RESISTANCE project

WP3 – Act. 1

Exchange and exploitation of projects' results

Deliverable 3.1.2

Guidelines sharing best practices and protocols useful for MSP

Final Version - 19/06/2023

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Summary

I- Introduction: Maritime Spatial Planning

Marine and coastal areas are extremely variable because of a wide range of natural, social, economic and cultural factors that have shaped them as highlighted in **figure 1**. Human settlements and activities, like, tourism or fishing are concentrated on the coastal zone, which unfortunately have produced problems and conflicts that arise between human activity and nature protection objectives. Therefore, flexible solutions are needed.

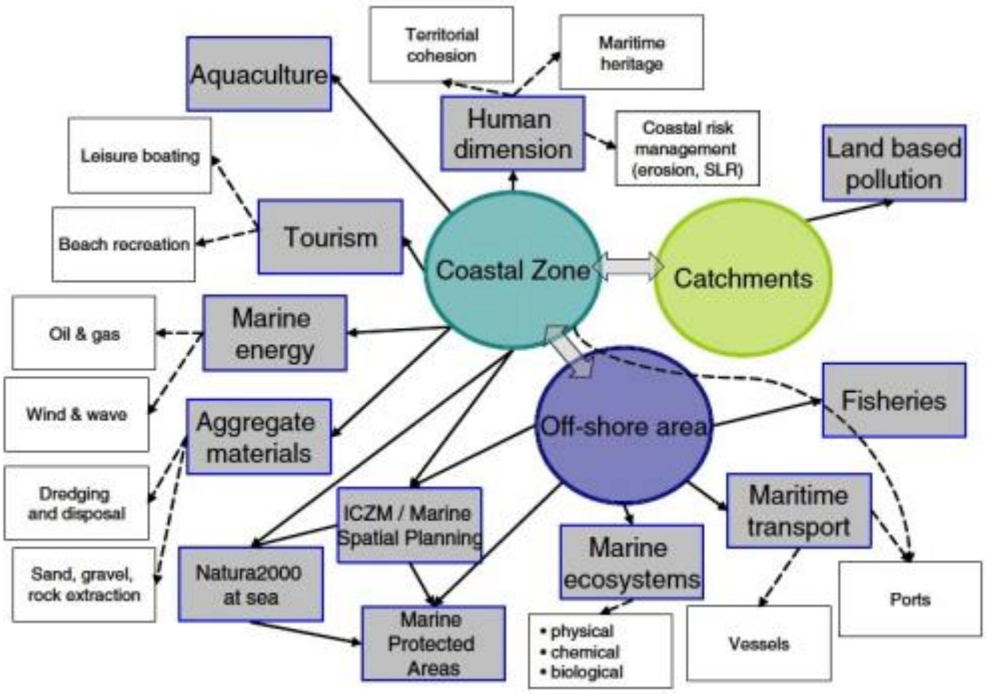

Figure 1. Outline of schematic framework of impacts that influence marine areas with the coast serving as a link between the terrestrial and marine areas (Meiner, 2008. EEA)

As mentioned by the United Nations (Sustainable Development Goal14), or by the Intergovernemental Panel on Climate Change, oceans are critical for stabilising climate and supporting life on Earth and human well-being. It provides key services like climate regulation, and is the home of biodiversity ranging from microbes to marine mammals representing numerous ecosystems. In the other hand, mmarine environment is also a socio-economic space that supports thousands of communities and presents growing opportunities for the future, like for instance in offshore renewable wind energy, aquaculture and marine protection. As a consequence, it is important to maintain healthy marine ecosystems since they provide substantial benefits in terms of food production, recreation and tourism, climate change mitigation and adaptation, shoreline dynamics control and disaster prevention.

However, as mentioned by Galparsoro et al. (2021), globally, the demand for coastal and marine ecosystem services is high and continues to grow, resulting in the diversification and intensification of maritime activities, which puts more pressure on marine ecosystems and increases competition for space at sea. Furthermore, as marine activity intensifies and expands, the potential for tension between stakeholders increases and new challenges concerning the protection of the marine environment from damage and overexploitation emerge.

For instance, conflicts of use are recurrent in fishing activities, since fisheries often operate in the same coastal areas while using different capture methods, depending on their degree of species selectivity and their ability to deployment in space. Conflicts tend to take two main forms: direct conflicts of access to areas where captures take place and indirect conflicts of appropriation of fish species.

Several studies reveal that the high and rapidly increasing demand for maritime space for different human activities as well as the multiple and cumulative pressures on marine and coastal resources require coordinated consideration (Galparsoro et al., 2021; Lees et al., 2023); indeed, if not managed properly, human activities can lead to a deterioration of environmental status and loss of biodiversity. This underlines the need for collaborative, inclusive and cross-sectoral Maritime Spatial Planning

Elher et al. (2019) define maritime spatial planning (MSP) as „*managing the distribution of human activities in space and time to achieve ecological, economic and social objectives and outcomes. It is a political and social process informed by both the natural and social sciences*“. In addition, Ehler and Douvere (2009) indicate that MSP does not lead to a one-time plan, but is a continuing, iterative process that learns and adapts over time (**figure 2**). The development and implementation of MSP involves a number of steps, including:

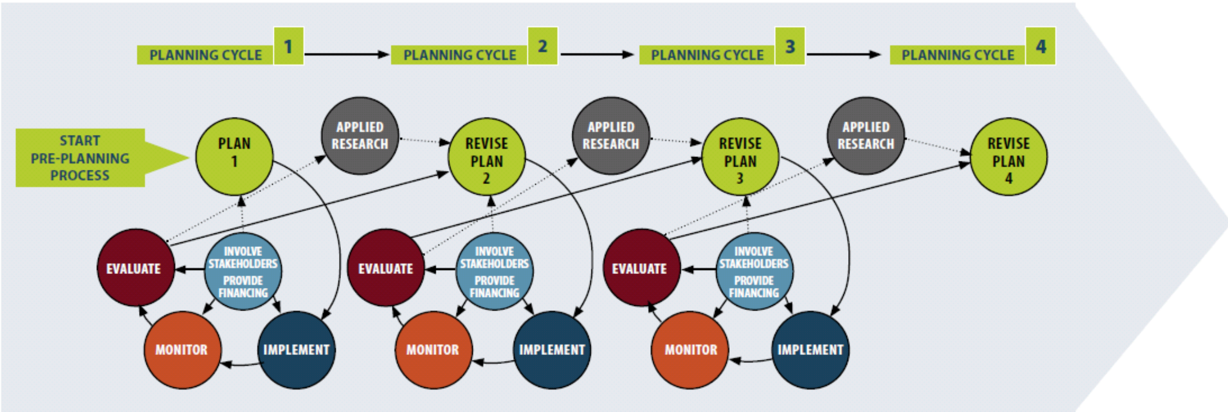

Figure 2: MPS implmentation (from Ehler and Douvere, 2009).

Maritime Spatial Planning (MSP) is defined in the EU Directive on MSP as „**a process by which the relevant Member State's authorities analyse and organise human activities in marine areas to achieve ecological, economic and social objectives**", while the European Commission mentions that Maritime Spatial Planning (MSP) is the **tool to manage the use of our seas and oceans coherently and to ensure that human activities take place in an efficient, safe and sustainable way**.

At European level, the Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning, defines MSP as:
"a process by which the relevant Member State's authorities analyse and organise human activities in marine areas to achieve ecological, economic and social objectives".
And its objectives are defined in Article 5:
1. When establishing and implementing maritime spatial planning, Member States shall consider economic, social and environmental aspects to support sustainable development and growth in the maritime

sector, applying an ecosystem-based approach, and to promote the coexistence of relevant activities and uses.

2. Through their maritime spatial plans, Member States shall aim to contribute to the sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and improvement of the environment, including resilience to climate change impacts. In addition, Member States may pursue other objectives such as the promotion of sustainable tourism and the sustainable extraction of raw materials.

3. This Directive is without prejudice to the competence of Member States to determine how the different objectives are reflected and weighted in their maritime spatial plan or plans.

Furthermore, the same directive provide indications for Setting-up of maritime spatial plans (Article 8):

1. When establishing and implementing maritime spatial planning, Member States shall set up maritime spatial plans which identify the spatial and temporal distribution of relevant existing and future activities and uses in their marine waters, in order to contribute to the objectives set out in Article 5.
2. In doing so and in accordance with Article 2(3), Member States shall take into consideration relevant interactions of activities and uses. Without prejudice to Member States' competences, possible activities and uses and interests may include:
    - aquaculture areas,
    - fishing areas,
    - installations and infrastructures for the exploration, exploitation and extraction of oil, of gas and other energy resources, of minerals and aggregates, and for the production of energy from renewable sources,
    - maritime transport routes and traffic flows,
    - military training areas,
    - nature and species conservation sites and protected areas,
    - raw material extraction areas,
    - scientific research,
    - submarine cable and pipeline routes,
    - tourism,
    - underwater cultural heritage.

The directive also states that as part of the planning and management process, Member States bordering marine waters shall cooperate with the aim of ensuring that maritime spatial plans are coherent and coordinated across the marine region concerned. (Article 11), like in the Adriatic Sea. Indeed, considering the characteristics of the Adriatic and Ionian Region, MSP can foster transboundary cooperation, defining common objectives, instruments and establishing a close coordination and integration between different administrative and manager levels (Menegon et al., 2023; Gómez-Ballesteros et al., 2021; Jay et al., 2016).

The Adriatic Sea is the northernmost basin of the Mediterranean Sea, stretching around 800 km from the Gulf of Venice in the north to the Strait of Otranto in the south, and never exceeding 200 km across. Despite its relatively small size of 138 600 km^2, it has an important role in the wider Mediterranean region due to its rich biodiversity, diverse geology and complex circulation patterns. For example, almost a third of all freshwater flow into Mediterranean comes through the Adriatic Sea, which exchanges its entire volume within three to four years – a strikingly short period.

The western Adriatic coast is predominantly alluvial and terraced, whereas the eastern coast is mostly made of limestone. Here, the chemical and mechanical erosion of limestone resulted a highly diverse coastline with over 1000 islands and numerous sinkholes, towers and caves.

Although a relatively small sea, the Adriatic hosts diverse habitats and species which make it a recognized biodiversity hotspot. The ecosystem services of the Adriatic Sea are, directly or indirectly, at the core of many local economies. Yet, the Adriatic Sea is exposed to numerous threats: global warming, pollution from land and sea sources, overfishing, intense maritime traffic, damage to the sea floor by oil platforms and uncontrolled coastal development and tourism. These threats can have a significant negative impact upon habitats and biodiversity, thus affecting millions of inhabitants and tourists visiting this attractive region.

The Adriatic sea is heavily populated by intensive maritime activities (from commercial ports and medium-small touristic marinas), a complex fishery system integrated with an extensive offshore gas extraction, making this area subjected to intense anthropogenic underwater noise pressure that affect its valuable ecological resources (e.g. nursery and spawning grounds of species of high commercial interest, seasonal hotspots of Species of Community Interest such as *Caretta caretta* turtles and marine mammals as *Tursiops truncatus*).

Within this context, the project IT-HR INTERREG RESISTANCE aims to “enhance” the cooperation of various experts, members of representatives of local, regional authorities, educational institutions, international environmental organizations, and jointly evaluate the good practices and guidelines developed in their previous projects for a sustainable use of marine and coastal resources. Indeed, all involved PPs work together to establish guidelines for preserving the wealth of the Adriatic Sea in order to reap maximum economic benefits while protecting the marine ecosystem. In accordance to the EUSAIR Pillar 3 and the relevant Flagship, the so far achieved experiences from the **projects DORY, ECOMAP, ECOSS, ML-REPAIR, NET4MPLASTIC, SASPAS** and **SOUNDSCAPE**, will be amalgamated to develop sustainable growth, to decrease pollution and contamination, and protect the unique biodiversity of the Adriatic Sea.

II- Thematics of the different projects

DORY

The project DORY, capitalizing the results of the IPA Adriatic ECOSEA project, promotes the adoption of common management models for supporting sustainable fisheries and development of alternative spatial management measures. In Adriatic Sea, despite the existence of protective measures, the increasing use of spaces and marine and coastal resources, in particular due to fisheries and aquaculture, which are key sectors of Adriatic Regions, has intensified pressure on ecosystems, threatening their health and environmental conditions.

Furthermore, Marine Protected Areas (MPAs) in the Adriatic are generally small and suffer the consequences of inappropriate planning and management processes and of the degradation of the surrounding unprotected ecosystem. As a consequence, more sustainable fisheries management considering scientific foundations, development of possible sustainable solutions to reduce the ecological impacts of fisheries and aquaculture, increased capabilities of integrated planning and application of ecosystem approach are common challenges for marine habitat and species protection in the Adriatic.

Numerous initiatives have been carried out in this direction, also through European Territorial Cooperation projects. In particular, the ECOSEA project (IPA CBC 2007-2013) has contributed to introduce integrated and common management principles to favor long-term sustainable use of marine resources, based on: the best existing scientific opinions, stakeholder involvement, sustainable practices and advanced Maritime Spatial Planning tools. In this context, the INTERREG IT-HR DORY project aims to capitalize on the results of ECOSEA to strengthen the institutional dialogue in the Adriatic basin and promote the adoption of common management models for sustainable fishing in order to reduce the impact of economic activities on Adriatic fish stocks and provide common tools **for improving biodiversity** (nursery and reproduction areas) and **reducing the ecological impact of aquaculture activities**. The pilot activities test innovative solutions for reducing the negative aquaculture ecological impact of the economic activities and to, on the other hand, enhance the biodiversity of fish habitats.

The results are particularly relevant for operators in the fishing sector who, together with political decision-makers and institutions, are called to encourage and support change to achieve greater social, economic, and environmental sustainability. **Consequently, they may be used to deal issues related to transboundary fishing issues and will be included in the section guidelines for biodiversity**.

ECOMAP

Project ECOMAP was driven by the need to improve the environmental quality conditions of the sea and coastal area connected to nautical ports and navigation. The objective of the ECOMAP was to help local ports to design better environmental strategies and to have access to suitable environmental management tools to remain competitive and to contribute to a more sustainable Programme area.

As mentioned by Pearson et al. (2016), harbors are critically important social and environmental places imbued with cultural meanings and complex values that attract diverse users and generate conflict. Harbor users seek to access a common pool of natural resources for different ends so there are often conflicts of interest.

Local context

This project helped smaller ports, the local authorities and organizations managing ports to address environmental issues. Most ports of the Programme area are small ports often combining shipping, fishing and leisure activities. Despite their small size, they have important economic, social and environmental links with their surroundings and a large cumulative impact. For instance, Boat tourism requires an intact nature, but may also be a threat to nature, and boat harbors can be an asset for cities' attractiveness if well located and structured. Therefore, they face environmental challenges from EU policy and legislation, and higher expectations from their users and local residents, but they lack the knowledge and tools to respond to these challenges.

Adriatic context and contribution to the EUSAIR

Project ECOMAP enabled stakeholders from Italy and Croatia to exchange knowledge and experiences, to develop and implement pilot actions, to propose new policies, products and services and to support investments in environment-friendly and sustainable operations of touristic and recreational ports at Adriatic coast, considering that there are more than 160,000 berths in Italy, with 194 marinas, while in Croatia, there are 56 marinas with capacity of 16,000 berths and 8,500 dry boat berths and other 30,000 berths in sport ports.

The marine environment, as one of the two topics within pillar 3 of EUSAIR – environmental quality, is considered to be improvable through ECOMAP – both in terms of waste management and preserving biodiversity. ECOMAP implementation contributed to the pillar of "Environmental Protection" of EUSAIR Strategy, with specific training and educative activities that gave a plus to the maintenance of the balance of the environment by preventing contamination and deterioration of natural resources, in particular by providing sustainable goods and services, new solutions in production techniques, new methods on waste treatment and disposal in separate environmental protection facilities, virtuous recycling systems and sensitization campaigns on prevention of landscape degradation.

As a consequence, small harbour requires careful management and assessment to identify precise guidelines to ensure sustainable use of marine and coastal ecosystems and resources. The project also proposed the use of a new coordination innovative methodologies to focus on thematic areas of the pollution anthropogenic activities and on sustainable use of water resources.

Through the constitution of the **ECOMAP Cluster of Smart port Cities,** "ECOMAP Cluster of Adriatic Regional Blue Technology Innovation Hubs" connected with an advanced common strategy for port cities' management characterized by an ECOMAP online platform to archive cross-border best practices and the **BLUE WAY brand marketing campaign** that engaged all stakeholders, ECOMAP has long-term and sustainable impact.

Broader context

ECOMAP contributed to the goal of eco-equilibrium and eco-efficiency. Project results raised awareness of the importance of regular monitoring of water quality in the area due to detecting and reducing sources of pollution and consequently protection of the environment and human health. Composed by an adaptation to the expected goals of UN Agenda 2030 and European objectives in this field (Blue Growth and EU StarFish Mission) and with the filled surveys gathered by marinas on "Smart Waste Management of Small Ports" that collected relevant data for the state-of-the art of the current waste management system by each port area.

The strategy compose itself also of the BLUE WAY brand marketing campaign and the ECOMAP online platform as all-major output Project contributed to inclusive growth through improved mobility of workforce in programme area, cooperation and "brain circulation" in the field of blue technologies and specific training to human resources employed in the sector in order to increase the quality and sustainability of services.

Strong focus on education and good practice exchange of port operators and local authorities managing the ports put in place through the actions, "ECOMAP Cluster of Adriatic Regional Blue Technology Innovation Hubs" and ECOMAP platform ensure expected long-term duration of increased and shared knowledge and dissemination in local environments, especially through new strategic projects and initiatives on maritime and port sustainability.

In addition, the partners have collaborated intensively to the ideation, with the main stakeholders along all the Adriatic coasts, of different virtual journey as also diving offers. The virtual tour is also enriched by a virtual documentary in the field of blue growth, underwater life and sustainable innovative solutions branded by the " UE ". Cultural heritage issues have also been discussed in relation to the Maritime Spatial Planning. It should be mentioned that the UNESCO Convention on the Protection of the Underwater Cultural Heritage (https://en.unesco.org/underwater-heritage/2001) is drafted in order to harmonize the protection of submerged heritage, which includes ancient shipwrecks and sunken ruins, with the protection already accorded to cultural heritage on land. The Convention encourages the responsible access of the public to underwater heritage and examples of Best Practices.

ECOSS

ECOSS overall objective is the establishment of the ECOlogical observing system in the Adriatic Sea (ECOAdS), shared between Italy and Croatia, able to integrate ecological and oceanographic research and monitoring with Natura 2000 conservation strategies. The characteristics of the western Adriatic coast and the geological complexity supports rich biodiversity and high degree of specialization in some of the species. So far, more than 7000 species have been recorded in the Adriatic Sea, many of them rare, endemic or endangered. Of commercially important species, two thirds are today considered over-fished.

Scientifically obtained inter-disciplinary knowledge is a pillar of any conservation initiative. Although the research and monitoring on various components of the Adriatic Sea started over a century ago, these programs were either limited on spatial scale or focusing on single topic, preventing from obtaining the big picture. Thus, preservation of ecosystems and biodiversity of the Adriatic Sea requires not only cross-border cooperation, but also integration of ecological and oceanographic research with conservation programs, such as Natura 2000. The integrative approach should encompass various disciplines and a wide range of temporal and spatial scales to include both coastal and off-shore areas. It further requires active involvement of all stakeholder groups, from scientists and conservation professionals, over businesses and decision-makers to local communities.

Building on the facilities, infrastructures and long term ecological data existing in the Programme area and developing specific case studies, ECOSS (**ECOlogical Observing System in the**

Adriatic Sea: Expected Results oceanographic observations for biodiversity) enhanced the marine observational capacities for improving the conservation status and the expansion of the marine component of Natura 2000 network. To achieve this, ECOSS:

- **Integrating knowledge**, assessing the current state of knowledge, merge the existing data infrastructures and create a basis for integrated future ecological and oceanographic monitoring in the Adriatic.
- **Engaging stakeholders** from scientific community, governance, local economies and general public.
- **Investing in our future** producing educational materials to engage future generations of marine scientists and conservationists.
- **Improved management of Natura 2000** sites to support decision making in a wider context.

- **Ecosystem indicators** for threatened Natura 2000 habitats and species in the Adriatic Sea to ensure alignment of the conservation measures with the requirements of EU directives.
- **Data management system** based on open science principles to provide support to Natura 2000 sites managers and scientific community and to enable long-term viability and transferability of project results.
- **Stakeholders involvement** to ensure that marine conservation measures in the Adriatic respond to needs of the society

The main output of the project is the "**ECOlogical observing system in the Adriatic Sea**", in short ECOAdS, which integrates ecological and oceanographic research and monitoring with Natura 2000 conservation strategies and in this why it directly responds to requirements set out in Marine Strategy Framework Directive, Habitats and Birds Directive and EUSAIR Action Plan. Shared between Italy and Croatia, ECOAdS enhances the marine observational capacities for improving the conservation status and the expansion of the marine component of Natura 2000 network in the Adriatic Sea. Such system could be adapted in order to be used for Maritime Spatial

Planning since it supports the coherent management and monitoring plans of both existing and future marine Natura 2000 sites, thus potentially becoming a **decision-support tool for governance and management**. In addition, through its web portal, makes available data and information, tools and facilities for local, regional and national public authorities, managers of protected areas and Natura 2000 sites, education and research organizations.

ML-REPAIR

Marine Litter (ML) is a common problem for countries facing on the semi-enclosed Adriatic basin, due to geographical aspects and anthropic pressures, and it has been assessed that the fishing sector has a potential in dealing with ML issue, for both prevention, by increasing awareness in a correct obsolete fishing gears disposal, and reduction, by acting in **Fishing For Litter** (FFL) initiatives. Indeed, the ML-REPAIR Project main issue was contribute to an environmentally sustainable growth of the touristic and fishery activities in the Adriatic Sea, providing efficient approaches and actions able to reduce anthropic debris and marine litter in the Adriatic Sea and consequentially improve environmental quality of its waters in the mid-long term, and facilitate management and extension efforts through comparison of proposed strategies and activities from both Italy (IT) and Croatia (HR), where social, legislative and economic differences exist.

In the ML-REPAIR project, these goals focused on strategic topics dealing with:

- Improvement of environmental education of coastal population and tourists, with attention to new generations, and fishery communities;
- Optimization of strategies for ML monitoring, management and scientific investigation that foresee an active and aware involvement of fishermen.

The objective of the project was to capitalize the DeFishGear project by educating and raising perception on marine litter problems and solutions within main target groups, that are both sources of the problem and affected by the problem: local communities, tourists, fishermen. A comprehensive cross border campaign was developed and implemented by a series of tools and activities such as exhibitions, workshops, video, posters, leaflets and work with the media.

Two pilot marine litter exhibitions, "*Plastica(mente)*" (IT) and "*fish market litter exhibition*" (HR) were successfully developed and installed along the cross-border area. "*Plastica(mente)*" consisted of panels and interactive games conceived for children. "*Fish market litter exhibition*" is an open area exhibition formed of litter collected on the beach, with information on litter statistics.

An educational programme for local communities' children was included and implemented in order to raise their awareness and understanding of marine litter problems. The reasoning behind it was as follows:

„*if children learn something about marine litter and all the related problems, then they will also influence their parents*"

The program consisted in:

- laboratories regarding marine litter issues, stimulating the autonomous work of the students;
- half-day workshops on marine litter topic which followed the exhibition Plastica(mente);
- three-day workshops including theory, fieldwork and the development of a small project;
- competition on the best marine litter project with a field trip as a reward;
- v) one-day workshop with kindergarten teachers.

Finally, activities were also dedicated to tourists with specific campaign to raise knowledge of tourists visiting the cross-border area on their contribution to the marine litter issue and how they can help to solve it. Communication material was produced with short and incisive messages and distributed on points most frequently visited by tourists, such as beaches, ports, ferries, marinas, tourism agencies, bus/train stops. Trainings to beach animators were also performed, so that they could in turn give correct information to tourists.

It should be highlighted that „*animation on the beach had a particular methodology and additional values such as creating excellent relationship between the time spent in the activity and number* *of people involved which leads to one-to-one people involvement, making tourists and local people closer to the aims and goals of the project*".

This project deals with the problem of marine pollution, specifically of plastic and other waste in the sea and, the interaction between scientists and fisheries stakeholders is a key tool for the success of every initiative concerning the marine environment. The project engaged fishermen in monitoring and collecting ML, also experimenting innovative and "smart" tools (an application for tablet or smartphone, see). The first thing done was to redact a first and comprehensive "map" of the actual state of the FFL activities in the main fishing ports (Italy and Croatia), thus giving to policymakers a useful tool to implement FFL plans. Successively FFL operations were organized in Italy and Croatia, following by the definition of the composition and quantities of marine litter. The ports involved in Italy were Chioggia (VE), Cesenatico (FC), Cattolica (RI) and Molfetta (BA), with total number of 23 fishing vessels actively participating to the activity. In Croatia, 9 fishermen's ports were involved, with a total of 37 boats.

For the FFL operations were used:

1- Specific datasheet by the fishermen to report onboard the types and quantities (weight) of ML collected during their normal fishing activity
2- Sampling on the quayside with the involvement of scientific operators that carried out a characterization of a sub-sample of the waste landed by the fishing vessels. Successively the waste was classified according to a common classification, weighed and recorded in the data collection form.
3- Use of a tablet to test the ML-REPAIR APP developed by the project to record the main categories of ML caught in the nets. The use of the APP allowed:
    - shorter times to record the data
    - an instant usage of the data from catches
    - visual proofs (pictures) of the catches

All the data collected by the fishermen were entered in a specific database different from the one used for the sampling on the quayside.

As a final step, marine litter and pollution in general of the Natura 2000 site was monitored. The purpose of seafloor monitoring activities was to improve the available data on quantities, composition, distribution and possible source of marine litter and abandoned, lost or discarded fishing gears (ALDFG) of chosen vulnerable sites suspected to be significantly loaded with marine litter. Depending on the preferences and equipment of the project partner in charge, different non-invasive sampling methods were used in different areas, like linear transects done by SCUBA divers and ROV (*Remotely Operating Vehicle*). Collected marine litter items were analysed onboard by being divided into 7 categories (artificial polymer materials, cloth/textile, glass/ceramics, metal, paper/cardboard, processed/worked wood, and rubber) and classified into 53 subcategories following the Master List described by the EU MSFD TG10 *"Guidance on Monitoring of Marine Litter in European Seas"* (Galgani et al., 2013; Vlachogianni et al., 2017).

NET4mPLASTIC

Marine litter is a global concern, affecting all the oceans of the world. In 2005, the problem was recognized by the UN General Assembly that calls for national, regional and global actions to address the problem of marine litter. It represents a serious hazard for the ecosystem: every year, millions and millions of tonnes of litter end up in the ocean worldwide, posing environmental, economic, health and aesthetic problems. In 2008, the marine litter was included in **the Marine Strategy Framework Directive** (2008/56/EC MSFD; EEC, 2008) as one of the descriptors for European marine waters' environmental status (Descriptor 10) and requires that ''Properties and quantities of marine litter do not cause harm to the coastal and marine environment" (European Commission, 2008).

Marine litter originates from different sea- and land-based sources and is largely based on the prevailing production and consumption pattern. Marine litter consists of a wide range of materials, including plastic, metal, wood, rubber, glass and paper. However, several recent studies conducted in EU projects on marine litter reveal that plastic is the most dominant type of waste in the marine environment.

Furthermore, various studies demonstrate that plastics also deteriorate and fragment as a consequence of exposure to sunlight and of physical and chemical deterioration, resulting in small plastic fragments, called micro plastics (from 5 mm to 1 m). In recent years the existence of micro-plastics and their potential impact has received increasing attention. Microplastic is a global concern and their accumulation on beaches, in marine sediments and in marine habitats is now well recognized by scientists and authorities worldwide. The ingestion of MP by marine organisms has also been demonstrated in laboratory studies as well as the presence of MP in fishes, crustaceans and a wide range of filter feeders including bivalves, polychaetes and whales. Indeed, microplastic particles can be ingested by marine organisms, with the potential for: physical disruption and abrasion; toxicity of chemicals in the plastic; and, toxicity of absorbed persistent, bioaccumulating and toxic (PBT) substances.

Nevertheless, knowledge about the origin, abundance and distribution of microplastics in marine systems is still poor. In addition, there is very limited data related to microlitter and microplastic in the Adriatic Sea. Furthermore, even if knowledge of the occurrence, composition, size and distribution of microplastics is paramount to understanding their risk, there is still a lack of standard operation protocols for microplastics sampling, detection and quantification and as a consequence there is a lack of reliable data on concentrations of microplastics and composition of polymers within the marine environment. Consequently, there is a need to improve and develop new methods to reduce the identification time and effort and to detect microplastics in environmental samples.

An integrated common system to support the monitoring of marine plastics, providing Early Warning in case of abnormal forecast values, including greater spatial and temporal coverage, as well as more rapid plastic detection and analysis is needed. By this way a monitoring model can be useful. It also appears that there is a strong relationship between microplastic abundance and both organic (%TOC) and fine fraction (< 63 μm) content in sediments, supporting the hypothesis that microplastics will accumulate in depositional areas and therefore transport model may be used to identify potential accumulation areas. Indeed, a few modeling studies have simulated the dispersion of microplastic particles at sea using three-dimensional (3D) hydrodynamic software. Transport models are currently used for forecasting accumulations of some substances, like as oil spill leakages. The models use meteo-marine and morphological data for identifying areas of accumulation.

The NET4mPLASTIC project, based on the collaboration between Croatia and Italy, aims to collect data on the distribution and composition of the microplastics along the Croatian and Italian coastal and marine areas in order to improve the environmental quality conditions of the sea and coastal area. The general objective of the proposal was to develop "**New Technologies for macro and Microplastic Detection and Analysis in the Adriatic Basin**" (NET4mPLASTIC). The driving idea was to bring together resources and knowledge across different fields, technologies, scientific disciplines, and research infrastructures for responding in an innovative way to specific challenges.

A common sampling and extraction procedure, based on standard operating procedure (SOP) for sampling microplastics in the different context, will be used by the partners to gain knowledge on MP accumulation in different environmental contexts (low sandy beaches, harbor, sea surface water and biota) in four macro-pilot areas. This project provides a systematic comparison on levels of microplastics on beaches, marine environment and biota at both a regional/local scale. The pilot areas were selected according to their geomorphological areas and the wave and meteo-marine conditions. A numerical model, already used by the Marche region was used to reproduce the marine transport processes of the microplastic in the Adriatic Sea and identify possible MP concentration zones in the two pilot areas according to fluvial discharge and marine conditions.

Field surveys were performed ù to validate the numerical simulations and map their distribution in the marine/coastal environment. Furthermore, drones and traditional approach were used during the field surveys. The drone images were used to identify the presence of macroplastic (>3 cm), while some other parameters will be measured in real time by installing a specific platform on boats or on marine drones. Sampling was done at the river mouth, in marine environment (along the coast, at sea), on the beach and collecting biota samples. Chemical and biological analysis allowed to identify the MP, possible origin of the MP and possible health impacts. Correlation between the presence of PCBs/Dioxins and MPs in bivalves were also investigated as well as the origin of the microplastics (thermal analysis).

All the results and data of the NET4mPLASTIC project were stored in an integrated online platform and the results were used to develop a **useful tool for forecasting MP accumulation** and provide **early warning system**, useful for the local authorities and shellfish farmers. This system provide indication in short-time in order to adopt mitigation measures if necessary. Finally, the possibility of recycling *micro* and *macroplastics* were analyzed and a specific recycling methodology was tested, using an existing International Patent.

SASPAS

The common challenge of Project SASPAS is to preserve and obtain a better conservation status of biodiversity of the Adriatic Sea ecosystem in order to decrease its vulnerability through a series of concrete pilot actions, accompanied by data collection and analysis. The overall goal is to improve marine seagrass habitat conservation and restoration by testing safe, ecofriendly anchoring systems, performing pilot transplantations, carrying out monitoring activities and defining a possible integrated management system for marine seagrasses in the Project areas and – in perspective - in similar Adriatic sites. The project's end result aims to increase the conservation status of habitats and species in the Natura 2000 sites involved in the Project areas.

In essence, the SASPAS project wants to achieve two significant goals:

- integration between the local community and environmental standards at a national scale for conservation
- proper and better use of natural resources by yachting and boating.

Marine seagrasses are widespread along part of the coastal areas of the Italy and Croatia, and their conservation status is similar in the two countries. Therefore, significant results can be achieved by establishing good cross-border cooperation between the Italian and Croatian key partners. The cross-border approach ensures coordinated actions in planning and performing the protection and restoration activities, as well as the foreseen Marine Seagrass Safeguard Integrated Management Program.

The project is in line with the EUSAIR strategy, as the planned activities aim to improve the marine and coastal environment, as well as to stop the regression and the consequent loss of marine seagrasses, in particular those of *Posidonia oceanica*, priority species included in the European Habitat Directive 92/43/EEC. EUSAIR encourages joint management in our cross-border area under the SASPAS project.

Different experiences in the Mediterranean Sea and especially in France and Spain were and are performed, but they are mostly punctual and localized experiences, developed mainly to offer a top-level service to pleasure boating customers, safeguarding local meadows, rather than being part of an integrated plan for the safeguard of the valuable habitats of the coastal zone. In the best of cases, where attention to the endangered seagrass meadows was paid, the experiences did not come to bring together in a single approach the two elements capable of making the difference for a truly integrated and advanced management of the coastal strip, namely: on the one hand a usable information base on the quality conditions of valuable habitats and on the existing pressures; on the other hand, the ability of the public administrator to use this information to implement concrete protection actions in the light of an integrated management of coastal areas, balancing the need for conservation and recreational tourism enjoyment.

SASPAS, even in a limited context of representative sites, tested some concrete actions to evaluate this possibility. The project also developed a shared concept for the realization of eco-friendly buoy fields, starting from solutions that obviously had some differences between the sites. These sites were chosen precisely because they represented different realities in terms of type of coast, underwater landscape, marine seagrass species and distribution, characteristics of tourist and nautical pressure and more.

SOUNDSCAPE

The SOUNDSCAPE project contribute to protect and restore biodiversity. The main objective of the project is to create a cross-border technical, scientific and institutional cooperation to face together the challenge of assessing the impact of underwater environmental noise on the marine fauna and in general on the Northern Adriatic Sea ecosystem.

Indeed, underwater noise pollution matters. Marine organisms infer relevant information by listening to the underwater soundscape and they can use sound for communication, foraging and navigation. Many of the human activities that take place at sea contribute to increasing underwater noise pollution. Anthropogenic noises have the potential to mask biological signals and to cause behavioral reactions, physiological problems, injuries and even death in marine animals. The Northern Adriatic Sea hosts a precious and very vulnerable biodiversity, Natura 2000 sites and marine and coastal protected areas (MPAs). Despite this, it is highly impacted by increasing tourism and resource exploitation. Maritime traffic is very intense inside the Adriatic Sea.

The noise in the ocean is the result of the propagation and interactions of anthropogenic and natural sources. Anthropogenic sound sources have a broad range of characteristics, including source level (sound level 1 metre from the source), frequency content (expressed in Hertz [Hz] or kiloHertz [kHz]), duty cycle (pattern of occurrence) and movement (i.e., stationary or mobile). Sound sources can also vary between coastal and open ocean regions (Van der Graaf et al. 2012, Tasker ML et al, 2010). Schematically we can associate typical noise sources with typical frequency bands for a general description of noise source contribution.

The low-frequency band (peak around 10-500 Hz but) is dominated by anthropogenic sources overall commercial shipping followed by seismic exploration. They contribute to the noise across the basin because low frequency have little attenuation and long range propagation. Shipping noise contribution increased in the last 10 years by 12 dB, correlated with the increase in number and size of vessels in the word (Hildebrand et al. 2009). In the same time oil exploitation and construction are moving from continental margins into the deep sea, so seismic signals are increased the range of propagation.

The medium frequency (peak around 500-25000 Hz) are propagating on local or regional range (10s of km) around the sources, so their contribution on ambient noise is spatially more limited. The noise in this frequency range is due to sea-surface agitation (breaking waves, bubbles, rainfall). Sonar and small vessels contribute as anthropogenic sources in medium frequency.

The high frequency (over 25000 Hz) is characterized by very high acoustic attenuation so the effect is only local close the source.

Anthropogenic noise sources vary in space and time, but may be grouped into general categories following TG noise recommendations (Van der Graaf et al. 2012):

a. maritime traffic
b. oil & gas exploration (airguns and other seismic exploration devices)
c. underwater warfare exercises (including military sonars),
d. offshore construction
e. fossil fuel extraction
f. offshore drilling implements
g. offshore wind-power construction and operations
h. research sound sources
i. ship-mounted sonars
j. small ships or recreational boats.

SOUNDSCAPE project considered maritime traffic (including shipping and passenger vessels, cruise ships, fishing vessels and small boats) as the main source of underwater noise, thus in presence of other relevant uses, present (i.e. gas extraction, infrastructures development) and/or future (e.g. hydrocarbon research and prospection, offshore wind farms, relict sand deposits exploitation). Shipping noise has been reported to disrupt traveling, foraging, socializing, communicating, resting, and other behaviors in marine mammals, reptiles and fishes, potentially leading to increased mortality and reduced ability to learn to avoid predators (Duarte et al. 2021).

Underwater noise mitigation may require a wide and diversified range of actions to be addressed. In order to guarantee systematicity to the framework of management measures identified by the study, a series of categories of measures were identified, and reported in section III:

Within the project, the intergration of the results from the established underwater noise observing system and the analysis of ecological targets, sensitivities and possible effects has allow to produce soundscape maps, carry out a preliminary risk analysis and inform possible policy actions for straightforward management of underwater noise in accordance with the MSF and MSP Directives, identifying feasible measures agreed upon with stakeholders to mitigate impacts of noise pollution on biodiversity while allowing sustainable development of maritime uses. The species considered within this projects were *C. caretta* and *T. truncatus*.

SOUNDSCAPE has offered the chance to review the existing knowledge on two target species bottlenose dolphins (*T. truncatus*) and loggerhead turtles (*C. caretta*), to study their spatial and temporal distribution in Cres-Lošinj archipelago (Croatia) and to investigate their relation with local environmental and anthropogenic factors, including noise levels.

III- Project Best Practices

In this report *Best practices* is seen as monitoring, planning or management tools that could be used for the implementation of MSP, taking into account the different step of the MSP (Ehler, 2009):

1. Identifying need and establishing authority
2. Obtaining financial support
3. Organizing the process through pre-planning
4. Organizing stakeholder participation
5. Defining and analyzing existing conditions
6. Defining and analyzing future conditions
7. Preparing and approving the spatial management plan
8. Implementing and enforcing the spatial management plan
9. Monitoring and evaluating performance
10. Adapting the marine spatial management process.

The best practices presented regard biodiversity, marine litter, underwater noise and underwater cultural heritage.

III. A - Biodiversity

Protection and Management of Marine Seagrass

Background information on project study sites monitoring methodologies The monitoring methodologies adopted in **SASPAS** refer to national and international protocols developed to evaluate the Ecological Status of seagrass meadows, with specific implementations in relation to taxa (e.g., Posidonia and other seagrass species) (OSPAR, 2009; ISPRA, 2012; APAT-SIBM-ICRAM, 2003; Buia et al., 2004; Water Framework Directive 2000/60/EC; Marine Strategy Framework Directive 2008/56/EC; RAC/SPA - UNEP/MAP, 2014).

Regarding the Italian guidelines, the considered parameters in this protocol also refer to the institutional methodological sheets of the Ministry of the Environment, drawn up in collaboration with ISPRA (Ministero dell'Ambiente and ISPRA, 2017).

At present, following the Water Framework Directive 2000/60/EC (WFD), *P. oceanica* is to be used as Biological Quality Element and several WFD-compliant biotic indices based on P. oceanica have been developed and applied in the Mediterranean Sea for the definition of the Ecological Status of coastal water bodies (Pergent-Martini et al. 2005; Gerakaris et al. 2017).

P. oceanica meadows is a good biological indicator because it is a benthic, long-lived species, widely present in the Mediterranean basin, and is susceptible to pollution and environmental disturbance; is also a useful tool for assessing the environmental impact of human activities, thus being adequate for determining the GES (Good Environmental Status) following the Marine Strategy Framework Directive 2008/56/EC (MSFD).

There are four species of seagrasses native of European waters:

- *Posidonia oceanica* (Neptune grass)
- *Zostera marina* (eelgrass)
- *Zostera noltei* (dwarf eelgrass)
- *Cymodocea nodosa* (little Neptune grass or slender seagrass)

These species are present in several classification systems adopted over the years by the European Union:

● Reference List of Marine Habitat Types for the Selection of Sites to be included in the National Inventories of Natural Sites of Conservation Interest (RAC/SPA - UNEP/MAP, 2016);

● Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and wild fauna and flora (Habitat Directive) – Annex I: Animal and plant species of community interest whose conservation requires the designation of special areas of conservation;

● CORINE biotopes;

● European Nature Information System (EUNIS) habitat classification.

They are also listed as threatened species in the Annexes of the following conventions and protocols:

● Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) - Annex II: List of Endangered or Threatened Species;

● Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD protocol)- Annex II: List of endangered or Threatened species;

● Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) - Appendix I: Strictly protected flora species. In the Habitat Directive, the only species of seagrass listed is the *P. oceanica*, but only as a habitat in Annex I and not a species in the other annexes.

Z. marina, *Z. noltei*, and *C. nodosa* are not considered as species in the Habitat Directive, but they can be considered as communities associated with Annex I: Habitats.

Various causes are behind the reduction of the seagrass population along the Italian and Mediterranean coasts: artificialization, modification and exploitation of the coastline, pollution, illegal fishing, pleasure boating, to mention the main ones.

Regarding recreational anchoring, which is connected to an important economic activity in the Mediterranean Sea, leisure boats usually prefer to anchor on seagrass meadows rather than on other bottoms (i.e.,sand, rock) in order to have a secure temporary mooring and because of they are considered a good anchoring ground.

Presently there are still no available guidelines, concerning the Adriatic Sea (Italian. Slovenian and Croatian coastlines) or the Italian seas all together, for the concrete sustainable management of the marine seagrass resource, related to the problem of anchorages. The marine protected areas implement an advanced management of the marine seagrass resource according to specific protocols, but very vast extensions of *P. oceanica* and other similar species remain currently excluded from a structured protection management.

In particular, the development and installation of environmentally friendly anchoring systems (anchorages and simple signaling buoys) can cancel or significantly reduce impacts on marine seagrass meadows caused by the anchorage, as well as by other minor causes (traffic, swimming and bathing, submersed garbage, diving, etc.). Furthermore, they can preserve seagrass optimal ecological status of key species, the ecological role they play in the habitat and numerous species that make it (benthic organisms, fish fauna), in addition to the stabilization of the erosion basins. Environmentally friendly anchoring system's main function is to reduce chain abrasion on the seafloor.

The environmentally friendly anchoring systems should be placed in areas where the ecological requirements are ensured, but plant are disappearing due to tourism activities. Furthermore, seagrass transplantations can help to re-establish seagrass meadows disappeared due to anthropic pressures. To be successful, the chosen sites should meet two basic requirements: a) historical presence of the meadows; b) termination or absence of impacts preventing their growth and development (assured also by placement of anchoring eco-buoys). The approach used in the SASPAS project is represented in **figure 3.**

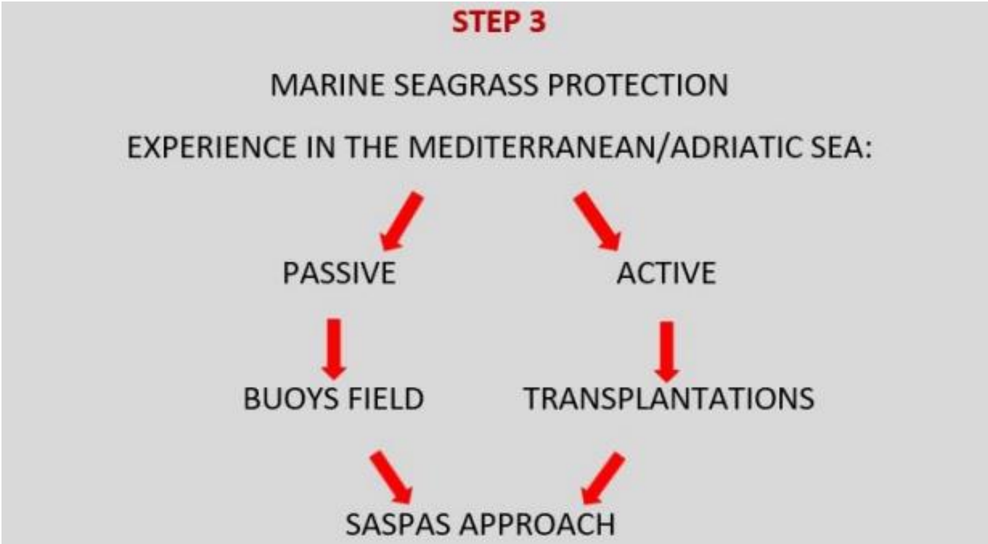

Figure 3: SASPAS Approach

SASPAS eco-friendly anchoring systems

Mooring systems have been proposed to test their implementation in the project sites and to address a new conservation policy in a framework of balancing protection of the ecosystem and use of the natural resources for touristic purposes.

The installation of moorings is preceded by preliminary surveys to gather the general information on seagrass distribution and related problems (fishing, areas of major pressure due to free anchoring or traffic, points of erosion and retreat of the meadows, typology of sediments, etc.) and identified potential sites for the installation of the ecological mooring field.

The starting criteria for choosing the site locations are:

- identification of a wide area, colonized by marine seagrasses;
- precise identification of punctual sites, without coverage, for mooring posts placement;
- sites had to be mooring areas for pleasure boats or mooring areas for recreational diving boats.

The moorings are preferably installed outside the meadows or within limited decolonized areas, if available. Depending on the type of sites, the sandy areas are preferred rather than the rocky areas, where the collateral damage for the installation could be greater.

Examples of anchoring systems

Figure 4 shows the positioning scheme of the pilot buoy field, with the relative distances between the buoys. In addition, it presents the characteristics of the single mooring points with the water heads, the corresponding approximate lengths of the mooring, and the anchoring method.

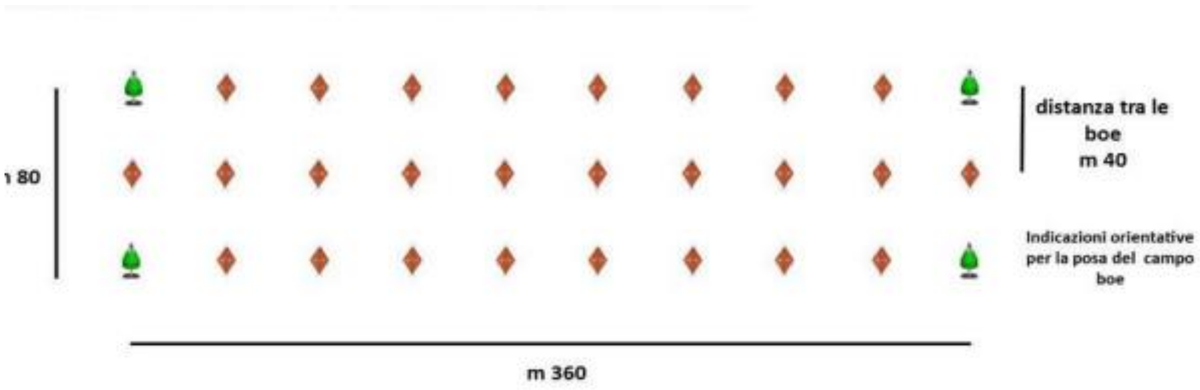

Figure 4. Buoy field and indicative representations for the functional positioning of the single mooring points.

Description of the system

Anchoring system:

- *variant 1* (mixed mud-sand-gravel bottom): screw drive system consisting of a 150 cm pole and two 20 cm diameter helical discs; solid round eyebolt 16 mm in diameter;
- *variant 2* (predominantly mud bottom): screw driven system consisting of a 200 cm pole and two 30 cm diameter helical discs; solid round eyebolt 16 mm in diameter.

The 30 anchoring points are connected to each other with a special line, in rows of 10, for easier maintenance and recovery in case of loss of the buoy.

Buoys:

- the 4 corner buoys are biconical, orange in color and fitted on the top with a special self-powered yellow night signaling LED lamp (**figure 5**);
- the remaining 26 mooring buoys are biconical, orange in color and equipped with a through shaft with two steel rings suitable for mooring boats.

Mooring rig, between buoy and sea-bottom:

- The connection system consists of a section of high tenacity 100% polyester rope with a diameter of 24 mm connected to the spliced ends and equipped with a galvanized iron thimble by means of 14 mm diameter shackles.

Figure 5. Buoys positioned at Monfalcone, in Panzano bay. On the left, an ordinary buoy and, on the right, a corner buoy, with lighting device.

Seagrass transplantation

As for the installation of the buoys field, preliminary surveys were carried out before the seagrass transplantations to gather the general information on their distribution and related problems (anchoring pressure, retreat of the meadows, etc.) to identify potential sites for seagrass transplantation and the most suitable techniques.

P. oceanica transplantation

P. oceanica transplants is carried out using two similar manual techniques.

Technique 1

The rhizome transplantation method can be carried out using an innovative patented (patents n. 0001400800/2010 and n. 102015000081824/2018) staple made up of a totally biodegradable polymer, with an appearance similar to plastic (Calvo et al., 2014; Scannavino et al., 2014). This biodegradable support consists of a purpose-designed star-shaped anchoring system with 5 arms to which fasten the seagrass rhizomes (**figure 6**). At the donor site, *P. oceanica* shoots are picked up by hand in submersion and subsequently keep in containers filled with sea water. Once back to the ground, *P. oceanica* rhizomes are fastened to the arms of the biodegradable staples, using tear-off bands. Two leaf bundles are fixed at each arm of each support, for a total of 10 leaf bundles per staple. After fixing the cuts to the armrests, the biodegradable supports are assembled at the central node and then anchored to the bottom sediment, by fastening the star staple centers with linchpins inserted in pre-installed biodegradable pickets by SCUBA divers.

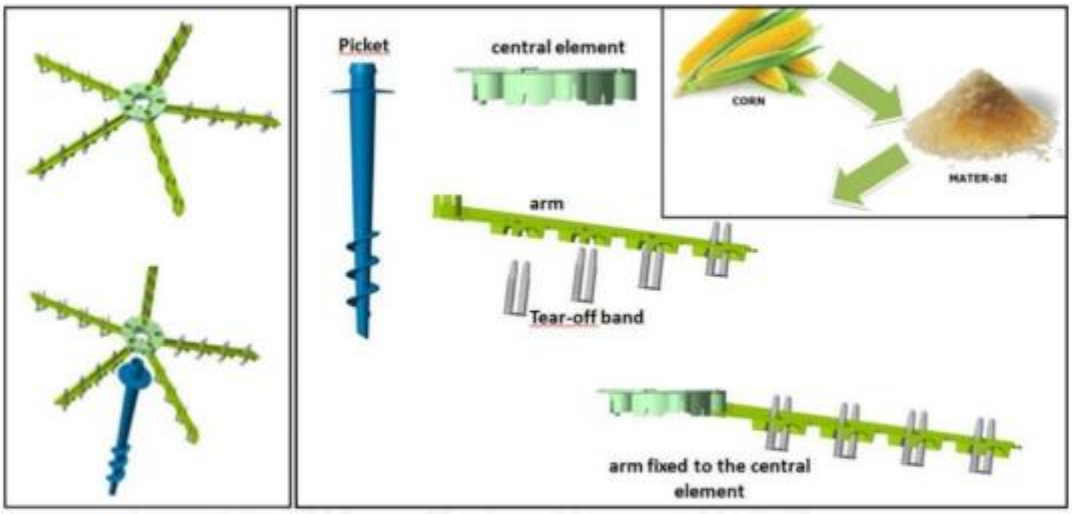

Figure 6. The biodegradable (Mater-Bi®) modular system used to anchor P. oceanica shoots to the substrate. On the left a general view of the star-shaped anchoring staple; on the right details of its components.

Technique 2

The rhizome transplantation method can be carried out using an alternative test to the technique 1. Shoots are mounted on exotic wood supports, heavy enough and of low degradability to resist on the sea floor at least for a couple of years. The cuttings, each of which is formed of at least three shoots of leaves, are attached with biodegradable plastic ties to the wooden supports, and the wooden base is fixed on matte with iron pin (**figure 7**).

Figure 7. P. oceanica attachment scheme and wooden base fixed on matte with iron pin

C. nodosa transplantations

Two techniques can be used to transplant *C. nodosa*. The first technique consists in the collection and planting of sods (i.e., planting units made up by plants with leaves, roots and rhizomes plus the native sediment that surrounds the rooting apparatus), while the second technique consists in the manual collection of shoots (i.e., planting units made up by bare root cuttings), which are subsequently re-planted thanks to anchoring staples.

The donor site and the recipient site are marked using poles and georeferenced by a GPS.

Technique 1

In agreement with many authors (e.g., Cancemi et al., 2002, Paling et al., 2009, Sfriso et al., 2019), transplantation of sods is carried out when the seagrasses are not in their growing period (since September to April) to minimize plant stress. At the donor site, *C. nodosa* sods are carefully collected from the substrate through a 21 cm diameter steel core drill (**figure 8**). Each sod is placed in a perforated bucket, covered with hemp fabric, to be transferred to the transplant site. Furthermore, during transport sods are constantly wetted to avoid drying. In the transplant site, holes with the same size of the collected sods (21 cm of diameter) are created in the sediment through the air-lift samplers. Within the same day of collection, sods are positioned in the donor site, where they are suitably oriented in the sediment together with the hemp fabric; all these operations ae carried out by SCUBA divers.

Figure 8. A typical steel core drill to extract C. nodosa sods from the donor site to transplant them in the acceptor sites.

Technique 2

Transplantation of bare-root transplant cuttings. The plants are collected using air-lift samplers, which allow to free rhizomes and leaves from the sediment (**figure 9**). During the removal and cleaning of seagrasses, it is important to ensure the presence of apical meristems of the growing rhizome in the individual planting units, as they provide a source of new shoots and horizontal growth for the colonization of new areas. For vegetative stocks, at least two apical shoot per planting unit are selected. Subsequently, sprigs are placed into tanks with flowing seawater, floating baskets, or similar carriers, to be transported to the planting site (acceptor area/site) within the same day of collection. The seagrasses are planted directly into the seabed, where they are anchored using U-shaped metal staples by SCUBA divers. Sprigs are attached to the staples by manually inserting the rhizome root portion of the plant fragments under the curved part of the staple and fixing the plants to the bottom sediment, to limit the impact of hydrodynamics and waves.

Figure 9: Example of one of the floating baskets used to carry C. nodosa shoots collected from the donor meadows to the acceptor area where they are planted.

SASPAS monitoring activities related to transplantation

After the preliminary survey, aimed to characterize the biodiversity of the project sites and gathering up-to-date information on the distribution and quality of seagrasses, monitoring campaigns are carried out to control the plant phenological life cycle and the spatial dynamics of marine seagrasses as a response to the concrete actions. The goal it to characterize and quantify, in time and space, the measured impacts and assess trends in biodiversity, as far as possible over the Project time frame.

By integrating the literature suggestions (Fonseca et al., 1998; Cunha et al., 2012; Pirrotta et al., 2015; Calvo et al., 2021) with the operational framework of the project, annual campaigns are organized to monitor the conditions of natural control meadow sites, transplantation plots and prairie areas close to eco-buoy fields. As reported by Calvo et al., (2020) mentioned that "a good result in the early stages of transplantation does not necessarily correspond to a real success of the transplant, and vice versa a low initial performance does not necessarily compromise its positive outcome in the future" since it is important to follow the transplant plots over time in the middle and long term.

P. oceanica

A monitoring plan should be prepared that provides in each transplanted parcel the selection and labelling of some anchor modules for each of the patches implanted. In each bracket of anchor module, the following variables are evaluated for each monitoring campaign:

- evidence of eroded leaf apex,
- length of rhizome,
- total number of shoots in the arm,
- number of shoots of the external cutting,
- longest leaf length, in the outer cutting.

Therefore, the following variables are derived for each monitored anchor module:

- total number of cuttings,
- number of beams per cutting,
- number of total bundles,
- number of dead beams.

C. nodosa

For *C. nodosa* the transplantations state and progress are monitored evaluating the following parameters:

- survival rate of the transplanted sods,
- survival rate of the transplanted shoots (by staples),
- colonization of the seabed,

- leaf/rhizome development.

The conceptual scheme of **figure 10** shows the guidelines developed in SASPAS with an approach oriented to the different processes of analysis of the site conditions, of the existing pressures and of the possible protective actions to be implemented in favor of marine seagrasses.

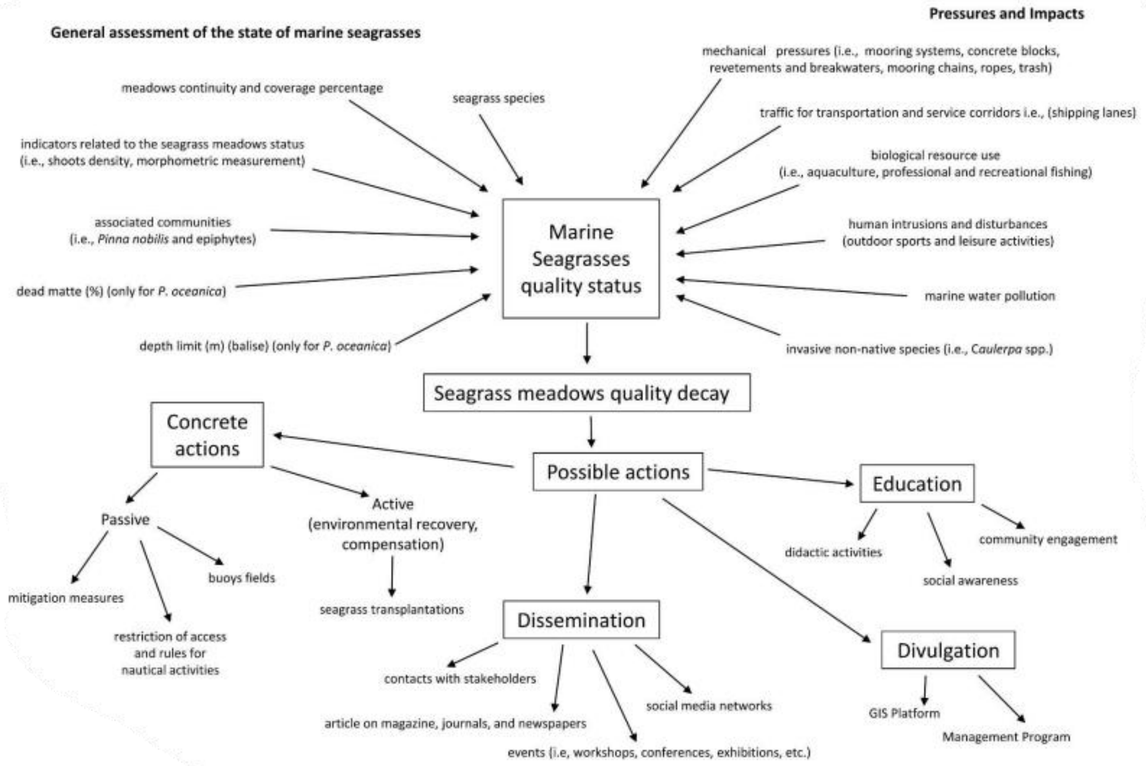

Figure 10. Conceptual scheme for the protection and management of Marine Seagrass

Marine Ecological Observatories

Marine observatories (MO) represent excellent structure that could be implemented within maritime spatial planning since they represent observing and experimenting infrastructures necessary to collect high-resolution oceanographic data in selected marine regions, both in coastal and offshore areas, in order to assess their state and modifications due to human- and climate-induced changes. Indeed, they are crucial for producing knowledge and supporting evidence-based decisions addressed towards ocean management. To be effective, MOs are requested to adopt a holistic view of the marine ecosystems, including biological and ecological processes, which are intrinsically entangled with the oceanographic ones.

Marine Ecological Observatories (MEOs) incorporate this approach and represent a further advancement of the MOs perspective. They broaden the spectrum of marine observations, arranging and maintaining harmonized and coherent long-term observations and linking oceanographic and ecological monitoring with the effectiveness of the protection and restoration measures.

MEOs entail the ecological connectivity concept, which is one of the main driving forces of marine ecosystems' functioning, embracing the complex interconnections among natural processes, species, life cycles, and environment.

MEOs should be platforms able to generate knowledge on the dynamics that vitally interconnect the human dimension and the natural systems. They should involve researchers, policy makers and the civil society to collect a variety of knowledge and viewpoints and to favour innovation and development in information creation and management at the proper spatial scales.

Consequently, MEOs should incorporate the following essential attributes, developed in ECOAdS within the project **ECOSS**:

- Agreed conceptual framework for the harmonization of monitoring schemes, data acquisition and analysis at national and trans-regional levels.

  The framework is based on assessed criteria and selected environmental monitoring indicators, recognized for being adequate to describe the state of the marine environment, coherently with the EU legislative requirements and to support global frameworks (i.e., the Essential Biodiversity Variables and the Essential Ocean Variables).

- Adoption of the Open Science approach - Data platforms to deliver oceanographic and ecological information should create the conditions for the exchange of knowledge among scientists, decision-makers and citizens, enhancing the transformation of a typical top-down flow of information into a multi-players dialogue.
- Cooperation among the fragmented multi-level governance - MEOs should inform policies and strategies dealing with marine protection, planning and management, at multiple spatial scales, harmonizing and creating synergies among all the different jurisdictional instruments.
- Knowledge co-production - MEOs recognize the role of multiple knowledge sources, by entailing local and traditional knowledge and directly engaging local communities as part of the observatory system itself and support its governance and management system.

The ECOAdS Data Portal overall architecture is presented in **figure 11**.

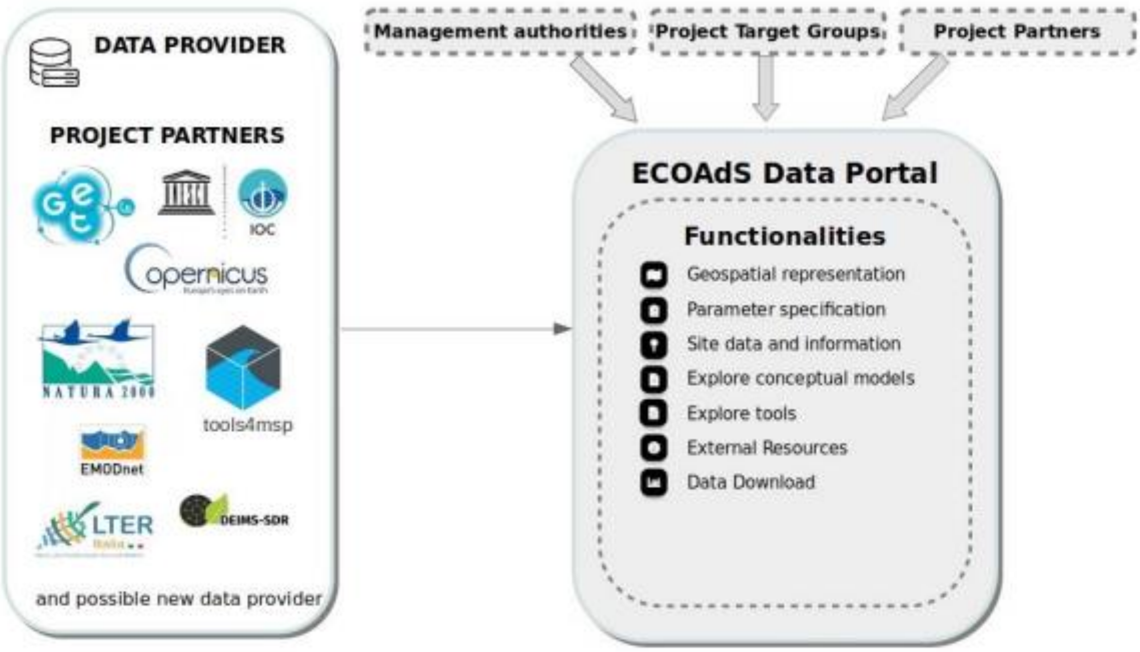

Figure 11. Overall architecture of the ECOAdS Data Portal infrastructure

Four main users groups have been identified, which are: i) management authorities (full access); ii) Universities and research institutes (data access and download); iii) Local, regional and national public authorities (Long Term Ecological Research - LTER - and Natura 2000 sites; monitoring stations locations, metadata and download access); iv) Education and training organizations (LTER and Natura 2000 sites and download access).

The project further suggests that such observatory should have the following **functionalities**

1. Geospatial representation of the observatory: presenting location of LTER sites, Natura 2000 sites and Fixed-Point Observing Systems.
2. Access to site data and information: presenting detailed information (metadata) about the studied sites (e.g. denomination, description, domain area, management authorities, external

reference), linkage to monitored parameters and linkages with additional information resources (e.g. conceptual models, measurements, tools, maps).

3. Preview and access to external resources.
4. Explore and download time-series data of monitored parameters.
5. Explore target species and ecological processes relationships.
6. Explore and download geospatial information.

In addition, the observatory includes some useful **tools** aims at providing interactive applications to respond to the needs of the sites involved in the ECOlogical observing system in the Adriatic Sea (ECOAdS) for the conservation strategies of the Natura 2000 sites and the contribution to the main EU directives. The ECOSS Tools provide graphical representations of monitoring activities at the sites, leveraging the information collected by the ECOSS project by means of their integration with other information sources already available on the internet.
The tools developed within ECOSS project (https://ecoads.eu) are directive contribution and conservation strategy. Especially these tools allow to: evaluate the LTER-and-Nature2000 sites' contribution to the Marine Strategy Framework Directive (MSFD) monitoring activities (Directive contribution, and, evaluate the Natura2000 sites' contribution to the conservation of the specific target species and habitats included in the site (Conservation strategy).

Fishing issues

The recommendations of the **DORY project** have been elaborated on the results concerning the scenarios of possible transboundary spatial management measures for fisheries and the feasibility study related to the establishment of a transboundary marine protected area.
The biological, social, and economic effects of these alternative management measures have been elaborated by applying the DISPLACE bio-economic model together with the comparison with the management measures currently in force for fisheries. Such model simulate the effects on fish stocks of the ban on fishing in small and large areas, including economic assessments of spatial restrictions and the bio-economic consequences of the redistribution of fishing effort.

Description of the Maritime Spatial Planning tool: DISPLACE

The DISPLACE bio-economic model allows to simulate the behaviour of fishermen (e.g., choice of fishing areas, capture of the various target species, management costs and earnings, etc.) and the effects of fishing on fish stocks. Specifically, it is a simulation model based on agents, like individual fishing boats, which calculates the socio-economic and ecological effects on an individual scale. Successively, the individual effects are aggregated in order to highlight the global effects (e.g. the fishing fleet as a whole or other components of the marine ecosystem). The most important component of this model is the spatial one, in fact all economic and biological information are georeferenced within GIS. The spatial component allows to accurately test all possible management measures through simulation scenarios (e.g., closure of certain marine areas to fishing, technical measures in specific areas, etc.).

The DISPLACE model was created for the management of fisheries resources in the North and Baltic Seas, and was adapted and applied in the central and northern Adriatic (GSA 17) for the Italian demersal fishery (Bastardie et al., 2017). The model was based on a previous individual-based model (Bastardie et al., 2010) evaluating the bio-economic efficiency of fishing vessel movements from recent high resolution spatial fishery data.

In the initial version, the model enables a set of independent vessels to act and disperse within a given fishery region from the start to the end date of the simulation period at regular discrete time intervals (e.g., every hour, h) and to a discrete number of positions (nodes).

Three factors were considered:

- vessel-based fuel consumption
- energy efficiency (quantity of fish caught per litre of fuel used)
- profitability to develop a spatially explicit individual-based model (IBM) for fishing vessel movements.

The observed spatial and seasonal patterns of fishing effort for each fishing activity are evaluated against three alternative effort allocation scenarios for the assumed fishermen's adaptation to these factors:

- preferring nearby fishing grounds rather than distant grounds with potentially larger catches and higher values
- shifting to other fisheries targeting resources located closer to the harbour
- allocating effort towards optimising the expected area-specific profit per trip.

In addition, as described by Bastardie et al. (2010), a vessel is defined by a set of specific attributes, which are: the vessel name, the vessel maximal speed, the carrying capacity (kilo), the fuel tank capacity (litres, l), the fuel consumption rate (l per h), the total time for rest in harbour (h), the number of visited grounds per trip per quarter, a list of specific fishing grounds, and a list of specific harbours. Other vessel attributes are outputs that are tracked throughout the simulation, such as the cumulative landings (kilo) per species, the cumulative fuel consumption (l), the cumulative time for rest (h), the vessel state (fishing/non-fishing), the geographical position (latitude, longitude), and the route listing the remaining successive discrete positions to be gone through). *The model is described in Bastardie et al., 2010.*

In the previous, the assumption was constant underlying resource availability, while the successive version (Bastardie et al., 2014 and 2017) considers the underlying size-based dynamics of the targeted stocks. The stochastic fishing process is specific to the vessel catching power and to the encountered population abundances, based on disaggregated research survey data. The impact of the effort displacement on the fish stocks and the vessels' economic consequences are evaluated by simulating individual choices of vessel speed, fishing grounds, and ports. On an individual scale, the simulations led to gains and losses due to either the interactions between vessels or to the alteration of individual patterns. The authors demonstrate that integrating the spatial activity of vessels and fish abundance dynamics allow for more realistic predictions of fishermen behaviour, profits, and stock abundance.

The input data for DISPLACE was updated within the DORY project by inserting new target species, new stock assessment data and data of the Croatian fleet active in the GSA17 (e.g., catches, technical data, spatial distribution of fishing effort, etc.).

Management Scenarios

Five hypothetical spatial fisheries management scenarios and their potential medium-term effects on six fish stocks (hake, sole, red mullet, Norway lobster, mantis shrimp and cuttlefish) were simulated. Within the Dory project, a special focus was reserved for the stock of sole (Solea solea) and cuttlefish (Sepia officinalis), as both species play an important economic role for fisheries both in Italy and in Croatia.

The tested scenarios are:

1. **Status quo**, which includes all restrictions on fishing activities currently in force in Italy, Croatia, and Slovenia.

2. **Prohibition of trawling up to 4 nautical miles from the coast on the Italian side** (GSA17), which is supposed to reduce the fishing pressure in the first growth areas of many species exploited by fishing, in particular sole and cuttlefish.

3. **Prohibition of trawling up to 6 nautical miles from the coast, on the Italian side (GSA17).**

4. **Closure of an area known as the "sole sanctuary"** for all the towed gear of the Italian and Croatian fleets engaged in demersal fishing.

5. **Increase in the selectivity of gillnets** by adopting a minimum mesh size (72mm stretched) and **increase the minimum landing size of sole to 25 cm** (currently 20 cm).

Note that in scenarios 2 and 3 Croatian and Slovenian waters were excluded due to the complex geomorphological characteristics of the eastern Adriatic coast, and of the seaport of Monfalcone and Trieste.

Recommendations - guidelines

Sole sanctuary

The spatial management measure "sole sanctuary" is strongly recommended, recommendations that have already been presented to policy makers and validated during the meeting of the Scientific, Technical, Economic Committee for Fisheries "STECF EWG 19- 02: Multi- Annual

Plans for the fisheries exploiting demersal stocks in the Adriatic Sea" and published in the associated report (STECF, 2019).

The closure of the area would further reduce the small fishing effort currently exerted by trawling and dredging on sole reproducers, in fact the current fishing effort is very low when compared with the rest of the GSA17 due to the concurrence of some factors.

For example, the distance of this area from the main ports and the benthic organisms that populate the substrate, such as for example the bryozoan (*Amathia semiconvoluta*) which blocks the meshes of the nets making fishing very difficult and some species of sea cucumbers which can turn the catch yellow, reducing its commercial value. Furthermore, the ban on fishing in the "sole sanctuary" could be seen as a precautionary measure. In fact, some technological expedients on the networks could allow their exploitation in the future, compromising the stock of reproducers, which is currently exploited in a tolerable way.

In relation to the results obtained with DISPLACE, the exclusion of fast fish from the *"sole sanctuary*" would lead to a decrease in total fishing effort and landed fish, but also in the discard rate for this species. It is useful to remember that sole is the main target species for this gear. This scenario would lead to an increase in catches per unit of effort in the medium term thanks to the increase in the reproductive potential of the species.

Excluding trawling from the *"sole sanctuary*" would lead to a decrease in total fishing effort, number of trips per boat, catches per unit of effort and total landed. On the other hand, the duration of outings and sole discards would increase. However, it should be remembered that sole is not target species for this gear, constituting only a small fraction of the landed of this segment.

Excluding gillnets from the *"sole sanctuary"* would lead to an increase in catches per unit of effort and sole landings in the medium term. Also, there would be a reduction in the discarding of this species. Based on the results obtained with DISPLACE and current scientific knowledge, the exclusion of gillnets from the submitted area is strongly recommended, at least from December to February, during the peak of the sole spawning season. This would allow adults breeders to increase the reproductive potential of the stock and thus help regenerate the stock with new recruits. Currently, the catch composition in GSA17 is dominated by small individuals (ages 0+

and 1+), with a low percentage of large individuals. The minimum legal size is equal to 20 cm, while it has been estimated that the length at which 50% of sole individuals has reached sexual maturity is 25 cm.

Minimum landing size and selectivity for sole

According to the data collected during the "*SoleMon, scientific fishing survey"* (Scarcella et al., 2014), individuals of sole aged 0+ tend to aggregate along the Italian coast, mainly in the area near the mouth of the Po. Growing, at an age 1+ they gradually migrate offshore until the adults (age >3) concentrate in the deeper waters at the centre of the GSA17, between the Italian coasts and southern Istria.

The entire life cycle of the sole would seem to follow the Adriatic circulation and the displacement of the water masses that form in the autumn in the northern and central Adriatic, in correspondence with the reproductive season of this species. As a result of these periodic changes in resource availability, local fish markets are supplied with large quantities of some species for relatively short periods, and prices can plummet if supply exceeds demand. As a result of the different spatial distributions, the juveniles are exploited almost exclusively by the Italian fishing fleet, by the swifts and gillnets, while the adults are mainly caught by the Croatian and Slovenian fishing fleets in their respective national waters and by the Italian fleet operating in the international waters. However, since Italian catches are decidedly higher than Croatian and Slovenian ones, global catches are dominated by sole aged 0+ and 1+ (STECF, 2017).

As already mentioned, the minimum landing size for this species is 20 cm, a measure unquestionably far from that of first sexual maturity, estimated at 25 cm and 25.8 cm.

Demographic erosion affects not only the stock's reproductive capacity, but also the average market price and consequently the revenues from fishing activities. The increase of the minimum landing size to 25 cm would shift the fishing target towards the adult portion of the population, guaranteeing young to complete the migration, reach the spawning stock and reproduce at least once before being captured. Furthermore, a complementary measure could be to protect young people even when they are stationed near the coast along the Italian coast. The use of a gillnet with a mesh size of 72 mm would help reduce the capture of juvenile specimens.

Protection of 6 nautical miles from the coast

The implementation of the spatial management measure currently in force (3 nautical miles) with an extension to 6 nautical miles would have the potential to substantially improve the current dynamics of exploitation of fisheries resources.

The *Italian Ministry of Agricultural, Food, Forestry and Tourism Policies* (MIPAAFT) regulates the temporary closure of trawl fishing activities for demersal species and pelagic trawlers in the Adriatic Sea. Since 2012, this regulation also provides for temporary spatial restrictions:

- Vessels authorized for inshore fishing (<6 nm from the coast) or with an overall length below 15 metres cannot operate within 4 nautical miles from the start of the temporary closure until 31 October.
- Vessels with an overall length over 15 metres cannot operate within 6 nautical miles from the start of the temporary closure until 31 October.

These regulations exclude the maritime compartments of Monfalcone and Trieste because these fishing areas have a limited spatial extension.

Currently, small Italian trawlers classified as "coastal fishing" operate between 3 and 6 nautical miles from the coast. The trawl fleet with vessels above 15 metres of length and with a higher fishing license generally exploits the offshore fishing areas, except for vessels using the "fast" trawler, which usually operate in shallow waters deep (depth up to 50 metres). The exclusion of small trawlers and fast trawlers from the 6 nautical miles could generate spatial conflicts in the sea area on the outer 6 nm limit along with potential socio-economic problems for these fleet segments. Gillnet fishing will benefit from the prohibition of 6 nautical miles trawling and fast trawling in terms of catches per unit effort of sole.

Based on the results of the DISPLACE model and scientific knowledge, the application of this measure would protect not only sole, but also all those species for which the coastal strip represents a first growth area, in particular cuttlefish. In fact, in spring the cuttlefish adults migrate from offshore to coastal waters to reproduce. The juveniles stay near the coast until the end of the summer and then make a migration in autumn towards the deeper waters, where they will remain until the spring of the following year. With this managerial measure part of the cycle could be preserved while ensuring better recruitment. There is currently no minimum landing size for this species.

Furthermore, to increase the reproductive success of the cuttlefish, a good practice could be to let the eggs hatch attached to fixed mail tools (e.g., traps, creels, etc.) avoiding cleaning them with a pressure washer, a practice currently in use in many Adriatic navies. For this purpose, special artificial structures have been tested for the deposition of cuttlefish eggs.

III. B - Marine Litter

Fishing for Litter

Application

The project ML-Repair provides tools and guidelines related to **Fishing for Litter** (FFL) that could be used for monitoring activities within MSP initiatives. The FFL scheme is a clean-up activity that aims to remove marine litter from the seafloor: fishing vessels collect marine litter caught in their nets during fishing activities and dispose of it on the quayside. FFL initiatives, at the present time, are strongly recommended by International Organizations as UE, UNEP MAP (Decision IG.22/10 Implementing the Marine Litter Regional Plan in the Mediterranean), as a key activity to remove marine litter from the sea by involving and sensitizing fishermen, the main stakeholders of the sector. Despite the increasing number of directives and strategies to address marine litter and the extensive public interest and media coverage, barriers to implementing the FFL scheme in the Adriatic-Ionian macroregion are still in place (Ronchi et al., 2019). One of the aims of the project was to facilitate the implementation of FFL schemes by creating useful tools for decisionmakers, in order for them to promote a National strategy for FFL implementation. In particular, the project aimed to verify and clarify needs and concerns of the full implementation of the FFL in the two countries and to improve the available data on quantities and composition of marine litter and ALDFG (Abandoned, Lost or otherwise Discarded Fishing Gears) both on the seafloor and in vulnerable Natura 2000 sites.

In addition, within this project an innovative and "smart" and innovative tool (e.g. an application for tablet or smartphone, **figure 12**) has been developed and maybe adopted/used for MSP initiatives for monitoring purpose and to involve fishermen. ML-REPAIR APP allows fishermen engaged in **FFL activities** to have a simple and fast device for entering data on collected marine litter. These data can be very useful for the scientific community to know the state of the seabed, assess the quantities of waste and define the areas of greatest accumulation. The APP allows the "marine waste fisherman" to enter, at the end or during the fishing day, the type (plastic, glass, rubber, etc.).

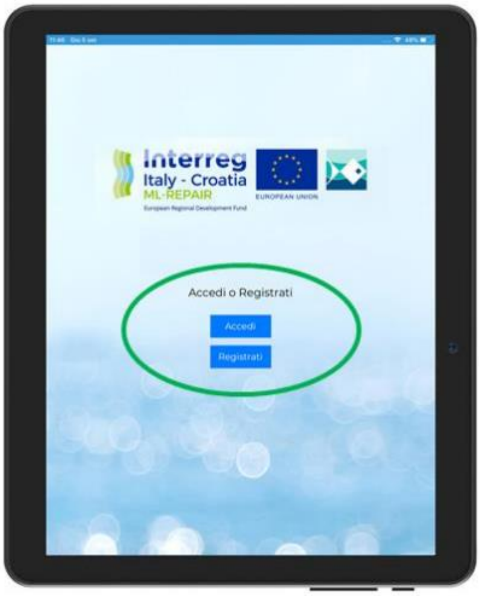

Figure 12: App developed in ML-REPAIR

The access to the page needs first to be registered, and successively, the app allows to:

- add or take a photo
- choose a marine litter category

- Add new marine litter categories.

While in the lower part of the APP's page, there is a panel that allows to:

- Insert a new report
- Look at your submitted or pending reports
- Access to your account details (Account)

Marine Plastics Characterization Protocol

Within ML-Repair a specific protocol regarding waste sample collection and sample preparation to be combined with the contemporary quantification of the ML collected during FFL activities has been developed, and could be adopted in MSP initiatives.

Sampling site selection and planning of monitoring campaigns

The selection of sampling stations could be determined by the presence of waste disposal sites authorized by pertinent authorities. Moreover, these sites are generally present in port areas, so it is necessary to check in advance the need to request access permission and check available access options to areas where the storage containers for ML are present. If disposal sites are available, the choice can be steered by:

- logistical accessibility to the sites;
- type of fishing carried out in the area;
- amount of waste delivered;
- number of fishing boat involved in FFL activities;
- fishing area

Moreover, it should be noted meteorological and oceanographic change, or sedimentological and geomorphological characteristics can affect the fate of plastic litter discharged in the marine environment. Therefore, the choose of period for a sampling campaign must consider also potential causes triggering processes of dispersion and accumulation of ML on the seafloor. Therefore, it is important to record all available information in order to support the results obtained. For example, presence of rivers or streams and their hydrological behavior or marine currents should be taken into account in relationship to the fishing area involved.

Sampling methodology

The materials collected into special bags during Fishing for Litter activities are first subjected to visual inspection during the contemporary evaluation of quantity and typology of Marine Litter. During this step, it is important to individuate and select five (or more) FfL bags, choosing those with most heterogeneous and abundant content in terms of plastic items, and it should noted that a first separation is carried out between waste materials.

1- first step: A) Fishing Related Items (FRI) are separated from B) Other Items (OI);
2- second step: these two macro categories are further subdivided, obtaining different groups based on typology of fishing gear:
    a. for FRI (**a1**_Mussel Nets, **a2**_Gill Nets, **a3**_Other Nets, **a4**_Pots & Traps, **a**5_Ropes, **a6**_Cables, **a7**_Foderone [Bottom Panels] and **a8**_Other),
    b. for B) OI recovered waste is separated according to a compositional approach: **b1**_Plastic, **b2**_Metal, **b3**_Rubber, **b4**_Glass, **b5**_Paper, **b6**_Textile, **b7**_Wood and **b8**_Mixed.

These materials are physically separated and spread on the working ground, allowing the selection of items to pick up for the characterizations in field and laboratory. Plastic litter is recovered principally from b1, b3 (for scientific purposes synthetic rubber and other elastomers can be considered as part of the plastic polymer category) and from the plastic fraction in A, which often represents the largest fraction of this macro category.

The overall Plastic Marine Litter Sample (PMLS) is, therefore, assembled according to the following procedure:

- estimate the plastic fraction weight and/or plastic items number collected in each FFL bag up to a total of 5 bags;
- assign an identification code to each FFL bag involved in the sampling;

- select 100 items in proportion to their bag weight with respect to the total weight of all 5 FFL bags or in proportion to the number of items per bag with respect to the total number obtained from all FFL bags. The latter selection is preferable because less affected by the presence of big items in the bag and is easier to perform. If the total number of collected plastic items is <100, additional samples should be selected from further bags (annotating the ID of supplementary bags selected) until that value is reached;
- select sections of approximately 5/6 cm in size from the chosen items (for the bottles take the upper section, including the cap, the seal ring and expiration date, if present) by cutting them with scissors or nippers. If the partial item does not allow to individuate its category of items for further classification, mark the piece and annotate the referring mark;
- for each FFL bag separate fragments according to RFI and OI categories and collected subsamples in separate containers. Simple plastic bags (such as freezer bags) can be used as samples containers. If possible, rinse the fragments roughly with tap water before putting them in the bag. Merge the two subsample containers in a single container related to the FFL bag. Label the container with the following data:
    1) Location (State international code and sampling site location, preferably with geographic coordinates)
    2) Date of sampling campaign
    3) FFL bag ID
    4) Macro category acronym (for subsample container)

Safety regulations and personal protection devices

Disposal containers for FFL bags are generally available in port areas, which are assimilable to industrial area. From an administrative point of view, it could be necessary to request access permission to related authorities. Another important issue in such activities in port areas is relative to safety rules and practice to be strictly followed. Such rules can be specific for each site;

therefore, it is very important to ask for specific instructions to managing authorities before accessing the site.

Moreover, it is anyway imperative to adopt good safety practices:

- Pay attention and avoid hindering the movement of vehicles and personnel in operation.
- When operating near disposal site containers, it is important to control presence of cutting or abrading objects, as well as pest or other animals (rats, gulls, etc.) that may constitute a health risk for the operators.
- Personal protective equipment is highly recommended if not even mandatory when operating in such areas; the equipment to be adopted may be the following:
    - work gloves cutting and abrasion resistant,
    - puncture resistant gloves,
    - safety shatterproof glasses,
    - Dust masks (if necessary),
    - Safety work trousers with tear-resistant fabric,
    - Disposable non-woven suit (e.g. Tyvek),
    - Safety shoes with toe cap and reinforced sole.

All the actions carried out in the field or in the laboratory must be in accordance with the national laws and regulations regarding safety in the workplace, based on Council Directive 89/391/EEC — Measures to improve the safety and health of workers at work. For instance, for Italian operators the referring text is the D. Lgs. n. 81/2008 "*Testo unico in materia di salute e sicurezza nei luoghi di lavoro*", while for Croatian operators the referring text is Act of June 5, 2014 on Occupational Safety (Text No. 1334), NN 71/2014 "*Zakon o zaštiti na radu*".

Sample preparation for analysis

Plastic items recovered on the seafloor are subjected to various physical, chemical and, particularly, biological processes. Items can be buried by sediment, damaged by currents (abrasion, dent and breakage), covered by algal or bacterial biofilm and encrusted by colonial benthic organisms, bivalve molluscans or worms. As a consequence, it is required to clean the surface of analyzed PMLS fragments, in order to correctly characterize their polymer composition through spectroscopic analytical techniques (Raman, Fourier Transform InfraRed-FTIR, Near Infrared Spectroscopy-NIR).

Cleaning operations can be synthetized as:

1- **First step**: roughly rinse each item and fragment with tap water in order to massively remove the sediment deposits. In some cases, such incrustations can be removed also by drying samples and shaking them.

2- **Second step**: Second washing operation using brushes to remove residual silt and clay. If possible, such step should include also the elimination of dent or other crushing, which do not permit to effectively clean the collected ML fragments.

3- **Third step**: Removal of biofilm and bioorganic deposits that generally covers the surface of ML plastic fragments using a mild oxidation with Sodium Percarbonate instead of using H_2O_2 (Hydrogen Peroxide) solutions. This salt, Sodium Percarbonate, is also preferable to Sodium Perborate, which is recently suspected of posing some environmental concern.

   It is possible to find it commercially in formulations without additives. The Sodium Percarbonate is a solid adduct of sodium carbonate and hydrogen peroxide, whose formula is $2Na_2CO_3\ 3H_2O_2$ (CAS Number 15630-89-4). The solubility in water is approx. 150 g/L and the molar mass is 156.98 g/mol. A 80-100 g/L water solution of sodium percarbonate has been demonstrated to be a good oxidizing agent for cleaning ML plastic items, but the concentration can be increased, based on the organic load, toward its limit of solubility. Plastic fragments can be left to soak for one or two days in the solution at room temperature. Then they should be rinsed thoroughly with tap water (or demineralized water, if possible).

   During such operations, it is important to wear protective glasses and protective gloves since Sodium Percarbonate is an irritant and oxidizing agent, as clearly declared on the packaging.

4- **Fourth step**: Biogenic carbonate encrustation dissolution: the carbonate fouling can be removed by acid dissolution, by applying a water solution of a weak organic acid. Citric acid has been adopted in order to avoid handling strong acids, such as Hydrochloric acid and sulfuric acid, which would require the use of a chemical hood (recommended also for Acetic Acid). Moreover, Citric Acid is more effective than acetic Acid since it is also a metal complexing agent. Indeed, Citric acid is available in the form of a salt allowing the direct preparation of the solutions without the dilution of concentrate acid solutions of which could be irritating to the respiratory tract, such as Hydrochloric and Acetic acid.
Citric acid is commercially available at low costs. It is a tricarboxylic acid with formula $C_6H_8O_7$ (CAS Number 77-92-9). The solubility in water is very high, approx. 592 g/L at 20°C and the molar mass of 210.04 g/mol (as monohydrate salt). For the plastic cleaning a 150g/L water solution of Citric acid can be prepared: it proved to be a good acid descaler for cleaning ML plastic items. Plastic fragments can be left to soak for one or two days. Then, they should be rinsed thoroughly with tap water (demineralized water, if possible). After the rinse step, plastic items should be accurately dried before storing them for following analysis.
During such operations, it is important to wear protective glasses and protective gloves since Citric Acid is a skin and eye irritant, as clearly stated on the packaging.

Methods and instruments for classification and polymer identification applied to Plastic Marine Litter Samples (PMLS)

It is important to highlight that code assignment is important in the case of creation of a database, for multicriteria evaluations performed at different time, for repeated analysis with different instruments and in the case of historical specimen archive development.

Waste classification and description

Items are classified according to the *TSG_ML General- Code proposed by the MSFD Technical Subgroup on Marine Litter in the Annex 8.1 - Master List of Categories of Litter Items from the Guidance on Monitoring of Marine Litter in* European Seas (Hanke et al., 2013).

Polymer Characterization with Fourier Transform Infrared Spectroscopy-Attenuated Total Reflectance (FTIR-ATR), Raman spectroscopy coupled to optical microscopy (µ-Raman), and Near InfraRed Spectroscopy (NIR).

For each item or section, in the case of composite or assembled materials, identification data has been obtained by results of more measurements on the examined surface.

At least three analysis have been carried out on different areas of collected items (generally two main surfaces can be individuated) or different sections with µ-Raman and FTIR-ATR.

Afterwards, acquired spectra have been used to identify and confirm the composition of investigated materials by using a reference database generated by standard material characterization. A rapid identification of material composition has been provided by using a handheld NIR spectrometer, which allows an automatic spectrum interpretation performed directly by instruments.

Sentinel del mare

Based on the experience of the Marche Region, a network of sea observators, called „*sentinel del mare*“, which is a fishermen network, was developed within the project NET4mPlastic. The „*sentinels del mare*“ contribute to identify and localize floating (mainly plastic) items on the sea surface. Once identified, the observators send georeferenced images to the NET4mPLASTIC webplatform, and consequently their observations are stored in the database of the integrated platform providing complete and punctual information of possible concentration zones of MPs to local authorities and scientists. Such information can succcessively been used to monitor the impacts of measures aiming to reduce marine litter pollution.

Within NET4mPLASTIC project, two different procedures, based on a common concept, have been developed and tested. The concept used was that the applications should be easy and fast in order to allow the fishermen to capture photo while working.

With **the first procedure**, for the capture of geo-referenced images, the fishermen will use the mobile devices (Smartphones and tablets) they already own in which apps that can be freely downloaded from Google Play will be installed. The apps were developed by the Marche Region In details:

• the first app: **GPS Map Camera** implements the functions of a digital camera capable of taking georeferenced photos (LAT-LON coordinates, date and time) and storing them in a specific folder in the internal memory of the device (**figure 13**);

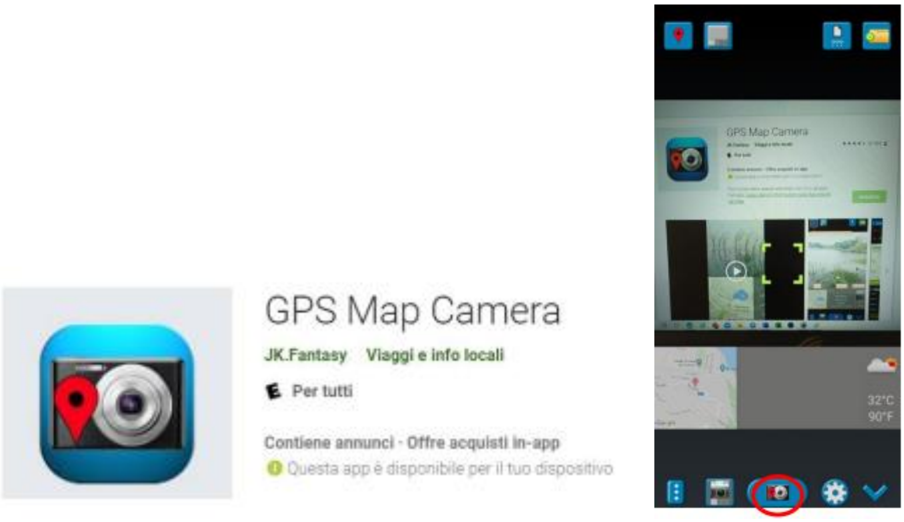

Figure 13- Apps used for the application developed by the Marche Region

In alternative, the GPS Map Camera: Geotag Photos and Add GPS location can be also used (**figure 14**).

Figure 14: alternative app

• the second app: FolderSync or OneSync (**figure 15**), runs automatically when the device is turned on and, when connected to the Internet. The app uploads the geo-referenced photos taken through GPS Map Camera in a Microsoft OneDrive folder connected to personal accounts of the "Sea sentinels" and accessible to the project team. Once stored in this folder, the Marche Region project team will examine the photos and will store them in a further folder whose access is open to the project partners

Figure 15: Second app

Alternatively, OneSync app can also be used (**figure 16**).

Figure 16: Alternative app

The **second procedure** was developed by Hydra Solution, partner of the project, for which the volunteers are required to own a smartphone/tablet recent enough to be able to satisfy minimum requirements, like 2+ Megapixel camera, and active email address.

The procedures to be carried out by the volunteer are as follow:

Non-recurrent procedures (to be performed only once):

- Installation and configuration of the georeferenced image acquisition software (**figure 17**);
- Acquisition of a valid Email address;

Figure 17: App used for the second procedure

<u>Recurring procedures</u> (to be performed each time):

- Start of the software for the acquisition of georeferenced pictures and related activation (unless permanent) of geolocalization services (GPS ON);
- Acquisition of georeferenced frames;
- **Sharing** via Email client of georeferenced pictures at the address mp@net4mplastic.net

Details of the two procedures are available on the NET4mPLASTIC website.

Early Warning System

The main goal of the NET4mPLASTIC project was to achieve an efficient monitoring system for plastic and MP distribution along the Croatian and Italian coastal and marine areas in order to improve the environmental coastal and marine sea quality conditions.

The design of the EWS - Early Warning System includes:

- a control center, based on system hardware and network, and a EWS application integrated with the transport model and external systems (such as the oceanographic model -);
- Integrated Marine Drone, for collection of MP - microplastic, and geolocalized water indicators on the route;
- Integrated Marine OBU, a unit to be installed on board of ships for improved MP collection with geolocalized water indicators on the route.

The design was carried out with the modern system engineering approach based on UML – Unified Modelling Language (Hydra Solutions). This EWS was based on the following main software modules:

- MP Transport model, providing data with distribution and concentration,
- MP WebGIS platform, for:
  - Display MP data (historical, actual forecast, 24-72h forecast)
  - Early warning provision, based on the transport model
  - Data entry, recording & replay MP DB, the DB for collecting data
- A mobile APP, for starting/closing the field activities and for data reporting
- Firmware for marine remote units - Integration with external system, for meteorological/other data
- The functionalities provided by the software platform include:
- The visualization on a web-GIS map of the prediction model data related to meteo-marine conditions of the latest 5 years in specific Adriatic Sea areas (test sites areas of the Net4mPlastic project);

- The visualization on a web-GIS map of the seasonal trend of microplastic coastal distributions and related main sources (**figure 18**);
- The uploading and visualization of survey campaigns data related to the collection of beach and sea surface micro and macro plastic data, and chemical-physical parameter of sea water;
- The uploading and visualization of laboratory data analysis results;
- The export of all data indicated above in excel or text format;
- The visualization of georeferenced pictures of macroplastic (marine litter);
- The production of a periodical bulletin indicating eventual critical conditions of microplastic coastal distribution.

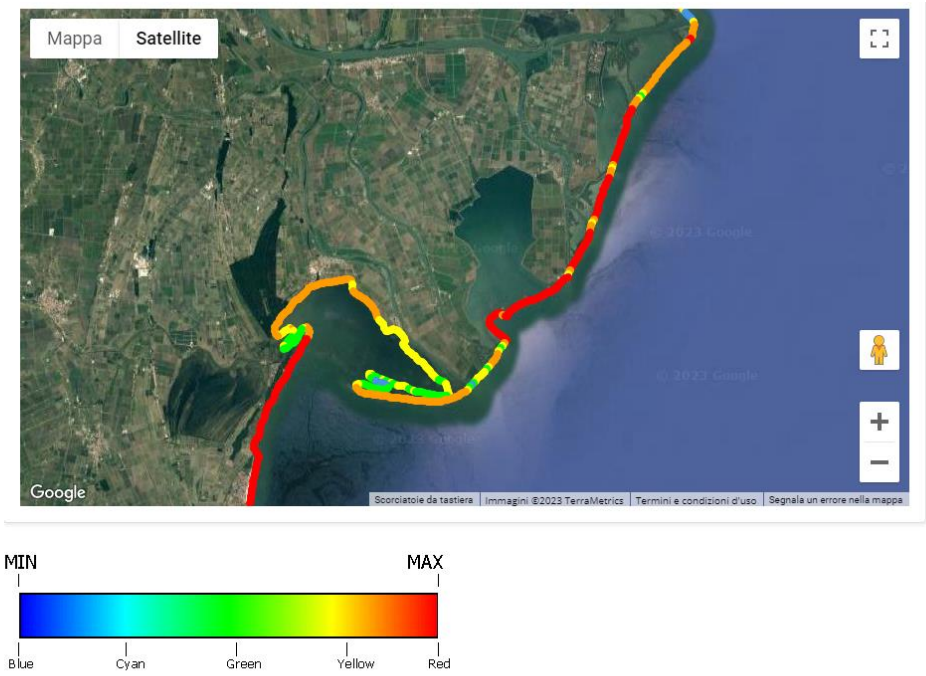

Figure 18: Example of microplastic distribution

Biota survey

Sampling

Biota can be sampled from the environment in many ways including trawling, nets, cages and hand collection from shore. When collecting mussels for microplastic analysis, it is important to carefully remove the byssus threads from the substrate to avoid stressing them. The time between collection and preservation should be as short as possible to minimize stress. Furthermore, to avoid the loss of microplastics possibly present inside the mussels it is necessary to freeze them immediately after sampling, as when mussels are stressed they close.

Natural banks

In natural banks the mussels will be harvested using different techniques depending on their position in the water column:

- Mussels on the surface (0-1 m) will be harvested by hand picking;
- Mussels submerged will be collected by snorkeling.

In this case it is necessary to create the global sample consisting of 3 elementary samples taken at the surface, in the middle and at the bottom of the natural banks.

Mussel farms

In a long line type mussel farm, sampling involves the creation of a global sample composed of 3 primary samples which will be performed on three different depth levels:

- greater depth
- in the middle
- at 50 cm from the surface

It recommended to collect for each sampling station about 3 kg of mussels (size 4-7 cm in length), which kg must be frozen immediately after collection as they are used for the detection and quantification of MP and for chemical analyzes related to the determination of the presence of PCBS / Dioxins / PAHs and heavy metals (lead, cadmium, mercury).

During the sampling it is recommended to record a series of parameters, present in the appropriate sampling sheet (**figure 19**), in order to have more information on the sample taken.

Sampling BIOTA form

Partner/Organizzation	Date of Sampling	Country - Macroarea	Species sampled	Weather condition (rainy –sunny – cloudy)	*Remark*

ID campione	
Start/end time	
GPS latitude	
GPS longitude	
Habitat (natural bank or mussel farm)	
Depth	
Collection method	
Average T° water	
Wind (direction and speed)	
Date and time of arrival in the laboratory	

Water column parameters		
Surface	T (°C)	
	Ph	
	Salinity (ppt)	
	O_2 (mg/l)	
Intermediate	T (°C)	
	Ph	
	Salinity (ppt)	
	O_2 (mg/l)	
Bottom	T (°C)	
	Ph	
	Salinity (ppt)	
	O_2 (mg/l)	

Quantity for each sampling: 8-10 kg of mussels (size 4-7 cm):	
☐	For MP quantification: about 2 kg
☐	For Chemical analyses: about 4-5 kg
☐	For Clearance experiment: about 2 kg

Figure 19: form to be filled during field campaign

Laboratory analysis

Initial sample preparation

Mussels will be processed in a clean laboratory environment to reduce sources of contamination.

- A sample size of at least 30-50 specimens is recommended
- Defrost mussel samples
- Individuals will be measured with calipers before opening. Soft tissue will be excised from the shells and weighed (g, w.w.)

The method used for the microplastic separation (figure 20) is based on a digestion procedure using 30% H_2O_2 solution to degrade natural organic matter in order to facilitate detection of small microplastic particles, and consists in the following steps:

- Add 20 ml of 30% H_2O_2 per 1 g of soft tissue
- Incubate for 24 h at 55 - 65°C (cover with aluminum foil to avoid air contamination)

- After samples will be removed from the incubator and cooled, the homogenate was filtered under vacuum into membrane filter (Whatman, Glass Microfiber filters GF/D, 2.7 μ)
- Rinse the conical flask 3 times with 50 ml of distilled water and filter this water.
- Dry the filter paper at room temperature overnight (cover e.g. in petri dishes).
- Check the filter paper for microplastic particles by the use of stereo microscope (LEICA MZ6) with image analysis software (Image management systems-IM LITE).

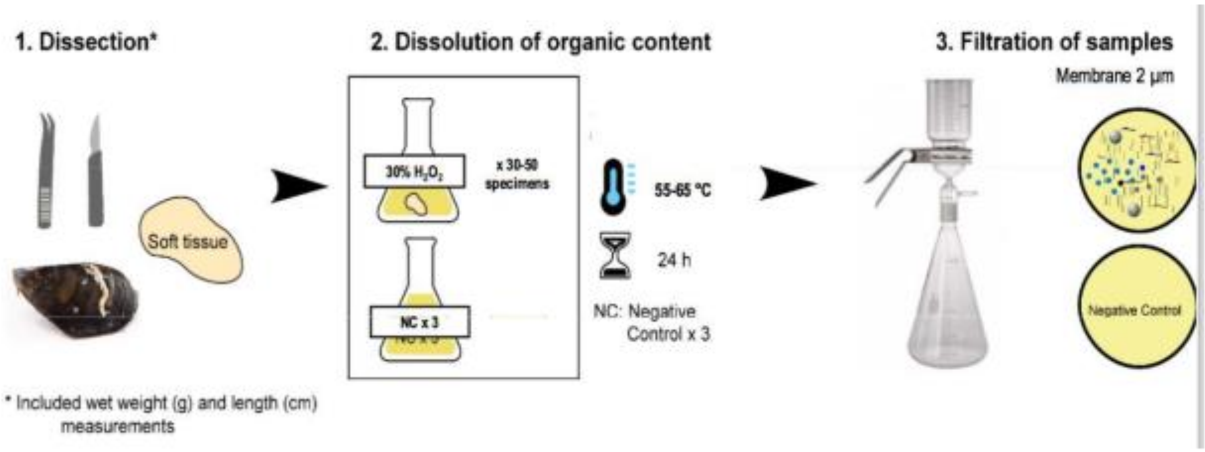

Figure 20: Laboratory procedure

Note: It possible to use other reagents for digestion procedure: Alkaline digestion: 10% KOH solution mixed digestion: 10% KOH: 30% H2O2 acid digestion: HNO3 69% solution.

The microplastic items that will be found inside the mussels will be categorized for:

- colour (white, clear, red, blue, green, yellow, black, other colours);
- type (fragments, pellets, filaments, film, foam, granules, not categorized);
- size class (15 µm, 15-50 µm, 50-100 µm, 100 -500 µm, > 500 µm) (Fig 16: MP classification table)

Negative controls and blanks

In the process of degradation, the negative control should be included (the conical flask with 20 ml of 30% H_2O_2 and 180 ml of distilled water is incubated with the other samples and after incubation the solution is filtered and filter paper checked under the stereomicroscope)
Chemical analysis are performed using the *DeFishGear* protocol that suggest ATR-FTIR spectroscopy and Micro ATR-FTIR spectroscopy analysis.

Guidelines and indicators for proper consumption of mussel and shellfish to prevent toxicity and human health risks

The results of NET4mPLASTIC highlight the need to continuously monitor the presence of microplastic in the environment as well as the presence of MPs in human food. Indeed, results show that microplastic is present in all the pilot sites (sea surface water, on beach sediment and in mussels. In addition, attention should regard the exposition of human health to chemical contaminants such as heavy metals and persistent organic pollutants (POPs) which tend to accumulate in many organisms including in bivalves (like mussels). As a consequence, it is necessary to continuously monitor the concentrations of these chemicals on different locations in the Adriatic Sea as well as the concentration of these chemicals in the soft tissue of mussels intended for human consumption.
The potential health hazard related to food/microplastic "combination" concerns the following factors:

1) **The dose / response relationships** to detected the exposure assessment. These data initially obtained from the literature ("*DeFishGear project"* - IPA Adriatic Cross-border Cooperation Program), were subsequently verified with tests of biological effects in relation to the concentration of microplastics used in experiments ("number of MPs particles per gram") and to time of exposure. For lowering the number of MPs in the mussels and shellfish it is possible to use methodology described previously.
Results of clearance experiments performed by IZSAM (Istituto zooprofilattico sperimentale dell'Abruzzo e del Molise) suggest that very short exposure times (10, 20 and 40 minutes)

to spheres of microplastics do not give evident results because three exposure times are too short to allow mussels to accumulate these contaminants, while exposition of 24 hours to 3 days are significant.

Regarding purification process, results of the experiment suggest that after a 7-day purification period, allow a statistically significant decrease (p value 2.5E14) in the presence of the number of microplastic particles found per gram of soft tissue of the analysed mussels.

2) **Prevalence or exposure assessment** which depends on the consumption of mussel and shellfish frequency and serving size in the in the food combined with the concentration of microplastics time of consumption.

3) **Composition of microplastics**. There are different types of plastics on the market, the most common are polystyrene (PS), polypropylene (PP), high density polyethylene (HDPE), low density polyethylene (LDPE), polyethylene terephthalate (PET) and polyvinyl chloride (PVC). Based on the types of plastics identified, three different shapes were selected to simulate the microplastic particles type observed in the real environment, such as in the study of Qu et al.(2018).

Compared to the experiment conducted in the tank, in the marine environment the microplastics present in the mussels are much lower and consequently the housing times may be much lower to guarantee plastic-free mussels. Therefore, the housing times must be estimated in relation to the pollution encountered in-situ (requiring continuous monitoring). This depuration time allows disability-adjusted years of life (DALY) to approach zero. The life (DALY) is a common metric or indicator of time lived with a disability and time lost due to premature mortality associated with the adverse effect.

4) **Plastic particle size and "Determination of the fate of microplastics within cells".** Evidence suggests that MPs of size that MPs of size <20 µm can penetrate organs, and MPs <10 µm can penetrate cell membranes and cross the placental barrier in exposed cells or laboratory animals. Therefore, more research is very much needed to understand its toxic mechanisms and to determine the potential internalization of all the dimensions of PS-MPs by the cell lines.

The results have also demonstrated the extreme danger of 1 and 2 µm size microplastic materials, and consequently it is recommended in fish and aquaculture farms to perform analyses that exclude the presence of very small microplastics within fish products.

5) **Possible presence of inorganic (heavy metals) and organic (POP, OCP, IPA and PCB) in mussels and shellfish,** information that can be used to design areas for aquaculture or fish farming. The results show that these pollutants were very low or undetectable in the pilot site. However, these parameters are generally high in molluscs collected in areas characterized by a strong anthropogenic impact, i.e. in the area of large ports, marinas, industrial areas, etc. In these areas it is forbidden to collect shellfish, crabs and fish.

In a complete bibliographic search of the entire Adriatic Sea, they found several hotspots due to the high concentrations of metals including the stations of Valona (Hg, Ni, Cd, Cr, V); Kepi Rhodon (Ni, Zn, Cr; Kotor Pb, Cr); Neretva (Cu); Ragusa (Cu, Pb); Neum (Cr, Ni); Novigrad (Cd, Hg, Ni, Pb); Vasto (Zn, Ni, Cd); Tremiti (V, Cd, Pb); and Taranto, which stands out as the site most contaminated by Hg.

III. C - Underwater Noise

Underwater sound is a dominant feature of the underwater marine environment because of natural (biological sources, underwater earthquakes, wind) and human-made (anthropogenic) sound sources. In addition, nthropogenic sounds may be short- (e.g. impulsive forms such as seismic surveys, piling for wind farms and platforms, and explosions) or long-lasting (e.g. continuous in the form of dredging, shipping and energy installations), and affect organisms in different ways (Filiciotto et al., 2013, Maccarrone et al., 2015). For instance, shipping noise has been reported to disrupt traveling, foraging, socializing, communicating, resting, and other behaviors in marine mammals, reptiles and fishes, potentially leading to increased mortality and reduced ability to learn to avoid predators (Duarte et al. 2021).

The MSP directive indirectly apply the apply the ecosystem-based approach with the aim being to ensure that the collective pressure of all activities is kept within levels that are compatible with the achievement of GES (Douvere, 2008). Within the project **SOUNDSCAPE**, some mitgation measures to reduce underwater have been defined and could be applied to improve marine environment conditions and successively monitored.

Underwater noise mitigation may require a wide and diversified range of actions to be addressed and a series of categories of measures were identified. They can be classified in:

- **Main measures** (defined as measures that directly affect noise emissions):
    1. Strategic measures
    2. Spatial-Temporal measures, regulating activities with reference to specific areas and/or periods
    3. Behavioral measures, sustaining good practices and minimizing environmental impacts
    4. Technical and technological improvements, concerning ships and their components, methods of navigation, tools, devices, products, processes and any element useful to improve the sustainability of activities
- **Support measures** (defined as measures that do not directly generate a decrease in noise emissions but are functional to the effective implementation of the main measures):
    5. Monitoring, control and surveillance, aimed at measuring the trend of parameters relating to underwater noise and the characteristics of marine ecosystems.
    6. Economic, financial and other measures: measures encouraging the active participation in decision-making and management processes, dealing with economic aspects (including taxation) and aimed to identify financial resources to support the performance and sustainability of activities, together with measures aimed at training of operators on specific technical topics.

For each considered measure, the following attributes were defined:

- Typology: the measures are categorized in governance, technical (permanent) or operational (temporary)
- Description

- Applicability: focus on how the measures can be implemented in all and/or specific ship types (e.g. cargo, tankers, cruises, passenger, fishing, touristic vessels) according to their features in both new building as well as retrofit projects and Adriatic fleets specificities.
- Possible implementation issues (e.g. times, costs, uncertainty of effectiveness, enforcement, voluntary approaches)
- Examples, experiences and good practices (when available).

The number of possible mitigation measures is summarized in **table 1**.

Type of measure	**Code**	**Name**	**Short/Medium/ Long Term (S/M/L)**
Strategic	1a	Include specific noise mitigation objectives within maritime plans(*strategic*)	M
	1b	Coordinated port development plans in the whole area(*strategic*)	M/L
	1c	Dynamic Ocean Management of maritime traffic (*strategic*)	M
Spatial-Temporal	2a	Rerouting (*operational*)	S
	2b	Establish “Particularly Sensitive Sea Areas” (PSSAs) *(governance)*	S/M
	2c	Establish “Areas To Be Avoided” (ATBAs) *(governance)*	S/M
	2d	Limitations to recreational boating *(operational)*	S
Behavioural	3a	Speed reduction *(operational)*	S
	3b	Convoy *(operational)*	S
	3c	Using tugs *(operational)*	M
	3d	Optimize Ship Handling *(operational)*	S/M
	3e	Regular hull and propeller maintenance polishing *(operational)*	S
Technical/ Technological	4a	Install ducted propellers *(technical)*	M
	4b	Install skewed propellers *(technical)*	M
	4c	Reduction of propeller speed per Knot (TPK) *(technical)*	M
	4d	Install water jets or pump jets *(technical)*	M
	4e	Install CLT propellers *(technical)v*	M
	4f	Electric machinery *(technical)*	M/L
	4g	Machinery treatments *(technical)*	M

	4h	New hulls designs *(technical)*	L
Monitoring, control and surveillance	5a	Live mapping of underwater noise sources and intensity (*operational*)	S/M
	5b	Development of a pilot registration system through transparent management and live use of AIS data for all the vessels (including leisure boats). (*operational*)	S/M
	5c	Better knowledge Continuous mapping of the distribution of target species, their variability and their life cycle, and understanding of their responses to noise exposure (*operational*)	S/M
Economic, financial and other supporting measures	6a	Promote and finance innovative technologies geared to noise emission reduction (*strategic*)	S/M
	6b	Offer best practice training programs to shipping companies (*operational*)	S
	6c	Literacy and awareness raising (e.g. local communities, nautical sector, citizens)	S

Table 1. Synthesis of the possible mitigation measures for each category and typology (from deliverable D.5.4.1 SOUNDSCAPE project, Farella et al., 2021)

Successively is reported the applicability of the measures. For major detail, see deliverable 5.4.1 (Farella, et al., 2021).

Strategic measures

Measure 1a: Include specific noise mitigation objectives within maritime plans

Specific conservation targets could be included in marine plans, fostering the management, limitations and possible exclusion of noisy activities altogether from certain habitat areas.

Applicability: the strategic measure is proposed in compliance Maritime Strategy Framework Directive (MSFD 2008/56/EC) Descriptor 11 “Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment" and the Maritime Spatial Planning Directive (MSPD 2014/89/EU).

Measure 1b: Coordinated port development plans in the whole area

Transboundary approaches are therefore called for the management of underwater noise in the Adriatic basin, throughout:

- Clustering port activities/services throughout the region, harmonizing the ports processes through a common ITS (Intelligent Transport System).
- Improving and harmonizing traffic monitoring and management, strengthening exchange of information between coastal countries through the development of a Common Adriatic-Ionian Vessel Traffic Monitoring and Information System
- Developing ports, optimizing port interfaces, infrastructures and procedures/operations.

Applicability: the strategic measure is proposed in compliance with EUSAIR Action Plan, Pillar 2 (COM(2014) 357 final).

Measure 1c: Dynamic Ocean Management of maritime traffic

Dynamic ocean management more closely aligns management response times with the scales of variability in the environment, in marine species movements, and in resource use. Proper dynamic ocean management can result in smaller, dynamic management boundaries, providing protection equal to large-scale closures but with less impact on resource users, i.e. rapid communications to users, e.g. using hand-held technology may allow vessels to adapt their behavior in relation to ecological observations, showing the presence of highly mobile species of concern in specific areas.

Applicability: the reliability of technology and data to apply dynamic ocean management is strongly dependent on the assumptions and the quality of the available data. Improvements should be fostered on the processing and analytical capability, integration of datasets, production of reliable forecasts at appropriate timescales, and communication with vessels at sea, permitting resource users to adapt to management measures in near real time. The expansion of low-cost cellular coverage makes the application of dynamic management applications feasible.

Spatial-Temporal measures

Measure 2a: Re-routing

Setting up traffic separation schemes (TSS) that force all vessels to follow a general direction in a given zone is are already considered to regulate the traffic, and are usually ruled by the International Maritime Organization (IMO) and incorporated in the International Regulations for Preventing Collisions at Sea.

Applicability: TSSs have been already established in the Northern Section of the Adriatic Sea covering respective solutions in the Eastern Part and the Western Part. Traffic could be further managed exploiting bathymetry and geographical features of the Adriatic sea, establishing TSS or navigational areas in shallow waters and eventual canyon areas in order to benefit from bottom absorption, surface waves diffusion and to confine the noise generated by the vessels.

Measure 2b: Establish "Particularly Sensitive Sea Areas" (PSSAs)

Particularly Sensitive Sea Area (PSSA) is an area that needs special protection through action by IMO because of its significance for recognized ecological / socioeconomic / scientific reasons and which may be vulnerable to damage by international maritime activities. In such area, specific measures can be used to control the maritime activities .

Applicability: Proposals for new PSSAs must come from coastal states, and need to be formally recognized and adopted by the International Maritime Organization (IMO).

Measure 2c: Establish "Areas To Be Avoided" (ATBAs)

Avoided areas (ATBAs) offers one mechanism to help achieve underwater-noise mitigation objectives. It is a particular type of ships' routing measure, defined by IMO as "an area within defined limits in which either navigation is particularly hazardous or it is exceptionally important to avoid casualties and which should be avoided by all ships, or certain classes of ship".

Applicability: the establishment of an ATBA follows the submission of a proposal by local authorities responsible for marine traffic to the IMO, which then takes charge of reviewing and approving the proposal, and gaining it official recognition at international level.

Measure 2d: Limitations to recreational boating

Specific limitations to recreational boating should be considered within and in proximity of protected sites (e.g. Marine Protected Area, Natura 2000 sites) and may include temporal institution of no access zones in highly sensitive areas.
Applicability: limitation to recreational boating should be fostered through proper education and enforcing activities, with specific inclusion within protected sites regulations.

Behavioral measures

Measure 3a: Speed reduction

Reduction of speed has the immediate effect of reducing UWN radiation, especially if the speed reduction reaches less than CIS, its effect becomes more significant (IMO-MEPC, 2014). Although slow steaming reduces the noise level in the area, the duration of the noise propagation in the area increases, because ships spend more time in an area (McKenna et al., 2013). The mitigation effect from slow steaming is not equal between different ambient sound conditions, species, and vessel
In general, model indicates a 10% reduction in speed would cut global underwater sound energy from shipping by around 40% (Leaper, 2019).

Applicability: When re-routing shipping lanes are not possible, reducing vessel speed may be the only alternative method to mitigate UWN immediately (Vakili, 2018).

Measure 3b: Convoy

Recommending target speeds of the vessels entering the route-systems (e.g. TSSs) in order to guarantee a minimum and/or a maximum distance between successive vessels, and/or to form groups of vessels capable of sailing at the same speed.
Applicability: convoying ships requires the reduction of the ship speed.

Measure 3c: Using tugs

The tugs may play a significant role in developing the sustainable shipping in port areas. It requires more efficient, and quieter tugs to be used in the area. Using tugs with LNG and methanol engines, or using fuel cells and hybrid batteries on the tugs can have significant roles in reducing both emissions and the UWN radiation.
Applicability: this measures requires more efficient, and quieter tugs (e.g. LNG and methanol engines, or using fuel cells and hybrid batteries).

Measure 3d: Optimize Ship Handling

Description: Variable loading of the ship alters the propeller depth from its design and, consequently affects in the inception of cavitation. Ships should be handled at proper specific speed and load conditions. Optimum trim for specified draft and speed and ballast for trim and steering conditions could help in optimizing fuel consumption and reduce noise propagation.
Applicability: the need for proper and optimized ship handling is particularly compelling for tankers or bulk carriers.

Measure 3e: Regular hull and propeller maintenance polishing

Regular hull and propeller maintenance can improve efficiency and reduce UWN by up to 1- 2 dB (Baudin and Mumm, 2015).
Applicability: all vessels.

Technical and technological improvements

Measure 4a: Install ducted propellers

A ducted propeller uses a duct around the perimeter of the propeller to modify the propulsion performance and noise characteristics of the propeller.
Applicability: the cost of replacing conventional propellers with ducted propellers is three to five times the cost of a conventional propeller, while its fuel efficiency can be similar or higher than conventional propeller at low speeds. This type of propeller is estimated to be 5 dB (ref 1μPa), more silent than conventional propellers but only a low speeds. Therefore, speed limitations should be also considered.

Measure 4b: Install skewed propellers

Propeller with high skew is affected by the ship generated wake field in a more gradual manner, improving cavitation patterns and resulting in the reduction of propeller cavitation and increased cavitation inception speed. This could help achieving a reduction of underwater noise up to 10 dB (ref 1μPa), depending on wake field characteristics, especially in the low frequency range (40-300 Hz).
Applicability: Its fuel efficiency and its cost is similar than conventional propellers for new ships and and economically and technically feasible for existing ships which makes it the best option for retrofitting, especially for tanker, cargo, cruise ships and passenger vessels.

Measure 4c: Reduction of propeller speed per Knot (TPK)

Reducing propeller rotational speed per knot of speed causes a reduction of the flow velocity at the blade tip. The effect is to increase cavitation inception speed and to mitigate all forms of propeller cavitation (especially propeller tip cavitation). This could help achieving a reduction of underwater noise at all frequencies.

Applicability: This solution enhances efficiency and is recommended for the new build of all the ship types and to both fixed and control pitched propellers (CPP).

Measure 4d: Install water jets or pump jets

Noise reduction promoted by the higher cavitation inception speed and by isolating the propeller from the sea, in all frequencies noise can be up to 15 dB (ref 1μPa) compared to conventional propellers.

Applicability: both water jets or pump jets are applicable to new builds of high-speed ships. In fact, this solution is also used for some naval ships (high speed corvettes and frigates), it is applicable to fast passenger vessels and could also enhance efficiency at high speed, especially for fast, shallow draft vessels.

Measure 4e: Install CLT propellers

Designed with an end plate which reduces the tip vortices, thereby enabling the radial load distribution to be more heavily loaded at the tip than with conventional propellers. In turn, this means that the optimum propeller diameter is smaller, and there is the possibility of reducing cavitation.

Applicability: The cost of this type of propellers, good for improvements on cargo, tankers and passenger vessels, is estimated 20% higher than conventional propellers.

Measure 4f: Electric machinery

Electric transmission enables and facilitates many noise reduction approaches, from the use of mounts and enclosures to active noise cancellation, rather than mechanical. A wider range of propulsor selections are available, with highly variable costs and benefits.
Applicability: New builds.

Measure 4g: Machinery treatments

Machinery treatments for both new builds and retrofit could highly reduce the the transmission of vibration energy from machinery, and the generation of energy into the water from the hull. For effective noise reduction, consideration should be given to mounting engines on resilient mounts, possibly with some form of elastic coupling between the engine and the gear box. Vibration isolators are more readily used for mounting of diesel generators to foundations. Vibrations generated by the engine is transmitted to the hull of the ship and into the ocean, with a significant low frequency content (below 40Hz) in presence of high harmonics. A Double stage vibration isolation system could be considered using one or several pieces of machinery mounted on an upper layer of mounts supported by a raft (steel structure) which is further supported on the hull girder on a lower level set of mounts. This reduces noise by creating an extra impedance barrier to the transmission of vibration energy. It is often used for engine/gearbox or engine/generator. Small diesel and gas turbines may also adopt acoustic structures designed to enclose a specific piece of machinery, absorbing airborne noise, reducing the transmission of energy and the generation of URN from the hull.
Applicability: New builds and retrofits.

Measure 4h: New hulls designs

Hydrodynamically efficient hull forms reduce power requirements and therefore both machinery and propulsor noise. This will reduce cavitation as the propeller operates in the wake field generated by the ship hull. While flow noise around the hull has a negligible influence on radiated noise, the hull form has influence on the inflow of water to the propeller. Design innovation such as hatches for the hollows in the bow, aft thrusters and stabilizers fins (closed during sailing), together with damping treatment to the hull and bulkheads would form better interactions between the hull and the propeller and UWN radiation can be mitigated. The use of lightweight materials, such as fiber reinforced plastic (FRP) composites for craft with length up to about 50 m and aluminum alloys for vessels up to about, could allow to require less power which will imply to a reduction in the ship's acoustic signature, mainly through reduction of propulsion power, if properly designed.

Applicability: primarily intended for consideration for new ships. For effective reduction of underwater noise, hull and propeller design should be adapted to each other

Monitoring, control and surveillance

Measure 5a: Live mapping of underwater noise sources and intensity

Passive acoustics monitoring (PAM) systems allow underwater acoustic data to be acquired and analyzed from this perspective. Estimating the spatial-temporal distribution of noise levels generated by human activities at sea and assessing the source contributions to the global noise field could help the dynamic management of an area trough faster and efficient application of management measures, especially close to protected areas.

Measure 5b: Development of a pilot registration system through transparent management and live use of AIS data for all the vessels (including leisure boats)

In order to enforce surveillance and monitoring, the introduction and integration of VMS and AIS systems could allow the improvement of the quality and descriptive capacity of data on maritime traffic and the distribution of different types of vessels, especially in the coastal areas where smaller vessels operate most, throughout the expansion of the use of the AIS system to small boats (over 12 m) and the adoption of a low cost systems (e.g. 4G/NB-IoT or LoRa) for vessels under 12m.

Applicability: The measure will make it possible to fill the descriptive gaps of the current monitoring systems support local and international management plans and enforce the compliance with existing rules. An adequate and efficient use of traffic monitoring technologies will also significantly reduce the overall cost of traditional control and surveillance operations.

Measure 5c: Better knowledge of the distribution of target species, their variability and their life cycle, and understanding of their responses to noise exposure

Available knowledge on species and habitats can be limited when they have been poorly surveyed as a whole, thus limiting the availability of accurate geo-referenced maps and detailed quantitative data. Consequently, main risks derived from underwater noise cannot be adequately assessed. Consequently, there is a compelling need to design of a network of Adriatic marine observatories and monitoring systems for continuous mapping of species distribution and assessing of environmental risks as a coordinated and transnational effort.

Applicability: Monitoring the area implementing mitigation measures whenever necessary could foster the proposal for shared visual monitoring protocol, e.g. through observers, and infrared technologies and passive acoustic monitoring (PAM) to detect and localize cetaceans both surfacing and deep diving (ACCOBAMS-MOP7/2019/Doc 31Rev1). The data collection of abundance, distribution and behavioral data throughout the survey would also support dynamic management if properly connected to modeling and data sharing networks.

Economic, financial and other supporting measures

Measure 6a: Promote and finance innovative technologies geared to noise emission reduction

Design optimization in ship's hull and propeller, insulating the engine and refitting or considering operational measures such as reducing speed to less than Cavitation Inception Speed (CIS), hull and propeller maintenance, rerouting and using technologies to reduce noise are some actions that can be considered to mitigate URN pollution (IMO MEPC, 2014). Creating incentive (e.g.

discounts on the port dues and operation costs in port) can encourage companies to utilize mitigating measures.

Measure 6b: Offer best practice training programs to shipping companies

Applicability: Training and engagement of operators could improve the effectiveness of specific technical topics and encourage the active participation in decision-making and management processes.

Measure 6c: Literacy and awareness raising (e.g. local communities, nautical sector, citizens)

Education on the possible effects of noise-related pressures on ecosystems and key species, together with the information on good-practices and behaviors in order to minimize impacts, could foster the voluntary adaptation to the new rules, the effectiveness of specific technical topics and encourage the active participation in decision-making and management processes.

III. D - Underwater Archeology – Underwater Cultural Heritage

Given that the Art. 1 of the 2001 Convention on the Protection of Underwater Cultural Heritage defines exactly what Underwater Cultural Heritage is:

1. (a) "Underwater cultural heritage" means all traces of human existence having a cultural, historical or archaeological character which have been partially or totally under water, periodically or continuously, for at least 100 years such as:

(i) sites, structures, buildings, artifacts and human remains, together with their archaeological and natural context;

(ii) vessels, aircraft, other vehicles or any part thereof, their cargo or other contents, together with their archaeological and natural context; and

(iii)objects of prehistoric character.

Established that the Underwater Cultural Heritage is the witness of our common memory, across millennia, considering that all the waters OCEANS, SEAS, TRANSITION WATERS, LAKES, RIVERS, ARTIFICIAL BASINS, and CANALS constitute areas to be protected, aware of having a discipline that deals with this sector that is Underwater Archaeology, a science dealing with the study, excavation, surveillance, documentation (scale drawing, photography, inventory, cataloging), historical location, predictive and preventive verification of archaeological interest, direct investigations and remote sensing, conservation of anthropic traces of the heritage with more than 100 years, we have to remind that Underwater Cultural Heritage is a non-renewable resource that, if destroyed, is lost forever.

It is therefore important to preserve and document artifacts as well as the context in which they are found. In situ conservation should always be considered as a first option and non-destructive methods of investigation should be used where possible (UNESCO 2001 - Convention on the Protection of Underwater Cultural Heritage https://www.unesco.beniculturali.it/la-convenzione - about-world-heritage/ - https://whc.unesco.org/en/conventiontext/)

In Italy, the Decree of the President of the Council of Ministers of 14 February 2022 (Official Gazette - General Series n.88 of 14 April 2022), presents the Guidelines for the procedure for verifying archaeological interest and identification of simplified procedures.

The guidelines regulate the verification procedure envisaged by the Italian Cultural Heritage and Landscape Code (Art. 28 paragraph 4 of Legislative Decree 42/2004) and by the Public Procurement Code (Art. 25 of Legislative Decree 50/2016) aimed at ensuring speed, efficiency, and effectiveness of the procedures.

The ICA - Central Institute for Archeology (Italy) has dedicated a section of its website to the new guidelines and new operational tools (descriptive and application standards) for the preventive archaeological investigation procedures during public works: http:// www.ic_archeo.beniculturali.it/it/275/archeologia-preventiva.

The National Superintendency for Underwater Cultural Heritage (Taranto, Italy) is working on a better definition of the guidelines for the underwater and coastal areas, however, we can propose a first brief set of guidelines that may be of international utility.

The development of technology for underwater remote sensing in the industrial sector has introduced new technologies that can also be applied in underwater archaeological research. Through increasingly advanced tools from an engineering point of view, it is now possible to survey large sectors of the seabed in a detailed and systematic way by acquiring extremely precise data in a non-invasive way.

The most commonly applied underwater remote sensing technique in the submerged cultural heritage sector, used in the preventive archaeology, and in the more general context of the research and planning of the maritime space, is remote sensing, employing magnetometer, sonar, echo side scan sonar, single and multibeam, sub-bottom profiler. These instruments are transported on boats, research vessels, or equipped underwater vehicles (AUV Autonomous Underwater vehicles and ROV Remotely Operated Vehicles); in other cases, they are settled on hydrographic drones. Sometimes mini submarines are also used.

These are non-destructive technologies, which allow you to investigate the seabed and inland waters by offering overviews and details without diving.

These tools are used for:

a) determine the depth (hydrographic surveys)
b) explore the seabed to identify superficial and deep sediments, geomorphological and archaeological features, structural works, and systems
c) measure the thickness of the layers that characterize the sedimentary cover at the bottom, detect gas pockets, reservoirs, rocky outcrops, geological hazards, wrecks, traces, and ancient and modern anthropic structures
d) identify objects, wrecks, and structures half-buried or buried in sediments

The methodological aspect provides a systematic sequence (for archaeology, but also all the sector of planning):

II. Topographical arrangement of the survey area
III. Hydrographic survey with on-site data acquisition
IV. Data transmission to computers
V. Data processing with management software

VI. Interpretation of anomalies

In the archaeological field, it is necessary that the instrumentation can acquire data with an adequate resolution so that the anomalies detected can be traced back to unambiguous interpretations.

Remote sensing investigations constitute the basis for all research and protection activities of the underwater archaeological heritage.

1. Always plan major works bearing in mind from the outset the participation of a team of qualified archaeologists in order to be able to examine the consistency of the cultural heritage of the construction site in the preliminary phase of the works, whatever the work to be done.
2. Always consider that many geological investigations are also very useful for the preventive verification of the archaeological interest, therefore coordinating the activities together.
3. The instrumentation allows non-invasive investigations starting from a depth of 30 cm (with the use of hydrographic drones suitably equipped with geophysical instruments): we have to investigate also very shallow waters.
4. The tools (magnetometer, sonar, echo side scan sonar, single and multibeam, sub-bottom profiler) can be used for non-destructive surveying, mapping, imaging, research, inspection, and monitoring of submerged sites, whether exposed or buried.
5. All the surveys must be carried out with a quality that allows the interpretation and reading of the data in a detailed manner (the resolution that possibly offers a centimeter reading of the seabed) so that the preventive verification can play the role of indicator useful for the planning of the works. All the tools will be calibrated by specialized personnel capable of making sure that the return of the data is functional to archaeological reading, facilitating the hermeneutical process of mapping.
6. Correct positioning of anomalies and findings forms the basis for developing research and specific protection actions.

7. All the work carried out must be carefully filed, through data exchange systems, for this reason, it would be very important to standardize and systematize the databases relating to underwater cultural heritage at an international level.

IV - Conclusions: Recommandations for MSP

Scientific knowledge is an important factor in providing new information to improve on specific issues useful for PSM implementation.

Thanks to the different monitoring approaches developed during our clustering projects it was possible to identify that a good MSP management have to:

- define different design scales
- identify the existing environmental status, socio-economic and cultural conditions
- analyze future conditions and trends to evaluate possible synergies and trade-offs between human and environmental interests
- coordinate within Member States to streamline decision-making processes, to support cross-border cooperation and consultation
- develop of public information systems involving stackholders such as the general public, non-governmental organizations (NGOs), and anyone who may be interested in the development of a given maritime region

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