located at the perimeter of the Taranto Gulf. It is interesting to note that the city of Bari ranks 5th, contributing 1.8%, despite its location on the opposite shore of the Salento Peninsula but as a main source for litter in the Adriatic and Northern Ionian Sea. In the Gulf of Taranto, a highly variable mesoscale circulation appears, controlled primarily by the wind, and without any stable direction.

Plastic dispersed along shipping lanes is the main contributor (56.2%) to the Torre Guaceto MPA. Not surprisingly, Bari ranks second, contributing 14.5%, followed by Monopoli with 6.6%. The connections between these sources and the MPA are governed by the WAC. The Buna/Bojana River entering the Adriatic Sea on the opposite coast ranks 4th, supplying 6.1% of the plastic pollution to the Torre Guaceto MPA. This riverine source is the second largest land-based source of plastics in the whole Adriatic, exceeded by only the Po River (Liubartseva et al., 2016). The drift of plastic from Buna/Bojana to the MPA is forced by the Eastern Adriatic Current (EAC) flowing northwest along the eastern Adriatic coast, and the cyclonic South Adriatic Gyre (SAG). The city of Brindisi is located 15 km southeast of MPA and provides 4.0% of the plastic, ranking 5th among the top 5 plastic sources. Transport of plastics from Monopoli along the prevailing southeastern WAC is the main reason for a disproportion between Monopoli (less populated) and Brindisi (more populated).

For Ethniko Thalassio Parko Alonnisou Voreion Sporadon MPA, plastic dispersed along shipping lanes also accounts for the highest contribution (84.0%). The Evros River (10.6%) represents the second greatest contributor, followed by the city of Alexandroupoli (2.6%), and the Rivers of Vardar (1.7%) and Haliacmon (0.4%). The transport of plastic is driven by a basin-scale cyclonic circulation receiving the Black Sea Waters (BSW) and freshwater inputs from rivers. The area north of the MPA is affected by a cyclonic North Sporades Eddy (NSE) while the southern area is directly influenced by the BSW. There is however a lack of understanding about the role of the BSW plume in the plastic pollution problem, which motivates further research of this issue.

Interestingly, the modelled amounts of litter stranding in MPAs was in the same order of magnitude than the number of accumulation areas found in chapter III.1. The model is applicable to any Mediterranean MPA and other methodologies that can reveal anthropogenic drivers generating potentially negative effects. This conclusion may change dramatically due to litter mismanagement within the MPAs, adverse trends in plastic inputs in the Mediterranean, or science-based evidence that shows even low plastic concentrations in the environment may cause real risks in terms of toxicity.

The applied model approach will help in the assessment of site-specific management of sources of marine plastic litter and the development of mitigation strategies for the Mediterranean MPAs to maintain good environmental status in accordance with Descriptor 10 of the EU Marine Strategy Framework Directive (MSFD, 2008/56/EC).

3.2.2 Mesoscale simulation and Interconnectivity between MPAs: A case study in the North Thyrennian Sea (Doronzo et al., 2018, Numerical modelling of plastic marine litters. Technical Report / AMARE project, doc, Doc-Id: REP-CONN_TYRR, 20pp)

The main objective of this study were the development of methodologies and tools for the evaluation of marine litter impacts, through mesoscale modelling for a better understanding of the environmental connectivity mechanisms between Marine Protected Areas. It was performed within the AMARE project.

Simulations were performed through a Lagrangian approach (simulating the release of a number of particles from specific sources), regarding the potential impact of some marine Litter (ML) sources distributed along the coasts of the Tyrrhenian-Ligurian sea, in their ability to contribute to ML pollution and impacted areas and to clarify some possible mechanisms of connectivity between the various areas in the zone.

Plastic Marine Litter (PML) sources being either punctual, linear (as along ship lanes) or distributed, the drift simulations of the PML were therefore approached studying how the ML is distributed starting from a very large number of sources (Liubarsteva et al., 2018), or assuming that the marine debris concentration is mainly determined by accumulation or dispersion mechanisms linked to marine hydrodynamics (Mansui et al., 2015). Hydrodynamic simulations were performed by using the model ROMS-Tyrreno (Tyrrhenian and Ligurian model) available at LaMMA with a western boundary at the east of Toulon, a horizontal resolution of 2 km and a vertical discretization of 30 sigma-levels. The bathymetry (resolution 500m) was extracted from the EMODNET dataset. The model is configured with a third-order upstream horizontal advection where the horizontal mixing parameters are intentionally taken as zero. Air-sea interactions are imposed using fluxes derived from an implementation of the WRF-ARW model over the central Mediterranean area at 3 km resolution. ECMWF analysis data were used as initial and boundary conditions for air-sea forcing. Turbulent fluxes on the ocean/atmosphere interface are estimated using bulk flux formulation. Turbulent momentum, heat and mass exchange processes are realistically reproduced in the model taking into account latent/sensible heat fluxes, radiative heat flux (including the effect of cloud cover), evaporation and precipitation. Such hydrodynamic models were also validated by using data measured through the HF radar network managed by LaMMA. A special attention was given to the possible connection and relationship between some major plastic discharges (some main rivers and ports) along the Tyrrhenian coast and their impact on the Corsican coastal areas. These sources are supposed to be a major source of plastic pollution affecting several coastal areas in the North-Western Mediterranean area in not a trivial way, also because marine currents in this area are not at all permanent, but characterized by strong sub-seasonal variability.

The NOAA GNOME (General NOAA Operational Modeling Environment) software, for Linux machines, was used (Zelenke et al. 2012) to estimate the drift of marine debris. No consideration was given to vertical mixing (plastic is buoyant with temporary mixing only in the upper layer). Moreover, in our simulations, wave driven transport mechanisms (Stokes drift) that can be significant in some cases, as in shallow waters or under stormy conditions, was not accounted.

The plastic drift model was validated during the failure of waste-water treatment in the Salerno Gulf, with some million plastic filters discharged into the Tyrrhenian Sea and massively beached in several points along the Tyrrhenian coast. LaMMA was sollicited by the "CleanSeaLife" life project, to contribute to the interpretation of such existing evidences, through modeling activity. A number of backwards simulations were made to estimate the likely source of release.

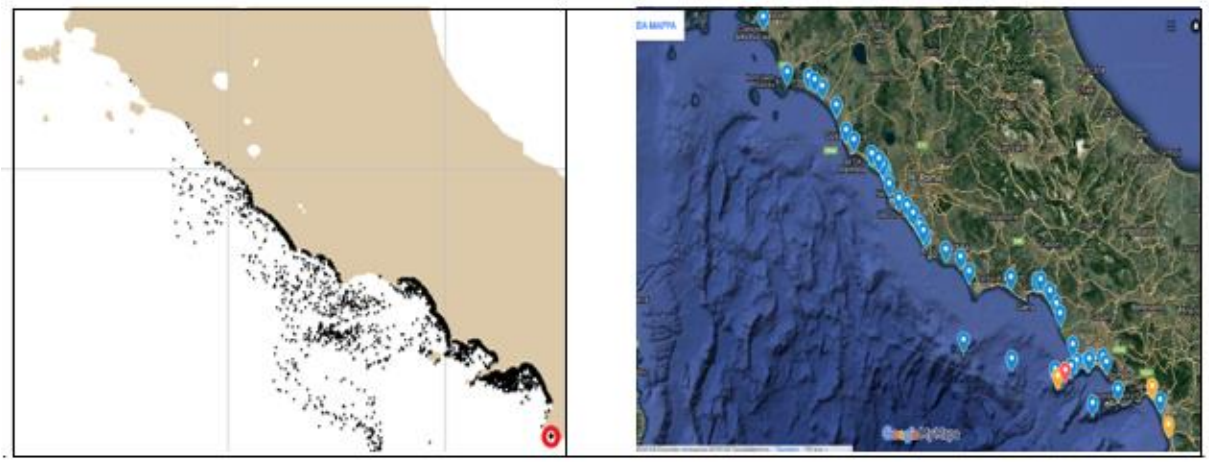


Figure 5: Backward GNOME simulation (left, red circle indicated the most likely pollutant source) and sightings map of plastic filters discharged into the Tyrrhenian beaches (right, from www.cleansealife.it)

Once the source identified, the presence of these disks was simulated on the entire coast, highlighting that the map of the beaching of the discs reconstructed with the LaMMA model output was highly correlated with the map of observations, a unique opportunity for model validation.

Only very light effects due to wind were considered in the model. In addition, a random diffusion coefficient, to take account of the spreading of discs, was used. Using this approach, we have simulated the impact of various pollutant sources of the Ligurian/North Tyrrhenian Sea, here mainly identified in large ports and main rivers.

A continuous release of PML was simulated, estimating the amount of them on the basis of river flows and some datasets (https://www.theoceancleanup.com/sources/), taking account also of the size of the city close for harbors. Five rivers (from South to North: Volturno, Tevere, Ombrone, Arno, Serchio and Magra) were selected and three major ports (Napoli, Livorno and Genova). Other ports in the area, like Civitavecchia, Piombino or La Spezia, were not considered because they do not have a large city nearby. The simulation, has a duration of one year (Sep 2017 - Aug 2018), this to take into account the variability of the circulation at seasonal scale during the year.

Looking at the figures, although they represent two instantaneous situations, it is possible to identify two different main current regimes, during the summer and winter seasons. The water movements during the winter season are predominantly northern directed. In our assumptions the main contribution to PML in the Ligurian sea/Tuscan Archipelago area is from the Tevere River. Conversely, in the summer season, the contribution from rivers and ports from the Ligurian Sea

(Genova, Arno and Magra rivers) increases, as also a southern directed transport component is present.

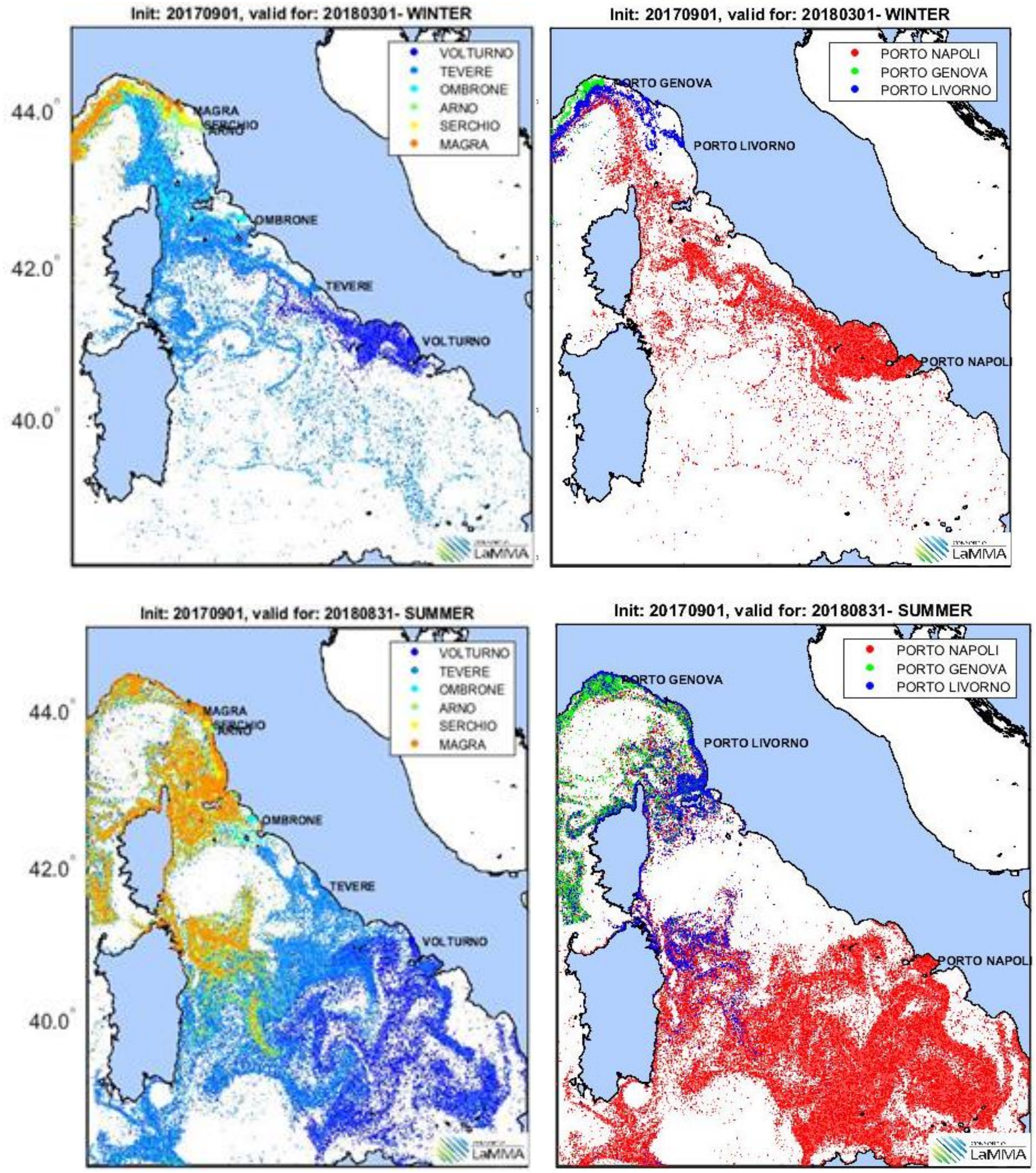
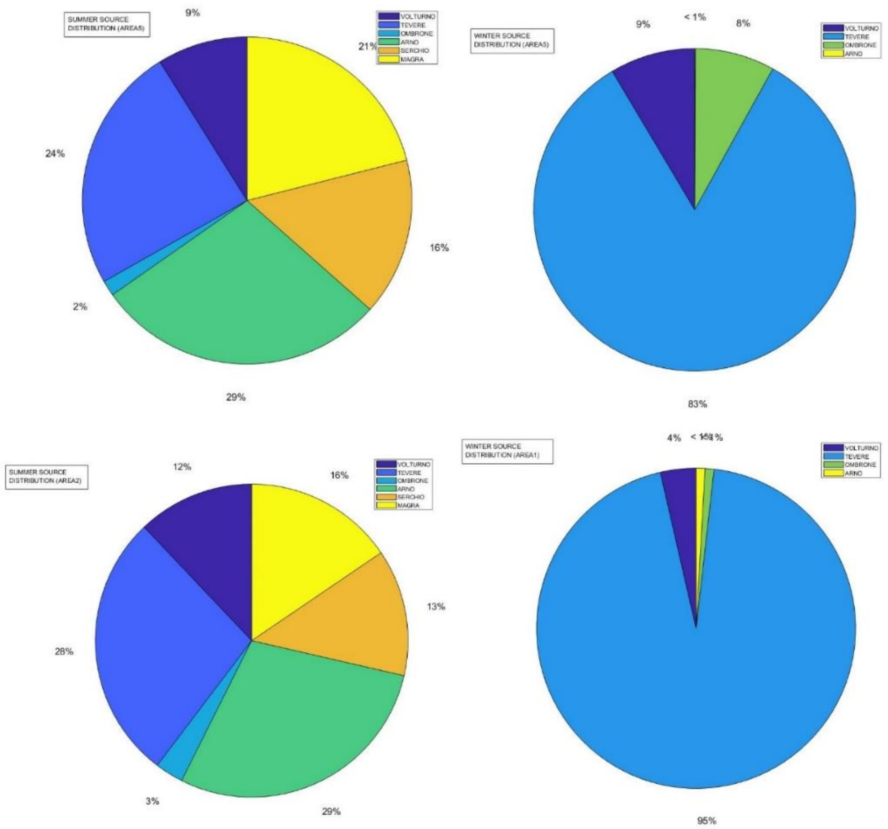


Figure 6: Multicolor splots for the river (left) and for the harbors pollution (Right) are shown, during the winter (northern directed transport flow) and summer (southern directed transport flow seasons).

In the pie graphs, it is also possible to observe in detail the different contributions from each source, in particular rivers. In summer, Marine litter comes from northern rivers (on the left top and bottom). In the winter the plastic pollution comes mainly from the Tevere River.

A preliminary analysis of these results indicates that there is a remarkable connection between the plastic emissions from Tyrrhenian rivers/ports and the pollution of ML along the Corsican coast and the Bonifacio Strait MPA. That connection, as illustrated, is evident in both the winter and the summer season, although the contribution of sources to the concentrations of ML in this area is quite different.



EC BS

Figure 7: Origin of plastic pollution (Pie graphs) along Eastern Corsica coast (EC) and in the Bonifacio Strait AMPs (BS), in summer (left) and winter (right).

The river Tevere is considered to be a major source of pollution in the Tyrrhenian coast. In winter, the plume caused by the southern Tyrrhenian sources (such as the Tevere and Volturno rivers and the Napoli harbor) extends the influence until the northeastern Corsica. An important concentration of inputs from Tevere is observed also in the summer season into the Bonifacio AMP and on the northwestern coast.

Other important connection can be observed, mostly during the summer season, between the Corsican coastline (eastern and northwestern) and some sources from the North Tyrrhenian and Ligurian coast (Arno, Magra and the Genova harbor).

Overall, the study confirmed the importance of the importance of various sources and their consequence on the connectivity between the various MPAs from the northern Thyrennian Sea. Hydrodynamics support the transport and stranding of marine litter, and potentially, the settling of rafted species. It may cause issues to MPA managers who may be limited in their actions on external sources of litter.

3.3 Towards a monitoring protocol for monitoring beached materials through aerial footage. A study in the Maltese Islands (Deidun A., Gauci A., Lagorio S., F.Galgani (2018). Optimising beached litter monitoring protocols through aerial imagery. Marine Pollution Bulletin, 131, 212-217, https://doi.org/10.1016/j.marpolbul.2018.04.033)

This study aimed to identfy coastal hotspots of accumulated beached marine litter, to check whether tourism or local activities are unfortunately influencing the accumulation of litter along the coastlines.

Data was collected using an aerial drone to test how the acquisition of related data in a wide area of study and in a short period of time can be possible, as constrained by a maximum capacity/flight autonomy of almost 20 mins for each battery. The study defined a new MSFD Descriptor 10 monitoring protocol, which should be included in the achievement of the Good Environment Status of the Marine Strategy Framework Directive (by 2020).

For the drone flights to spot marine litter along coastal stretches in the Maltese Islands, within the AMARE project, study areas were selected following the successive rationale (i) Topography, since litter of a marine origin is expected to accumulate only along gently sloping coasts, (ii) Location, (iii) Exposure, to ensure that the beaching of marine litter along the same sites is feasible, and (iv) Accessibility to allow repeated monitoing flights..

Three different beaches situated within the North-East Marine Protected Area of the Maltese Islands were selected. These three beaches, which are the western and eastern side of Bahar Ic-Caghaq and Qawra Point, all consist of rocky stretches, which are located on the island of Malta and which are considered as hot spots. Hydrodynamic conditions, such as the wind parameters (wind speed, wind maximum and the average of wind speed -m/s-) and the surface currents prevailing on each sampling occasion, were also taken into account to observe if they influence the accumulation of litter or if the humans' activities prevail over natural forces.

Qawra (35.960004° N/ 14.428632°E) Bahar Ic-Caghaq (35.945297°N / 14.454251° E)

Figure 8: Sampling sites for aerial drone experiments and related transects. 6 (Qwara point), 8 Bahar Ic-Caghaq, western side) and 6 (Bahar Ic-Caghaq, eastern side) transects were performed between 23/05/2017 and 29/07/2017. AMARE project, University of Malta

The drone was pre-programmed to fly along a well-defined transect path to encompass both a marine and a proximal terrestrial monitoring area at each study site, enabling observer to identify (i) litter which had been beached a certain distance up on land, (ii) litter of a terrestrial provenance, (iii) litter which was still water-borne and not yet beached. The adoption of pre-determined, fixed transects as monitoring flight paths allowed us to maintain a consistent monitoring protocol at each of the study sites.

The drone was set to fly at an altitude of 30 meters (3.5m/s, before 9 am and after 6 pm) and this measure was identified following different preliminary flights, observing that, when low altitudes were adopted, the images had a very good resolution but the area covered was small. At this 30m flying altitude, each captured frame covered a ground area of 45 meters by 25 meters.

The drone was programmed to capture an image frame every 3 seconds to ensure that each image frame overlapped with the consecutive one.

Figure 9: Drone and monitoring screen used for marine litter survey. AMARE project, University of Malta

The "exif" (extended range image) files were captured by the drone and analyzed by Matlab in order to extract the coordinates for each image. The shutter speed and aperture were set 1/320sec and f/2.8 respectively. The image ISO level was also kept fixed at 1000 to avoid changes in the intensities between images. Custom Matlab code was then implemented to georeference, project and fuse all images into one ortho tiff file, allowing the scenes to be imported in Google Earth.

Different colours were given to different categories (BLUE/PLASTIC, GREEN/ ROPE; RED/ WOOD, RUBBER /BLACK and OTHER/ WHITE) and items recoded and categorized in terms of size (square/ < 25 cm; diamond/ <50 cm and circle / > 50 cm). Some controls were performed on site, including an evaluation of sizes. A major constraint of the drone-mediated monitoring was its dependence on prevailing weather conditions, such that a predetermined regular monitoring plan could not be followed due to the sporadic occurrence of strong winds which precluded any drone flights on the day.

Results showed how this experiment gives a good validation of the protocol. Once all the images collected during an individual survey were interpolated in one single picture, spatial analysis was conducted using Google Earth

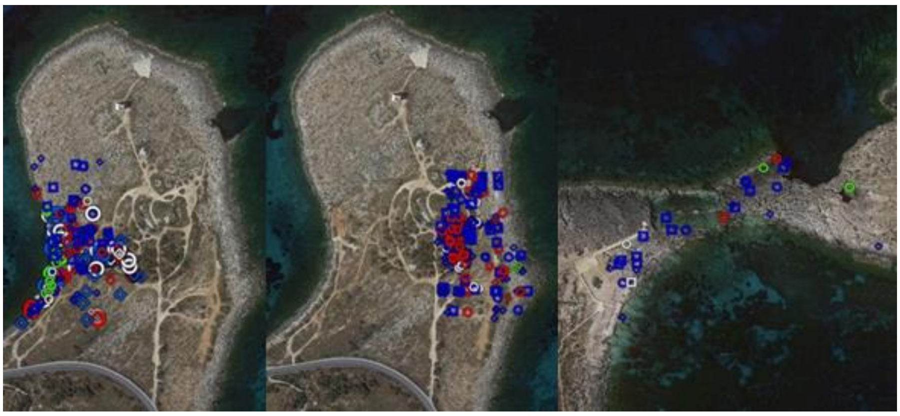


Figure 10: Total items found in Bahar Ic-Caghaq (western and eastern) and Qawra Point. (AMARE project/ University of Malta)

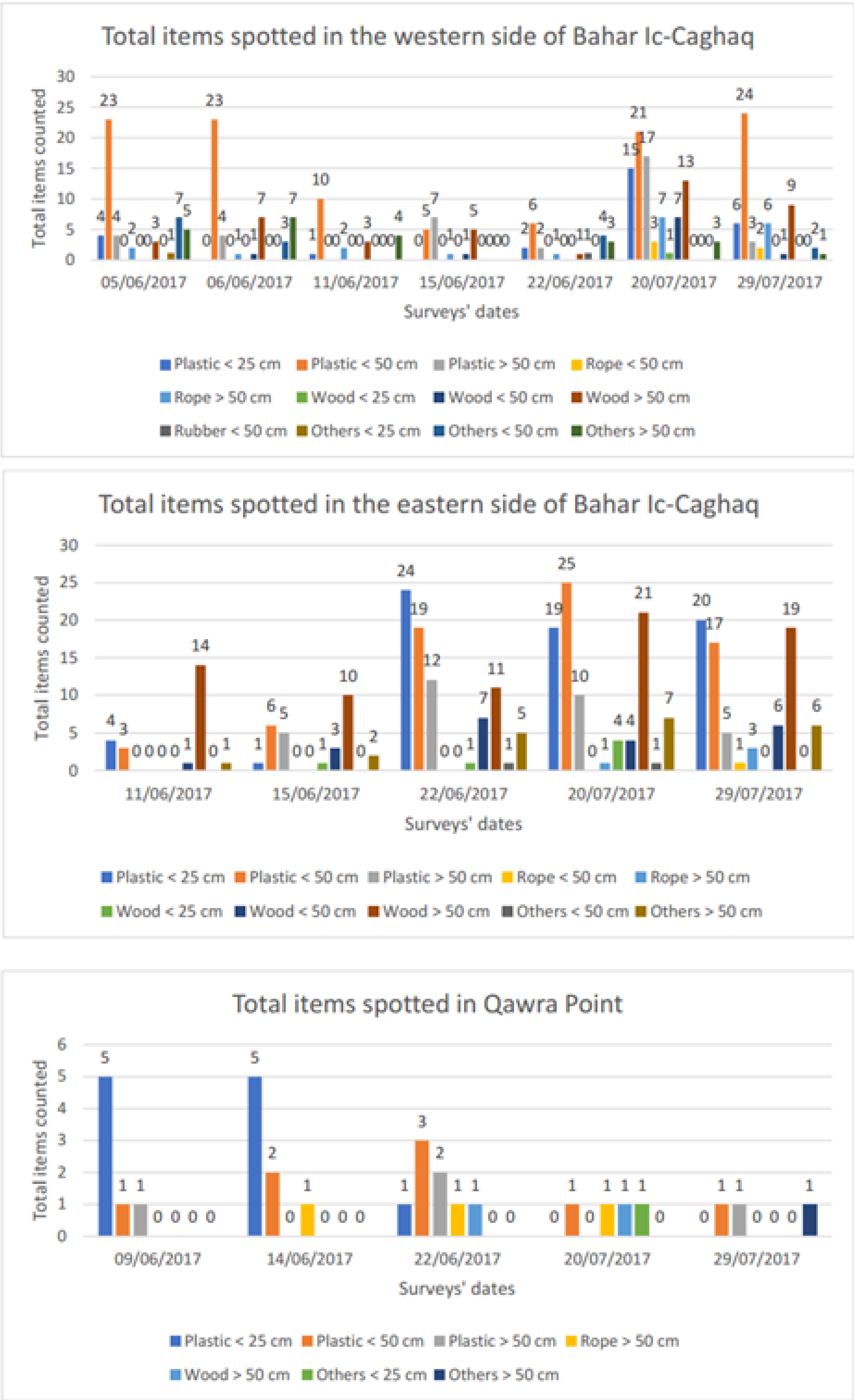


Figure 11 : Variation of abundance of litter items found along the western side of Bahar Ic-Caghaq Bahar Ic-Caghaq (western and eastern) and Qawra Point during the summer 2017 (AMARE project/ University of Malta)

The total number of litter items recorded at the two monitored sites (Bahar Ic-Caghaq and Qwara) was considerably different (30 items vs 578 items, respectively) as a possible consequence of differences in the dynamics of coastal currents, coastal topography and human activities between the sites. Bahar ic-Caghaq is, in fact, much more accessible from land to vehicles, making dumping of litter from the land side a feasible prospect. It has been observed that many barbeques are held in this area and this could explain the accumulation of wood items in the area, along with that of plastic bags containing discarded food, further confirming the popularity of the site for recreational purposes. This typical situation could be found in MPAs and where managers may implement management measures impinging on beach or coast uses. The relative accumulation of rope fragments along the western side of Bahar ic-Caghaq progressively increased in summer was related to berthing and aquaculture areas further up the coast, another possible consequence of a conflictual us of coasts within an MPA. Less litter was recorded at Qawra and this was mainly composed of plastic, an indirect consequence of enhanced tourism levels in the area.

After univariate/multivariate statistical analysis of the results, period (without difference between weekends or weekdays) and location were the most important effectors when the size and types of litter was the most discriminating attribute

One of the goals of this study was to create a protocol and a methodology which would be useful in meeting both MPAsand MSFD monitoring constraints . Generally and technically, the use of aerial drones showed a great potential as a new monitoring tool for the indicator 10DC1 (stranded litter), further contributing to bridge the current operational monitoring gaps.

In conclusion, this case study represented the first attempt at quantifying and characterizatingbeached litter accumulated in coastal areas through drone-mediated photography. It has been observed that a relatively large sampling area can be covered through drone flights within a short period of time. The same flight path can be reproduced faithfully on successive occasions due to geo-referencing, making the monitoring program a spatially-consistent one. Moreover, using Google Earth to geo-reference spotted marine litter further saves on photo analysis time and allows further manipulation of the resultant images and maps.

A more comprehensive drone-mediated monitoring protocol could be implemented all over the Islands, through the deployment of a number of drones which would cut down greatly on operating costs of the monitoring programme (no boats and less man hours needed,) whilst prioritizing coastal areas for grooming, possibly directing clean-up teams to these areas.

Besides, this study also contributes to the monitoring obligations within the MSFD and upcoming MPA management plan monitoring obligations, and presents a useful deliverable to the Interreg-MED AMARE (http://msp-platform.eu/projects/amare-actions-marine-protectedareas) project.

The strategy is now for a mandatory protocol to be in place for anyone planning to fly a drone as a well as a proficiency test for drone pilots which needs to be followed prior to such flying. The feasibility of formulating an optimal drone-mediated protocol for monitoring beached litter quantities and characteristics, collecting useful monitoring data on abundance and characteristics of beached marine litter from drone flights, and investigating possible correlations between hydrodynamical phenomena, human coastal activities, and characteristics of beached marine litter has been demonstrated through this study.

3.4 Automated parametrisation of beached LMPs

Four sandy beaches on the island of Malta in the Central Mediterranean were regularly sampled for Large Microplastic (LMP) particles having a diameter between 1mm and 5mm, at stations located at the waterline and 10m inshore. The total 10975 extracted LMP particles were characterised (dimensions, surface roughness, colour) through unaided visual observation, through microscopic analyses and through an ad hoc mathematical algorithm developed within the current study.

Ultimately, it was decided to obtain images of the LMPs through scanning on a flatbed scanner at a high resolution. In particular, data was obtained using an HP Scanjet G3010 with a resolution of 600 dots per inch (dpi). This technique produced images having 5100 x 7020 pixels. The saved individual JPEG files had a size of about 1.6Mb. Even after considerable zooming, each individual LMP could be identified within the image. The LMPs collected from each quadrat were randomly positioned on the glass of the scanner and scanned. One of the preliminary steps of the algorithm developed in this study is to identify every LMP as an individual entity. Therefore, for better accuracy, the particles were scattered in a way such that they did not touch each other.

In order for real length measurements of the LMPs to be obtained, the calibration coefficient to convert pixel length measurements into spatial coordinates (having millimeters as units) had to be identified. This was inferred by scanning a custom-designed resolution pattern made up of boxes with different dimensions. Following the scanning of this ad hoc image, conducted at the same resolution (i.e., at 600dpi), the number of pixels between each horizontal and vertical pair of black/white intersections was determined. Since the actual length comprised by this number of pixels was known, the dimensions of each pixel could therefore be worked out. This was done for all possible combination pairs and the average value was determined. This value, quantified as 0.04008mm, can be adopted for all the images obtained using the same scanning device set at the same resolution. If a new scanner model or resolution settings on the same model are used, then the corresponding pixel dimension calibration coefficient has to be re-determined.

Following the acquisition of a number of test images, the corresponding algorithm was developed and fine-tuned using Matlab software. Images were processed individually. Each scanned RGB (Red Green Blue Channel) LMP image was initially converted to grayscale and normalised so that all pixels attributed a value ranging between 0 and 1.

The algorithm developed through the current study performed reasonably well in determining the dimensions and colour of the limited number of LMP particles subjected to different assessments. No performance evaluation through a corresponding microscopic analyses exercise for LPM particle surface roughness was conducted and thus the algorithm's performance for this parameter could not be assessed. Given the small-scale algorithm performance evaluation exercise conducted in the current study, it is recommended that the same algorithm is subjected to a more comprehensive validation process prior to its broader application.

The contribution beyond the current state-of-the-art of marine environmental monitoring proposed by this study is along the same lines as that proposed by Deidun et al. (2018) for automated coastal litter monitoring by aerial drones. In fact, the high degree of robustness of the image analyses algorithm developed in the current study, as supported by the results of the comparative statistics obtained, suggests that the same methodology is at a high readiness level and next to uptake within the revised MSFD round of monitoring indicators (scheduled for released following the end of the first MSFD six-year cycle in 2018) as a routine and recognised protocol.

3.5 Wave gliding for Marine litter

The Wave Glider is the first autonomous marine robot to use only wave energy for propulsion (http://liquidr.com/index.html). Because of its energy independence, its long persistence and its cost-effective operation, the Wave Glider platform is able to collect and transmit data over distances of thousands of miles across wide geographic areas and specific areas of interest and operation, with a strong potential to replace ships, satellites or buoys when considering the surface of the sea. Many applications have been described, including (i) the Tracking of ocean salinity, temperature, primary production and ocean CO_2, (2) the continuous acoustic monitoring of fish, micro nekton populations and tagged mammals or sharks, (3) the Monitoring of Hurricanes and earthquakes, and (iv) the environmental monitoring of oil fields or radioactivity (review at http://liquidr.com/resources/downloads.html). To date, the use of video has not been tested for regular and distance surveys. A first application of video-camera to monitor surface/subsurface marine litter at sea was proposed in 2013 (Galgani et al., 2013), using a a HD Gopro2 Long-Play camera in resistant tube fixed on ballast, sea surface oriented to enable observation in the 0-4.5 meter subsurface layer. A speed never above 1.5 Knots and the immersion of the camera provided consistent and stable images along straights routes.

Within the project AMARE, experiments were performed to replace the video with camera systems in order to facilitate the storage of pictures and future data screening through image analysis software.

The robustness of the system was tested during a survey of 13 days (July 2018), of which 4 were used to test the camera.

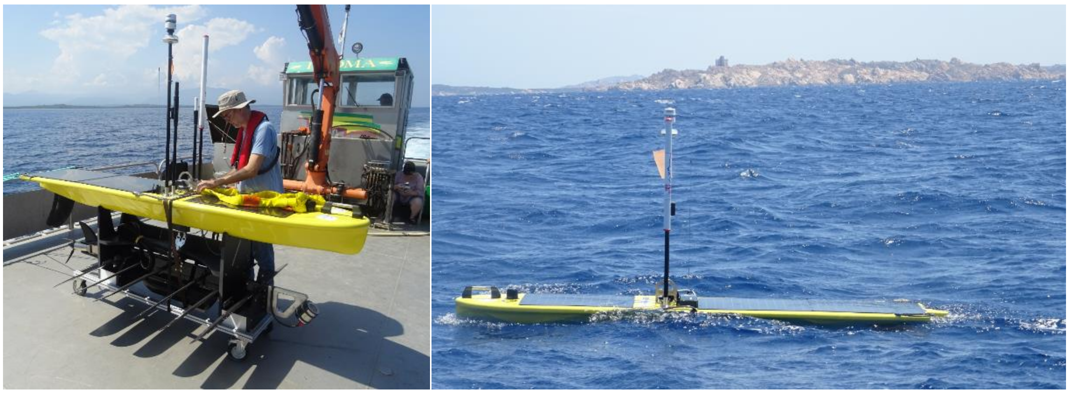


Figure 12: Waveglider (floater + ballast) before release (July 2018, A) and at sea in the strait of Bonifacio (B)

Figure 13: Camera system fixed on waveglider's ballast designed for continuous data collection of sub surface litter (GOPRO 3 type, Design and picture IFREMER).

In order to save space and autonomy, the installation of a prototype camera-video has been validated with a Power supplied on board through a solar panel, allowing continuous use. The tests have validated the principle of shooting "Photo" mode with GOPRO 3 better suited to the enclosure. The camera was programmed for acquisition every 7 seconds to limit the number of images to a full coverage of the track followed without overlapping images. This average period corresponds to previous tests and makes it possible to limit the useless use of the memory of the camera (optimization of the shots). The camera (256 GB memory card) was mounted on the drone ballast, oriented at 45 ° for a surface coverage of 12.4 meters in width. Good quality images were obtained enabling observations of both litter and large planktonic organisms or fish Approximately 45,000 images were obtained over a period of 4.5 days (images taken between 07:00 and 21:00).

In July 2018, a survey was performed to test the possible long range survey of sub-surface marine litter. The survey was possible with consistent data and 45000 stable images recorded, enabling an assessment of marine debris in the sub surface layer (O-4.5m). 6 debris per km2 were counted, in the range of visual approaches (Suaria et al., 2016). The monitoring of the waveglider was, however necessary in areas where recreative boating is important. This was the case in strait of Bonifacio where the automatic identification system (AIS, International maritime organization) from the glider detected many large yachting boats, limiting the use of the glider in very coastal waters.

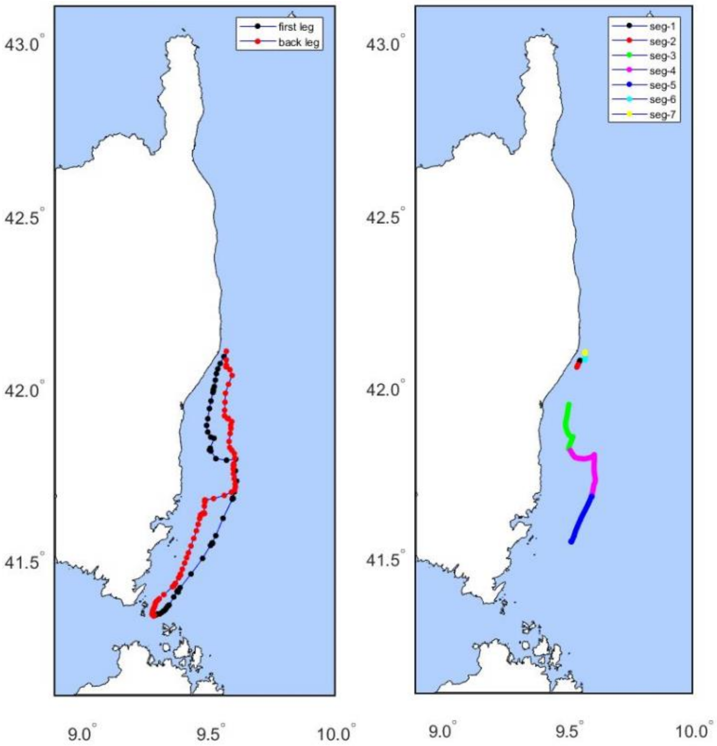


Figure 14: AMARE experiment: Wave glider route (A) during the camera survey (13 days, July 218) and (B) the 7 sequences with operating camera (marine litter survey).

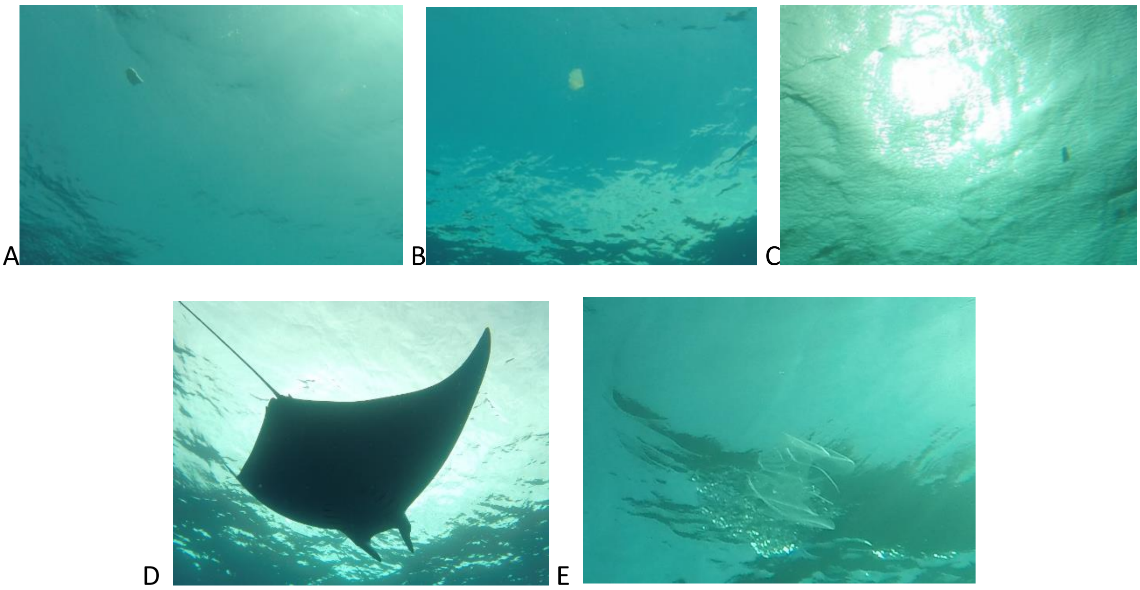


Figure 15: Images collected at sea by the waveglider: (A), (B) & (C) subsurface marine litter. (D) Sample of Modula modula macrofauna. (E) Plankton species (unidentified).

Overall, results showed the possible long-term and large scale utilization of the waveglider as a monitoring tool. It is well adapted to cover large coastal or oceanic zones for monitoring surface (0-4.5m) debris, then for large MPAs (i.e. Pelagos sanctuary in the NW Mediterranean Sea). Data are relevant, but some constraints such as recreative boating will limit the interest of the tool in very coastal waters during touristic seasons, to avoid any risk of collision.

3.6 Monitoring entanglement in MPAS (after Galgani F., Pham C.K., Claro F., Consoli P. (2018). Marine animal forests as useful indicators of entanglement by marine litter . Marine Pollution Bulletin , 135, 735-738 . https://doi.org/10.1016/j.marpolbul.2018.08.004)

Entanglement of marine fauna is one of the principal impacts of marine litter, with an incidence that can vary strongly according to regions, the type and the quantity of marine litter. Although entanglement has been documented in many different types of debris, most records involved fishing gears, especially abandoned, lost, or otherwise discarded fishing gear (ALDFG), with an incidence that can vary strongly according to regions, the type and the quantity of marine litter. There is a direct link between the occurrence of entanglement in epibenthic invertebrates and the spatial distribution of fishing effort and this may be of higher importance for many Mediterranean MPAs that are affected by fishing. On the seafloor, areas dominated by sessile suspension feeders, have been termed “animal forests” and have a strong potential to monitor the temporal and spatial trends of entanglement by marine litter, especially fishing gears. Several characteristics of these organisms represent advantages while avoiding constraints and bias (Galgani et al., 2018).

In the Mediterranean, RAC SPA (2017) has already suggested using benthic invertebrates as entanglement indicator, since it offered the possibility of monitoring this impact at a wide range of depths. A report from the INDICIT project (file:///C:/Users/fgalgani/Downloads/INDICIT-PILOT-AND-FEASIBILITY-STUDIES-February-2018%20(1).pdf) confirmed the potential of epibenthic invertebrates for monitoring entanglement. This group of organisms is widespread, and sufficiently abundant for relevant monitoring programs.

Monitoring activities could, be operated on a regular basis by ROVs or through diving. Monitoring of entangled corals would have to be performed in areas with rocky substrate, the main constraint of this method being its cost, which can be high depending on the vessel used. However, opportunistic approaches such as regular surveys for biodiversity in MPAs has a great potential (Consoli et al., 2017). Additional records of litter and interactions with marine organisms will provide sufficient information for measuring the indicator 10DC4 that has become mandatory within MSFD. This approach is well adapted for MPAs that are regularly recording data on biodiversity (abundance, distribution). For that the metrics must consider the number of individuals entangled or damaged, but also any interaction that may represent an alteration of the natural community. Methods , ROV or diving, used for monitoring/exploring the seabed are tailored according to each dive’s objective, but generally result in underwater observations or footage that are georeferenced. The Observations/images are then annotated, providing a wide variety of information. For monitoring purposes, a specific sampling scheme has to be defined (length of transects, distance above the seafloor for adequate observation/image resolution etc.). In particular, the locations should be chosen according to strict criteria, based on the level of the available knowledge for the area, for example, a good understanding of fishing activities. Once collected, protocols for image annotation and analysis needs to be defined. An important constraint, which has no simple solution, lies in determining how the occurrence of entanglement is linked to the number of litter items. For instance, a high occurrence of entangled invertebrates in an area might not be caused by separate litter items, but by a single longline of several kilometers long. Within AMARE project, and in collaboration with the French National Museum of Natural History, a protocol for monitoring the interactions between debris and benthic invertebrates has been elaborated. It must be considered as part of sea floor litter monitoring, and, in the case of MPAs, can be advantageously operated back to back the monitoring of biodiversity. It proposes the following data recording form for observations, considering the associated categories of impacts

OBSERVATION FORM									
Date				Name Marine Park					
Code Dive				Name observer					
Location of diving				Code transect					
Duration				Coordinates beginning/ending					
Orbs #	Time	Latitude	Longitude	Impacted species	Entanglement yes /no	Covering yes/no (%)	Debris material**	Debris category	Impact (N° picture)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Figure 16: A Proposed template for recording Interactions between Marine litter and invertebrates Through visual observations (By diving or ROV) in MPAs, also recommended as part of regular surveys of biodiversity and/or marine litter on the sea bed (Diving or ROV)

** CATEGORIES OF MATERIAL RESPONSIBLE FOR ENTANGLEMENT/SMOTHERING

N°	Category	Examples of details
1	plastic	Bottle, rope, package, sheet, fishing debris (net, line etc.)
2	manufactured wood	
3	foam/rubber	
4	sanitary debris	
5	cloth/natural fibers	Piece of fabric, entire cloth, etc.…
6	metal	anchor, can, pot etc.
7	paper/cardboard	
8	natural material	
9	glass/ceramics	
10	other	

*** CATEGORIES OF IMPACT

When possible, take one or several pictures with incrustation of date /location: No damage/ smothering - covering (precise %)/ Damage (precise) / broken branches/ wounds / decreased mobility / death / other (precise)

4. RECOMMENDATIONS AND PERPECTIVES

MPAs in the Mediterranean Sea are most often coastal areas, including shallow waters and are often affected by tourism, due to their attractiveness and site promotion, and fishing. Water movements may also largely affect the distribution of litter and their transport, meaning some possible massive stranding on coastlines. Methodological standards are currently available for monitoring, but priorities must be given in relation to (i) the local context of MPAs and specific constraints, and (2) management measures. In some MPAs, Monitoring will require additional experiments in order to define the best strategy. Overall, indicators must enable to assess distribution, hot spots and trends and may be specific of typical items or categories or items to measure the efficiency of specific reduction measures.

For monitoring MPAs, different indicators are available, but they must be adequately chosen in order to optimize both the strategy and operations. On the basis of existing data, experiments, knowledge, available protocols and existing monitoring, the AMAREe project propose the following priorities:

- Because of its simplicity, operational costs, the significance of the results and the cost effective evaluation of impact of reduction measures or cleaning, monitoring Beach Litter (10DC1) must be considered in priority. Ideally, an assessment of accumulation areas, based on the experience of MPA managers or on an extensive mapping of litter accumulation, will provide first critical information on areas to be monitored and cleaned. Then, the use of referenced protocols (MSFD) will enable to better assess sources, trends and necessary measures. This will enable to compare results from different MPAs and coordinate both monitoring and reduction measures.

As a second priority, regular sampling of biodiversity, by diving and/or exceptionally by using ROVs, must be used as a platform to measures seafloor litter (part of 10DC1), especially on shallow waters. A special consideration of entangled organisms, especially in fishing gears, will also enable to monitor the indicator 10DC4, on a regular basis, and provide critical information on trends of impacts.

For the indicator 10DC4, Even if additional research work is needed, we recommend an approach consisting of recording data on litter brought back to their nests by seabirds. This approach is routinely used in many sites all over the world, especially in protected areas (Votier, 2011). In the Mediterranean, this approach is still experimental, but has been used in some areas (Cadiou & Fortin, 2015) and presents a strong potential for setting up future monitoring of impact of litter.

Because of water movements, microplastics in sediments will be the third priority, providing information on trends, when floating microplastics or litter ingested microplastics, may just provide snapshots with possible interferences due to patchiness.

Assessments of floating litter, including microplastics, will then serve MPA managers when massive inputs of debris from other areas or possible invasion by non-endemic species may be critical. For this, a simple monitoring scheme will then have to be considered.

For monitoring of the ingestion of litter, the use of relevant species such as sea turtles is generally operated at large scale, because of a low prevalence. Then measurement in an MPA may provide only few data. Work is still required to identify the most representative bird species in the Mediterranean. Monitoring the ingestion of micro-plastics by fishes or invertebrates presents also a good potential for monitoring the ingestion of litter by marine species in the Mediterranean. Supplementary work is however necessary to complete a rigorous protocol which eliminates any risk of contaminated samples and thus of false positives (RAC SPA, 2017). More generally, AMARE recommend to consider the indicator 10DC3 as part of a monitoring scheme operated at larger scale, where a MPAs will contribute. This approach will need coordination, a requested task for monitoring MPAs.

Using the most relevant protocols in terms of feasibility, significance, management and implementing are the necessary steps before regular monitoring. Initial assessment, definition of Hot spots, selecting the most relevant indicators, optimizing the processes will ensure a regular and efficient monitoring of the MPA coastlines and waters. In some cases, this may be relevant only as part of a monitoring network operated at larger scale. It is then proposed to ensure that assessments are compatible within MPAs, in a coordinated manner, under the auspices of an institution. The AMARE platform, UNEP MAP or MEDPAN could provide such a framework, networking all MPAs to harmonize monitoring, controlling the quality, managing data, and cross mapping pressures and impacts to support risk assessment and management measures.

5. AKNOWLEDGMENTS

This work was performed within the AMARE project. We thank INTERREG/ MED for supporting this project, AMARE MPA partners for their contribution and logistic support (the National Park of SES Salines d'Eivissa i Formentera, Nature Reserve of Bouches de Bonifacio, North-East Malta MPA, Specially Protected Area of Porto Cesareo, Community Importance Site of Torre Guaceto).

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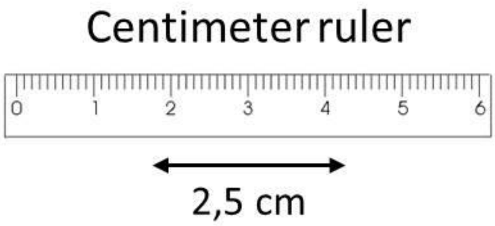
7. ANNEX 1: A MPA dedicated Simplified Beach litter Survey Form and shortened list of categories (categories of items). This form is UNEP: UNEP/MAP and MSFD compatible

MPA Beach Litter Survey Form



Name of the beach:	
National beach ID:	
Contracting Party:	
Date of survey (dd/mm/yy)	
Number of surveyors:	
Responsible of this survey:	Name:
Previous conducted survey (dd/mm/yy)	

Additional Information

Did you divert from the predetermined 100 metres:	No Yes, please specify new GPS coordinates

Did any of the following weather conditions affect the data of the survey:

Wind ☐ Rain ☐ Sand storm ☐ Fog ☐

Snow ☐ Exceptionally high tide ☐

Did you find stranded or dead animals?

Yes ☐ No ☐ If so how many:

Describe the animals, or note the species name if known:

Stranded animals Dead ☐ Alive ☐

Is the animal entangled in litter? Yes ☐ No ☐ If so, specify litter item

MPAs simplified Beach Litter Survey Form		
ID	PLASTIC/POLYSTYRENE	Nº units
G3/ G4/G5	bags incl. pieces	
G7/G8	Drink bottles	
G9/G10/G11/G14/G1	Other bottles & containers	
G21/24	Plastic caps and lids (including rings from bottle caps/lids)	
G34/35	Cutlery and trays/Straws and stirrers	
G53-G54	Fishing nets	
G42 to G52, G55 to	Other fishing related objects	
G67	Sheets, industrial packaging, plastic sheeting	
G75/G76/G77	Plastic/polystyrene pieces	
G124	Other plastic/polystyrene items (identifiable) including fragments	
ID	RUBBER	Nº units
ID	CLOTH	Nº units
ID	PAPER / CARDBOARD	Nº units
G27	Cigarette butts and filters	
G158	Other paper items, including fragments	
ID	PROCESSED / WORKED WOOD	Nº units
ID	METAL	Nº units
G175	Cans (beverage)	
G198/G199	Other metal pieces	
ID	GLASS	Nº units
G200	Bottles incl. pieces	
G210a	Other glass items	
ID	CERAMICS	Nº units
ID	SANITARY WASTE	Nº units
G95	Cotton bud sticks	
--	Other sanitary waste	
ID	MEDICAL WASTE	Nº units
G99	Syringes/needles	
G211	Other medical items (swabs, bandaging, adhesive plaster etc.)	
PRRSENCE OF INDUSTRIAL PELLETS ?		
ADDITIONAL COMMENTS:		

II. Floating litter Survey Form and list of categories (TG ML compatible)

Cruise :		DATE :	Start time:	End time	duration:
		Observer:			
N° sample:		Start lat:	Start long:	End Lat:	End Long:
		cape_deg:	speed (knt)	Sea(Beaufort)	Wind direction:

CATEGORIES	Master list	items	NUMBER	SIZE (1 = < 10cm, 2 = 10 à 50 cm, 3 = > 50cm)	Comment
Plastics /Polymers		Bags			
		Bottles			
		Containers			
		Sheets			
		gloves/shoes			
		Synthetic rope			
		Fishing net			
		Plastic box			
		Polystyrene box			
		Buoys			
		Large sheets			
		Polyurethane			
		Small Pieces			
		pellets			
		Other polymers			
Rubber		Balloons /balls			
		Tyres/ belts			
		other rubber			
Textiles (Natural)		Clothes/ shoes			
		Carpets/sheets			
		ropes (natural)			
		Other textiles			
Papers cardboards		carboards			
		paper bags			
		journals			
		Other papers			
Man made wood		Pallets			
		Boxes			
		Panels			
		Other wood			
Metal		Cans			
		barrels/cans(large			
		Other metal			
Other					

II.5.4. MPA Sea Seabed litter Survey Form and list of categories (UNEP/MEDPOL/ TG ML compatible)

CRUISE/CAMPAIGN:		DATE:	HAUL:	RESPONSIBLE:
	LITTER_CATEGORY	Number	Weight	OBSERVATIONS
	L1 PLASTICS / POLYMERS			
	L1a. Plastic Bags			
	L1b. Plastic Bottles			
	L1c. Plastic Food wrappers			
	L1d. Plastic sheets			
	L1e. Hard plastic objects			
	L1f. Fishing nets (polymers)			
	L1g. Fishing lines (polymers)			
	L1h. Other synthetic fishing related			
	L1i. Synthetic ropes/ strapping bands			
	L1j Other plastics			
	L2 TOTAL RUBBER			
	L2a. Tyres			
	L2b. Other rubber (gloves, floats, etc.)			
	L3 TOTAL METAL			
	L3a. Beverage cans (metal)			
	L3b. Other food cans/wrappers			
	L3c. Middle size containers (paint, etc.)			
	L3d. Large metalic objects			
	L3e. Cables			
	L3f. Fishing related (hooks, spears, etc.)			
	L4 TOTAL GLASS/ CERAMIC			
	L4a. Glass/ceramic Bottles			
	L4b. Pieces of glass			
	L4c. Ceramic jars			
	L4d. Large objects			
	L5 TOTAL NATURAL TEXTILS / FIBERS			
	L5a. Clothing (other than polymers)			
	L5b. Large pieces (carpets, etc.)			
	L5c. Natural fishing ropes			
	L5d. Sanitaries (non polymers)			
	L6 TOTAL Wood processed			
	L7 TOTAL Paper and cardboard			
	L8 TOTAL Other			
	L9 TOTAL UNSPECIFIED			
	TOTAL LITTER			
	TOTAL FISHING GEARS (L1 to L3f, L5c)			
	NO LITTER			
	START POSITIONS :	Duration:	Depth:	Mean opening:
	END POSITIONS :	Distance:	Surface:	Mesh:
	Trawl type :			
	Comments:			

*Surveys through commercial fishing may use only the main categories (L1 to L9)

. II.6.5 MPA Microplastic Survey Form and list of categories (UNEP/MEDPOL/ TG ML compatible)

<table>
<tr><td rowspan="2">Cruise:</td><td>DATE :</td><td>Start time:</td><td>End time</td><td colspan="3">duration:</td></tr>
<tr><td colspan="2">Observer:</td><td colspan="4">Comments</td></tr>
<tr><td rowspan="2">N°sample :</td><td colspan="2">Start position:</td><td colspan="4">End position:</td></tr>
<tr><td>cape:</td><td>speed (knt)</td><td colspan="2">Sea(Beaufort):</td><td colspan="2">Wind direction:</td></tr>
<tr><td colspan="2" rowspan="2">CATEGORIES</td><td colspan="5">NUMBER / Size</td></tr>
<tr><td><1mm</td><td>1-2mm</td><td>2-5mm</td><td>Total
< 5mm</td><td>> 5mm</td></tr>
<tr><td rowspan="8">Plastics</td><td>rounded</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>angular</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>industrial pellets</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>fibers</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>film</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>foamed plastic</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>granules</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>styrofoam</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Other</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Comments:</td></tr>
</table>

II.7.2 Survey Form and list of categories for Ingested litter indicators

Site :	SamplingDate	Date of analysis	Species:	
	Observer:		Organ*:	
N° sample:	Sampling conditions			
	storage conditions (fresh/frozen, duration)			
Item	category	Size (1 = < 2,5cm, 2 = 2,5-5cm, 3 = 5-10cm, 4 =10-20cm, 5 = > 20cm)	weight	Colour
Comments				

*oesophagis and/or stomach and/or Intestine,

List of categories

	Master list	items
Plastic Polymers		Plastic bags
		Plastic sheets
		Balloons
		Synthetic rope
		Fishing net
		Hard Plastic
		Polystyrene
		Pieces of plastic (>5mm)
		pellets
		other microplastics (<5mm)
Rubber		
Textiles (Natural)		
Papers/cardboards		
Wood (man made)		
Metal		Hooks
		Other metal
Other		