WP3 – Activity 3.4
ICT –GIS data set

- Deliverable 3.4.2

Knowledge of alterations to marine physicochemical, trophic and marine ecosystems in coasts / ports

- Deliverable 3.4.3

Integrated methodologies protocols such as geophysics, geochemistry, geomorphology, biology, ecology, etc., for the geomorphological and hydrodynamic characterization of sea areas, coastal marine areas and tourist harbors to rebuild with great detail the batimetry map, the depositional and structural layout of sedimentary layers up to a depth of several meters under the seafloor

- Deliverable 3.4.4

Surface sampling on sites chosen appropriately, to know the surface sediment distribution and the stratigraphic structure of the subsoil. Samples serve to calibrate geophysical surveys and will be subjected to laboratory analysis for compositional and biological characterization

- Deliverable 3.4.5

Identification of environmental pressure sources to be managed

- Deliverable 3.4.6

Development of Integrated-Coastal Zone Management (ICZM) tools to respond dynamically to ongoing changes

- Deliverable 3.4.7

Installation of continuous monitoring networks in the marinas

- Deliverable 3.4.8

Remediation programs for pollution of the water resources and sediments

- Deliverable 3.4.9

Valorization of water resources will cover the natural cycle but also the gestion systems of water resources derived from rain drainage, recovery of the gray waters, wastewater recovery

Project Acronym	ECOMAP
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Project Title	Ecosustainable management of marine and tourist ports
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Contents

Introduction - pressures on the coastal zone

The project IT-HR INTERREG "ECOMAP" aims to define strategy for implementing eco-sustainable management of marine and tourist ports. Indeed, the project foresees *"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"*.

Coastal zones, where a large proportion of the world population lives, form the interface between the land and sea or ocean hosting key infrastructures, ecosystems and about 40% of the world's global population (Martinez et al., 2007). In addition, the coasts undergo constant changes due to fluvial sediment input, nearshore currents and wave sediment transport. Extreme events, like sea storms or sea level rise, may also accelerate the coastal morphology inducing erosion and leading to possible irreversible changes (Nicholls et al., 2007). Coastal zones are therefore under serious threat because of extreme events and flooding, urbanization, sand extraction, salinization of estuaries and of coastal aquifers, and shoreline erosion and retreat (see Figure 1).

Human presence also leaves a strong footprint, either through planned exploitation of coastal resources or as a side effect of activities that result in deterioration of the coastal environment (Mentaschi et al., 2018). For instance, breakwaters, jetties and other large-scale port structures affect local wave conditions, currents and sediment transport processes, that in turn cause significant changes in the configuration of the adjacent shoreline as reported in literature (Kudale, 2010). Similarly, Schoonees et al. (2019) explained how wave reflection caused by emerged shore-parallel structures increases wave energy in front of the defence, increases scouring, and may result in erosion and the loss of intertidal. The same authors provided a review on coastal infrastructures, giving information on which type of solution is suitable for given characteristics.

The construction of coastal infrastructures and related-dredging activities interfere with the coastal processes of the coastal areas. Kolman (2014) reported that "Everyone seems to agree that dredging is an activity that puts pressure on the ecosystem but how severely, how often and how long lasting? And what about the social and economic importance of maritime infrastructure and port development?". An important study regarding the impacts of the infrastructures on coastal zone and sediment management has been PROVIDED by Bianchini et al. (2019). Indeed, in harbour/marina areas, the hydrodynamic conditions may induce sediment deposition resulting from solid transport. As a consequence, ordinary dredging operations should be performed to maintain, for instance, the navigation conditions. However, these operations have environmental impacts on marine flora and fauna. The sediments are often polluted, with e.g. heavy metals (such as copper, cadmium, mercury, etc…), and consequently limiting management options (Svensson et al., 2022) to avoid the remobilization and dispersion of contaminants and pollutants present in the silted sediments (Bianchini et al., 2019).

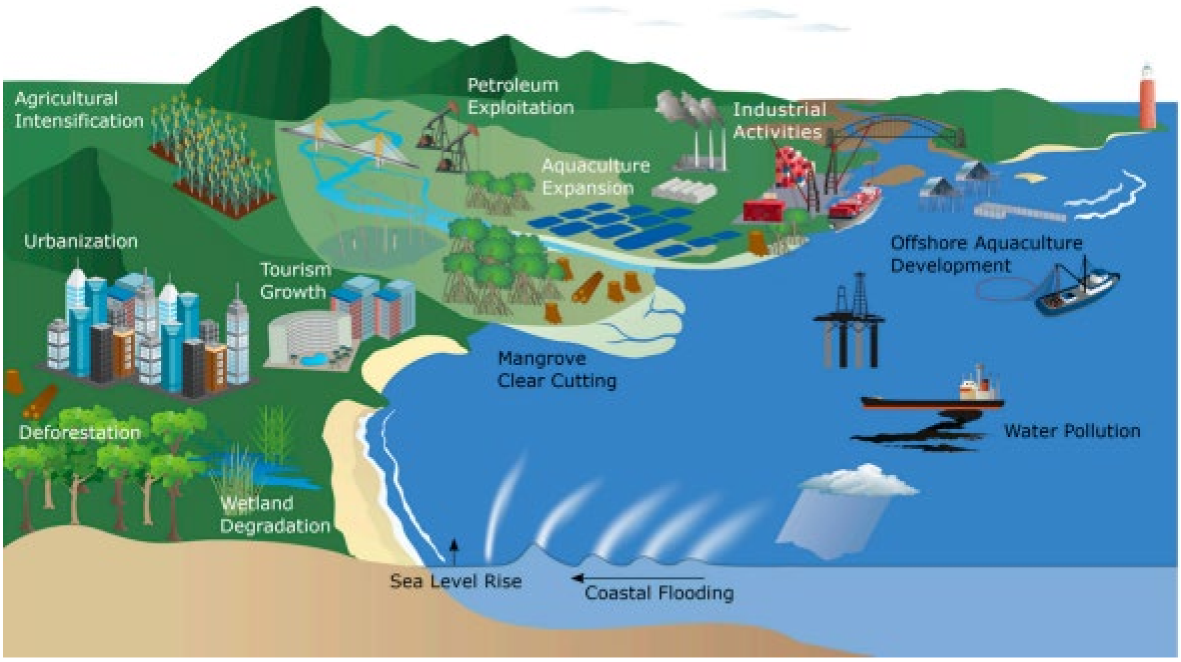

Figure 1: Activities and impacts in the coastal zone (from Ottinger and Kuenzer, 2020)

Where sediments contain contaminants, these may be released by dredging. Most contaminants of concern are of two broad types: organic compounds and heavy metals. Many organic compounds, are degraded by bacteria, and only those which are both toxic and slow to degrade are of major concern. Such compounds include polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides, polychlorinated biphenyls (PCBs) and petroleum hydrocarbons.
Regarding the contamination of re-suspended sediments, Roberts (2012) reviewed the toxicological effects on benthic fauna and associated species in relation to the remobilization of particulate-bound contaminants into the water column. He analyzed over 100 scientific papers and reported that Nelson et al. (1987) measured elevated particulate-bound Cu and PCB concentrations for approximately 2 days after dredging operations at sites (Black Rock Harbour, USA) up to 400 m from the dredging location. Cornelissen et al. (2008) also observed a

remobilisation of contaminants. In addition, the same authors reported that dredging operations in sites without a confinement sill showed increased fluxes of PAHs and PCBs to the dissolved phase during deposition of dredged materials in a confined aquatic disposal facility. Nevertheless, Urban et al. (2010) did not observe short-term toxicity with waters collected before or during the dredging operation, even if low level of contamination lowered the water quality in the near-field water column without causing significant acute toxicity effects on the organisms tested.

Dredging operations may also affect the provision, protection and regulation of ecosystem services. UNEP (2014) highlighted that although the consequences of substrate mining are hidden, they are tremendous ().

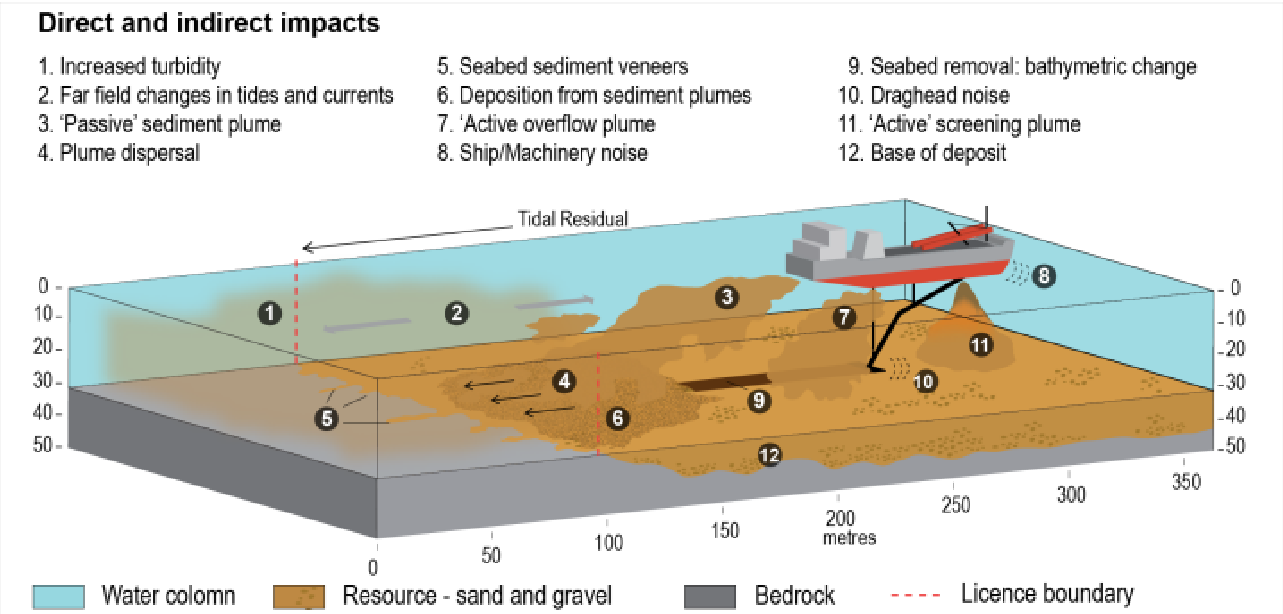

Figure 2: Direct and indirect consequences of aggregates dredging on the marine environment (UNEP, 2014, adapted from Tillin et al., 2011)

Marine sand mining has had an impact on seabed flora and fauna (Krause et al., 2010). Dredging and extraction of aggregates from the benthic (sea bottom) zone destroys organisms, habitats and ecosystems and deeply affects the composition of biodiversity, usually leading to a net decline in faunal biomass and abundance (Desprez et al., 2010) or a shift in species composition. In addition, dredging operations, essential for harbour maintenance, inevitably re-suspends sediments in the water column, increasing turbidity. Turbid waters directly impact fish species

when their larvae confuse sediment particles for food, resulting in less food eaten and far less larval survival (Partridge and Michael R. J., 2010). Turbid waters contribute to the deterioration of microbiological water quality since resuspended particles can contain large numbers of attached allochthones microorganisms, including pathogenic ones.
Furthermore, dredging operations also lead to severe changes in the coastal morphology, which may modify the currents, waves and water quality in the coastal area. These effects include:

- Changes of the seafloor morphology
- Changes in circulation patterns and sediment transport processes;
- Low mixing and poor water quality near the bottom of dredged basins and channels, resulting in low levels of dissolved oxygen;
- Potential for increased salinity intrusion in estuaries;
- Potential for local increase in wave heights due to changes in wave refraction patterns;
- Potential for increased sedimentation rates and future maintenance dredging requirements and
- Potential for beach erosion due to loss of sand sources

Such effects have been reviewed by Esfandiari et al. (2015), Lalèyè et al. (2020), Erftemeijer et al., 2012, Bonvicini pagliai et al. (1985), Guerra et al. (2009).

Moreover, additional environmental issues, considered as important challenges to sustainable development in the coastal zone, are illustrated in the literature and include:

- Waste disposal: for instance, Zhai and Hawkins (2002) observed an increase of nutrient causing eutrophication due to sewage discharge, and having negative effects on aquaculture with the potential for toxic blooms. The same authors reported that sewage discharge may also cause serious public health problems.
- Degradation of Coastal Ecosystems: sandy beaches have given way to tourism or other forms of development, reducing turtle nesting habitats. Mudflats, salt ponds and coastal lagoons have been filled to provide sites for urban development eliminating breeding grounds for marine organisms and birds. (UNEP, 1989). Other examples are provided by coastal construction that threaten beach and dune stability, or the construction of groins, sea walls and jetties.
- One of the largest threats to the sustainability of the coastal zone is the growth in coastal populations. Coastal population growth increases demand for a continuing supply of

clean water, waste disposal, public health, food and protection from natural disasters (Duxbury and Dickinson, 2007)

- Increased pressures on ecosystems from recreation and tourism, and from the infrastructure needed to accommodate these in the form of roads, bridges, parking lots and sewers (Duxbury and Dickinson, 2007).
- Land use changes and conflicts.
- Fishery activities, aquaculture, etc…

For instance, Gupta et al. (2005) reported that various port and harbour activities including dredging operations, materials disposal, shore zone development, increased maritime traffic and vehicular traffic in the port can results in the release of natural and anthropogenic contaminants to the environment. The pollution problems usually caused by port and harbour activities can be categorized as follows (Gupta et al., 2005):

1. Coastal habitats may be destroyed and navigational channels silted due to causeway construction and land reclamation.
2. Unregulated mariculture activities in the port and harbour areas may threaten navigation safety.
3. Deterioration of surface water quality may occur during both the construction and operation phases.
4. Harbour operations may produce sewage, bilge wastes, solid waste and leakage of harmful materials both from shore and ships.
5. Human and fish health may be affected by contamination of coastal water due to urban effluent discharge.
6. Oil pollution is one of the major environmental hazards resulting from port/harbour and shipping operations. This includes bilge oil released from commercial ships handling non-oil cargo as well as the more common threat from oil tankers.
7. Air pollutant emissions due to ship emissions, loading and unloading activities, construction emission and emissions due to vehicular movement.

One of good indicators of the level of ports' pollution, but also of how responsibly ports activities are managed, is the microbiological quality of seawater and sediments. In these areas, sea currents, wave action, and sediment transport can contribute to the spread of contaminants into adjacent marine ecosystems. Although bathing and recreation are prohibited in ports, so the microbiological quality of seawater does not directly affect human health risk, many ports are located near beaches and vulnerable areas and thus pose a risk to the health of the ecosystems themselves and to humans if potentially pathogenic microorganisms enter bathing waters. There are several sources of microbiological pollution in ports: pollution from adjacent areas from waves and currents, uncontrolled discharges from restaurants and boats, seabirds accompanying boats or congregating in ports in search of food. Since there are no regulation for the microbiological quality of water in ports, the goal of the ECOMAP project was to achieve at least good water quality according to the regulation on bathing water quality, the EU Bathing Water Directive (EU, 2006). Such water quality would be evidence of good management of the port, but also of an acceptable risk of negative environmental impacts, as well as the risk of recreation in bathing waters in adjacent areas.

Additionally, anthropogenic pressure in the area can be also assessed using other indicators, such as chlorophyll *a* (Chl *a*) and heterotrophic bacteria (HB) (Smith et al., 1999; Cotner and Biddanda, 2002).

From this short overview, it clearly appears that the management of coastal areas regards multiple problems and sources of those problems, multiple objectives to produce desired outputs from the use of coastal resources. As stated by the European Commission “Because the well-being of populations and the economic viability of many businesses in coastal zones depend on the environmental status of these areas, it is essential to make use of long-term management tools, such as integrated coastal management, to enhance the protection of coastal resources whilst increasing the efficiency of their uses.”

The concept of sustainable development

In 1987 the World Commission for the Environment and Development, in the Brundtland Report (WCED, 1987), elaborates the concept of sustainable development as

“the form of development that meets today's needs without compromising the ability of future generations to meet their own needs”

The Commission's hope for the future is conditional on decisive political action now to begin managing environmental resources to ensure both sustainable human progress and human survival. Sustainable development becomes a necessary condition so that the heritage of natural resources is not irremediably damaged, thus attempting, for the first time, in the name of the principle of intergenerational equity, to combine economic development and environmental protection. Indispensable main components of sustainable development; environmental sustainability, economic sustainability, social sustainability and political sustainability, and it is emphasized that sustainable development can take place if environmental, economic, social and political sustainability is achieved (Kuleli et al., 2022).

Successively at the **Earth Summit in Rio de Janeiro**, Brazil, in 1992, the UN Conference on Environment and Development adopted two seminal documents that define the sustainable development paradigm:

- the Rio Declaration on Environment and Development, a statement of 27 principles that outline the common narrative and vision of the international community in regards to the challenges posed by the integration of environment and development;
- and Agenda 21, an action plan and blueprint for achieving sustainable development. Agenda 21 notes that 'strategies, plans, policies, and processes are crucial to its successful implementation, including national and international economic policies.In order to develop the appropriate policies, the document calls for broad public participation and the active involvement of nongovernmental organizations (NGOs) and other major groups.

The Rio Declaration adopts and broadens the new approach, adding other corollaries, such as the need for a global partnership for the protection of the environment with common responsibilities but differentiated, the obligation of information and public participation in decision-making processes, the obligation of the prior evaluation of environmental impact of the main national activities having effects on the environment and the promotion of economic tools to identify the costs for protecting the environment. In particular art. 10 of the Rio Declaration mentions
"*Environmental issues are best handled with the participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided*."
As reported by El-Sabha et al. (1998), the Council of the Organization for Economic Cooperation and Development (OECD), in 1993, adopted a series of recommendations on designing and applying new coastal zone management models that incorporate environmental and socio-economic concerns. That same year, the first World Coastal Conference, held in the Netherlands, produced a set of guidelines for the integrated management of coastal zones (Noordwijk Declaration), including institutional and general public roles and responsibilities in the coastal zone.
In November 1994, the Intergovernmental Oceanographic Commission (IOC) convened the "Second International Conference on Oceanography: Toward Sustainable Use of Oceans and

Coastal Zones” in Lisbon, which re-affirmed the long-term commitment of the international marine science community to achieving sustainability in ocean use.
The interest of the European Union in sustainable development grew in parallel with the initiative of the United Nations on the same issue. Indeed, at EU level, the Convention ('The Convention for the Protection of the Mediterranean Sea against Pollution and its Related Protocols') after its adoption in 1976 entered into force in 1978 (PAP/RAC-MAP, UNEP, 1995). The original text of the Convention, as adopted in 1976, remained unchanged until its recent revision in 1995.
UNEP/MAP and the Contracting Parties to the Barcelona Convention – 21 Mediterranean countries and the European Union -- have progressively erected a uniquely comprehensive institutional, legal, and implementing framework integrating essential building blocks for sustainability in the Mediterranean. The Convention, together with its 7 Protocols, forms a legislative framework of the Action Plan for the Mediterranean (MAP), which represents one of the various UNEP Programs on the “Regional Seas”, and a programmatic reference framework, the implementation of which is achieved precisely through the adoption of specific protocols that embody the principles set out therein.
The MAP also has another important legal document, "Regional Climate Change Adaptation Framework for the Mediterranean Marine and Coastal Areas ", approved in February 2016. The main objective of the Framework is to define a regional strategic approach to increase the resilience of the Mediterranean marine and coastal natural and socioeconomic systems to the impacts of climate change, assisting policy makers and stakeholders at all levels across the Mediterranean in the development and implementation of coherent and effective policies and measures (UN Environment, 2017).
There are also conventions that deal with specific aspects relating to excavation/mining activities and, as a matter of fact only marginally concern the coastal management as a whole. For instance, the 1996 Protocol to the 1972 London Convention on the prevention of marine pollution caused by waste immersion. It represents a major change of approach to the question of how to regulate the use of the sea as a depository for waste materials. Rather than stating which materials may not be dumped, it prohibits all dumping, except for possibly acceptable wastes on the so-called "reverse list" (https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/PROTOCOLAmended2006.pdf)
Similarly the European Directives concerning the identification of coastal marine environments for conservation purposes such as Directive 92 / 43 / EEC of the Council of 21 May 1992, relating to the conservation of natural and semi-natural habitats and of wild flora and fauna, which in Annex I - "Types of natural habitats of community interest whose conservation requires the

designation of special areas of conservation ”, identifies among others: 1.1 Marine waters and tidal environments; 1.2 Sea cliffs and pebble beaches; 2.2 Sea dunes of the Mediterranean coasts.

ICZM Protocol

Relate to Deliverable 3.4.6 – WP3

The Protocol on the Integrated Coastal Zone Management of the Mediterranean (signed in Madrid on 21 January 2008), ratified by the EU on 13 September 2010 with Council Decision 2010/631/EU and entered into force on 24 March 2011. The ICZM Protocol aims to promote a common framework for the integrated management of Mediterranean coastal areas.
According to the **ICZM Protocol**, integrated coastal zone management refers to
“*a dynamic, multidisciplinary and iterative process to promote sustainable management of coastal zones. It covers the full cycle of information collection, planning (in its broadest sense), decision making, management and monitoring of implementation. ICZM uses the informed participation and cooperation of all stakeholders to assess the societal goals in a given coastal area, and to take actions towards meeting these objectives. ICZM seeks, over the long-term, to balance environmental, economic, social, cultural and recreational objectives, all within the limits set by natural dynamics. 'Integrated' in ICZM refers to the integration of objectives and also to the integration of the many instruments needed to meet these objectives. It means integration of all relevant policy areas, sectors, and levels of administration. It means integration of the terrestrial and marine components of the target territory, in both time and space*.”
(EEA definition, https://www.eea.europa.eu/help/glossary/eea-glossary/integrated-coastal-zone-management).

However, in the literature we may found different definitions of Integrated Coastal Zone Management like:

- “*A continuous and dynamic process that recognises the distinctive character of the coastal zone -itself a valuable resource- for current and future generations*” (Cicin-Sain, 1993);
- “*A holistic approach, in which the ecosystem as a whole (all the biotic and abiotic components) and all kinds of coastal use, as well as all use -use and use- ecosystem relationships are included*” (Vallega, 1993)
- “*The integrated planning and management of coastal resources and environments in a manner that is based on the physical socio-economic, and political interconnections both*

within and among the dynamic coastal systems, which when aggregated together, define a coastal zone" (Sorensen 1997);

- "*Integrated coastal management is a process that recognises the distinctive character of the coastal area -itself a valuable resource- and the importance of conserving it for current and future generations*" (Cicin-Sain and Knecht 1998)
- "*ICZM aims to preserve coastal resources, their ecological functioning and ultimately their values by applying adequate land use planning within a social, institutional and economic context*" (Skourtos et al 2005)

Regarding the European policy on coastal zones, it is important to remind the "Fifth Program of Action for the Environment" as well as the "Sixth Program of Action for the Environment" (2002 - 2012), in response to a request from the European Parliament and Council to define a global strategy for Integrated Coastal Zone Management.
The Fifth Programme set the following targets for 2000:

- better coordination of relevant policies at and between all levels of administration;
- a framework for integrated coastal zone management;
- development of criteria for a better balance of land-use, conservation of land and use of natural resources;
- awareness raising of the public and economic and public sectors.

The Sixth Programme promotes full integration of environmental protection requirements into all Community policies and actions and provides the environmental component of the Community's strategy for sustainable development.
In addition, it is important to cite the "Demonstration Program" on ICZM launched in 1996 by the European Commission, to provide technical information about sustainable coastal zone management, and to stimulate a broad debate among the various actors involved in the planning, management or use of European coastal zones.

Based on the outputs of the Demonstration Programme, eight EU ICZM principles were agreed upon (COM 2000), which are also referred to as eight best practice principles (Table 1) that the Member States have to consider when developing their strategies for ICZM.

Table 1: Eight principles for the best practice of coastal management (from Tuuli Veersalu, Kalev Sepp, Henri Järv, Maaria Semm, 2011, The best practices of coastal zone protection and conservation in spatial planning)

	Principle	Explanation
1	A broad holistic perspective (thematic and geographic)	• holistic nature, interconnected natural systems (holistic principle) • treatment of coastal zone as a whole: terrestrial + marine areas
2	A long term perspective	• application of precautionary principle • the needs of both present and future generations must be considered equally and concurrently (now)
3	Adaptive management – gradual process	• adjusting new information and new circumstances – an ongoing process that does not end • needs a good scientific basis on the evolution of coastal zones
4	Reflect local specificity, we base on a specific situation	• specific issues get specific solution • a comprehensive approach will realise through specific solutions
5	Work together with natural processes	• respecting the carrying capacity of the ecosystems – emphasising the ecosystem-based approach
6	Involving all the relevant stakeholders - participatory planning	• involving all stakeholders into the coastal management process • sharing responsibility, obtaining approval
7	. Support and involvement of all relevant administrative bodies	• involvement of administrative bodies of national, regional and local level (and policies) and coordinated cooperation
8	Use of a combination of instruments (legal instruments, economic instruments, technological solutions, research, voluntary agreements, social stimuli etc.) to achieve results	• coherence between sectorial policies • coherence between planning and management (implementation)

Nowadays, it is widely known that the implementation of ICZM is a medium-term, complex, multidisciplinary and iterative process, which needs to be gradually established, adapted and improved. The process is seen as a progressive cyclical development and it includes several steps; from the moment in which a coastal management process begins to the point when the ICZM is completely and successfully established. Based on the experience of many countries, it takes from 8 to 12 years to go through an ordinary ICZM process. It is usually represented by the ICZM policy cycle, like the cycle represented in Figure 3, but always has the basic idea of the **initiation–planning–implementation–evaluation** steps. In other words, it begins with the identification of issues, adoption of an action plan and ensuring availability of necessary funding and will be completed by implementation process.
Each cycle could be considered as an ICZM program in itself and is limited by the geographic area covered and by the number of stakeholders and economic sectors involved. Once one ICZM program is successfully accomplished, the outcomes of the cycle are evaluated and used to improve the existing policy and action plan and the program can become wider in scope.

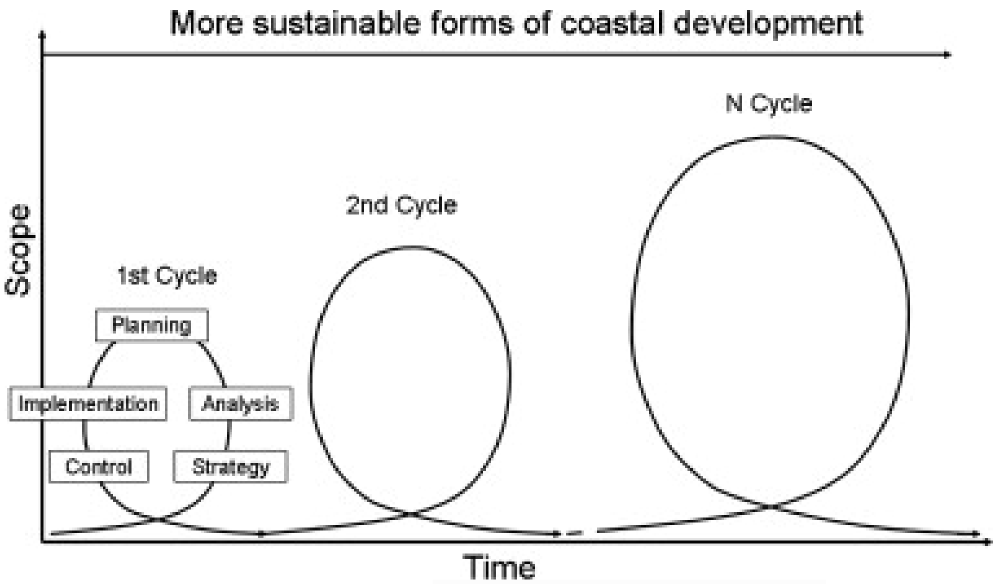

Figure 3: ICZM policy cycle (from González-Riancho et al., 2009).

Based on the experiences and results of the demonstration program, the European Union then adopted two relevant documents

- **Communication COM / 2000/547** from the Commission to the Council and the European Parliament on integrated coastal zone management: a strategy for Europe of 27 September 2000. It aims to promote a collaborative approach to planning and management of the coastal zone, within a philosophy of governance by partnership with civil society (https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2000:0547:FIN:EN:PDF).
The Communication of the European Commission COM / 2000/547, illustrates the Community work program to promote the integrated coastal zone management through the use of Community tools and programs, proposing a collaborative approach to the planning and management of coastal zones to the Member States.
- **Recommendation 2002/413 / EC** of the European Parliament and of the Council on the implementation of integrated coastal zone management in Europe of 30 May 2002.
It proposes to the Member States to adopt a strategic approach for the management of their coasts based on a series of actions for the protection of coastal ecosystems, for the development of employment and for economic and social development preserving the environmental values.
Further strategies have been adopted to protect the marine environment, and in particular the "**Marine Strategy Framework Directive**" (MSFD, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32008L0056&from=EN), which aims to protect the marine environment. It requires the application of an ecosystem-based approach to the management of human activities, enabling a sustainable use of marine goods and services. In order to implement the Directive each member state is required to:

- describe what they consider is a clean, healthy and productive sea i.e. Good Environmental Status
- **monitor** and assess the quality of their seas against Good Environmental Status, and
- ensure they take appropriate action by 2020 to maintain or achieve Good Environmental Status.

Like for the ICZM strategy, the MSFD is a cyclical process with each cycle taking 6 years (Figure 4). It requires EU countries to develop marine strategies following a specific timeline. The process follows a logical sequence of looking at the current state of the marine environment and setting targets, developing monitoring to measure progress against the targets, identifying measures that are needed to achieve the targets and then ongoing monitoring, evaluation and adaptation.

Figure 4: MSFD process (from the European Commission https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/implementation)

Therefore, as well illustrated by Creamer et al. (2020), the Directive enshrines in a legislative framework the ecosystem approach to the management of human activities having an impact on the marine environment, integrating the concepts of environmental protection and sustainable use. According to the MSFD, marine strategy should be adopted that includes 5 steps (Figure 5)

Figure 5: How EU Member States develop marine strategies (from Creamer et al., 2020)

In addition, we should also consider the **Integrated Maritime Policy (IMP**) of the European Union (EU) is a holistic approach to all sea-related EU policies. It is based on the idea that the Union can draw higher returns from its maritime space with less impact on the environment by coordinating its wide range of interlinked activities related to oceans, seas and coasts. Indeed, it encompasses fields as diverse as fisheries and aquaculture, shipping and seaports, marine environment, marine research, offshore energy, shipbuilding and sea-related industries, maritime surveillance, maritime and coastal tourism, employment, development of coastal regions, and external relations in maritime affairs. Hence, the IMP aims at strengthening the so-called blue economy, encompassing all sea-based economic activities. It set in place in 2007 (Blue Paper (COM (2007) 0575) with a corresponding Action Plan (SEC (2007) 1278).
The **IMP** is a framework to facilitate the development and coordination of diverse and sometimes conflicting sea-based activities, with a view to:

- maximising the sustainable use of the oceans and seas, in order to enable the growth of maritime regions and coastal regions;
- building a knowledge and innovation base for maritime policy
- improving quality of life in coastal regions
- promoting EU leadership in international maritime affairs

- raising the visibility of maritime Europe, and
- creating internal coordinating structures for maritime affairs and defining the responsibilities and competences of coastal regions

To reach these IMP suggests several tools and cross-cutting policies:
• Blue Growth a cross-cutting policy tool
• Maritime Data and Knowledge
• **MSP** (economic pillar that helps Blue Growth to evolve)
• Sea-Basin Strategies
It should be mentioned that the Marine Strategy Framework Directive stands for the environmental pillar MSP is presented as the economic pillar that helps Blue Growth to evolve

Maritime spatial planning – MSP

The Maritime spatial planning (MSP – Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for Maritime Spatial Planning) 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. Specifically, the objectives of the MSP directive are reported in Art. 5 which are:
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.”
Information regarding MSP in Italy are reported in European Commission (2020)
It is also important to highlight that the adopted MSP Directive requires maritime spatial plans to “take into account” land-sea interactions as maritime and coastal activities are closely interrelated as illustrated in Figure 6.

Source: Willemijn Lambert

Figure 6: Maritime Spatial Planning and Land-Sea Interactions (from Creamer et al., 2020)

MSP strategy is an important concept for harbour development, where several conflicts and pressures occur. The development of maritime spatial plan will favor stakeholders' involvement, which is crucial for environmental management issues. Environmental Management Plan (used in MSP process) is a suitable tool to support the analysis and monitoring of pollution levels, to identify sources and to ensure adequate intervention and management practices. The concept of collaboration with stakeholder involvement in the development of port activities has been further discussed in the literature. For instance, Hall et al. (2013) explores the role of stakeholder collaboration in the adoption of innovations within the environmental and sustainability agenda of West coast port gateways (USA), while Dooms (2019) underlines the growing importance of local community inclusion for port sustainability and identifies key elements to be taken into consideration in future port planning and design processes. More recently, Zaucha and Kreiner (2021) analyzed engagement of stakeholders in the marine/maritime spatial process and concluded that stakeholder engagement is among the key factors of MSP success regardless of the level of prosperity of the country or advancement of the MSP process. The same authors highlight that such process requires a conscious approach, preferably including the preparation of a stakeholder engagement strategy, or a continuous process of capacity building of MSP stakeholders, even done outside the formal MSP process.

An interesting paper dealing on the implementation and development of the MSP is given with the management of the Port of Ravenna with the creation of a Locally Integrated Partnership useful to develop a multi-term Smart Port Management Strategy to support innovation processes in the sustainable and safe management of the port (Campisi et al, 2022). In the Port of Ravenna, the state-owned areas managed by Port Authority (public authority managing the port area) are limited to 50 mt-width harbour quay, while the remaining areas are owned by private companies. The authors described how it was possible to implement a SPMS of Ravenna with a multi-stakeholder participatory approach, which favoured the activation of many public funds to modernize port infrastructure, as well as private investments for the development and dissemination of innovations and for the sustainable use of port area (Campisi et al., 2022). This study demonstrated the benefits of a participatory and inclusive process in decision-making processes, with a benefit for all the key aspects of sustainability for a modern port or productive hub.

Relevant Definitions

Relate to Deliverable 3.4.3 – WP3

The monitoring activities associated to harbour may concern the following issues (a) water quality; (b) coastal hydrology; (c) bottom contamination; (d) marine and coastal ecology; (e) air quality; (f) noise and vibration; (g) waste management; (h) visual quality; and (i) socio-cultural impacts. However, before discussing the physical monitoring through bathymetry surveys, it may be necessary to provide some definitions regarding the coastal areas.

From a holistic point of view the "coastal zone" does include the land, seabed, marine waters, terrestrial waters and aquifers, atmosphere above, and associated areas of vegetation, animal habitat, and human activity. But one important question regards **where does the coastal zone begin and ends**? The definition is variable and tends to depend upon the problem, subject area or ecosystem under consideration. The coastal zone is considered as a transitional area between land and sea. It is defined, as a strip of land and sea of varying width depending on the nature of the environment and management needs. For practical planning purposes, the coastal zone is a special area endowed with special characteristics, of which the boundaries are often determined by the specific problems to be tackled

However, there is a great disparity in the literature relating to the definition and delimitation of the coastal zone, in particular with regard to landward boundaries. However, there is a general conformity that the term “coastal” conveys the notion of a land–sea interface. This interface has two axes, one parallel to the shore (long-shore) and the other perpendicular to it (cross-shore) (OECD, 1993, Massoud et al., 2004).

Massoud et al. (2004) highlighted that “the inland definitions of the coastal zone vary from those that include **entire** watersheds to those that comprise only the immediate strip of shoreline adjacent to the coast, while the seaward limit can extend as far as the maximum reach of the jurisdiction of a country.” Carter (1988) defined the coastal zone as the space in which terrestrial environments influence marine (or lacutsrine) environments, and vice versa. It is of variable width and may also change in time. For Cicin-Sain et al. (1995) coastal areas are the interface or transition areas between land and sea, including large inland lakes. Clark (1992, 1995) defined the coastal zone as the inter-tidal and supra-tidal areas of the water’s edge; specifically, all the coastal floodplains, mangroves, marshes and tide flats as well as beaches and dunes and fringing coral reefs.

In addition, Cicin-Sain and Knecht, (1998) identified five main zones in the coastal-marine spectrum:

- inland areas, which affect the oceans mainly via rivers and non-point sources of pollution;
- coastal lands--wetlands, marshes, mangroves, swamps, flood plains, Beaches, dines, wave-cut platforms, cliffs, rock ledges and escarpments, and associated environment - where human activity is concentrated and directly affects adjacent waters;
- coastal waters--generally estuaries, rivers, streams, lagoons, and nearshore waters, sea bed and reef - where the effects of land-based activities are dominant,
- offshore waters, mainly out to the edge of national jurisdiction (200 nautical-miles offshore); and
- high seas, beyond the limit of national jurisdiction.

In Figure 7 are illustrated some important concepts generally used for coastal management and planning. These are defined as: Littoral, Coastal Zone, Coastal Border, and Coastline.

Another important concept is the **closure depth**, which definition, according to (Kraus et al., 1998) is:

The inner depth of closure marks the transition from upper to lower shoreface, corresponding to the most landward depth seaward of which there is no significant change in bottom elevation during a given time intervalhttp://www.coastalwiki.org/wiki/Closure_depth_-_cite_note-kraus_et_al_1998-1. The outer depth of closure marks the transition from lower shoreface to continental shelf, and corresponds to the depth where the influence of wave action on cross-shore sediment transport is on average insignificant compared to other influences.

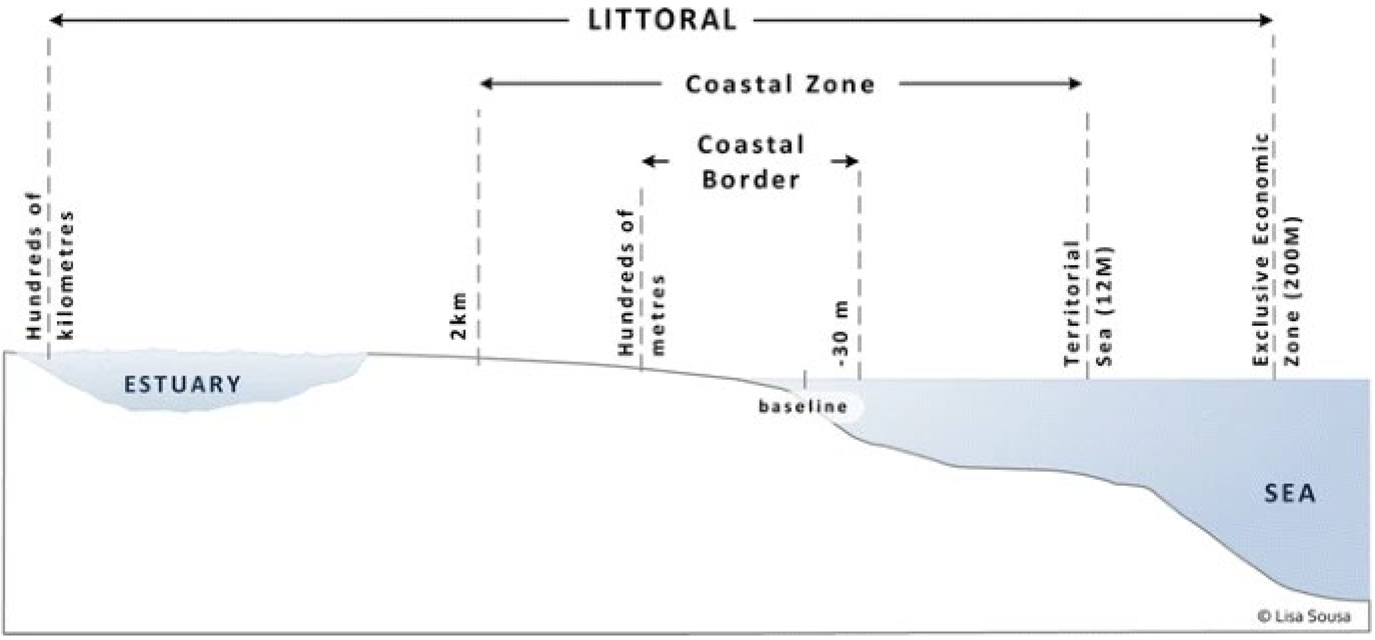

Figure 6: Coastal zone concepts and boundaries (source from Alves et al., 2013)

Finally, it should be also illustrated the concept of **resilience**, which is well illustrated by Creamer et al. (2020). These authors reported that" there are new and increasing pressures on marine and coastal resources with socio-economic and environmental changes and challenges through the exploitation of marine resources, decline and regeneration of coastal communities, and the predicted impacts of climate change. Such issues may be informed by resilience thinking in order to guide future changes."

The same authors reported that Holling (1973) interpreted resilience as the ability to 'bounce back'. Successively the concept included an an ecologic (Folke 2006) and a co-evolutionary perspective (Davoudi, 2012; Tempels, 2016 - Figure 8) to acknowledge the interdependencies between social and ecological systems. Definitions of resilience can contain any combination of 3 major principles (Folke et al. 2002, Bernhardt & Leslie 2013):

- the magnitude of shock or pressure that a system can absorb while remaining within a given state;
- the degree to which the system is capable of self-organisation in light of the shock or pressure; and
- the degree to which the system can build capacity for adaptation and learning to skip towards a new, more sustainable framework.

Resilience is not merely the ability of a system to maintain the status quo but its capacity to prepare, adapt and innovate, and take advantage of emerging transformative opportunities (Folke, 2006). Ultimately, at the core of any definition of resilience, is the capacity of a system to keep functioning even when disturbed (Levin & Lubchenco 2008). Protection of the ecosystem services provided by the marine environment requires that the resilience of marine ecosystems is maintained.

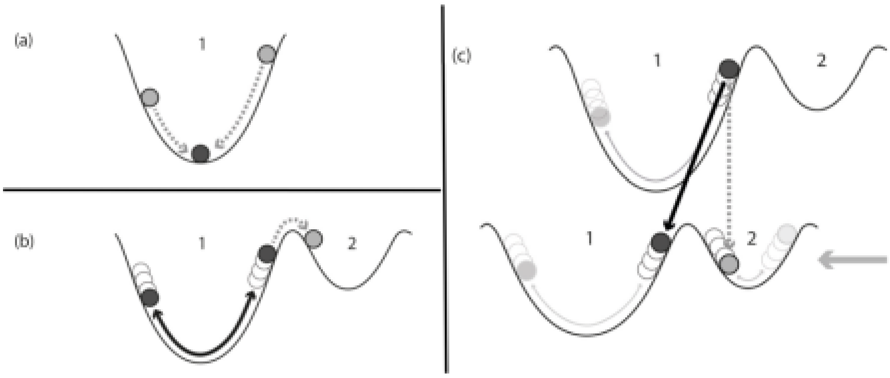

Figure 7: Engineering, ecologic and co-evolutionary resilience (source: Tempels 2016)

Monitoring bathymetry techniques

As previously mentioned, the different hazards affecting the coastal zone are expected to increase due to the combined effects of sea level rise, climate change, and increase in human activities. The response of coastal environments to natural and direct/indirect anthropogenic forcing factors depend on the characteristics of the forcing agents, as well as on the internal properties of the highly dynamical coastal systems. Coastal observations of various types need to be collected and analyzed to better understand changes affecting coastal zones and provide crucial information to decision-makers involved in adaptation and mitigation of environmental risks.

The definition of Bathymetry provided by Emodnet (European Marine Observation and Data Network) is the following:

"Bathymetry is the information that describes the topography of the seabed. It is an essential component in understanding the dynamics of the marine environment, both in terms of sediment transport but also in the prediction of tides, currents and waves. Safe ocean navigation relies on

accurate bathymetry data, which are also essential for planning marine installations and infrastructure such as wind turbines, coastal defences, oil platforms and pipelines. Bathymetry plays also a key role in the distribution of marine species. Overall bathymetry forms the foundation of any comprehensive marine dataset; without it, the picture is incomplete."

In other word, bathymetric surveys are a type of hydrographic survey which map out the details of underwater terrain, illustrating the depth and land that lies beneath a body of water. Data can be collected for a variety of water bodies, including rivers, lakes and estuaries, and the data can be used to inform flood assessments and project developments. Detailed information on hydrographic survey is provided in the Manual of Hydrography (IHO, 2005) or by https://www.umesc.usgs.gov/documents/bathymetry/methods.pdf

The accuracy requirements for a bathymetric surveying system depend on the application of the data. In general, coastal applications require more precise nearshore bathymetry than commonly used (Aubrey et al., 1980; Plant and Holman, 1997). In addition, as observed by Melet et al. (2020) estimates of the coastal zone topography and bathymetry with high spatial and temporal resolution and a good accuracy is a prerequisite to model or estimate different drivers of coastal hazards or hazards themselves (Cazenave et al., 2017). Inaccurate or outdated coastal Digital Elevation Models (DEMs) (including topography and bathymetry) lead to flooding modelling errors that can ultimately mislead coastal risk management (Neumann et al., 2015).

Bathymetric survey of the shallow can be carried out using different techniques like with single beam or multibeam or instrumentation on routes that are much closer together the stronger the spatial variability of the morphology. However, International Hydrographic Organization (IHO) has fixed the requirements for bathymetric survey, so the necessary precision and accuracy of the hydrographic echo sounder are defined in IHO special publication S-44 (IHO, 2008).

The first proof on bathymetry measurements can be found in old Egyptian tomb painting showing a man utilizing a long thin shat as sounding pole on the bow of a huge vessel under paddle and sail (Hanif Hamem and Md Din, 2018). However, one of the earliest known systems to obtain continuous beach profiles was associated with the Wave Project, commonly referred to as "Wave Observations and Beach Surveys (WOBS)," (Bascom and McAdam, 1946). The system, known as the **Duck w** was used to obtain profiles extending to water depths exceeding 15 m at high tide along the US west coast in the 1940s (Komar, 1978). Depth measurements were made by lead sounding, while a transit onshore sighted the angle of the splash of the lead line relative to a shore parallel base-line on land. The position of the watercraft was determined using the measured angle through triangulation. Cross-shore sample spacing was approximately 9.75 m.

The stage of the tide was calculated and removed from the measurements to reduce the elevations to Mean Lower Low Water (MLLW).
Another system used for bathymetry measurements is the **sea sled** (Figure 9), which does not estimate the water level variation (Carli et al., 2004). The sea sled is a sled on which a graduated rod is placed in a vertical position. The sled is pulled offshore by a water vehicle and onshore by a truck and pulley system. The sled has a tall mast with two reflecting prisms for use with an ETS to provide readings of horizontal and vertical position and a measurement of tilt. In alternative the sled may also have a rod that emerges from the surface of the sea indicates the depth of the water which is read from the ground with a telescope. Beach sled is probably the technique with the most adequate accuracy for sediment budget studies, especially under the presence of waves; however, it is not used in Italy and in spite of being an extremely simple instrument, it faces some operational problems (Pranzini and Rossi, 2013).

Figure 8: Beach profiling sled (Ocean Survey, Inc., from Pranzini and Rossi, 2013)

Another system for bathymetry survey is represented by the **CRAB** - Coastal Research Amphibious Buggy, which aims to provide a stable platform for collection of accurate bathymetric data (Figure 10). A typical survey of a cross-shore profile consists of about 50 data points over a 1,100 m length. Data point spacing is variable, with more points taken over complex parts of the profile. Each point takes about 10 seconds to obtain, and one profile requires about 45 minutes to complete.

Figure 9: Coastal Research Amphibious Buggy (CRAB) used for beach profile measurements at the U.S. Army Corps of Engineers Field Research Facility, Duck, North Carolina. From Pranzini and Rossi, 2013)

However, today, modern bathymetric survey techniques are based on the use of sound waves (singlebeam and multibeam echo sounders) and electromagnetic waves, that is, visible light (aerophotogrammetric cameras, LiDAR systems) and radio waves (altimetric radars). Measurements are carried out in different media depending on the technique: in the aquatic environment in the case of the use of sound waves; in the air and in the aquatic environment when visible light is used and, only in the air, when bathymetry is derived from information from altimetric radars.

Single-Beam Echo Sounder (SBES)

Traditionally, bathymetric surveys are conducted using an echo sounder attached to a survey boat. The echo sensor consists of sound sources whose specialty is depth measurement. As the boat moves across the water, the echo sounder will generate electrical signals and the system measures the time interval between the output and arrival of the same acoustic pulse to the transducer. These are then converted into soundwaves by an under-water transducer. Therefore, soundwaves will bounce off features under the water and this echo is then identified by the echo sounder and the distance to the identified feature is calculated (two-way travel time, Ferreira et al., 2022, Figure 11). For this, it is necessary to know the speed of sound propagation, considering that the speed varies in time and space, since it is mainly dependent on salinity, temperature and pressure (depth).
Bathymetric survey systems rely on highly accurate GNSS (GPS) systems to link each measured distance to a particular depth on the surveying map. Once the data has been acquired, the next

stage in a bathymetric survey consists of transforming the captured from the boat into an elevated model.
"*Single beam echo sounders have reached a sub-decimetre accuracy in shallow water. The market offers a variety of equipment with different frequencies, pulse rates etc. and it is possible to satisfy most users' and, in particular, the hydrographers' needs*. (…)" (Emodnet www.emodnet-bathymetry.eu)
Because of its ease of use in terms of data interpretation and operating costs, SBES is particularly useful in very shallow waters, less than 5–10 m deep (Cesbron et al., 2021). In addition, planning, operation, processing and analysis are quite simple (Ferreira et al., 2022). This method provides single lines of data along the track of the ship. There is no information about the depth either side of the ships track. Water depth measurements are only acquired underneath the transducer. A SBES survey is usually conducted using parallel lines or tracks at a set spacing (according to the required resolution), generally perpendicular to the underwater slopes. In addition, tie lines (longitudinal lines) are run perpendicular to the primary survey lines but at wider spacing and act as a quality assurance cross-check on the acquired field data (El-Hattab, 2014). As a consequent, undetected features can exist in-between these lines. Which is a major disadvantage of this method. To overpass this disadvantage, accurate modelling bathymetric models, like Digital Terrain Models (DTM) are crucial to interpolate the depths and fill the gaps between the survey lines. According to IHO (2008), DTM with regular grids are used for determining the bathymetric model which is defined as "*a digital representation of the topography (bathymetry) of the seafloor by coordinates and depths*" Therefore particular attention should be taken when selecting the gridding interpolation technique, which directly affects the DTM uncertainty.
In the literature, several papers analyzed the effects of interpolation techniques, like Erdogan (2009), El-Hattab (2014) or Parente and Vallario (2019). Erdogan (2009) for instance investigated the size and spatial patterning of errors in digital elevation models obtained with direct survey methods for large-scale areas, comparing Inverse Distance Weighting, Radial Basis Functions and Kriging interpolation methods to generate digital elevation models. He demonstrated how the accuracy of the digital elevation model is related to data density and the interpolation algorithm used. El-Hattab (2014) provided relevant information regarding interpolation techniques (Inverse distance to a power, Kriging, Mimum curvature, modifies Shepard's, Natural neighbour, Nearest neighbour, Polynomial regression, Radial basis function, Triangulated irregular network, Moving average, Data metrics and Local polynomial.

Furthermore, Ferreira et al. (2022) further report that there is a huge range of equipment operating at low frequencies (12kHz-50kHz), high frequencies (100kHz-700kHz) and even at dual frequencies (24kHz/200kHz, 33kHz/200kHz, 50kHz/200kHz, etc.). Generally speaking, low frequencies are less attenuated in water and therefore have a greater range. Typical frequencies used in bathymetric surveys are, in general (IHO 2005, Sherman and Butler 2007):

1. frequencies above 200 kHz for depths below 200 meters;
2. frequencies between 50 and 200 kHz for depths below 1500 meters;
3. frequencies between 12 and 50 kHz for depths greater than 1500 meters.

Parente and Vallario (2019) indicate that most hydrographic operations use a 200 kHz transducer, which is suitable for inshore work up to 100 meters in depth. Deeper water requires a lower frequency transducer as the acoustic signal of lower frequencies is less susceptible to attenuation in the water column. Commonly used frequencies for deep water sounding are 33 kHz and 24 kHz

SBES is still the most common tool used in port and harbour surveys and will continue to give valid results when used correctly in a well planned and executed survey (El-Hatttab, 2014). However, it should be noted that such system is too time intensive for mapping large areas.

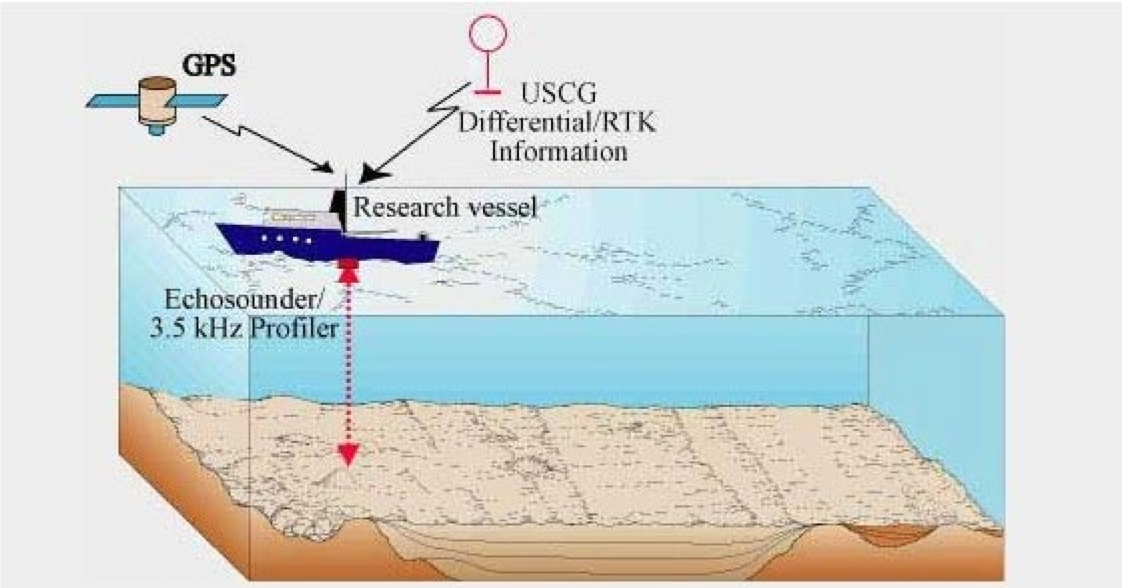

Figure 10: Single Beam Echo Sounder Principle from Kulunk (2017)

Examples

Such technique has been used to observe and monitor sea floor morphological change. In particular as underlined by El-Hattab (2014) bathymetric survey data may be used to determine

and model seafloor levels, which are essential to avoid unnecessary over-dredging and extra costs.
Single beam surveys have been used to analyze the morphodynamic development and sediment budget of the Dutch Wadden Sea over the last century (Elias et al., 2012). Their results show that over the period 1935-2005 an abundant sediment supply, primarily by eroding ebb-tidal deltas, has so far delivered sufficient sediment to increase the sediment volume in the Dutch Wadden Sea with about 600 million m^3
Echo sounder survey (200 Hz) was used to realize a morphobathymetric survey of a coastal lagoon south of the modern Po delta (Gasperini, 2005). Additionally, reflectivity maps provided by the analysis of sediment samples were also performed. The results of this study show that the combined analysis of morphobathymetry and reflectivity maps identified arcuate, sand-rich features not in equilibrium with the present-day 'low energy' regime of the lagoon. According to the author, these features might constitute the substratum over which the lagoon system has been formed, not completely overprinted by anthropogenic and biogeochemical processes at the lagoon bottom.
Single beam bathymetric surveys were used by Ferrrari et al. (2014) to investigate the efficiency of a rocky headland in delimiting littoral cells and preventing sediment bypass was investigated in a coastal area of Liguria (Italy, NW Mediterranean). These surveys were carried out in order to update historical data on the morphology and hydrodynamics of the area.
The impact of 3 km long low crested breakwater structures (LCSs) at Punta Marina (Ravenna, Italy) on environmental and biological condition was analyzed through a 3-years long multidisciplinary study (environmental and biotic data) (Munari et al., 2011). In particular, topographic surveys were undertaken using a differential GPS system in RTK mode achieving sub-centimeters accuracy, which was interfaced with a depth echo-sounder single frequency (single-beam) for bathymetric surveys. The surveys were carried out from the upper part of the backshore to a water depth of 6–7 m along profiles perpendicular to the coast spaced at about 100 m along shore. The authors observed that the sedimentary budget was positive at the landward side while seaward it was negative.
More recently, single beam bathymetry data were acquired to characterize the underwater topography, geomorphology and sediment Source in Qinzhou Bay (Cao et al., 2021). Indeed, single-beam bathymetry coupled with sediment sampling and analysis were performed to ascertain submarine topography, geomorphology and sediment distribution patterns, and explore sediment provenance in Qinzhou Bay, China. The results of the bathymetric surveys demonstrate that the bathymetry of the Qinzhou Bay is complex and variable, with water depths ranging from 0 to 20 m. The same authors further identified four underwater topographic zones. In addition, four major submarine geomorphological units (i.e., tide-dominated delta, tidal sand

ridge group, tidal scour troughs, and underwater slope) and two intertidal geomorphological units (i.e., tidal flat and abrasion platforms) were recognized. The authors concluded that human activities for exploitation and utilization of coastal zones have transformed coastline morphology and severely changed regional flow fields, underwater topography, and sediment distribution in the sea.

Multi-Beam Echo Sounder (MBES)

The evolution of single beam sounders culminated in the emergence of multibeam echo sounders (MBES). MBES determine depth by accurately measuring the angles of emission, reception and two-way travel time for a pulse of sound energy from the emitting instrument (transducer) to the seabed and back. (White et al., 2007, Jakobosson et al., 2016). Cesbron et al. (2021) reports that “MBES allow the detection of depths by scanning a wider seafloor area. MBES emit a sonar pulse that is reflected from the bottom and received by an array of receivers at different angles. The swath angle varies between systems but generally ranges between 120° and 170°, giving swath widths on the seafloor of the order of 3.5–25 times the water depth. Vessels equipped with the multibeam sonars provide hydrographic surveying results that can map the bathymetry at a horizontal resolution of about 0.5 m. However, the use of echo sounders involves mobilizing a ship and its crew, sometimes for several days, or in areas that may be hazardous to the crew, which can be very costly.”

This technology allows almost 100% coverage of the submerged bottom. Multibeam echo sounder technology offers great potential for accurate and total seafloor search if used with proper procedures and provided that the resolution of the system is adequate for proper detection of navigational hazards. For instance, Westley et al. (2019) used high-definition 3D imaging obtained with MBES to map historic shipwrecks

As a matter of fact, MBES has more advantages, including improved accuracy, if compared to the SBES. Indeed, Ferreira et al. (2022) comparing the SBES and the MBES report that while single-beam systems perform a single depth record at each transmitted acoustic pulse, resulting in a line of points immediately below the vessel’s trajectory, the multibeam performs several depth measurements with the same ping, obtaining measurements of the water column in a range perpendicular to the vessel’s trajectory. MBES allow the detection of depths by scanning a wider seafloor area Figure 12 and may delineate a small object as well as provide full bottom coverage.

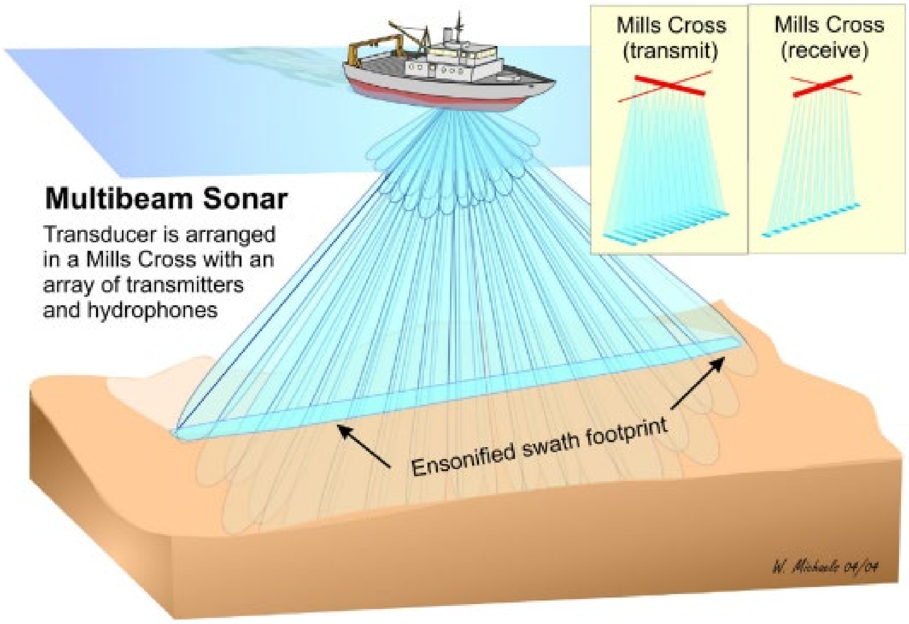

Figure 11: Multibeam echosounder principle (Source: Anderson et al., 2007)

Ferreira et al. (2022) indicate that MBES traditionally obtain depth through the process of electronic beamforming. Alternatively, some equipment (interferometric sonars, interferometric multibeam, interferometric sidescans, bathymetric sidescans or Phase Differentiating Bathymetric sidescan Sonar PDBS) employs “interferometry” to measure depth. The same authors further mention that PDBS system has several advantages, the main one being related to the background coverage, in some cases up to 12 times the nadir depth. This means that, at 4 m depth, interferometric sonar should be able to cover a range close to 50m, while a standard multibeam could cover about 12-16 meters at this depth (3 to 4 times). Further information can be found in Ferreira et al. (2022).

Compared to single beam, multibeam systems provide greater coverage, productivity, resolution and accuracy, but have high cost and complex operation. In the market, there are multibeam systems with the most varied characteristics, basically the frequencies range from 12 to 700 kHZ, while the opening angle (swath) and the number of beams formed can reach, respectively, 165 and 1600 beams.

Advances in acoustic mapping of the seabed also include MBES), which allow data collection of the submerged bottom at different frequencies, in only one survey, which allows a better

characterization of the submerged bottom. The study of Brown et al. (2019), concluded that the development of multibeam echosounder systems with multispectral backscatter capabilities is an exciting and innovative opportunity to improve the way that we map seafloor geology and benthic habitat. Their results show that such system allows the same patch of seafloor to be imaged very close to the same grazing angle (i.e., nadir from one ping is nadir from an adjacent ping, and therefore all the imaging geometries for each frequency are co-located for every part of the survey area).
Moreover, an interesting aspect related to MBES, for instance for mapping marine habitat, is that MBES can also measure the amount of acoustic backscatter from the seabed for each acoustic beam. Such information is well-described in White et al. (2007) who explained that backscatter information is perfectly co-located with the seabed bathymetry information and makes MBES unique in the ability to simultaneously collect bathymetry and backscatter information in a single survey. The same authors explain that only part of the acoustic signal emitted will be reflected back to the receiver from the sea floor, part may be transmitted into the sediment and part scattered in a different direction by the seafloor. The way the seafloor interferes with the acoustic signal and the returned echo can be used to characterise the seafloor material. The transmission and scattering will depend on the frequency of the MBES, the angle of incidence and the type of sediment – its density and porosity Figure 13.

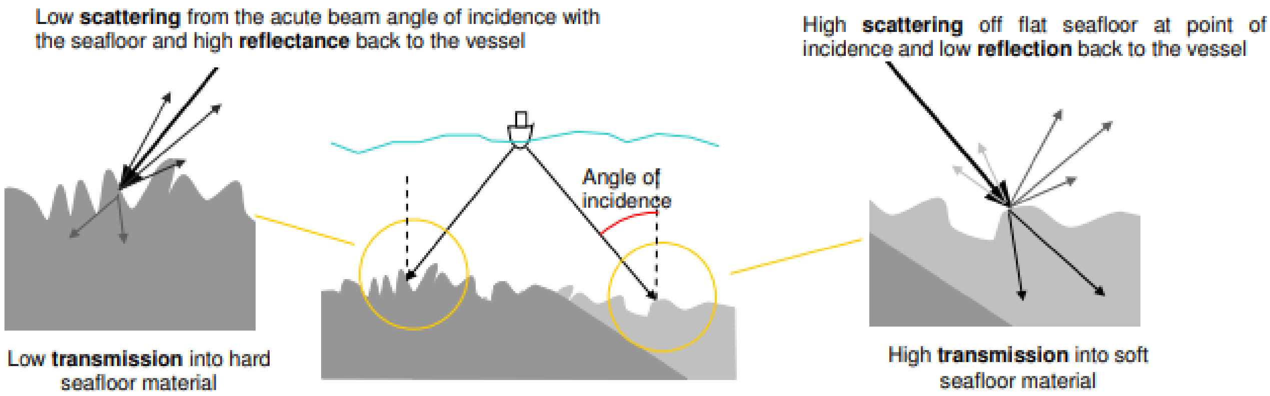

Figure 12: Reflection, transmission and scattering of the acoustic signal. (From White et al., 2007)

Cesbron et al (2021) also indicate that modern multibeam echo sounders have a size and power consumption that make them suitable for autonomous operations on aquatic drones. According to this author, the use of autonomous surface vehicles (ASV) and autonomous underwater vehicles (AUV) equipped with such echo sounders can release ships from dedicated mapping

activities. AUVs and ASVs are programmable robotic vehicles that, depending on their design, can drift, drive, or glide through the ocean without being controlled in real time by human operators.
As reported by IHO (2005) and White et al., (2007), following data collection, processing should be undertaken. This includes offset correction, attitude correction, tidal offset and cleaning of erroneous echoes present as outliers in the data. Like for SBES, the soundings can then be built into a Digital Terrain Model (DTM) for 3D viewing of the sea floor, creation of sun-illuminated imagery and contour maps.

Examples

In the literature we may find several studies on seafloor morphology based on MBES surveys often associated to SBES. For instance, Sarretta et al. (2010) used different maps to assess the sediment budget in the Lagoon of Venice (Italy). In particular, the authors used a "Multibeam" bathymetric acquisition system for the main channels (depth>5 m) and seaward inlets, while for shallow waters and secondary channels (depth<5 m), a single-beam echo-sounder was used. At shallower depths near saltmarshes and on tidal flats, data are collected by the traditional topographic method (stadia rods coupled to a GPS). Their results allowed identify the timing and pattern of geomorphic changes and the calculation of sediment deposition and erosion for the entire lagoon and sub-basins. Similarly, Carniello et al. (2012) used MBES and SBES data to develop a mathematical model for sediment entrainment, transport and deposition caused by the combined action of tidal currents and wind waves in shallow micro-tidal basins
Utizi et al. (2016) performed topo-bathymetrical surveys with Real-Time Kinematic (RTK) GPS, multi-beam surveys, sediment samplings, wave data records, dive inspections and numerical simulations over a 3-year monitoring period to analyse the process-response mechanism of a coastal mixed intervention, to assess the main factors affecting its and the possibility of using fine sediments for nourishment practices. The intervention consisted in a small beach nourishment, shallow feeder berm construction, and the placement of an artificial reef to retain the sand fill. A result of the survey is provided in Figure 14

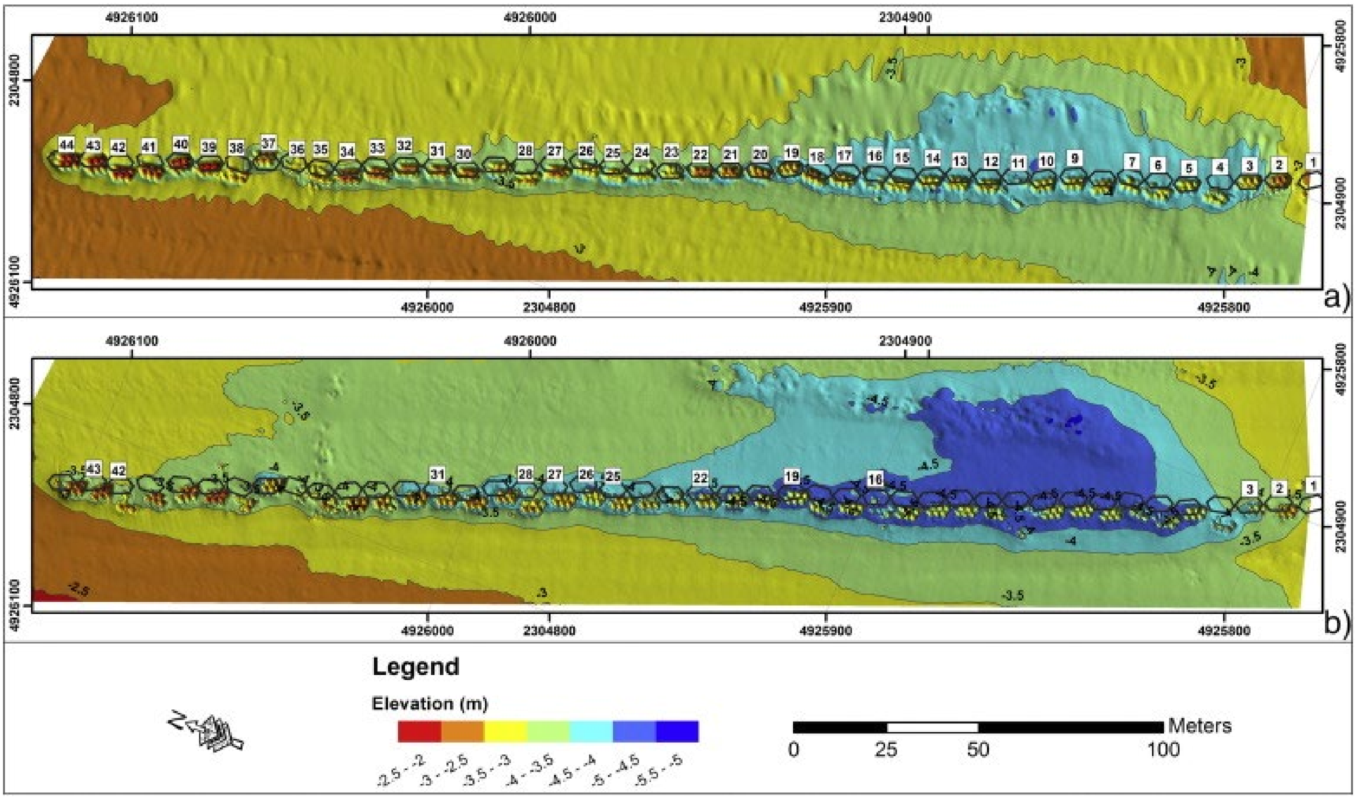

Figure 13: Map of elevation around the artificial reef (modules' original position and number are also reported) of 06/2012 and b) 05/2013 obtained from MBES surveys. Both the images show a cross-shore erosive channel in blue (from Utizi et al., 2016)

Another example is given by Bosma et al. (2015) who obtained a high-resolution bathymetric map through multibeam echo-sounders data and generated accurate Digital Terrain Models in order to analyze the morphological setting of active volcanic areas (Lipari Island, Italy). The authors obtained a new ultra-high resolution bathymetric map at 0.1-0.5 m allowing the observation of large spectrum of volcanic, erosive-depositional and anthropic features. In particular, the recent morphological evolution of the shallow coastal sector of this active volcanic island allowed to identify the presence of potential geo-hazard factors in shallow waters.

Airborne Sensors or Lidar

Cesbron et al. (2021) provided the following description regarding Lidar Bathymetry: "Airborne LIDAR Bathymetry (**ALB**) is an effective and cost-efficient technology to capture both the land topography and ocean bathymetry simultaneously, in order to provide a continuous, detailed 3D elevation model in coastal zones". It is a technique for measuring the depths of moderately clear, near-shore coastal waters and lakes from a low-altitude aircraft using a scanning, pulsed laser beam (Estep, 1993). It is also known as airborne lidar hydrography (ALH) when used primarily for nautical charting. It should be reminded that the term "lidar" is an acronym which stands for Light Detection And Ranging.

Why is this new technology important? It is well known that the hydrographic charts for many of the world's coastal areas are either out of date or non-existent (Nordstrom, 2000). Considering that coastal zone engineers and managers need coastal bathymetric data for a wide variety of environmental applications, ALB represents a technology that can deliver faster and cheaper shallow-water surveying for both hydrographic and bathymetric purposes, which is critically needed. Indeed, ALB has proven to be an accurate, cost-effective, rapid, safe, and flexible method for surveying in shallow water and on coastlines (Wellington, 2001).

Guenther (2007) also highlighted that the costs of operations for all current ALB systems are reported most often as 15-30% of the standard survey cost, depending on location, depth, and survey density. Soundings are densely spaced, typically on a 4-5 meter grid, within a wide swath under the aircraft, whose width is roughly half of the altitude.

The major limitation is water clarity. For areas with very clear water, the advantage of surveying a wide swath at aircraft speeds can be obtained for depths as great as 50 meters or more. In addition, another advantage of this method is provided by its capacity to measure land topography and survey simultaneously on both sides of the land/water boundary (Guenther 2007) as illustrated in Figure 15.

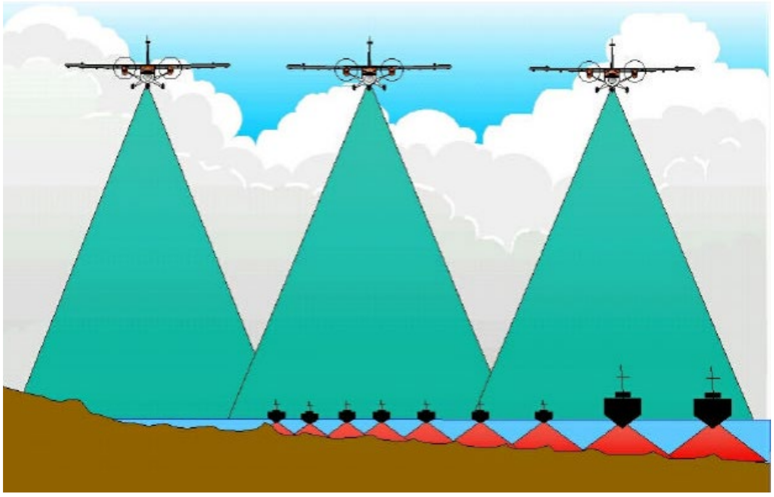

Figure 14: Depiction of lidar and multibeam sonar operation in shallow water to emphasize lidar capabilities and efficiency (from Guenther, 2007)

Cesbron et al. (2021) further explained that as opposed to airborne topographic LIDAR, which uses an infrared wavelength of 1,064 nm, bathymetric LIDAR systems use a green wavelength of 532 nm to penetrate the water column for measuring the seafloor down to 75 m depth. According to this study, ALB system is able to measure more than 140,000 points per second, resulting in surveys with over 5 points per m^2 with a vertical accuracy of 0.15 m in shallow water. Piel and Populus (2007) clearly illustrated the functioning of Lidar bathymetric technology, which utilises the reflective and transmissive properties of water and the sea floor to enable measurement of water depth. The authors explained that when a light beam hits a column of water, part of the energy is reflected off the surface and the rest, unless absorbed by particles in the water, is transmitted through the column. As the light travels through the water column and reflects off the seafloor, scattering, absorption, and refraction all combine to limit the strength of the bottom return, and therefore the system's maximum extinction depth. This depth is a function of water clarity, and is generally about 2 to 3 times the Secchi depth. Further details may be found in Coggan et al. (2007).

<u>Examples</u>

Webster et al. (2016) used ALB data to investigate the water quality issue at Little Harbour in Nova Scotia (Canada). The authors used a Chiroptera II integrated topographic bathymetric lidar sensor equipped with a 60-megapixel multispectral camera. The system incorporates a 1064 nm near infrared topographic (topo) laser for collecting ground returns and a green 515 nm laser that penetrates the water column to collect hydrographic (hydro) returns as illustrated in Figure 16.

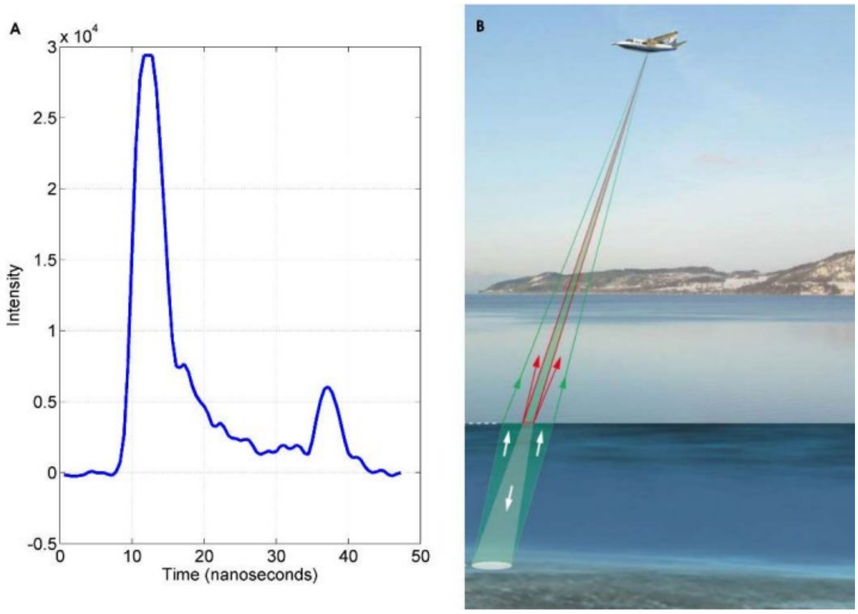

Figure 15. (A) Example of the Chiroptera II green laser waveform showing the large return from the sea surface and smaller return from the seabed. (B) Schematic of the Chiroptera II green and NIR lasers' interaction with the sea surface and seabed (from Webster et al., 2016)

The authors obtained a different high-resolution data such as Digital Elevation Model (DEM), Digital Surface Model (DSM), depth-normalized intensity and true colour aerial photo mosaic.

Hillade and Raff (2007) assessed the ability of airborne LiDAR to map river bathymetry from the perspective of its application toward creating accurate, precise and complete streambed topography for numerical modelling and geomorphological assessment, while Pastal (2011) described the French experience in performing Lidar Bathymetry for coastal hydrographic experience. Two ALB surveys were performed to understand the capabilities and limitations of using a bathymetric LIDAR for coastal surveying. The main scope of this study was to develop suitable procedures (guidelines) for conducting detailed bathymetric and hydrographic surveys in the coastal zone.

An interesting paper is provided by Robert et al. (2022) that developed an automatic classification and mapping of the seabed using airborne LIDAR bathymetry. The authors identified nine classes of geomorphological bedforms and three classes of anthropogenic structures. They were automatically mapped by Geographic Object-Based Image Analysis and machine learning supervised classifiers. In addition, the calculation of the Multiresolution Index of Ridge Top Flatness (secondary feature) was used to quickly and automatically determine sandbar crests and ridge tops.

Side-scan sonar systems

Another system uses in marine monitoring is represent by the side-scan sonar (SSS), which is a category of sonar system that is used to efficiently create an image of large areas of the seafloor (Bai and Bai, 2019). Side-scan sonar is based on the same acoustic principles as the single beam echo sounder and the multibeam echo sounder (Coggan et al., 2007). All three have transducers which comprise:

- a transmitter which emits a sound pulse into the water column down to the sea bed
- a receiver which picks up the reflected sound from the sea bed as a vibration which is converted into a digital or analogue signal and recorded on a survey vessel

Common frequencies for side-scan sonar systems lie in the range 100 –500 kHz. Very high frequency side-scan sonar instruments (.1000 kHz) exist for small-target mapping as well as low-frequency systems (,10 kHz) for deep water applications (Somers et al. 1978).
Detailed information on side scan sonar system is provided by Coggan et al. (2007) or by Jakosson et al. (2016). Bai and Bai (2019) reported that SSS is "used for mapping the seabed for a wide variety of purposes, including creation of nautical charts and detection and identification of underwater objects and bathymetric features. Side-scan sonar imagery is also a commonly used tool to detect debris and other obstructions on the seafloor that may be hazardous to shipping or to seafloor installations for subsea field development. In addition, the status of pipelines and cables on the seafloor can be investigated using side-scan sonar. Side-scan data are frequently acquired along with bathymetric soundings and sub-bottom profiler data, thus providing a glimpse of the shallow structure of the seabed."
According to Jakobosson et al. (2016) Side-scan sonar systems differ from SBES and multibeam sonar systems because their main purpose is to provide acoustic images of the seafloor rather than measurements of depth.
<u>Examples</u>
Wilken et al. (2019) used geophysical survey in the Igaliku fjord in southern Greenland to understand the harbour setting of the former Norse settlement Garða. For this purpose, the authors used an integrated marine survey system consisting of a side-scan sonar and a reflection seismic system. The reconstructed coastline shows that a small island was connected to the shore

at low tide during the early Norse period. In addition, reflection seismics and side-scan sonar images reveal a sheltered inlet with steep slopes on one side of the island, which may have functioned as a landing bridge used to load ships.
Another example is provided by Goncharov (2020) that assessed the condition of the Igarskaia Protoka on the Yenisei (Russia) using side-scan sonar imagery interpretations and bathymetry. The author estimated the amount of sunken timber and its location. Indeed, the obtained results allowed to locate and identify at least five large shipwrecked vessels in the Igarskaia Protoka along with at least twenty sunken small craft. Applying SSS revealed large amounts of river debris left over from shipping operations and human activity in this part of the Arctic.

Satellite-Derived Bathymetry

As reported by Cesbron et al. (2021), satellite altimetry has made it possible to estimate the bathymetry of the world's oceans in deep waters, but with an average achievable resolution of 8 km. Satellite altimetry measures the height of the sea surface, which is affected by the gravitational effects of topographical features on the seafloor. The horizontal resolution of altimetry-derived bathymetry is much lower than that of direct echo sounder measurements, but it has enabled seabed mapping on a global scale.
Smith and Sandwell (1997) obtained a digital bathymetric map of the oceans with a horizontal resolution of 1 to 12 kilometers by combining available depth soundings with high-resolution marine gravity information from the Geosat and ERS-1 spacecraft. Furthermore, the map shows relations among the distributions of depth, sea floor area, and sea floor age that do not fit the predictions of deterministic models of subsidence due to lithosphere cooling but may be explained by a stochastic model in which randomly distributed reheating events warm the lithosphere and raise the ocean floor.
Westley (2021) provided relevant information regarding satellite-derived bathymetry (SDB), technique that covers a range of techniques which derive water depths from space-based sensors. Such technique includes approaches that rely on gravity measurements, nearshore wave characteristics, stereo photos, space-based laser, and multispectral imagery, the last one being the most widely used. According to Westley (2021) the multispectral imagery is based on:
"the principle that amount of electromagnetic radiation (i.e. light) reflected from the seafloor is dependent on water depth. Light is attenuated by water, thus attenuation increases with depth. When viewed from above, clear shallow water appears bright because light reaches and reflects from the seafloor, whereas deep water appears dark because light is absorbed before reaching the seafloor. Other factors also play a part. Suspended sediment can also reflect or scatter light, and it can also be scattered in the atmosphere before reaching the water. The wavelength of light is also important since longer wavelengths are absorbed faster by water. Therefore, the blue (0.45–0.52 μm) and green (0.52–0.6 μm) parts of the electromagnetic spectrum tend to be used

for SDB as they have the greatest through-water penetration. In theory, once water column and atmospheric effects are accounted for, the energy reflected back to a satellite should be inversely proportional to water depth (Figure 17).

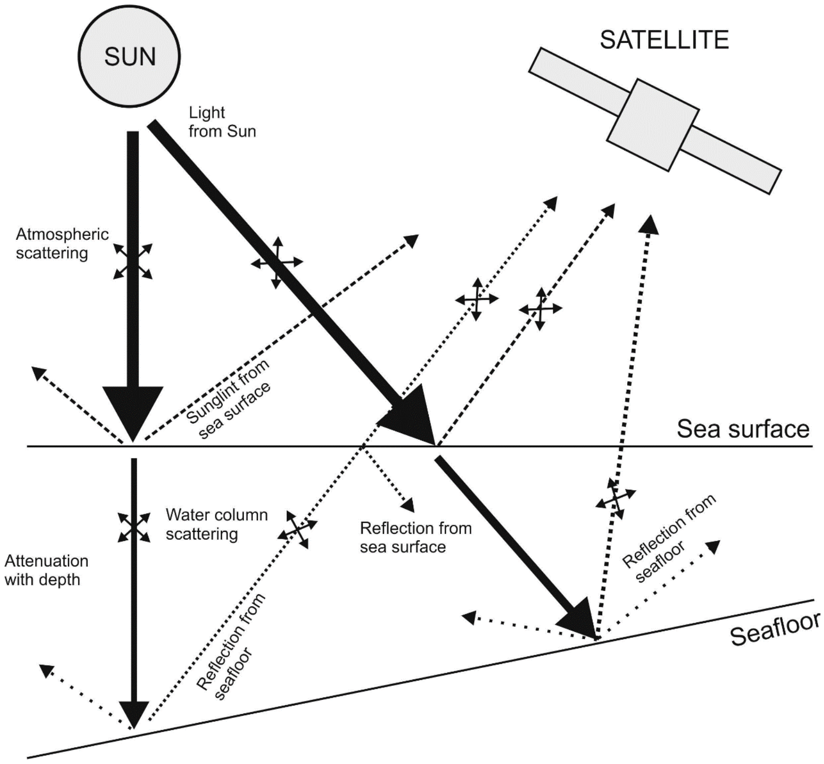

Figure 16: Schematic representation of SDB. Multiple scatterers in the atmosphere and water decrease the signal returning to the satellite. Not shown are seafloor variations (e.g. substrate) which also affect the returning signal via differential absorption or scattering (from Westley, 2021)

Cesbron et al. (2021) provided relevant information regarding satellite-derived bathymetry and in particular on Multispectral Inversion, Wave-Based Inversion, Satellites for Satellite-Derived Bathymetry.

Examples

The paper of Pe'eri et al. (2014) describes the development and testing of a procedure using publicly-available, multispectral satellite imagery to map and portray shallow-water bathymetry in a GIS environment for three study sites: Northeast United States, Nigeria, and Belize. The authors used landsat imagery and published algorithms to derive estimates of the bathymetry in shallow waters, and uncertainty of the satellite-derived bathymetry was then assessed using a Monte Carlo method. Their results indicate that the practical procedures developed in this study are suitable for use by national hydrographic offices.
Almar et al. (2019) provided a wave-derived coastal bathymetry from satellite video imagery: A showcase with Pleiades persistent mode. This article shows the capacity do derive depth using the sub metric Pleiades satellite mission in persistent mode, which allows acquiring a sequence of images (12 images) at a regional scale (~100 km^2). The results show that the accuracy increases with the number of images in the sequence and with a fine resolution. Furthermore, the authors reported that despite their noisy nature, newly available time-updated satellite bathymetries can be used to understand coastal evolution at several scales and improve risk mitigation strategies through modelling.

Integrated monitoring system

In literature there are only few examples of integrated monitoring system and such systems are not commonly used considering the dimension of the coastal and marine environment. One of these examples is provided by Fuchs and Tuell (2010). The system presented by the authors consists of a lidar sensor integrated with a hyperspectral imager and a high-resolution frame camera. The simultaneous application of a suite of remote sensing sensors provides multi-dimensional information for active-passive data fusion algorithms for post processing. In addition, the authors highlighted that the Ethernet-based design of the **CZMIL** platform can accommodate the integration of different peripheral sensors, specifically tailored to the need and budget of the end user. The structure of the system is presented in Figure 18.

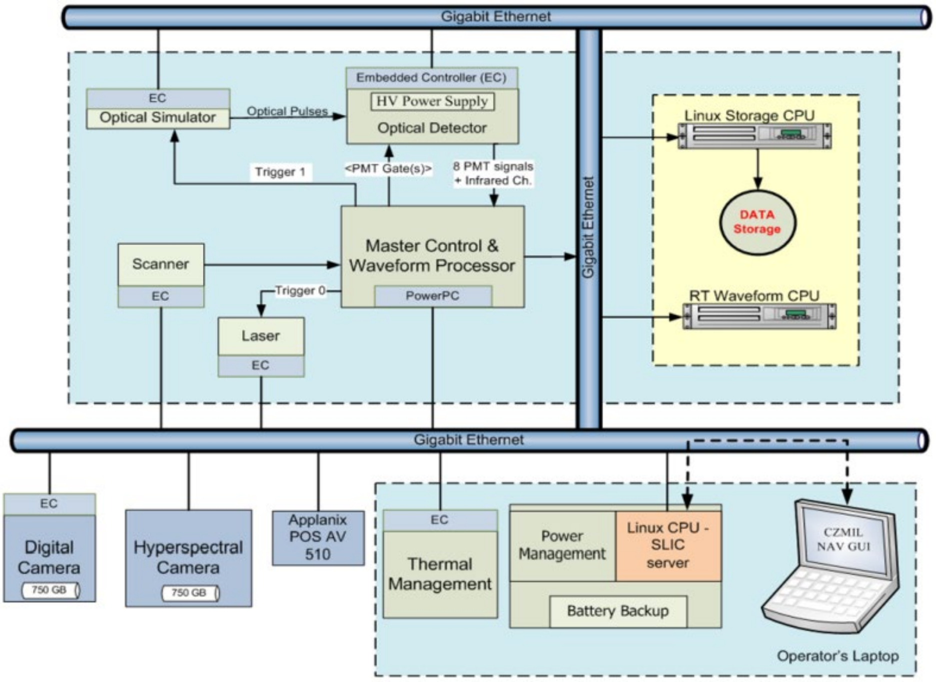

Figure 17: CZMIL Data Acquisition System Diagram (from Fuchs and Tuell, 2010)

Additional information of this system is described in Ramnath et al. (2015). The authors reported that the CZMIL system is an integrated lidar-imagery sensor system, and its complementary HydroFusion software suite is designed for the highly automated generation of physical and environmental information products for mapping the coastal zone. CZMIL is designed to survey over a wide range of water types, ranging from moderately clear to predominantly turbid

Another example is provided by the “Coastal Observation System for Northern and Arctic Seas” **COSYNA** (Riethmüller et al., 2009a and b). A major challenge of COSYNA is to tightly merge data from a dense observational network and modelling via data assimilation. The integrated system will focus on daily-to-weekly processes providing objective measures of uncertainty in the state estimates and forecasts. The system presented by the authors is represented in Figure 19. The system comprises installations at selected fixed or mobile platforms to provide the necessary coverage for a characterisation of the highly dynamic, interconnected and heterogeneous environments. This layout also implies a wide vertical coverage of the system ranging from the benthic boundary layer, through the water column to the water-air interface.

It should be noted that COSYNA will intensively use platforms-of-opportunities like North Sea ferries, freights ship and offshore research platforms and wind mills.

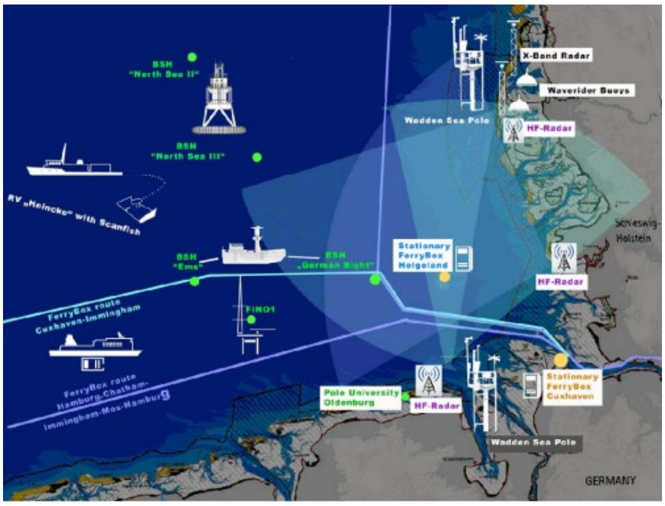

Figure 18:Principle layout of COSYNA in the German Bight (from Riethmuller et al., 2009a and b)

Another example of integrated monitoring system regards is related to the creation of an integrated coastal sea-ice observatory: System components and a case study at Barrow, Alaska (Druckenmiller et al., 2009). The observatory includes: (1) satellite remote-sensing datasets distributed in near real-time; (2) a coastal sea-ice radar and webcam that monitor ice movement and evolution; (3) a mass-balance site that provides temperature profiles and thickness information for ice and snow; (4) sea-level measurements; (5) periodic ice thickness surveys using direct drilling and electromagnetic induction sounding; and (6) a program of regular, undirected observations (Druckenmiller et al., 2009).
More recently, in 2019, a novel solution to large-area, continuous coastal monitoring has been presented by Bird et al. (2019). The system as described by the authors consists in a shore-based radar station, which has been designed to collect image data within a 6 km range and derive a number of datasets including intertidal topography, subtidal bathymetry and surface currents. Successively, the data are used in the development of beach management options to inform the Wyre Beach Management Outline Business Case (UK). The system uses existing infrastructure in the form of a 12 m CCTV column. A radar antenna is fixed onto a bespoke mounting plate allowing it to be bolted to the top of the lighting column. It also includes a meteorological sensor, a CCTV camera and an AIS receiver to enable validation of detected vessels during data analysis. The 9.41 GHz antenna projects radio-frequency electromagnetic waves with a centimetre-scale wavelength. These waves interact with wind-generated capillary waves on the sea surface and produce strong backscatter signals through Bragg Scattering, allowing waves and the breaking

waterline to be clearly imaged with a marine radar (Please refer to Bird et al. (2019) to obtain further information).
In Italy an experience of integrated system for coastal monitoring is represented by the "SAM" (Advanced Systems for Automatic Monitoring of the marine coastal pollution) (Zappalà et al., 2002). The multidisciplinary research programme project, funded by the Italian Ministry for Scientific Research, aimed at the installation of an integrated coastal monitoring network and at the development of instrumentation and analytical procedures to be applied in nowcasting and water quality assessment (faecal pollution microbial indicators). The project didn't focus on hydrography or hydrodynamic processes.

Bathymetric survey – Information regarding positioning system and datum

The following information has been obtained from UK Hydrographic Office (2020).
In its most basic form, bathymetric data must consist of position (X & Y) and depth (Z) information. Measuring the depth is covered in section 2 above. This section covers the determination of the X & Y components.
In the past, positioning was obtained using sextants and observations to celestial bodies, then as technology improved, land-based radio navigation systems were introduced, such as Loran.
Currently, in the marine environment, most positioning systems use one or more of the GNSS (Global Navigation Satellite System) services, such as GPS, Glonass, Galileo etc. The user often doesn't even know which of the systems is being used, just that the position is derived using satellites. A GNSS system can determine the position of its antenna via observations to orbiting satellites. Used on its own, a GNSS positioning system can be horizontally accurate to around +-10m. The accuracy of GNSS systems can be improved by using corrections. The corrections are determined using GNSS devices situated over known locations (benchmarks) on land. The errors in the GNSS position can be determined and transmitted to the vessel so that it can apply the same corrections and improve its position accuracy. This is called Differential GNSS or DGNSS. The transmission of the corrections can be via radio link, mobile phone network or from a communications satellite. There are different levels of corrections and different ways to obtain them. Some are more accurate than others, some are free, and some are paid for service
The most basic DGNSS system is accurate to around +-1m. Some of the paid for services can improve the accuracy to better than 20cm and in some cases better than 5cm.
Remember, the above accuracies are for the position of the GNSS antenna. For bathymetry it is the position of the depth on the seafloor that is important. So, to obtain the best accuracy, either the GNSS antenna needs to be located above the echo sounder transducer or the position needs to be transferred from the GNSS antenna to the echo sounder transducer. Transferring the

position requires an understanding of the offsets between the equipment and also a continual update of the heading of the vessel (and in some cases additional knowledge of the pitch and roll of the vessel is used to refine the position accuracy even further), and the appropriate software to do the computations and transfer the position information.
It is also possible to “post process” logged GNSS data to improve accuracy from the standalone 10m to around 10-2cm. Relevant information regarding Datum is provided by UK Hydrographic Office (2020).

Monitoring program

The information reported below is extracted from Pranzini and Rossi (2013).
The role of coastal evolution monitoring is to forecast the future status of the coast, under natural conditions or following the implementation of coastal protection works. However, it is essential to know the history of the coastal section to be monitored in order to verify if interventions in act have altered past trends – and to what extent.
The definition of a new monitoring plan should be able to extract data from preceding data typologies, preparing them to be imported into a future database. In addition, it is necessary to identify the most appropriate survey and data analysis methodologies; caution should be taken not to oversample (space-wise and time-wise), which would bring unnecessary extra costs to monitoring.
That is why the cost of procedures becomes a crucial element in defining a monitoring plan. In fact, the high frequency of surveys required for short or medium term monitoring, and the possibility of eventually extending it in time, make it necessary to use a net of low frequency surveys, whereas the analysis of specific structure impacts requires data of high density, both in terms of space (microvariations in seabottom) and time (response to specific oceanographic events).

Monitoring campaigns which focus on the study of seafloor morphology should be carried in winter and summer (or, rather, after storm and swell conditions) so that maximum system variations are identified.
It is though not economically possible (and it is scientifically questionable!) to conduct two bathymetric surveys per year in a coastal segment where there are no defence interventions (which could indeed produce fast beach response). Surveys should be more frequent following the construction of a defence structure or nourishment works. In such cases, monitoring should start before the defence intervention begins to be built. In such manner, the information

necessary for the design phase, as well as metric calculations (pre- and post-work) in case of volumetric control, can be acquired. It is often necessary to allocate resources in the plan to cover an eventual repetition of surveys, such as after a severe storm event that can cause significant morphological changes on sandy shores. Shoreline survey can be repeated even more frequently, as they are far cheaper. If pre-existing surveys have been conducted, the new monitoring plan should predict a frequency similar to that of earlier surveys, allowing data to be comparable.
The timeframe of surveys could be defined according to the following:

- 5 years for evaluating the efficiency of a specific defence structure;
- 10 years for executing a coastal defence project;
- 30 years (or longer) for executing a coastal planning project.

Clearly, longer studies need be supported by archive data.
In addition, surveys should consider the wave climate which characterised the study area at the time when survey took place. Data should therefore be obtained from existing wave buoys or inferred from models. In some cases, wavemeters can be installed specifically for this purpose. Once all phases are defined, a schedule should be set for the programmed activities (Tab 3).

Table 2: Example of monitoring schedule for evaluating the efficiency of a specific coastal defence structure (from Pranzini and Rossi, 2013)

	Pre intervention	Endo of Works	6 months	12 months	18 months	24 months	36 months	60 months
Single beam topographic survey	■	■	■	■	■	■	■	■
Multibeam survey near the structures	■	■				■		■
Laser scanner survey of the structure	■	■				■		■

Normative bases of reference and cohesion

In the screening phase were collected the following regulatory sources to build a basis for highlighting actions and interventions regarding EU indications and national legislative coherence:

- Law on Physical Planning and Construction (Official Gazette 76/07, 38/09, 55/11, 90/11, 50/12,
- 55/12).
- Law on Maritime Domain and Seaports Act (NN 158/03, 100/04, 141/06, 38/09).
- Law on Concessions (Official Gazette 143/12).
- Public institution Department of Development, Regional Planning and Environmental Protection in the Primorsko-Goranska County.
- Regulation on standards of water quality at beaches (Official Gazette 33/96).
- Regulation on the quality of bathing water (Official Gazette 73/08).
- Regulation on the procedure for granting concessions in the maritime domain (Official Gazette 23/04, 101/04, 39/06, 63/08, 125/10 and 83/12).
- Regulation on the procedure for granting a concession agreement on the maritime domain (Official Gazette 36/04).
- Regulation on the types of beaches and the conditions that must be met (Official Gazette 50/95).
- Strategy for Sustainable Development Strategy (Official Gazette 30/09) and 2006/07/EZ Directive of the European Parliament and the Council concerning the management of bathing water.

Based on this planning platform, the actions found in the field and the revision of the evaluation criteria constitute a first reading of the cohesion between the two Adriatic shores.

The Coastal Cadastre

The coastal cadastre as an instrument of sustainability management and measurement of the coast is applied in the different Croatian counties by the County Institute for Development, which locally depends on the *"Ministarstvo prostornoga uređenja, graditeljstva i državne imovine"* (Ministry of Physical Planning, Construction and State Assets).
Topographic maps at a scale of 1:25,000 can be found in the publication 'Sea Beaches in the Area of Primorsko-Goranska County'. Land planning is a prerequisite for achieving a better distribution of economic functions in space, protection and enhancement of natural and manmade values

and an optimal distribution of the structures intended for certain activities, including nautical tourism.
Among all nautical harbours, tourism marinas require a high-quality coastal area, so the planning of their location in space has special significance. Historical and scenic city centres are what attract the most attention from yachtsmen, so the biggest trend in the construction of marinas is precisely in these areas. This represents a constant threat to an increasing balance of the carrying capacity of coastal stretches with high tourist demand.

Marinas and State Property

The Croatian coastline (2011 data to be updated with the ECOMAP project) is subdivided into 98 harbours, of which 61 marinas (including 11 land marinas) and 37 other seaports. It is a known fact that marinas are generally constructed in direct contact with areas of significant tourist and recreational capability, or within port basins near large urban centres. The total water surface area is 3,295,891 m2 with 17,059 moorings. On 31 December 2011 the number of permanently moored boats was 14,286, 1.0% less than on 31 December 2010. Of the total number of permanently stationed vessels, 85.5% used in-water moorings, while 14.5% used land-based moorings. One berth in a nautical tourism port is a space for a vessel of a standard length of 12 m, each of which has an accommodation capacity of a flat type or a 3-bed capacity.
The following space utilisation criteria have been defined based on the Spatial Plan of the Republic of Croatia:
- the capacity of nautical centres for commercial moorings shall be limited to a maximum of 1,000 moorings and a minimum of 200 moorings
- the determination of the number of moorings in nautical harbours through the purpose of the aquarium, while boating tourism harbours with less than 100 moorings will be considered ports in exclusive international nautical centres where yachtsmen demand top-quality services.
At a local level, management is performed according to the maritime domain management plans drawn up by cities/municipalities. In recent years, the local administration has operated beach management through concessions over its administrative area. Today, beach management has a much higher economic, social and ecological significance, which is why it should be based on sustainable development principles.
Recommendations for efficient management are mainly related to the following aspects:

- proactivity and future orientation with medium to long-term management assessments;
- coordination between institutions (national, regional and local) by aligning sustainability criteria;
- development of intellectual capacity and knowledge of management levels.

Carrying Capacity of Marinas

The number of berths in a tourist unit must not exceed 20% of the unit's total accommodation capacity, but not more than 400 berths. According to the Law on Maritime Domain and Seaports Act (NN 158/03, 100/04, 141/06, 38/09) and other similar sources, a berth in a nautical marina is a place for a boat of a standard length of 12 mt and a boat has a measurable accommodation capacity of 3 beds. The minimum capability defines the boundary on which the efficient use of municipal, technical and sanitary facilities and equipment depends. In terms of measurements, it requires a surface area of 112.5 m^2 for sea berths and 90.0 m^2 for dry/ land berths, or the total surface area per berth of 101.2 m^2 (land and water surface). Consequently, the water surface area for a marina for 400 yachts should be at least 45,000 m^2, or 4.5 ha, excluding the site of piers and other constructions at sea. The number of yachts per hectare of water area should not be less than 50 or more than 120 yachts. To accommodate the same number of vessels on land (dry berth), an area of 36,000 m^2 or 3.6 ha is required. The development of nautical tourism in Croatia envisages approximately 15,000 berths in the next 10 years through the development of new marinas, dry marinas and coastal and island marinas and moorings. The rehabilitation of degraded areas such as disused industrial and military facilities should be supported and encouraged.

In existing ports, a qualitative restructuring of capacity with an improvement in the quality of services is necessary to make the ports capable of meeting demand. In participating in strategic development, it is essential to characterize the infrastructure and order the logistical needs of marinas in a development path in order to establish cohesion actions and exchange of best practices towards mutual and sustainable growth.

Blue Flag Beaches

The beach management strategy in Croatia is constantly evolving. Beach exploitation models in Croatia are based on the practice of concessions. The regulatory sources regulating this complex issue are: Maritime Domain and Seaports Act (Kovacic et al. 2017), Regulation on the procedure for granting licences on the Maritime Domain (Luković et al. 2005) and in particular the Concessions Act.

The only initiative that appears to meet these criteria to some extent is the Blue Flag programme, although it is primarily oriented towards beaches as recreational resources and, as a result of the above, is mainly focused on urban and resort beaches. The Blue Flag for beaches and marinas is an international environmental programme for the protection of the sea and coastal areas, the objective of which is the sustainable management of the sea and coastal areas. The national coordinator and leader of the Blue Project programme in the Republic of Croatia is the environmental association *Lijepa naša*.

Key initiatives, programmes and studies focusing on several aspects of beach management include:

- Water quality monitoring programme and creation of a bathing water quality database;
- Creation of beach profiles that will be used to carry out bathing water quality assessments determined on the basis of criteria defined in the Bathing Water Quality Regulation;
- Creation of a project for the cartographic representation of beaches currently in Primorsko Goranska County and Dubrovnik-Neretva County in accordance with the Regulation on the Quality Standards of Maritime Beaches.

Sustainability descriptors

An interpretation system was developed on the basis of the data acquired in order to measure the degree of cohesion and then to identify and evaluate the feasibility of local development processes. The undoubted tourist vocation of the Croatian coast has determined a driving effect of the case studies on the east coast. The regulatory surveys represent a common platform where cohesion finds ample space to develop the levels reached by the project areas. In the same way, it is interesting to understand the dynamics for the local descriptors to bring out similarities and criticalities concerning the stations examined.

The following facilitation and cross-fertilisation themes for an approach to cohesion and sustainability have therefore been declined:

- Sustainable management services
- Interaction with the natural environment
- Effectiveness of supply chain interactions
- Sustainable development

Interazioni con ambiente naturale		
Sostenibilità economica servizi	3	1
Sicurezza sistemi produttivi antropici	2	1
Resilienza dei sistemi ecologici (blooms, eutrofizzazione, anossie) e processi produttivi	1	3
Impatto attività antropiche sul sistema produttivo	3	1
Livello di conservazione dei servizi ecosistemici	1	2
Dinamiche corpi idrici sull'area	1	3
Capacità di utilizzo dei servizi ecosistemici	1	2
Redditività utilizzo servizi ecosistemici	2	2
Progettualità e bisogni ambientali	2	2
Mitigazione parametri impatto	3	1
Vulnerabilità sistema produttivo alle criticità ambientali	2	2
Grado di valorizzazione territoriale del porto	3	1
Impatto del territorio sulle attività produttive	2	3
	26	**24**

For the individual items (descriptors) a rating scale from 1 to 3 was proposed on which to measure the deviation to the highest score (30). The value of the individual descriptors makes it possible to focus on single critical points or strengths. The confrontation of project areas allows reasoning on homogeneous platforms and descriptions already prepared for cohesion.
National area groupings could be interesting, as in this example, in which two decisively different realities as Ancona and Bibione are interpreted using the same descriptors to bring out similarities and degrees of local development.
The review of the deliverables made it possible to formulate some implementations on the criteria presented particularly in the Blue Flag theme and premises on the planning activities envisaged by the regulations in force. The prerequisite given by the lines of development of the individual local realities constitutes an indispensable tool for the interpretation of shared feasibility and/or for the identification of the project areas of evolution that can be applied and included in the cohesion process.

Criteria and explanatory notes for Blue Flag 2020 marinas - Advice on the application of the Blue Flag Programme on ECOMAP project sites

The following criteria are also described in "Blue Flag Guidance – Interreg Italy-Croatia ECOMAP" – WP4 act.4.2

CRITERION 1 - Information on locally relevant ecosystems and environmental phenomena must be available to marina users (I): Territorial awareness in marina spaces starts from what is already implemented in the resource protection area. It then becomes active interaction and optimization of management actions in synergy with governance components. In the case of the Špinut port associated with the adjacent Marjan Municipal Forest Park, interesting management synergies would be realized for mutual enhancement.

CRITERION 3 - Information on the Blue Flag Programme and/or norms for marinas and other FEE eco-labels should be displayed in the dock (I): Marinas would become the reference for the promotion of environmental education programs. They could cooperate with the University Department of Marine Studies and the Faculty of Maritime Studies in Split. Various environmental education modules already tested could be replicated in a joint action under the protection of the Blue Flag committee itself.

CRITERION 6 - At least twice a year, Blue Flag organizes a meeting with the staff on measures/ environment/sustainability (G). It represents an update for marina operators on economic, social and environmental sustainability issues. It proposes new professionalism in line with innovation and ecological transition.

CRITERION 7 - Every employee is aware of the Blue Flag and can communicate it to guests (G). In the same way as with criterion 6, Blue Flag could work towards specific education of the port crew on environmental management and protection. This would create a fruitful synergy link between stakeholders.

CRITERION 9 - The port must have an environmental policy document and an environmental plan (I). Drawing up an environmental plan allows the creation of standardised specifications and eventually innovative virtuous actions helpful for obtaining the Blue Flag. Ordinary maintenance of the hulls and the seasonal restoration of the antifouling cover should be noted. The provision of an ecological system to collect boat black water and hull wash water and the subsequent discharge into the sewage system after pre-treatment and separation of pollutants represents an essential step in water treatment. Water treatment is at the centre of a number of management options for reusing water resources. The collection of rainwater would allow the irrigation of vegetation, the use of showers and the washing of services and moored boats. Seawater circuit, instead of precious drinking water, would grant interesting management savings on hull washing and especially on depreciation of the purification system that would cover several marinas in a single service.

CRITERION 18 - If the pier has an area equipped for boat repairs or cleaning, no pollution shall be discharged into the wastewater system, the land and waters forming part of the port, or the surrounding natural areas (I). An environmental plan allows different ways of controlling pollutant emissions. Periodic hull cleaning with rotating underwater operations could replace the antifouling cover. Costs would be considerably reduced. Underwater work could then be replaced by modern systems of brush machines placed in isolated tanks in controlled water areas. Special facilities would allow effortless collection of biological fouling materials and their disposal. The phasing out of antifouling must become a reality, at least in marinas that would also offer this service to external users. Sustainability studies make this option reasonable, especially for 9-12 metre boats. In these cases, both the cost of antifouling coats, which last for a season or so, and the environmental impact are reduced.

CRITERION 22 - There must be an environmental policy and plan for the port. The plan should include data collection on water management, waste, and energy consumption, such as the use of environmentally friendly products. All employees should be informed and trained on these issues (G). Ports could install smart water counters and manage water supply according to consumption statistics: peak times, leaks in the system, etc.

CRITERION 25 - Only energy-efficient lighting systems should be used. Sensors regulating the use of light should be installed wherever they are considered suitable (G). Electricity savings can be achieved by using permanent low-intensity night lighting and solar panels, with sensors switching on additional lighting only when necessary, like when the movement of a boat or people is detected.

CRITERION 28 - Artificial green areas in the port must be maintained in a sustainable form (G). The re-vegetation of Mediterranean environments is particularly sustainable and water-efficient, but is essential in nature conservation and the maintenance of surrounding features.

CRITERION 36 - The water in the harbour must be visibly clean, with no evidence of pollution such as oily slicks, floating rubbish, discharges or other traces (I). It is possible to monitor how marina users observe regulations on discharge and maintenance of the sanitary water system. Touristic ports should conduct water quality controls in accordance with national legislation.

CRITERION 38 - The marina management must take at least two measures to encourage sustainable behaviour and fulfil its commitment to social sectors (G). Ports could offer free Wi-Fi. The only condition for free internet access could be to read online the basic information requirements of the Blue Flag to develop responsible behaviour in the marina.

Blue Flag beach criteria and explanatory notes 2020 - Advice on the application of the Blue Flag Programme on ECOMAP project sites

The following criteria are also described in "Blue Flag Guidance – Interreg Italy-Croatia ECOMAP" - WP4 act.4.2

CRITERION 2 - A minimum of 5 environmental education activities (I) must be offered to bathers each year. An 'adoption' programme for the beach must be created in which educational modules for studying the area are applied. The beach becomes the focus on local problems and environmental quality assessment. Environmental protection initiatives aim to create links between stakeholders and safeguard a heritage that means activity and income. The summer months become seasonal employment opportunities for a local student population that develops specific training within two to three years in high schools. The final year students would themselves become the trainers of the younger ones. Some interesting pairings are Podstrana and the nearby port of Strožanac, or Bibione beach and the port of Baseleghe. In general, among the similarities and differences in geomorphology and landscape, it is possible to construct development plans that, although starting from different bases, converge with shared functions. The important thing is to identify the most effective governance of the territory.

CRITERION 3 - Information on bathing water quality (I) must be posted. This is an important territorial approach that involves the coordinated efforts of various representative governancecomponents in the area. This must be associated with particular attention to the effectsdetermined by the positioning and hydro-morphological characteristics of the water qualityreference stations.

CRITERION 7 - The beach must fully respect the sampling and frequency requirements for bathing water quality (I). The Podstrana area has additional characteristics that link it to the previous situations. The Podstrana beach is close to the mouth of the river Žrnovnica and many underwater freshwater sources seasonally influence the water quality. Therefore, it is necessary to define the most representative and consistent sampling site on a comparative scale. Directive 60/2000 outlines suitable practices for defining and monitoring water quality.

CRITERION 9 - There must be compliance with the Waste Water Treatment and Wastewater Quality Directives. No wastewater discharge (urban or industrial) must affect the beach area (I). The Blue Flag considers contamination in its entirety. It should be noted that the seagull population gathering at the mouth of the river Žrnovnica may influence the water quality on Podstrana beach. More in-depth studies of the herring gull population and their emissions should prove eutrophication near the river mouth and the extent of contamination of nearby beaches.

CRITERION 12 - The local authority or beach operator should set up a beach management committee (G). According to an effective network vision, the committee's composition should involve both the port and the beach. For example, a representative of the adjacent Strožanac port would bring significant benefits both to the technical table and in sharing with the marina's service users the potential negative impacts on the environmental value of Podstrana beach.

CRITERION 18 - Separate containers for recycling (I) must be available on the beach. The Blue Flag not only registers the presence of different containers but also rewards the creation of a chain and a replicable modality on neighboring beaches encouraged by the involvement of the organized municipality.

CRITERION 24 - All buildings and equipment on the beach must be kept in good condition (I). First of all, sanitation and cleaning must be conducted by creating a circuit parallel to the water supply network fed by the local availability. Particular attention must be paid to the torrential regime and rainwater supply, which in the Split area is cyclic and predictable for non-potable purposes.
CRITERION 25 - Marine habitats close to the beach must be monitored (I). The criterion must consider their actual distribution in the proximity of the beach. Podstrana is the only station characterized by areas of marine phanerogams (*Posidonia oceanica*), while in the deeper and more offshore rocks, species that can be traced back to the coralligenous can be found, although they are not very representative. The part facing the beach is remodelled in its substrate components, also due to the fact that it is periodically nourished with new gravel. Maintenance, even more than bathers use, makes the presence of important species and habitats quite limited. They are therefore found at greater depths. Diving centre spots are located in the shallows and reefs that characterize the Brac Channel. Of minor significance is the impact of diving tourism, which is certainly characterized by inexperienced divers engaged in beginner dives from the shore, but on highly resilient seabeds.

CRITERION 26 - Sustainable ways of transport must be promoted in the area surrounding the beach (G). The integration of utilization and connection projects between tourist destinations depends on the reduced use of cars, especially if these destinations are part of a touristic offer in a single urban context. In the summer months and beyond, the viability of Split and several coastal towns depends on the organization of parking spaces and their availability. This leads to the avoidance of private car use in preference to alternative ways of reaching leisure and recreational destinations. The centrality of Split as the starting point of the routes to the islands leads to a problem of accommodation represented by the need for long-term parking for tourists travelling by sea.

CRITERION 29 - Emergency plans must be prepared for cases of pollution or environmental safety risk (I). Croatia, as well as Italy, has a number of risk plans that include the management of pollution and environmental safety emergencies. The possibility of contamination of the port of Strožanac and its impact on the beach should be considered.

Defining common bases allows the working group to grasp the differences in the management approach regardless of the evident environmental and morphological differences. For example, the idea of beach in Italy and Croatia is not so shareable, but the priorities that are identified by the stakeholders are quite similar. It is also true for marinas and services, for the education and culture of the users. Moreover, the disconnection between the simplicity of the requests and the development methods behind the various development paths of the territory should be highlighted. ECOMAP aims to fill this gap starting from the community regulatory mechanisms. The rules of national laws fall locally with the governance of the territories and effectiveness of the local management. ECOMAP must read further the basic needs and verify their results with the level of the local sustainable development path. As regards ports in Croatia, priorities focus on the use of services (e.g. fuel stations) and public facilities (showers, toilets); while in Italy the priorities are concentrated on meeting places and public facilities. This makes it clear that much more should be done in the field of environmental education and its use in the connecGon between sustainability and what is perceived at the level of the final user in regards to planning.

ECOMAP sampling sites

Relate to Deliverable 3.4.2 and 3.4.4 – WP3

The ECOMAP geophysical, geochemical and biological surveys have contributed to improving the knowledge, the dynamic processes and possible presence of pollutants of the test sites.
In particular, about investigated areas and results of geophysical, geochemical and biological surveys see:

- Work Package 3 - Action 1 – Deliverables 3.1.1 – 3.1.2 – 3.1.3 (Geophysical surveys)
- Work Package 3 - Action 2 – Deliverable 3.2.3 (Geochemical surveys of sediments)
- Work Package 3 - Action 3 – Deliverables 3.3.1 (Macrobenthos classification)
- Work Package 3 - Action 4 – Deliverable 3.4.5 (Microbiological parameters).

The multidisciplinary approach helped the ECOMAP partnership to better characterize the investigated areas.

Monitoring of microbiological parameters in the marinas and adjacent beaches

Relate to Deliverable 3.4.5 – WP3

The goal of PP4 in the ECOMAP project was to determine microbiological quality of water in four marinas (two in Croatia and two in Italy) and two beaches in Croatia and to assess whether the study areas are microbiologically loaded. We introduced new indicators, CHL *a* and HB, in our analysis to assess anthropogenic pressure. Our results from the previous two years in the Žrnovnica River estuary showed microbial contamination by *Escherichia coli* and intestinal enterococci, indicating a potential risk to human health. We noticed a great number of seagulls in the investigated area during sampling campaigns and we also supposed that the river could transport contamination deriving from humans. Thus, we added a new analysis to the project by applying a novel methodology MST. We conducted sanitary surveys during bathing season 2019 on various stations where contamination was expected using three microbial-source tracking (MST) markers, one for humans and the other two for seagulls to determine the sources of faecal contamination in the investigated area. Furthermore, one of the goals is that the beach Podstrana is awarded with the Blue Flag, which means that the quality of bathing water on the beach must be excellent.

Study area and sampling sites

Study areas, four marinas and beach in Podstrana, with sampling sites for determination of microbiological quality of water are shown on Figures 20-24.

Figure 20. Sampling sites in marina Strožanac and adjacent area

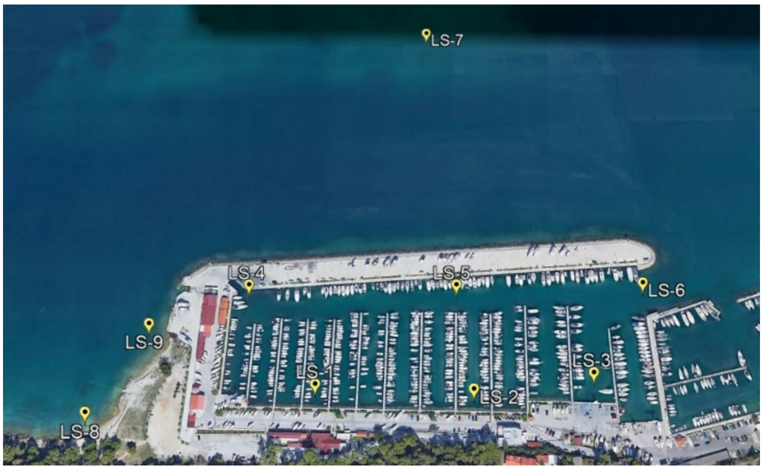

Figure 21. Sampling sites in marina Špinut and adjacent beach

Figure 22. Sampling sites in Marina Dorica

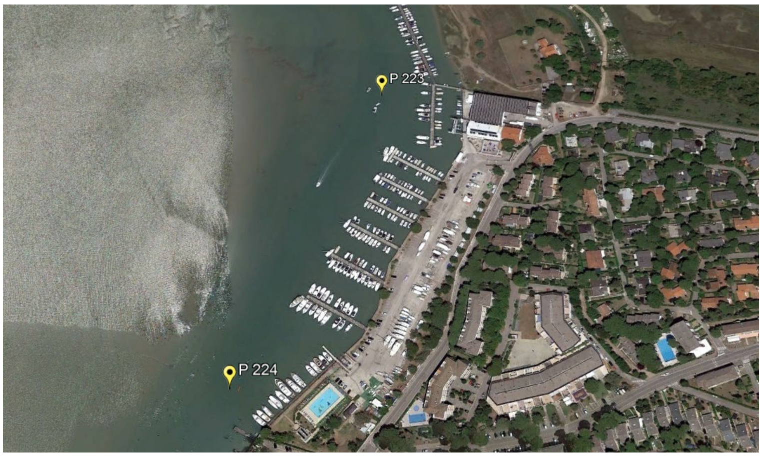

Figure 23. Sampling sites in marina Porto Baseleghe

Figure 24. Sampling sites in bathing water at beach in Podstrana

Sampling

Seawater samples for the determination of faecal indicator bacteria (FIB), Chl *a* and HB were taken under aseptic conditions using a hand-held sampler (a sampling stick) and sterile transparent glass bottles with a volume of 500 mL. The depth of sampling was 30 cm below the sea surface. Sampling was conducted from a vessel. Samples were stored in portable refrigerators immediately after sampling and delivered to the laboratory as soon as possible. Samples for HB were preserved in 2% formaldehyde and stored at 4°C. Seawater/water samples for microbial source tracking (MST) were collected in the same way but only at a few sampling sites in the estuary of River Žrnovnica (LP-6 – LP-9, LP-12).
Sediment samples were collected from the vessel using a Van Veen grab. The subsample from the top 1-2 cm of sediment was placed in sterile plastic containers with lids to prevent water loss, stored in a portable refrigerator, and transported to the laboratory as soon as possible. Samples were stored in the refrigerator at 4°C until analysis in the laboratory. The analysis was performed on the same day.
Temperature and salinity of the seawater were measured using the handheld probe YSI 63.

Methodology

Faecal indicator bacteria (FIB), *Escherichia coli* (*E. coli*) and intestinal enterococci, were determined using a membrane filtration technique. In Croatia, the temperature-modified method HRN EN ISO 9308-1:2014 (Jozić et al., 2018) was used for *E. coli* and HRN EN ISO 7899-2:2000 for intestinal enterococci. In Italy, UNI EN ISO 7899-2:2003 was used for enumeration of intestinal enterococci, while UNI EN ISO 9308-1:2017 was used for *E. coli* in Porto Baseleghe and ISO 9308-1:2000 in Marina Dorica. As an alternative to the TTC Tergitol 7 agar medium, the m-FC medium was also used for the determination of *E. coli* in Marina Dorica samples. The results were expressed as CFU/100 mL of water sample.

For sediment analysis, 30 g of wet sediment was added to 270 mL of sterile distilled water and 1.5 mL of Tween 80 and mixed in the Microtron® MB 550 blender (Kinematica AG) for two minutes at high speed to produce a homogeneous slurry. After the slurry settled, 100 mL of the supernatant was analysed by the MPN technique using the Colilert® -18 and the Enterolert® Rapid Enterococci Test. Results were recalculated and expressed as most probable number, MPN/100 g sediment.

Abundances of HB were determined using flow cytometry (Gasol and Moran, 2015). SYBR Green I stained HB were distinguished according to their relative green fluorescence, which is a proxy for the nucleic acid content, referred to as high nucleic acid (HNA), low nucleic acid bacteria (LNA) and light scattering. HNF cells were also stained with SYBR Green I dye.

Phytoplankton biomass was estimated by measuring the concentration of chlorophyll *a* (Chl *a*). Seawater samples of 1 L were taken in plastic bottles and filtered through glass fibre filters (Whatman GF/F) with a pore diameter of 0.7 µm, under a 65 kPa vacuum. Filters were deep-frozen (below −20 °C), homogenised and extracted in 90% acetone for 2 h in the dark, at room temperature. Samples were analysed for fluorescence (Chl *a*) using a Trilogy Laboratory Fluorimeter (Turner Designs) calibrated with a Chl *a* standard (Sigma) according to the method of Strickland and Parsons (1972). Concentrations of Chl *a* were measured during the 2021 year.

Temperature and salinity of the seawater were measured with the handheld probe temperature/salinity/conductivity.

Water quality of bathing waters of beach in Podstrana was determined in accordance with national regulation (OG, 73; 2008). Since there are no water quality criteria for marinas, the water quality categories for all marinas were determined using national coastal bathing water criteria. Water at sampling sites was categorized based on 90-th and 95-th percentile of FIB, using national criteria for coastal bathing waters (Tables 4 and 5). Because only four data (minimum number of data according to BWD) were available for each sampling site for Marina Dorica, the standard method prescribed by BWD for calculating percentiles could not be used. However, percentiles were calculated using the Hazen method as recommended by WHO (2018) if data are not normally distributed.

Table 4. Croatian standards for assessment of coastal bathing water quality at the end of bathing season and for three preceding bathing seasons.

Parameters	Excellent	Good	Sufficient	Poor
Intestinal enterococci (CFU/100 mL)	≤100*	≤200*	≤185**	>200**
E. coli (CFU/100 mL)	≤150*	≤300*	≤300**	>300**

* Based upon a 95-percentile evaluation
** Based upon a 95-percentile evaluation

Table 5. Italian standards for assessment of coastal bathing water quality at the end of bathing season and for three preceding bathing seasons (OG, 155; 2008).

Parameters	Excellent	Good	Sufficient	Poor
Intestinal enterococci (CFU/100 mL)	≤100*	≤200*	≤185**	>200**
E. coli (CFU/100 mL)	≤250*	≤500*	≤500**	>500**

* Based upon a 95-percentile evaluation

** Based upon a 95-percentile evaluation

Results

Faecal indicator bacteria levels and microbiological quality of water in marinas

Sampling in marina Strožanac and adjacent area was conducted at 12 sampling sites (Figure 20), once a month. At 6 sampling sites (LP-1 – LP-6), the reference site (LP-8) and the site at the mouth of the river Žrnovnica (LP-7), 30 sampling events were conducted from April 2019 to September 2021. Sampling at the other sampling sites in adjacent area, the sandy beach next to the marina and at the mouth of the Žrnovnica River (LP-9 – LP-12) began in June 2020, and a total of 18 samplings were conducted. The mean FIB values for all sampling sites are shown in Figure 25. The values of both indicators, *E. coli* and intestinal enterococci were higher as the sampling station was farther from the marina and closer to the mouth of Žrnovnica River (sampling stations on the graph LP-9 to LP-12 are arranged according to the distance from the marina). This indicates that the microbiological pollution probably originated from the river water.

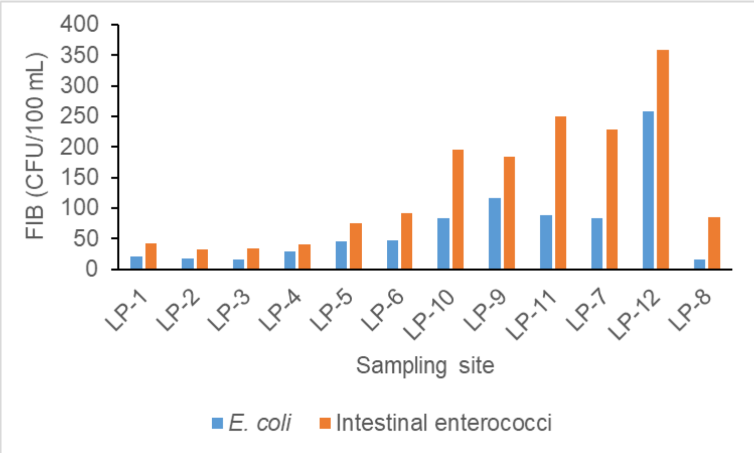

Figure 25. Mean values of FIB in marina Strožanac and adjacent area

Another important source of faecal pollution to the adjacent area is the numerous seagulls that congregate at the mouth of the river (Figure 26), leaving behind large amounts of faecal matter. To test this hypothesis, we collected water samples at two additional depths at the sampling site LP-12: at the surface with fresh river water flowing downstream along the riverbed, and at the bottom with seawater flowing back upstream along the riverbed. These two layers are stratified and do not mix, which is confirmed by temperature and salinity measurement. We found significantly higher FIB counts in fresh surface water than in the saline bottom water layer. This could be due to a higher FIB load from the fresh river water, but also to recirculation of the diluted faecal material through the bottom layer of the saltier water. To determine whether it was river faecal material diluted with seawater or faecal material originating from seagulls, we performed additional analyses based on molecular methods (MST).

Figure 26. Seagulls congregating at the mouth of Žrnovnica River

The quality of seawater in the port and surrounding area is consistent with the distribution of faecal pollution in the area. The seawater quality categories, when all results are considered, are shown in Figure 27a. Water quality was good at four sampling sites (LP -1 - LP -4), sufficient at one site (LP -5), and poor at one (LP -6). Water quality at the surrounding sites, including the reference site and the site on the river, was poor. After the exclusion of 15% of the data as exceedance, which is allowed by the BWD, the water quality has improved significantly (Figure 27b). As a result, at six sampling sites in marina area (LP-1 – LP-6) water quality was excellent (LP-1 – LP-4) and good (LP-5 and LP-6), which is in line with the project objective, to achieve at least good water quality. Water quality at sampling sites in surrounding area remained poor quality. This shows that despite the significant pollution of the area, the impact on water quality in the marina is not such as to pollute the marina to a significant and unacceptable degree. This is probably due to the favourable water flow in the area, which causes pollution to spread to the west side of the river mouth, opposit the marina.

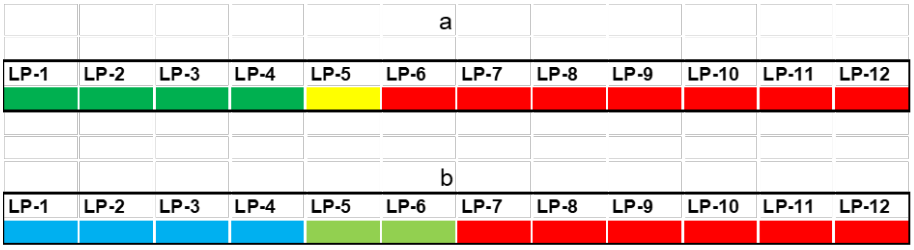

Figure 27. Bathing water quality in marina Strožanac and adjacent area (blue-excellent, green-good, yellow-sufficient, red-poor). a) All data, b) After removing of 15% data (exceedances).

Sampling in marina Špinut and adjacent beach was conducted at 9 sampling sites (Figure 21), once a month. At 6 sampling sites in the marina Špinut (LS-1 – LS6), the reference site (LS-7) and two sites at adjacent bathing water (LS-8 and LS-9) 29 sampling events were conducted from April 2019 to September 2021. The average FIB values for all sampling sites are shown in Figure 28.

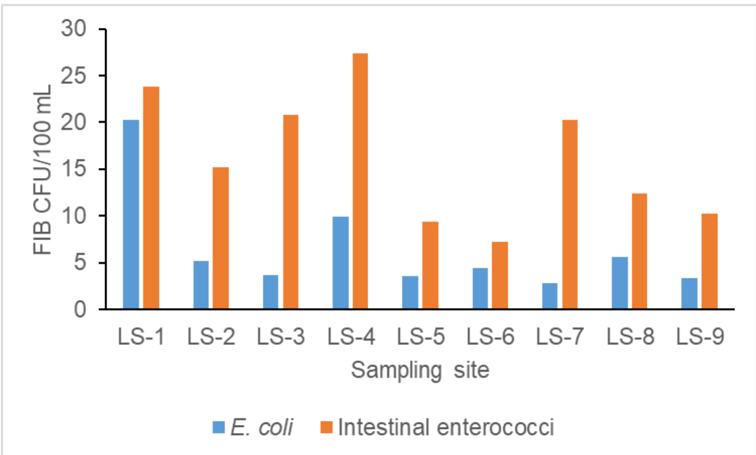

Figure 28. Mean values of FIB in marina Špinut and adjacent area

The results show that the water in marina is not significantly polluted and that marina has no negative effect to the microbiological quality of water at adjacent beach water (LS-8 and LS-9). At all sites, water quality was excellent (Figure 29), which is in line with the project objective, to achieve at least good water quality.

LS-1	LS-2	LS-3	LS-4	LS-5	LS-6	LS-7	LS-8	LS-9

Figure 29. Bathing water quality in marina Špinut and adjacent area (blue-excellent, green-good, yellow-sufficient, red-poor).

Sampling in Marina Dorica was conducted at 3 sampling sites (Figure 22). Historical data from 3 sampling sites (MID1, MID2 and MID3) were used. A total number of 6 sampling events were conducted from May 2017 to October 2019. The average FIB values for all sampling sites are shown in Figure 30.

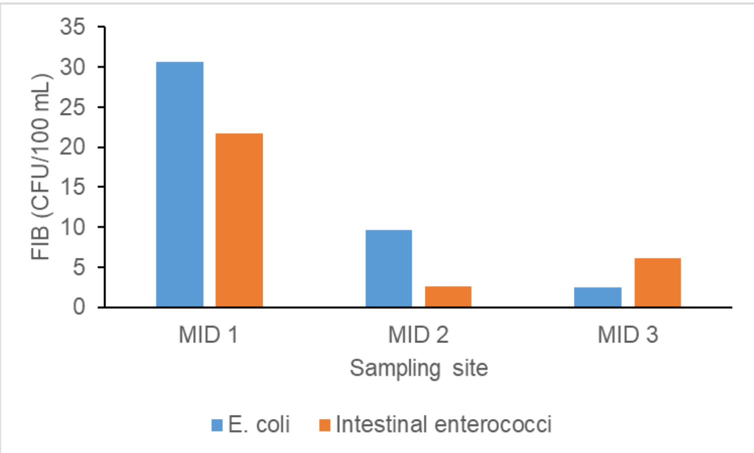

Figure 30. Mean values of FIB in Marina Dorica

The results show that the water in the marina is not significantly polluted. The microbiological pollution probably comes from the water outside the marina, since the average values of FIB are higher at the point next to the marina entrance and decrease towards the inner part of the marina. At all sites, water quality was excellent (Figure 31), which is in line with the project objective, to achieve at least good water quality.

MID 1	MID 2	MID 3

Figure 31. Bathing water quality in Marina Dorica (blue-excellent, green-good, yellow-sufficient, red-poor).

Sampling in marina Porto Baseleghe was conducted at 2 sampling sites (Figure 23), once a month. At both sampling sites (P223 and P224), four sampling events were conducted from June to September 2021. The average FIB values for all sampling sites are shown in Figure 32. The results show that the water in the marina is moderately polluted. A significantly higher level of *E. coli* compared to the level of intestinal enterococci is probably due to brackish water (recorded salinity is lower than 30) and also indicates fresh contamination. However, at both sites, water quality was excellent (Figure 33), which is in line with the project objective, to achieve at least good water quality.

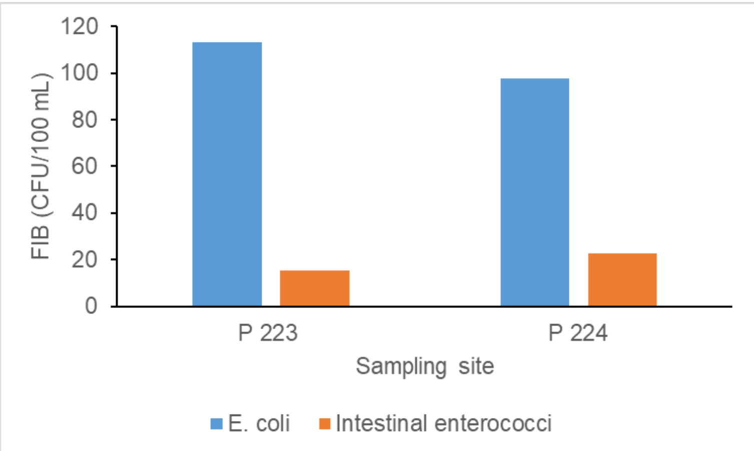

Figure 32. Mean values of FIB in marina Porto Baseleghe

P 223	P 224

Figure 3. Bathing water quality in marina Porto Baseleghe (blue-excellent, green-good, yellow-sufficient, red-poor).

Faecal indicator bacteria levels and microbiological quality of bathing water at beach in Podstrana

At 4 sampling sites at bathing waters on Podstrana beach (PP-1 – PP-4), 46 sampling events were conducted from April 2019 to September 2021. In the same period, 34 samplings were carried out at 3 additional sampling sites (PP-5 – PP-7) in the outer part of the beach waters, outside the beach barrier. These sites were chosen to test spatial distribution of microbiological pollution of bathing water at beach. The average FIB values for all sampling sites are shown in Figure 34a (all data) and 33b (data from bathing season).

The results show that the beach bathing water is not significantly polluted and that outer sites have lower mean values for both FIB. This indicates that the pollution is likely from other sources, such as underwater sources and bathers. This is confirmed by visual observations of freshwater inputs just offshore and lower salinity at the inner sampling sites. When all data (the whole year) were considered, bathing waters at the outer sampling sites were of good quality. When only bathing season data were considered, bathing waters at all sampling sites were excellent (Figure 35). This indicates that microbial contamination likely occurs during the off- season when rainfall is more intense. These results are line with the project goal of achieving excellent water quality in order to obtain the Blue Flag certificate.

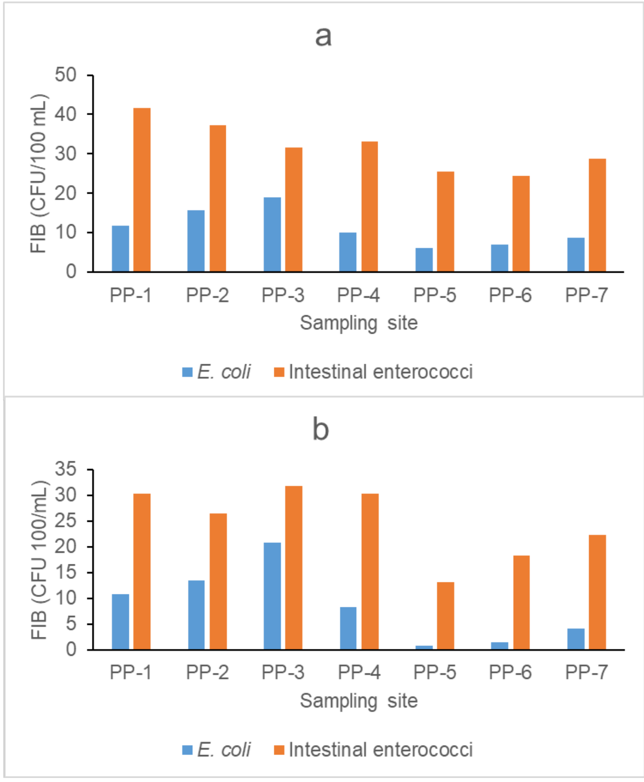

Figure 34. Mean values of FIB in bathing water at beach in Podstrana. a) All data, b) Bathing season data.

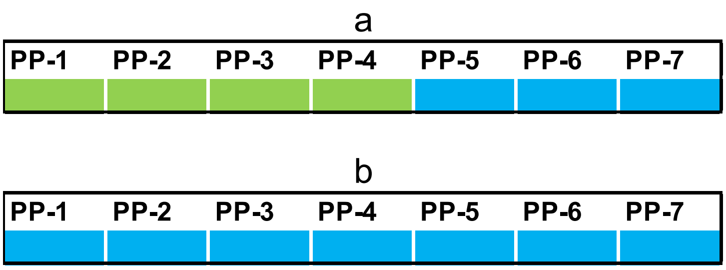

Figure 35. The quality of bathing water in beach in Podstrana (blue-excellent, green-good, yellow-sufficient, red-poor). a) All data, b) Bathing season data.

Faecal indicator bacteria levels in sediment in marinas

The analysis of FIB levels in sediment were performed in marinas Špinut and Strožanac. The sediment samples were collected at a few sampling sites in July 2019 and April 2021. The purpose of determining FIB in sediments was not to obtain a detailed analysis of its content in marinas sediment, but only to determine its spatial distribution and its potential impact on water quality in case of resuspension of sediments in water.

Mean FIB values (average of two values) at sampling sites in two marinas are presented in Figures 36 and 37. At all sites in marina Strožanac a relatively high and uniform levels of intestinal enterococci were recorded, while the mean values of *E. coli* varied between under detection level and 6130 MPN/100 g. The closer sampling site to the mouth of Žrnovnica River the higher *E. coli* levels were recorded. Given the much shorter retention time of *E. coli* in the marine environment and its distribution in the marina area, it is very likely that the pollution originated from the estuary. This is possible because all the openings of the marina face west, that is, toward the mouth of the river. *E. coli* is significantly reduced in seawater to the easternmost point of the marina, so its sedimentation is much less than at sites closer to the western part of the marina.

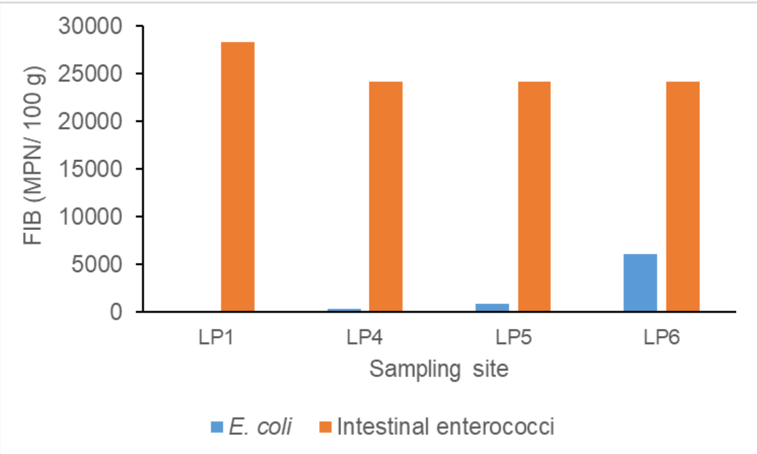

Figure 36. Mean values of FIB in sediment of marina Strožanac

The much more resistant intestinal enterococci are reduced less than *E. coli*, so their sedimentation and consequently their concentration in sediment is higher. However, the sediment in the marina has significant potential for contamination of the water column through resuspension, which is probably reflected in its quality, as the results of the water analysis showed.

Mean FIB values in marina Špinut were considerably lower than in marina Strožanac. Higher values were recorded on sampling site LS-1. It is the place closest to the crane where the boats are taken from the sea, but also the main opening through which the seawater of the marina communicates with the surrounding sea. The highest *E. coli* values were recorded at LS-4 site. This is the place closest to the main crane and the area of intensive boat maintenance. It also has a dock for the longest boats, so it is possible that they occasionally illegally discharge sewage. In addition, the area is under the direct influence of the neighbouring marina, so it is not possible to control possible pollution from this area. Sediment contamination was not constant, as the mean was calculated as an average between 300 and 24196 MPN/100 g. However, the results of the seawater quality analysis were satisfactory, so the sediment does not seem to have a significant influence on the pollution of the water column.

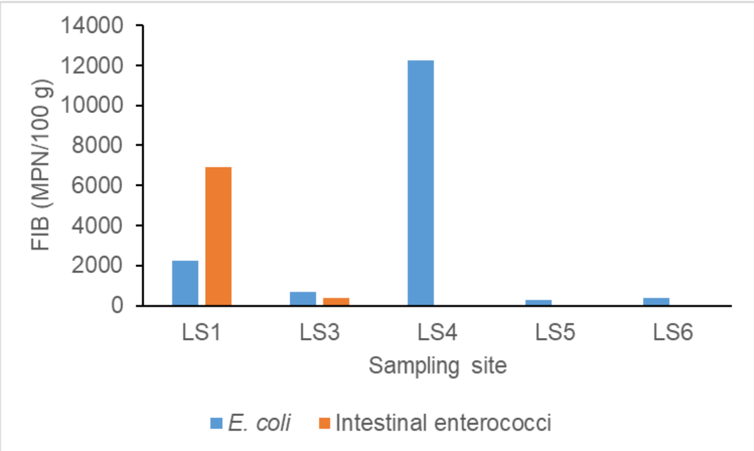

Figure 37. Mean values of FIB in sediment of marina Špinut

Microbial Source Tracking

There was a linear relationship between threshold cycle values and copy numbers of the targeted DNA fragment according to standard curves for a wide range of targets (Table 5.).

Table 5. Standard curve statistics for three qPCR assays with standardized post-processing.

Assay	Slope	Y-intercept	R^2	Efficiency (%)
HF183/BacR287	-3.48	37.28	0.99	0.93
Gull2	-3.78	38.39	0.99	0.83
LeeSeaGull	-3.49	37.55	0.99	0.93

In this study, gull markers were more frequently detected compared to human (Figure 38). The sampling point in front of the Žrnovnica River estuary (LP7) was always contaminated, by gull sources in June and July and by humans in August and September. The surface layer of the estuary (LP12-0-6) was positive for gull marker only in June. Sampling point LP11 near the estuary was positive for both gull markers in June, while LP9 at the beach was contaminated by gull sources in June (Gull2 marker), August and September (both gull markers). Contamination from all three investigated markers was detected in front of Port of Strožanac (LP6-8). It is known that gulls have high concentrations of enterococci in their feces and low concentrations of *Bacteroidales*, which are abundant in the human gastrointestinal tract.

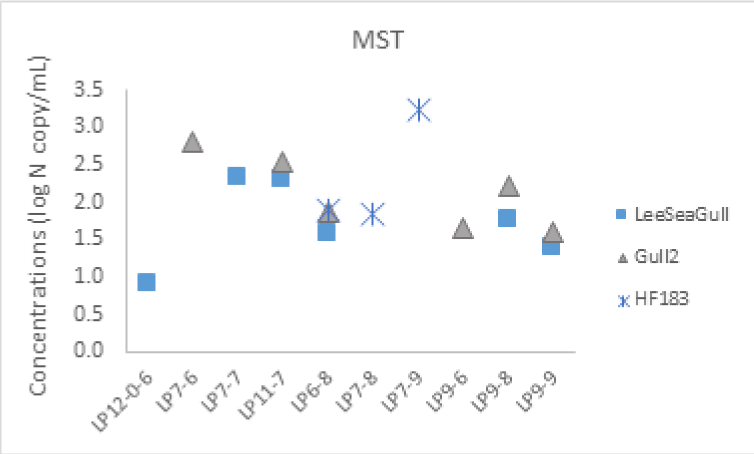

Figure 38. Concentration values (copies/mL) for the HF183, LeeSeaGull and Gull2 markers in the broader area of the Žrnovnica river estuary.

The investigated stations are located in the shallow estuary of the Žrnovnica River, which, according to the observed lower salinity values during summer, influenced the area. In addition, lower salinity was also detected in the wider area as salinity values also fluctuated at the control station. Therefore, we assume that human contamination originates from the river, while contamination from seagulls is more dispersed in the wider area of the Žrnovnica estuary due to their large numbers.

Picoplankton community and Chl *a*

During the whole research, HB reached the highest values in summer 2019 and 2021 for LS1 - LS5. At LS6, values peaked in summer 2019, autumn 2020 and summer 2021, while at the control station it peaked in summer 2021. At stations LS1 and LS7, HB was more uniformly distributed compared to the other ones. According to Smith et al. (1999), Chl *a* concentration, as a proxy of phytoplankton biomass, indicates the trophic status in marine coastal waters. As these values were below 1 µg L^{-1}, Port of Špinut can be characterised as an oligotrophic environment (Figure 38). The only exception is the control station in July when Chl *a* concentration was 1.51 µg L^{-1}. Figure 39 shows that HB and Chl *a* values fluctuated over time, especially for the control station. An increase was noticed towards warmer weather on LS1. HB never exceeded 10^6 cell mL^{-1}, which is also an indicator of the trophic status of the environment.

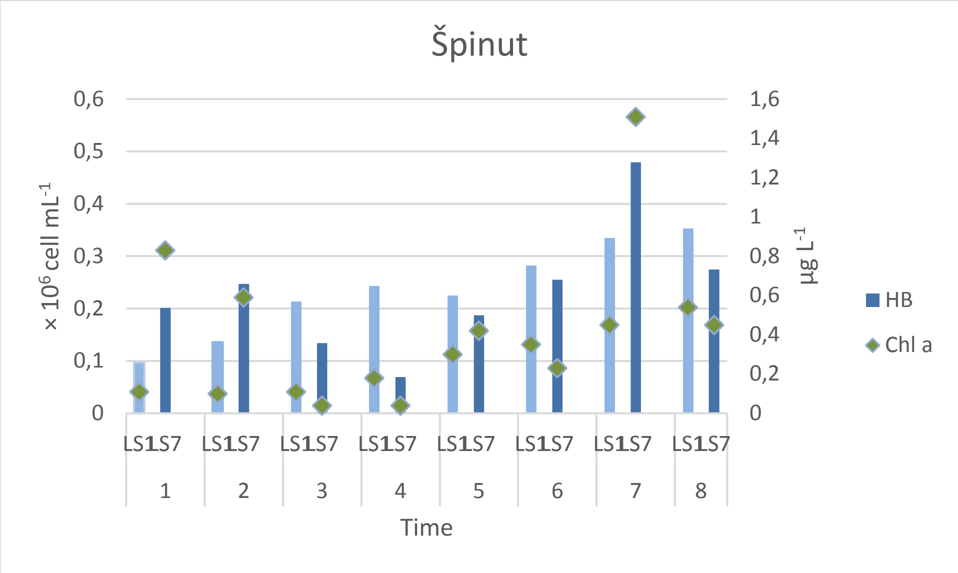

Figure 39. Comparison of chlorophyll a (Chl a) and heterotrophic bacteria (HB) values at stations LS1 and control station LS7 in the Port of Špinut.

A paired t-test revealed a statistically significant difference between the studied LS2 and LS3 points and control one (LS7) in the Špinut port (P≤0.05) as hypothesised. These two sampling points are enclosed inside the marina area, thus communicating less with the outer sea of Kaštela Bay. Related to LS1, by conventional criteria, the difference (P=0.0058) is considered to be not quite statistically significant.
During the whole research, HB reached the highest values during the spring and summer seasons. At station LP6, HB displayed the lowest measured values, with uniform distribution and moderate increase during spring and summer. At station LP6, HB was more uniformly distributed in comparison with the other stations. According to Smith et al. (1999), Chl *a* concentration, as a proxy of phytoplankton biomass, indicates the trophic status in marine coastal waters. As these values were always below 1 µg L^{-1}, the Port of Strožanac can be characterised as an oligotrophic environment (Figure 40). Abundances of HB never exceeded 10^6 cell mL^{-1}, which is also an indicator of the trophic status of the environment. Figure 4 shows that HB cell densities at both investigated stations displayed the same pattern, except in April. HB and Chl *a* values fluctuated over time, with higher towards warmer weather.

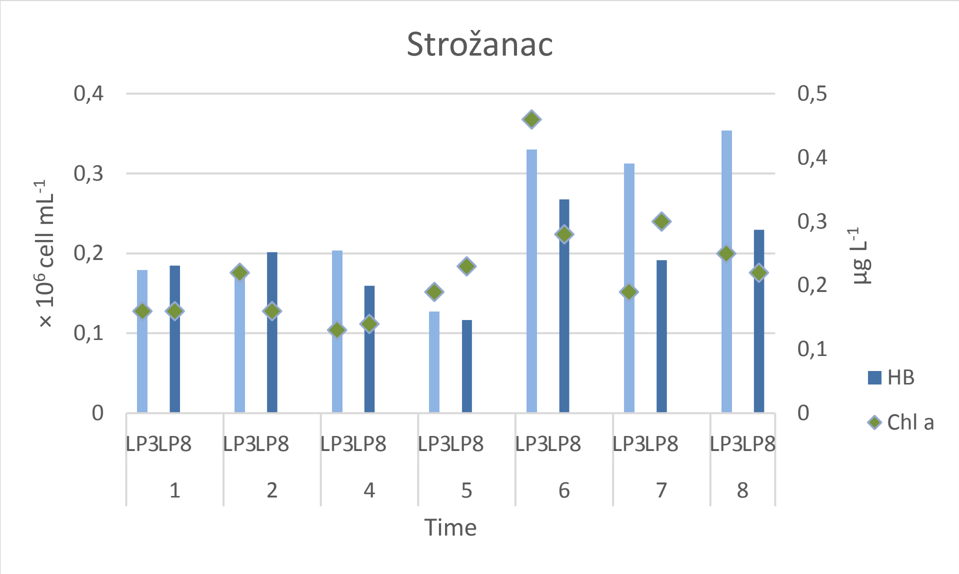

Figure 40. Comparison of chlorophyll a (Chl a) and heterotrophic bacteria (HB) values at stations LP3 and control station LP8 in the Port of Strožanac.

A paired t-test revealed there was no statistically significant difference between two out of six studied points (for LP1 $P=0.66$ and LP6 $P=0.16$, $P<0.05$) and the control point in Strožanac, as predicted. A statistically significant difference was determined for the remaining stations. This was expected since these sampling points (LP2-LP5) are located inside the Strožanac, although it is a small port that communicates well with the outer sea, especially the two sampling points that displayed no difference from the control point.

Highlights

- Based on the data collected in the ECOMAP project and the data from previous surveys for Marina Dorica, it can be concluded that the microbiological quality of the water in all marinas meets the requirements of the project, that is it is at least good. Moreover, the quality is much better, mostly excellent at all sites, except for two sites in the marina Strožanac, which are good.
- The results show that activities in marinas do not have a negative impact on water quality both in the marinas themselves and in the adjacent areas.
- The adjacent area of the marina Strožanac, the mouth of the Žrnovnica River, has a potentially negative impact on the microbiological quality of the water in the marina. The sources

of microbial contamination are the contaminated river water and seagulls that congregate at the mouth of the river, leaving behind large amounts of faecal matter.

- Sediments in the marina Strožanac and the adjacent beach next to the mouth of the river Žrnovnica have a great potential to contaminate seawater, as relatively high FIB levels were found in sediment samples.
- The microbiological quality of bathing waters on the beach of Podstrana was excellent in all sites during the bathing season, thus meeting the Blue Flag criteria for bathing waters.
- Since water quality at the beach is somewhat poorer when assessed based on year-round data, microbiological pollution appears to affect the beach occasionally, during rainy periods, or when contaminated water from the estuary spreads to the beach due to favourable winds.
- Since the aforementioned results of faecal indicator bacteria in the Žrnovnica River estuarine area showed the potential risk to human health for bathers due to their high concentrations, we conducted the sanitary survey to determine the sources of microbial contamination in the wider area of the estuary.
- Human and LeeSeaGull markers were detected, implying two different sources of contamination in the investigated area, human and gull.
- Samples from the broader estuarine area were more frequently contaminated by gulls than by human sources and in the broader area.
- Lower salinity was found in the wider estuarine area, including salinity fluctuations at the control station, indicating an influence of the river.
- Accordingly, we concluded that both markers are detected in the investigated area due to the mixing of the seawater with the freshwater layer.
- The river could be a source of human contamination, while seagull assays were selected because they were abundant in previous sampling campaigns.
- Taken together, the above results provide one of the few insights into microbial communities in port ecosystems in general.
- We confirmed the hypothesis that a small statistically significant difference is found in Špinut and Strožanac ports compared to control points.
- According to the concentrations of chlorophyll *a* and heterotrophic bacteria, the investigated ports are oligotrophic environments. Therefore, these ports do not contribute to anthropogenic pressure on the adjacent coastal environment.

Monitoring Networks in the marinas

Relate to Deliverable 3.4.7 – WP3

In order to continuously monitor the marinas and understand the trend of physical / chemical parameters, two kinds of monitoring networks were used in two marinas/sites of the project. Two different methods of data monitoring acquisition were chosen in order to understand if comparable and useful for the marinas.

This activity was carried out thanks to the collaboration between ECOMAP project partners. In *ŠŠpinut* marina (43.5151820, 16.4185480), a multiparametric probe (*HANNA Instruments*) was placed from February 2022 to the end of April 2022 (Figure 20).

The collected parameters (every three hours) were:

- Temperature (°C) (Figure 21)
- PH (Figure 22)
- Specific Conductivity (µS/cm)
- Absolute Conductivity (µS/cm A)
- Total Dissolved Solids (TDS) (ppm)
- Salinity (%) (Figure 23)

Figure 19: Photos of Multiparametric Probe used in Špinut marina (collab. PP1).

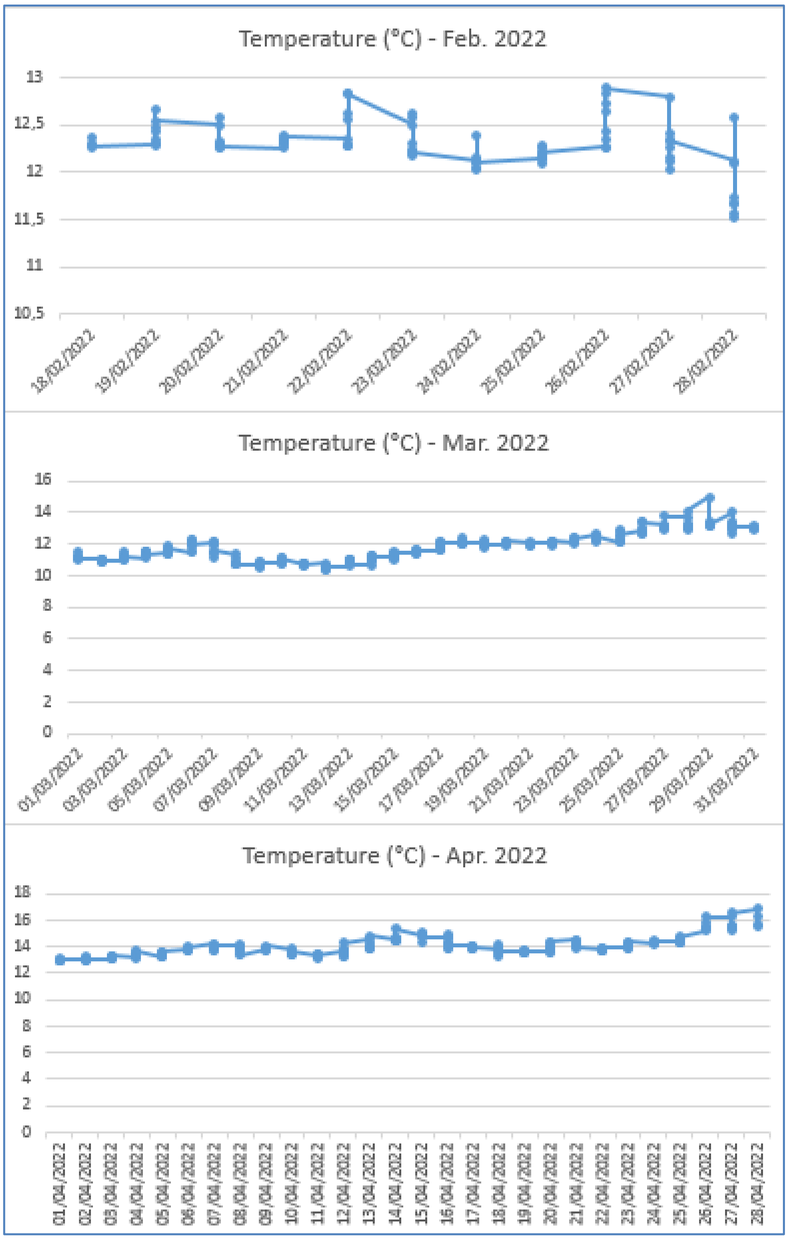

Figure 21: Temperature (°C) values collected thanks to the multiparametric probe (ŠŠpinut marina) (period February – April 2022).

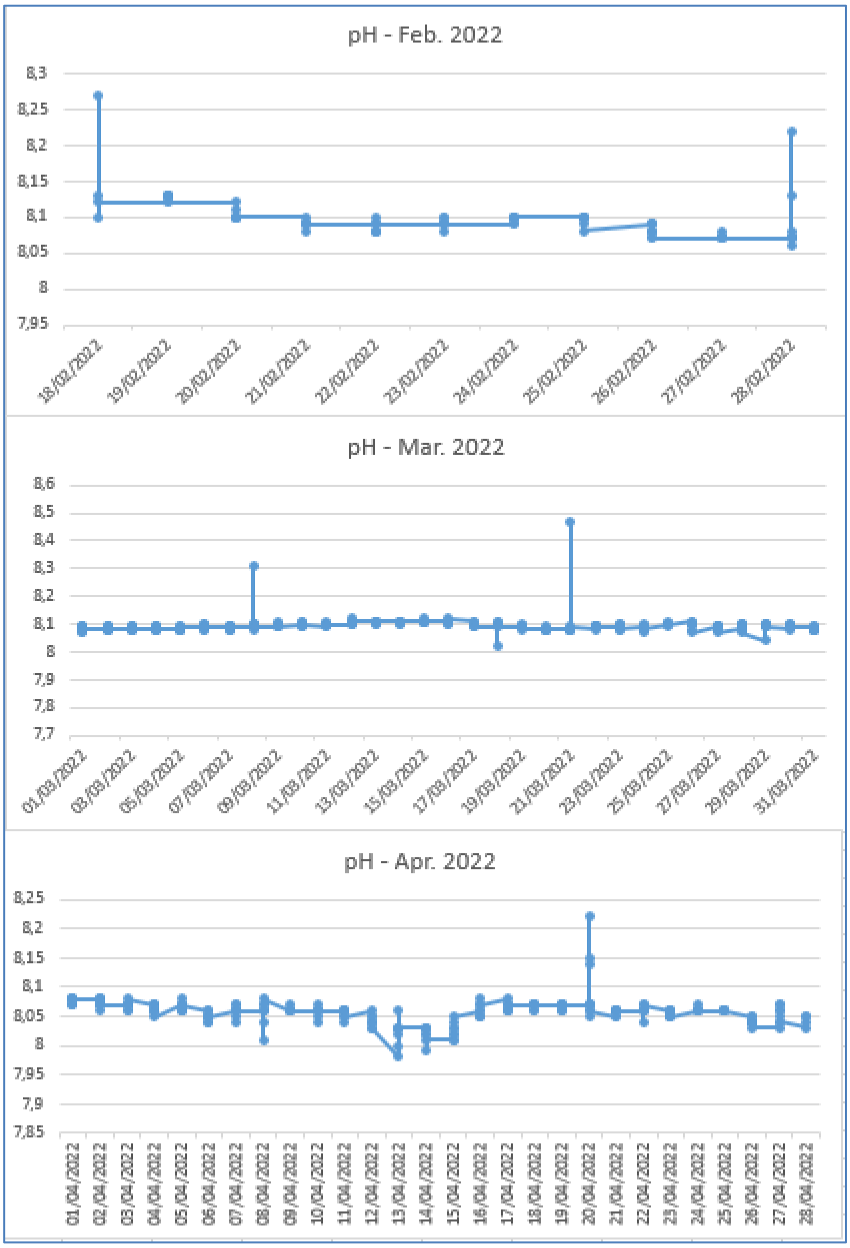

Figure 22: pH values collected thanks to the multiparametric probe (Špinut marina) (period February – April 2022).

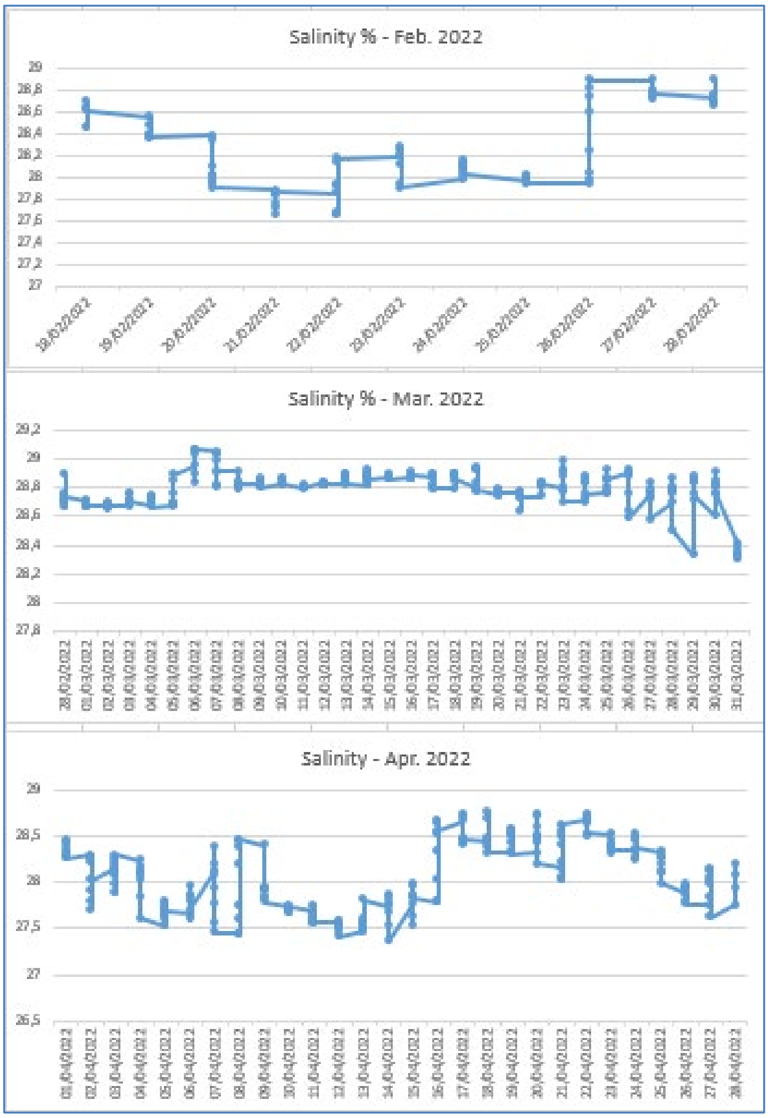

Figure 23: Salinity (%) values collected thanks to multiparametric probe used (ŠŠpinut marina) (period February – April 2022).

Thanks to the collaboration of PP6 in Bibione area, Temperature (°C), Salinity (%) and pH values were collected. Two sampling points were chosen (*45.63509632; 12.99488407* – ***S1*** and *45.63509631; 12.99488407* – ***S2***).

Samplings were carried out in two different periods:

- June/September 2021 (*monthly*) (Figure 24)
- April/May 2022 (*twice monthly*) (Figure 25).

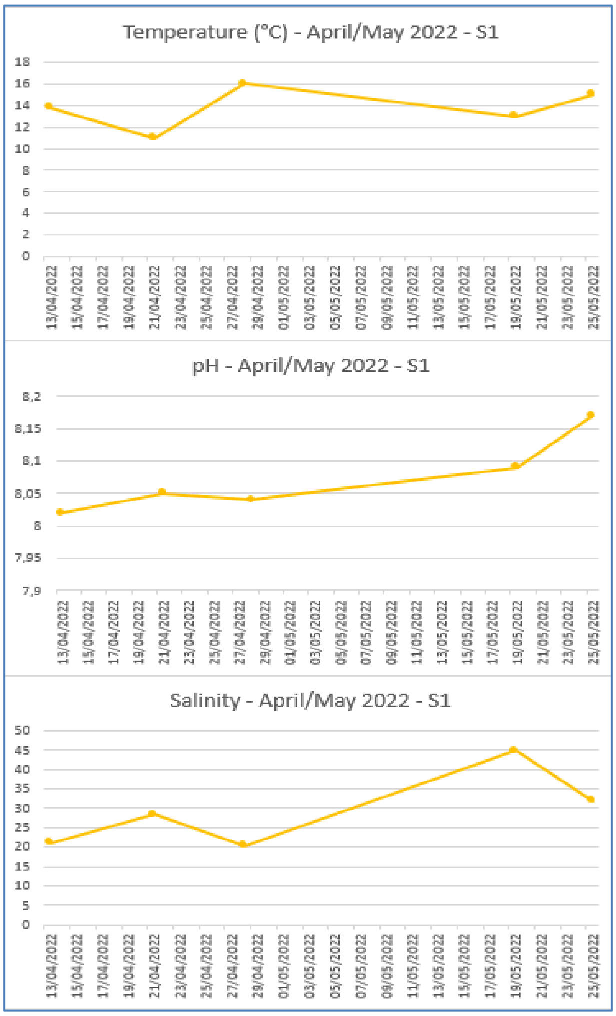

Figure 24: Temperature (°C), pH and Salinity (%) values collected during April/May 2022 (twice monthly). Site S1 (45.63509632; 12.99488407) (Bibione).

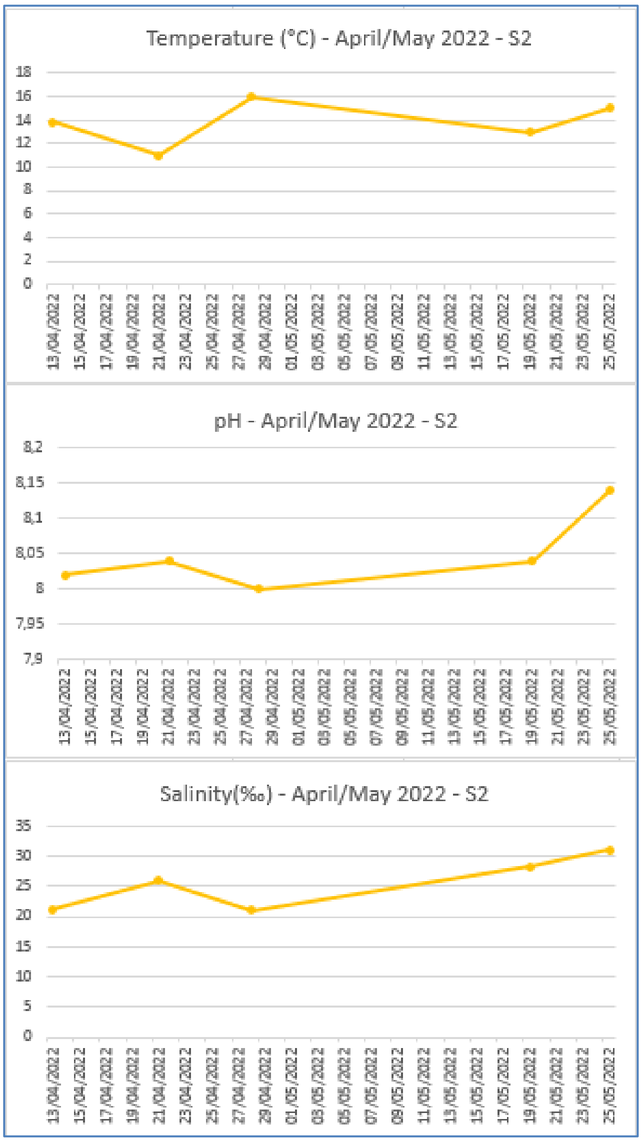

Figure 25: Temperature (°C), pH and Salinity (%) values collected during April/May 2022 (twice monthly). Site S2 (45.63509631; 12.99488407) (Bibione).

Identification of environmental pressure sources to be managed

Relate to Deliverable 3.4.5 – WP3

This impact analysis aims to identify the main sources of environmental impacts in order to propose useful solutions to support the managing bodies of the beaches and small ports towards a correct approach to pollution issues, as well as integrate intervention proposals strategies at Adriatic basin scale.
The analysis is performed in relation to the 11 descriptors of Marine Directive and it is to achieve Good Environmental Status of EU marine waters by 2020 MSFD. All these descriptors must be studied with a integrate multidisciplinary approach as they are interrelated and must be faced with a multidisciplinary approach that describes the morphological environments whose fragility is related to the characteristics of the Adriatic which is a semi-closed water body, of low depth (<50 m). Each descriptor has a link to the dedicated European Union website.

- **Descriptor 1.** Biodiversity is maintained
- **Descriptor 2.** Non-indigenous species do not adversely alter the ecosystem
- **Descriptor 3.** The population of commercial fish species is healthy
- **Descriptor 4.** Elements of food webs ensure long-term abundance and reproduction
- **Descriptor 5.** Eutrophication is minimised
- **Descriptor 6.** The sea floor integrity ensures functioning of the ecosystem
- **Descriptor 7.** Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
- **Descriptor 8.** Concentrations of contaminants give no effects
- **Descriptor 9.** Contaminants in seafood are below safe levels
- **Descriptor 10.** Marine litter does not cause harm
- **Descriptor 11.** Introduction of energy (including underwater noise) does not adversely affect the ecosystem.

Descriptor 1 (Biodiversity is maintained)

The ECOMAP project for the Descriptor 1 performed the biodiversity analysis in order to provide a useful reference to monitor on going climate changes in order to develop best practices able to ensure that biodiversity is "maintained" in relation to maintenance of the natural state appropriate to apply the Marine Directive. The Adriatic Basin, like all marine areas of the world, is recording the conditions of stress due to global warming, the increase of CO_2 in the atmosphere, which is reflected in the acidification of the sea and the melting of the glaciers. This situation will produce the change in the fresh water budgets in aquifer causing a reduction in the

amount of fresh water to the marine environment. All these pressure have impacts to biodiversity.
ECOMAP activities were carried out in order to:

- Characterize macro faunal communities in Croatian sites of Špinut and Strožanac Croatia and in the Italian site of Marina Dorica in Ancona (see results in D.3.3.4). The macro faunal abundance, diversity indices, species composition, together with the physical-chemical features of the surface sediments and their contamination levels, were used to evaluate the ecological status of the three marinas.

- Biodiversity analysis in relation to submerged wrecks. The CFR and UNIFE have analysed how the sandy and clayey sea bottoms become a great point of attraction for many living species, activating a sort of active transformation of the site and the natural environment. The potential key impacts related to the presence of metal wrecks are related to changes in currents and in the circulation of sediments producing positive and negative effects:

i) The submerged wrecks increases the protection of the natural biocenosis, reduces the mortality of young fish species and eggs, create dens and shelters for permanent species, attract and concentrate the pelagic species that find food in abundance on this reef species;

ii) The submerged wrecks can produce changes in currents and in the circulation of sediments due to presence of metal wrecks. They can damage the habitats and to the species and can be input to the introduction of new habitats also giving the variations of ecological relations. The Northern Adriatic area selected demonstrates a positive impact on the bottom of the sea and the biodiversity. The surfaces of the wrecks are covered by filtering organisms belonging to two main species: mussels (e.g. *Mitilus galloprovincialis*) develop in the most superficial area up to about 12 meters deep, while oysters proliferate with variable density and decreasing towards the bottom (e.g. *Ostrea edulis*). There are also other sessile organisms such as tunicates, coelenterates, as well as Porifera (abundant in the superficial and intermediate zone, in particular *Dysidea* sp.), Bryozoans and Polychaetes (in particular serpulids), Echinoderms, Holothuroidea, and Asteroids. Among the Echinoderms the most numerous exemplary are the Ophiuroids.
The typical fishes of the rocky bottoms: Brown meagre (*Sciaena umbra),* Saddled seabream (*Oblada melanura*), Sand steenbras (*Lithognathus mormyrus*), Black scorpionfish (*Scorpaena porcus*), European bass (*Dicentrarchus labrax*) and congers (*Conger conger*). Unfortunately, abandoned wrecks favour the accumulation of fishing nets and plastic which have a negative impacts on the healthy status of rocky outcrop ecosystems. This is because they affect the benthic and fishes community, altering the

microhabitat, occupying and covering part of the substrate and organisms, and obstructing reef crevices (Moschino et al. 2019). Fundamental to biodiversity are the rocky outcrops located along the coast of the Veneto Region, in particular from the mouth of the river Brenta to the city of Grado, are unevenly distributed, but seem to be positioned along parallel bands at 3–5miles, 10– 12miles and 20miles off the coast, at depths ranging from 8 to 40m (Newton and Stefanon, 1975; Stefanon and Boldrin 1979, Casellato et al 2007, Nesto et al 2020).

iii) The fresh waters outflowing from the seabed raise the pH and introduce calcium and magnesium, essential for the bioconstruction of the carbonates of the shells of foraminifers and melacofauna. Freshwater sources are therefore fundamental for biodiversity. OGS, Bibione Mare S.p.A. and UNIFE have investigated the plume of fresh water in sea environment to provides a reference for monitoring the impacts of acidification of the sea and for identifying the areas where the insertion of artificial reefs, can guarantee the construction of habitats useful for maintaining biodiversity and the abundance of fish products (i.e as nursery areas).

Bibione Mare S.p.A has participated in the biodiversity defences activities by capitalizing in ECOMAP the results of the project "*Bibione Reef*" in collaboration with VeGAL, the Coast Guard Delta Tagliamento and two recreational associations (A.S.D. Sea Sporting Portobaseleghe, A.P.S.D. Martin Pescatore, A.S.D. Sferasub). This artificial reefs can represent surrogate habitats for the natural reefs for habitat conservation and a tool for contrasting the trawling. Bibione offers tourists scuba diving paths in the coral areas that are developed on artificial reefs to learn about biodiversity (Pellizzato 2013).

Descriptor 2 (Non-indigenous species do not adversely alter the ecosystem)
The rising sea temperature is reducing the space of species that prefer cold environments, and for this reason, alien species are invading the Mediterranean Sea. They are carried by ship traffic or enter the Mediterranean through the Suez channel. Among these particularly invasive species are some molluscs such as *Anadara transversa*, observed in the Mediterranean since 1972 (Turkey) and recently also arrived in the Adriatic (Ancona and Cesenatico) and in Venice since 2000 (Mizzan, 2002; Mizzan L. and Vianello C., 2007).

Descriptor 3. (The population of commercial fish species is healthy) and Descriptor 4. (Elements of food webs ensure long-term abundance and reproduction)
The Adriatic Sea is a semi-closed water body, of low depth (<50 m), in which the soft substrates (rich in clay minerals) are increasing for the lower contributions of coarse sediments from the

rivers. The rising of the sea level has changed the equilibrium profile of rivers. So, erosion areas of the continental environment are transforming into sedimentation areas; the plain areas of the catchment area are expanding and the sediments are deposited without reaching the sea. Only the fine sediments reach the sea and this modifies the seabed.

The production of food through fishing is essential to fight poverty. The world population is increasing causing a greater request of food, while the fertile coastal areas are reducing due to the rising of the sea. The increase in inland floodplains fails to compensate the loss of arable land in coastal areas. The scenarios developed by the IPCC assumes a level increase of up to 2 meters by 2100, while NASA has published more optimistic forecasts that predict a sea level rise of about sixty centimetres compared to current levels.

According to Larour et al. (2019), a crustal uplift in the Amundsen Sea sector is helping to reduce grounding line retreat stabilizing the ice sheet and slowing its rate of mass loss. This effect that will not stop or reverse ice sheet loss, could delay the progress of dynamic mass loss of Thwaites Glacier by approximately 20 years allowing to lower greenhouse gas emissions with the ecological transition that many states are implementing.

In recent years, numerous international conventions have recognized the need to increase protection of marine resources of the Adriatic to reform sea management and to balance the multitude of human marine uses. The ECOMAP project is part of the analysis of the strategies and good practices to be adopted to support the significant efforts are taking place worldwide to reach the objective of protecting 10% of coastal and marine areas by 2020 (Aichi targets Convention for Biological Diversity (CBD) (https://www.cbd.int/2011-2020/goals/). For example, this effort sees nourishment interventions in coastal areas useful for countering erosion.

Descriptor 5 (Eutrophication is minimised)

The stratification of the chemical-physical parameters of the water column is altered. In fact, for long periods of the year there is a lack of oxygen combined with high temperatures, and polluting entrance from the rivers. An example is the drought of 2022 which is reducing the flow of rivers that are not always able to guarantee self-purification capacities with respect to the wastewater that is introduced into them. These conditions favour biological and ecological threats that negatively affect the ecosystem of the Adriatic Sea, inducing eutrophication, fragmentation of benthic habitats, and invasion of non-indigenous species.

Descriptor 6 (The sea floor integrity ensures functioning of the ecosystem)

This descriptor defines the need of Sea-floor integrity that must be at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected. Rice et al. (2021), analyzed the scientific literature addressing this problem and identified eight indicators of the seabed system that are adequate to provide information to meet requirements of the MSFD: "(i) substratum, (ii) bioengineering (iii) oxygen concentration, (iv) contaminants and hazardous substances, (v) species composition, (vi) size distribution, (vii) trophodynamics and (viii) energy flow and life history traits. Rice et al. (2021) also assert in accordance with the scientific literature that "Good Environmental Status "cannot be defined exclusively as" Pristine Environmental Status ", but rather status when impacts of all uses were sustainable. The pressures associated with those uses do not hinder the ecosystem components to retain their natural diversity, productivity and dynamic ecological processes. In the Work Package the analyzes performed by OGS, UNIFE, CFR and the IOF investigated the seabed in the test areas and performed measurements of the main chemical-physical parameters, providing useful data to define the environmental state in line with the suggestions of Rice et al. (2021) and MSFD. Work Package 3 activities provided the protocols for geophysical prospecting and analysis of the chemical, mineralogical and biological composition of the sediments and the water column, contributing to the implementation of the Marine Directive.

Descriptor 7 (Permanent alteration of hydrographical conditions does not adversely affect the ecosystem

The Marine Strategy Framework Directive (MSFD) requires assessment of good environmental status with an ecosystem approach at the scale of sea basins or "marine spatial planning". This assessment aims to understand the impacts of climate change, and in particular of global warming on a local scale in order to map the hydrographic variations that may occur due to variations in: thermal, salinity and/or tidal regimes; sediment and fresh water transport; current or wave motion and turbidity variations. The degree of variation can be correlated to the water column and the seabed for which it is necessary to define the current state and the reference values, monitoring the impacts over time. With the investigations carried out in WP3, ECOMAP investigated the physiography of the seabed, the qualitative state of the sediments and the chemical-physical characteristics of seawater column. These ones, also in relation to organic carbon and fresh water springs in the seabed. All these surveys are helpful for the knowledge of the current characteristics in the project test sites. These analysis, performed in small ports and beaches, are helpful to evaluate the effects of changes that could be caused by building activities, such as expansions or changes of the coast.

For example during winter in the northern Adriatic Sea, bora wind forced the formation of dense water. The cold seawater (enriched in oxygen and CO_2) has a density such that convective cells are triggered. In this way the cold seawaters are carried toward the seabed, feeding the deep water producing deep thermohaline cell in the Eastern Mediterranean. This represents one of the drivers of the Eastern Mediterranean thermohaline circulation (Orlić et al., 1992; Robinson et al., 2001). Souvermezoglou and Krasakopoulou (2021) pointed out how "the Adriatic Deep Water (AdDW) is produced through open ocean deep convection in the Southern Adriatic Pit, and then feeds the deep thermohaline cell of the Eastern Mediterranean constituting the main component of the Eastern Mediterranean Dense Water (EMDW)".
During summer, the excessive heating of the water produces an interruption of the exchange between surface and groundwater, with a consequent reduction in the concentration of oxygen in the water column. Vilibić et al. (2022) analysed the temporal sequence of changes in chemical-physical parameters. The hourly data in situ, collected continuously between 2014 and 2021 in the Pag bay, showed that <<the temperature variations were rapid on an hourly scale, up to 2 ° C / h. Most of these fluctuations occurred during the summer, could produce profound effect on bivalve growth and reproduction and recruitment processes. Intuitively, the summer maximum in high-frequency variability is - in addition to being triggered by rapid atmospheric forcing (e.g., storms summer and bora events) - mainly the result of high stratification conditions, in which a small forcing can cause rapid changes in the temperature near the surface >>. The alterations of both the thermoaline and the circulation properties cause traceable changes in the biogeochemical processes, not only as alteration of hydrographical conditions the biodiversity of the Adriatic Sea but also in the remarkably oligotrophic Ionian (Boldrin et al., 2002).

Descriptor 8 (Concentrations of contaminants give no effects)
To maintain this parameter in the project areas, suitable structural interventions have been carried out to improve the management of discharges such as adaptation of showers and interventions in port and marine areas for bilge water management.

Descriptor 9 (Contaminants in seafood are below safe levels)
This indicator was evaluated with the activities of WP3.3 analyzing the chemistry and mineralogy of the sediments in the test areas, not detecting problems of heavy metal pollution.

Descriptor 10 (Marine litter does not cause harm)
In order to increase knowledge on the degradation of plastics in this environment, in situ experiments were conducted in sub coastal environments of Goro lagoon (Ferrara). This study tested the degradation of six commonly used types of plastics and the possible factors

responsible for the degradation. The types of plastic used were polystyrene (PS), polypropylene (PP), high density polyethylene (HDPE), low density polyethylene (LDPE), polyethylene terephthalate (PET) and polyvinyl chloride (PVC). To proceed with the experiment, testing racks were built to allow the exposure of all types of plastics in the form of strips, so that they were individually traceable and equally exposed for each selected environment. Once built, the testing racks were suitably installed in the Goro lagoon at intertidal and subtidal depths. Sampling of the plastic strips was performed after 4, 8, 12, 16, 20, 28 and 36 weeks of exposure. At each sampling time point, total mass change and mass change after washing with hydrochloric acid were measured; from week 4 to week 28 samples *chlorophyll a* accumulation were measured. The 12 and 28 weeks exposure samples were also observed using the scanning electron microscope (SEM) and were subjected to leaching testing. Moreover, plastic strips exposed for 28 weeks in the lagoon and port environments were subjected to dissolution by acid attacks. Subsequently, factorial ANOVA was performed individually for each environment to assess the influence of plastic type, depth zonation, and deployment time, on apparent plastic mass change, biofilm mass accumulation, and *Chl a* accumulation. Furthermore, ANOVA was performed for the data of apparent mass change, fouling mass and *chlorophyll a*, considering the factors of location, zonation, deployment time and plastic type for the lagoon environment. The study showed that the rate of degradation and the type of degradation strongly depend on the environment and on the types of plastics were exposed. The agents that contributed to the degradation are many: exposure to UV rays, environmental temperature, water salinity, accumulation of fouling, oxygen availability, hydrodynamic energy. It was seen how the degradation was influenced by the depth of deployment. In intertidal/semi-floating conditions, in fact, due to the greater UV radiation, the greater thermal stress and the greater hydrodynamic energy, the plastic strips have undergone greater degradation compared to the subtidal/submerged conditions. The type of plastic also affected the rate of degradation. There was a greater degradation for PET and PVC and gradually decreasing for LDPE, HDPE, and PP.

Descriptor 11 (Introduction of energy (including underwater noise) does not adversely affect the ecosystem)
This parameter has not been evaluated as it is not the subject of the project activities.

Remediation programs for pollution of the water resources and sediments

Relate to Deliverable 3.4.8– WP3

Bilge water that is release into the sea

Bilge water is a mixture of hydrocarbon and water rich in pollutant (fuels, lubricating oil, cooling water, cleaning diesel oil, oily sludge and the spills deriving from machinery leakage and washing waters) accumulated in the bottom of the ships. The International Maritime Organization regulates the amount of bilge water that can be spilled into the sea. Moreover, the DIRECTIVE 2005/35/EC "on ship-source pollution and on the introduction of penalties for infringements" gives the absolute ban to discharges of polluting substances from any ship, irrespective of its flag. Warship, naval auxiliary or other ship owned or operated by a State are excluded from this directive.

These very restrictive conditions are justified by the following main impacts that oily substances have on the marine environment:

- The high salinity of the mixture of oils and seawater inhibits the biological degradation. Furthermore, the life time of the oily substances in the marine environment are very long. The oils present give rise to a thin film on the surface of the water due to the fluid-dynamic behaviour of the hydrocarbons with a density lower than that of water. The thin film prevents oxygen and CO_2 from entering in solution in the water impacting on the life of organisms that need oxygen and carbon. Moreover, this film favours the assimilation by organisms living on the water surface, so oily substances and metals associated with them enter in the food chain with an impact on the health of marine organisms and on the quality of fishery products;
- Oily substances dispersed by boats can accumulate in the shorelines reducing the multiple ecosystem functions that sand beaches provide including: regulation of biogeochemical self-depuration cycles; maintenance of genetic and biological diversity through the provision of habitat to vertebrate populations (McLachlan and Brown, 2006, Schlacher et al., 2008).

Unfortunately, despite the legal restrictions, bilge oil spills occur frequently in the sea because of maritime accidents or illegal discharge.

The ECOMAP project has developed actions aimed to favouring the correct management of Bilge water, which consist of:

1) educate yachtsmen and port-goers with signs that inform about good behaviour. In particular, the municipality of Ancona with the management body of Marina Dorica has distributed the 'Etiquette of the sea', where pills are imprinted to stimulate respect for the sea ". CFR, IOF and Bibione Mare S.p.A. have drawn up the manual of the Blue Flag. Bibione Mare S.p.A has defined, with the Port Authorities, the Ordinance 43/2010 for the management regulation of the Port of Baseleghe which also includes the management of bilge water;
2) improve wastewater treatment systems. Bibione Mare S.p.A (in the Port of Baseleghe) and the Municipality of Ancona (in the port of Marina Dorica) have a collection facility within the port where boats entering the proto are obliged to deliver the waste produced from the ship and from the cargo residues (art. 2 c. 1 lett. e of Legislative Decree 182/03). The recovered waste is then transferred to the appropriate disposal facilities.
Marina Dorica has promoted good behavioral practices looking at environmental sustainability. The Municipality of Ancona (in collaboration with Marina Dorica) has built a transportable drainage of waste, which reduces the inconvenience for yachtsmen and port-goers, encouraging them not to abandon water waste and Bilge water on the open sea before entering the port. Thanks to the ECOMAP project, a pumping station for black water was inaugurated on May 12th, 2022. Moreover, an on-board kit for collecting hydrocarbons from bilges and engine compartments was delivered to stakeholders and boaters in the port that is a patent of start-up "Test 1 Srl - Greennovation" against spills during the 'Think blue' event. Stop sea pollution.

Valorization of water resources

Relate to Deliverable 3.4.9 – WP3

With the ECOMAP project, the following steps were taken to achieve environmental improvements:

- Construction of a drainage and wastewater recycling system developed in the Marina Resort Porto Baseleghe and on the four managed beaches to intervene on the showers in order to guarantee a high quality of the used water;
- Marina Dorica has promoted good behavioral practices looking at environmental sustainability. Thanks to the ECOMAP project, a pumping station for black water was inaugurated on 12 May 2022 and an on-board kit for collecting hydrocarbons from bilges and engine compartments was delivered to stakeholders and boaters in the port. start up "Test 1 Srl - Greennovation" against spills during the 'Think blue event';
- The Etiquette of the sea has been drawn up, where pills are imprinted to stimulate respect for the sea;

- A dedicated volume to the blue flag has been produced, in which good practices are highlighted for the enhancement of beaches and small ports, in order to guarantee the maintenance / improvement of the health of the sea and coastal environments;
- The thermal stress was analysed, which is a fundamental parameter for the correct use of the beaches, and to reduce the pressure on the tidal area;
- The municipality of Ancona has a plan for the use of the landslide drainage water to irrigate the lawns and trees of the perimeter areas of the port area and for the use of this fresh water for boat maintenance activities.

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