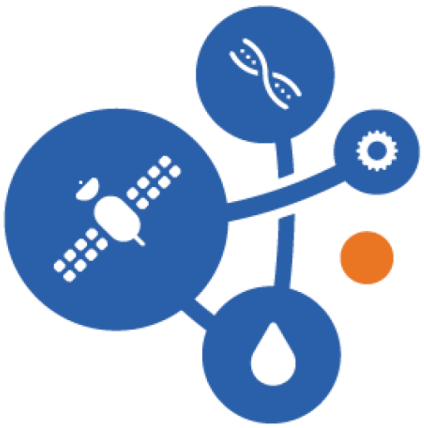

DiverSea

DELIVERABLE 5.7
POLICY-RELEVANT SYNTHESES & POLICY BRIEF I

Funded by the European Union

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TABLE OF CONTENTS

1.SUMMARY

This Deliverable presents the preliminary syntheses of policy relevant results of DiverSea in the reporting period (September 2023 – August 2025) and is linked to Task 5.2.

2. INTRODUCTION

To establish context, some relevant Information on the DiverSea project:

- **Objective O1: *I*mprove and strengthen molecular Biodiversity parameters & indicators in the context of EBVs by developing key innovations and addressing existing knowledge-needs;**
- **Objective O3. Perform case studies showcasing developed emerging methods with existing observational networks and on-going field monitoring programsfor input into O4 & O5 ->** DiverSea will catalogue of multi-layer biodiversity & physio-chemical datasets from important marine habitats throughout EU marine waters, focusing on identified important species, habitats and ecosystems under the Birds and Habitats Directives (BHD);
- **Objective O5. Design & implementation of an interactive, interface for stakeholders for evidence-based policy recommendations and support for decision making implementing sustainable ocean governance;**
- **Objective O6. To boost transdisciplinary approaches to marine science and science-based information, thinking, policy and communication for sustainable ocean governance and Marine Protected Area (MPA) implementation;**
- DiverSea results are expected to include new field observations, approaches for data processing and analysis, and knowledge structuring and outreach tools. The combined toolbox of approaches and instruments will facilitate understanding of the indirect drivers of biodiversity loss in these ecosystems, allowing for effective formulation of, and evidence-based planning for **'do not harm' biodiversity policies;**
- DiverSea integrates with global observation networks and the tools developed will facilitate support of implementing EU and international environmental policies and conventions;
- DiverSea will develop eDNA protocols complementing established biological indicators in context of WFD/MSFD, including both new WFD/MSFD molecular indicators and complimentary eDNA data interpretation - Specific scope (SS) SS2;
- Case-studies showcasing the new techniques and technologies developed during DiverSea will emphasize and improve knowledge on BHD species and habitats (SS5).

DiverSea is committed in producing clear, accessible, and policy-relevant syntheses (PrS) of its research outcomes. These syntheses will be publicly available ensuring broad access for stakeholders, policymakers, and the public.

2.1 Policies, regulations and commitments of relevance

This section introduces the main instruments that represent the key components of EU legal framework for biodiversity protection, but also highlights regulations that may impact biodiversity loss, such as sectorial policies.
Integrating (do not harm) biodiversity considerations across (effective) policies is imperative and key for the sustainability and health of our planet, people and marine ecosystems.

The knowledge produced (results) by the DiverSea team will be of interest in a number of relevant policies & regulations related to Biodiversity and ecosystems, at various spatial resolution. From international, european to local/municipal scale, as well as from species to habitat scale.
The most relevant European Union (EU) **biodiversity-related** legislation for the coastal and marine ecosystems are:

- **Marine Strategy Framework Directive (MSFD, 2008/56/EC). T**his is the primary legislation for EU marine environmental policy. This Directive requires Member States to take measures to acheive and maintain Good Environmental Status (GEnvS) of the marine environment. The GES is defined by 11 Descriptors (& indicators), such as D1 Marine Biodiversity, D2 non-indigenous species, D3 Commercial fishing and shellfish, D4 Food webs, D5 Eutrophication, D6 Seabed integrity, D7 Hydrographical conditions, D8 Contaminants, D10 Marine litter and D11 Energy, including underwater noise.
- **Water Framework Directive (WFD, 2000/60**). This directive´s goal is to achieve Good Ecological (and chemical) Status (GEcS) of all ground and surface waters (rivers, lakes, transitional waters and coastal waters) This is based on biological elements such as phytoplankton.
- **Natura 2000. Birds & Habitat Directive** (BHD)**.** Birds Directive was adopted in 1979 and amended in 2009, whereas the HD was in 1992. The target of both directives is to ensure the long-term sustainability of the habitats and species they have been set up to protect. The Special Protected Areas (SPAs) classified under the Birds Directive, and Special Areas of Conservation (SACs) designated under the Habitats Directive form the **Natura 2000 network.** Thus, Natura 2000 is a network of **protected areas** covering Europe's most valuable and threatened species and habitats. The sites within Natura 2000 are designated under the Birds and the Habitats Directives.
- **EU Biodiversity Strategy 2030.** This is a long-term plan to protect nature and reverse the degradation of ecosystems. EU countries should protect 30% of their seas by 2030, with 10% under strict protection. **National Biodiversity Plans.** This European strategy is a part of the European **Green Deal**.

EU Restore Nature Plans, include seagrass. Member States are expected to submit **National Restoration Plans** to the Commission within two years of the Regulation coming into force (by mid 2026).

- **Kunming-Montreal Global Biodiversity Framework (KMGBF)** was adopted by the UN Convention on Biological Diversity (CBD) in December 2022. This Framework aims to halt and reverse biodiversity loss by 2030 and achieve a global vision of living in harmony with nature by 2050. It contains four global goals for 2050 and 23 targets for 2030. Target 14 is to Integrate Biodiversity in Decision-Making at Every Level. National Biodiversity Plans should be prepared.

- European **Green Deal,** launched in 2019, this initiative is a comprehensive strategy aimed at making the EU climate-neutral by 2050, focusing on sustainable growth, reducing greenhouse gas emissions, and enhancing environmental protection (e.g. *Preserving and restoring ecosystems and biodiversity)*. The Green Deal is an integral part of this Commission's strategy to implement the United Nation's 2030 Agenda and the sustainable development goals.
- **EU Ocean Pact.** Brings together the European Union's policies and actions related to the ocean and creates a unified and coordinated plan for managing the ocean. This Pact supports six priorities, including: protecting and restoring ocean health; supporting coastal and island communities, and outermost regions; and advancing ocean research, knowledge, skills and innovation.
- **EU Mission Restore our Ocean and Waters** by 2030. This mission aims to protect and restore the health of our ocean and waters through research and innovation, citizen engagement and blue investments. The Mission supports regional engagement and cooperation through so-called area-based "lighthouses".

There is a range of policies and measures, related to planning and regulating the use of European seas covering a number of activities such as fisheries, aquaculture, offshore energy production, tourism, project development, dredging, port construction, waste management which may have an impact on biodiversity.
In this project one of the main objectives is gain a better understanding of biodiversity loss. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), an organization established to improve communication between science and policy on issues of biodiversity and ecosystem services. the main five key direct drivers/factors of biodiversity and ecosystem change (IPBES, n.d.) is:

- ✓ Changes in land & sea use – for example habitat destruction, with the construction of ports and hotels in ecologically vulnerable spaces;
- ✓ Climate change;
- ✓ Pollution;
- ✓ Invasive Species;
- ✓ Direct exploitation of natural resources, such as unsustainable fishing activity.

In addition to the five direct drivers, IPBES also identified indirect drivers that are more closely linked to the socio-ecological situations of different regions. These indirect drivers are shaped by societal values and behaviours, including production and consumption patterns, population dynamics and trends, trade, technological innovations, and governance at both local and global levels. The rate of change of these direct and indirect drivers varies across regions and countries (IPBES 2019). Indirect drivers, together with direct ones, play a crucial role in shaping policies and management strategies for biodiversity conservation

Given the impacts and stressors of biodiversity loss and ecosystem change highlighted in the case studies so far, the results may hold relevance for sectoral and other policy areas

Additional policies and principles of interest include

- **Marine Protected Area (MPA)**
- **Ecosystem Based Approach** & **Ecosystem Based Management. T**he Ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way promotes conservaϴon and sustainable use in an equitable way
- **Ecosystem Services,**
- **IUCN Red List** (for threatened species),
- **Marine/Maritime Spatial Planning (MSP),**
- **Environmental Impact Assessment** (EIA) & Strategic Environmental Assessment. Carrying capacity.
- **Sustainable Development Goals (SDG).** The 2030 Agenda for Sustainable Development, was adopted by the United Nations in 2015, having identified 17 Goals (and 169 targets). **SDG 14 Live below Water** aims to “Conserve and sustainably use the oceans, seas and marine resources for sustainable development” and contains 10 target (T) including T14.1 reduce marine pollution, T14.2 protect and restore ecosystems, T14.5 conserve coastal and marine areas, T14.8 increase scientific knowledge, research and technology for ocean health (see section below)
- **Common Fisheries Policy (CFP).** This european policy ensures long-term sustainability for fisheries and aquaculture, the availability of food supplies and a fair standard of living for fisheries and aquaculture communities (Commission 2023),
- **Invasive Alien Species Regulation,**
- **Actions Plans,** e.g. on Marine litter (**EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil')**, on Climate Change,
- Precautionary Principle,
- Nagoya Protocol,
- Nitrates Directive. This Directive aims to protect water quality across Europe by reducing nitrates from agricultural sources that pollute ground and surface waters.
- Data Management Policies.

As DiverSea has a transdisciplinary approach, results may also be relevant for other policies which have not (yet) been identified. Results for communities and policies at a more local (municipal) level may also be of relevance.
#Science-Policy knowledge integration. #Structuring knowledge & Policy coherence

Sustainable Development Goals (SDG)

DiverSea will deliver results relevant to the various Sustainable Development Goals. These goals can be aggregated by biosphere (SDG 15, 14, 6 and 13), society (SDG 1, 11, 16, 7, 3, 4, 5 and 2) and economy (8, 9, 10 and 12), as shown in the SDG wedding cake (Figure 1).

Figure 1. Seventeen Sustainable Development Goals and its association with marine biodiversity and ecosystem (good) services. Credit of image on the left: Azote for Stockholm Resilience Centre, Stockholm University CC BY-ND 3.0 (Anon. 2025). [The SDGs wedding cake - Stockholm Resilience Centre]

The impact of DiverSea in SDG perceived from the preliminary results can be found in Table 1. Successful interaction of all project participants will contribute to the improvement of the state of the natural environment, awareness of interested persons, in-depth research in the field of marine biology. Work within the project will contribute to the growth of the qualifications of scientists, and thereby to the improvement of their well-being. Also, active communication between project members will contribute to international cooperation and sustainable development of society. Results will be most relevant to SDG6 Clean water and sanitation, SDG14 life below water, SDG13 Climate Action & SDG17 partnerships for the goals (international cooperation).

Table 1. Is DiverSea project to deliver results relevant for the following Sustainable Development Goals? These results were presented in first periodic continuous reporting – in the EU Portal

SDG Name	SDG number	Impact
Climate Neutrality	13	Full relevant
Clean Water And Sanitation	6	Full relevant
Life Below Water	14	Full relevant
Life On Land	15	Don't know
No Poverty	1	Don't know
Zero Hunger	2	Partially relevant

Good Health And Well-Being	3	Partially relevant
Gender Equality	5	Partially relevant
Decent Work and Economic Growth	8	Partially relevant
Affordable and Clean Energy	7	Don´t know
Industry, Innovation and Infrastructure	9	Partially relevant
Reduced Inequality	10	Don´t Know
Sustainable Cities and Communities	11	Partially Relevant
Responsible Consumption and Production	12	Don´t Know
Quality Education	4	Full Relevant
Peace and Justice Strong Institutions	16	Don´t Know
International Cooperation	17	Full relevant

Regional Sea Conventions

In terms of Regional Sea Conventions:

- **Barcelona Convention for the Protection of the Mediterranean** - the main aim is to protect the marine environment and the coastal region of the Mediterranean Sea. DiverSea case studies 3 and 4

- **Helsinki Convention** - **Convention on the Protection of the Marine Environment of the Baltic Sea Area** – aims to protect the Baltic Sea from all sources of pollution from land, air and sea, as well as to take measures on conserving habitats and biological diversity and promote the sustainable use of marine resources.

- **Bucharest Convention** - Commission on the Protection of the Black Sea Against Pollution (the Black Sea Commission) implements the provisions of the **Convention and the Black Sea Strategic Action Plan.**
  DiverSea case study 5

- **OSPAR Convention - Convention for the Protection Of the Marine Environment of the North-east Atlantic** the main aim is to prevent and eliminate pollution and shall take the necessary measures to protect the maritime area against the adverse effects of human activities so as to safeguard human health and to conserve marine ecosystems and, when practicable, restore marine areas which have been adversely affected.
  DiverSea case study 2

3. DIVERSEA POLICY RELEVANT SYNTHESES

This section provides a synthesis of relevant information and results compiled by the DiverSea Team so far.

3.1 Developing nucleic acid methods, integrating field technologies and applying them to field cases (WP 1)

The following section is presented by field case studies, also identified as Work Package 1 (WP 1) Subtasks.

- **Norwegian/Swedish coastal system**
- **Atlantic coast of Portugal**
  - Professor Luis Saldanha Marine Park
- **Western Mediterranean & Adriatic**
  - Balearic Island
  - Italian Adriatic Coast
- **Eastern Mediterranean, Aegean Sea, Dardanelles**
  - Hellenic Volcanic Arc (HVA)
  - Turkish Waters of the Aegean Sea
- **Shallow shelf regions Black Sea**

3.1.1 Norwegian Coast (case study 1)

Low-cost genome skimming methods enable scalable monitoring of genetic diversity, supporting biodiversity protection and MPA planning by identifying ecotypes and genetic hotspots, while addressing major data gaps. NTNU and UGOT´s experimental findings from a synoptic coastal expedition improve the accuracy and comparability of eDNA-based biodiversity assessments under the MSFD and WFD, combined with an integrated, multimodal sensoric approach from remote sensing to *in situ v*alidation of essential ocean variables and plankton biodiversity markers as well as emphasize the **urgent need for standardized molecular protocols across monitoring programs.**

In Nordic waters, observed shifts from diatoms to mixotrophs due to coastal darkening—detected using high-resolution data from HYPSO hyperspectral satellites and sensor networks—are likely to affect primary productivity and ecosystem functioning. **The data supports MPA management through near real-time biodiversity and water quality monitoring,** and also climate adaptation by incorporating light regime shifts into marine ecosystem management. **Vicarious calibration is essential to ensure the integration of hyperspectral data into EU Copernicus and national marine monitoring programs.**

In September 2024, automated imaging in Trondheimsfjord revealed clear shifts in phytoplankton communities linked to water column stratification and seasonal change. This supports real-time tracking of ecosystem dynamics under natural and anthropogenic stressors.

A multi-tiered phytoplankton monitoring approach was also tested, combining conventional microscopy, low-cost Planktoscope, and advanced tools like FlowCam and Cytosense. This

integrated approach enables flexible selection of monitoring techniques depending on the socio-ecological context. This provides a robust basis for assessing ecosystem condition and MPA performance, particularly under pressures such as coastal darkening.

Ongoing fieldwork by NTNU and UGOT covers two marine national parks in Norway and Sweden, as well as several aquaculture-impacted and contaminated fjords. Integrated monitoring and mapping techniques generate actionable data for adaptive management in protected areas. These activities help identify major drivers of biodiversity decline and guide mitigation strategies aligned with Norwegian and Swedish policy frameworks, contributing directly to the goals of the EU Biodiversity Strategy. **Focusing on identifying, monitoring, and mapping techniques of key drivers for biodiversity decline, and ecosystem structure and functional shifts, are growing demand from policymakers and managers to develop targeted mitigation measures and reduce pressures on coastal biodiversity.**

3.1.2 Portuguese Atlantic Coast (case study 2)

Professor Luiz Saldanha Marine Park

Multiple deployments of an Unmanned Aerial Vehicle (UAV) and an Autonomous Underwater Vehicle (AUV) were carried out in the Marine Protected Area (MPA) of the Professor Luiz Saldanha Marine Park (Sesimbra, Portugal) for integrated mapping of the coastal area. The data collected from sensors onboard the UAV, including cameras and LiDAR, and the AUV, equipped with Side Scan Sonar and camera, enabled the creation of high-resolution image mosaics of intertidal, shallow, and underwater areas, providing essential material for **species identification, habitat classification, and coverage assessment in different locations within the marine protected area.**

The periodic deployment of these robotic technologies in the same areas will also support temporal monitoring, providing valuable insights for conservation measures and potential future actions especially in areas of total protection within the Luiz Saldanha Marine Park. In addition, the integration of heterogeneous data from air and underwater domains demonstrates the potential of multi-platform robotic systems to bridge observation gaps across coastal gradients. These coordinated missions also contribute to ongoing research in automated image analysis and mapping techniques, supporting scalable, repeatable, and non-intrusive monitoring frameworks for marine conservation.

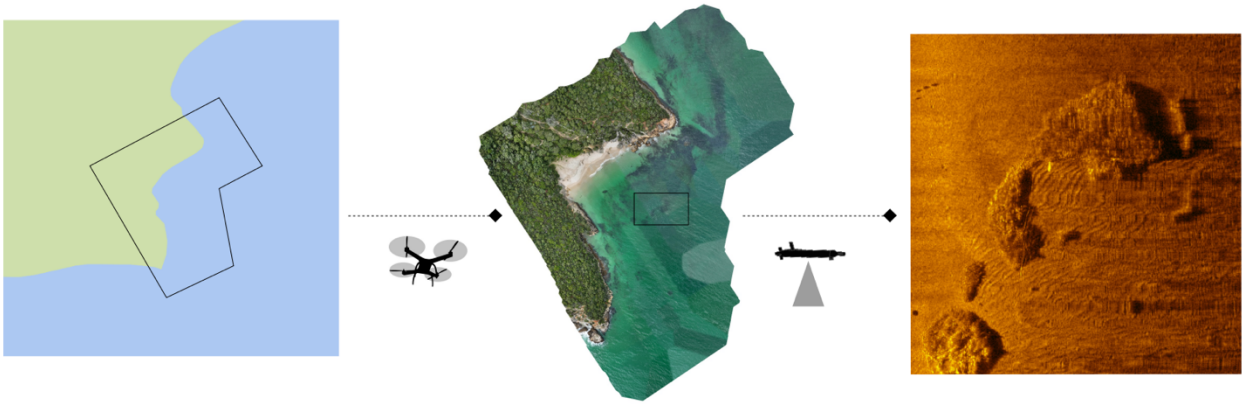

Figure 2. Integrated multi-robotic survey carried out by DiverSea partners UPorto and INEGI at Praia dos Coelhos, within Marine Protected Area "Parque Marinho Professor Luiz Saldanha", Portuguese case study. High-resolution Image orthomosaic of the area of interest generated by a UAV, further research conducted with an AUV equipped with Side Scan Sonar.

3.1.3 Western Mediterranean & Adriatic Sea (case study 3)

Balearic Island

DiverSea partner Tursiops Association (AT) requested the declaration of a protected marine area in northern Menorca, based on the description of a breeding zone.

As part of the sperm whale (P*hyseter macrocephalus*) population monitoring campaigns conducted by the Tursiops Association (AT) in the Balearic Islands region, a breeding area for this species has been identified in the northern part of the archipelago. This is the only one of its kind documented in the Mediterranean. Consequently, in March 2025, Tursiops proposed its protection before the Spanish Ministry for Ecological Transition and Demographic Challenge.

The area covers 34,172 km², and its boundaries have been established considering the existence of other adjacent protected zones, such as the Cetacean Migration Corridor, the Particularly Sensitive Sea Area, as well as the limits of Spain's Exclusive Economic Zone with France and Italy. Its declaration would complete a comprehensive spatial planning framework for marine protection in Spanish waters of the Mediterranean.

The need for protection of this area is detailed in the work by Brotons et al. (2024), published in Aquatic Conservation: Marine and Freshwater Ecosystems entitled: "**New Data on the Distribution of Sperm Whales in the Western Mediterranean Highlights Insufficiency of Currently Proposed Protection Measures**." This study describes the high presence of calves in the area, the threats faced by the species, and the legal protection framework of the surrounding zones. It justifies the urgency and necessity of safeguarding this habitat, as well as the importance of managing the entire area coherently, considering all adjacent protection figures—some

declared with different objectives by various institutions, including several involving multiple countries.

The declaration of this Marine Protected Area (MPA), along with the coherent management of threats, will significantly contribute to the effective protection of this IUCN-classified endangered species (Mediterranean subpopulation is listed as Endangered under criteria C2a(ii) - Brotons *et al*., 2024; Pirotta *et al*., 2021).

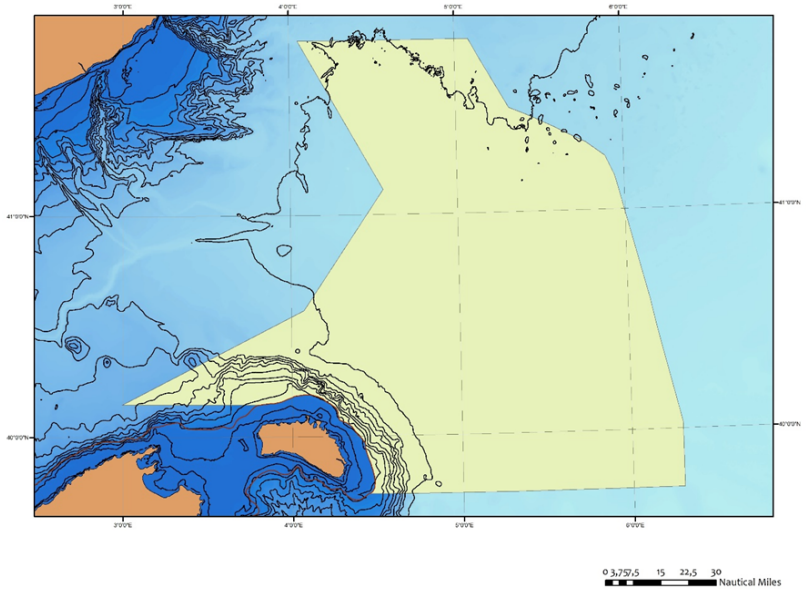

Figure 3. Map of the identified Marine Protected Area in the Balearic Islands (Spain), proposed in 2025, based on the breeding zone of sperm whale. Source: AT.

Italian Adriatic Coast

Field and laboratory activities combining traditional taxonomy (morphological identification of benthic marine life) with innovative molecular approaches (16S and 18S rRNA metabarcoding) and aerial drone surveys revealed spatial variation in biodiversity patterns along an anthropogenic pressure gradient. Early results indicate that eDNA-based approaches, while powerful in detecting hidden diversity, may underperform in resolving fine-scale faunal composition when used alone, particularly in dynamic coastal systems with complex sediment structures.
This Integrated Biodiversity Insights for Smarter Conservation in the Adriatic Sea highlights the need for of **hybrid monitoring frameworks** that merge morphological and molecular methods for robust biodiversity assessment These findings are relevant for the **design and evaluation of marine conservation measures** (e.g., MPAs or OECMs), where accurate biodiversity baselines are essential. Ultimately, this work advocates for the thoughtful **integration of molecular tools into national and regional monitoring protocols, not as standalone solutions**, but as complementary assets, clearly highlighting both their transformative potential and current methodological limitations.

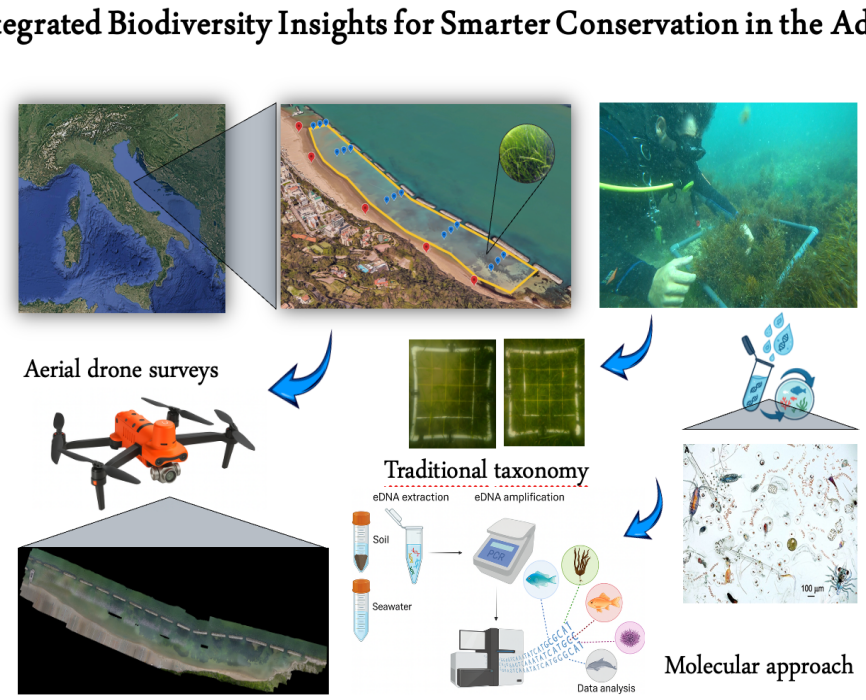

Figure 4. Integrated Biodiversity insights for smarter conservation in the Adriatic Sea. Field and laboratory activities combining traditional taxonomy with innovative molecular approaches and aerial drone surveys. Source: UNIVPM

3.1.4 Eastern Mediterranean, Aegan Sea and Strait of Dardanelles (Case Study 4)

Hellenic Volcanic Arc (HVA)

Preliminary insights on sampling and eDNA analysis for the Greek case study (ongoing & lead by partner NKUA) relevant to policy-oriented tasks. The Hellenic Volcanic Arc (HVA) provides a unique natural laboratory to investigate microbial communities—both bacterioplankton and phytoplankton—under multiple environmental stressors. Sampling sites affected by hydrothermal activity simulate conditions of marine heatwaves similar to those projected under extreme climate change scenarios, exhibiting temperatures more than 6 °C above nearby reference sites and pH levels comparable to future ocean acidification projections (and even lower). Investigating microbial community shifts in such hydrothermal environments can offer insights into the effects of the ocean climate crisis on biogeochemical cycling and primary productivity. Marine microbiota are among the first responders to exogenic pressures and play a central role in regulating global cycles and food web dynamics.

Several hydrothermally influenced sites were sampled, where temperatures range from 3 °C to 10 °C above non-impacted areas, and pH levels are markedly lower. eDNA metabarcoding

revealed a rich microbial diversity, with increased bacterioplankton species richness but lower eukaryotic species richness in hydrothermal sites. Functional trait assignment of planktonic unicellular eukaryotes indicated a dominance of heterotrophic and parasitic taxa under elevated temperatures, aligning with previous studies (e.g., Stefanidou et al., 2018; Ahme et al., 2025), and pointing toward a shift from autotrophy to alternative trophic strategies. Preliminary size-class analysis of planktonic protists further suggests that hydrothermal conditions (increased temperatures) favor smaller-sized organisms (e.g., Sommer et al., 2017a), which may alter carbon flow through marine food webs by promoting pathways that lead to trophic dead ends, such as jellyfish-dominated systems (Sommer et al., 2017b).

Higher bacterioplankton diversity, and the retrieved and previously overlooked taxonomic composition in hydrothermal sites, suggest a species turnover in stressed areas, where under-described groups are tasked to perform complex metabolic functions, mainly linked to nitrogen and sulfur cycling (Terpsidou, 2025; Stranga, 2025).

More detailed trait annotations and functional diversity estimations are necessary to connect biodiversity estimators to Ecosystem Services, to propose indicator species or functions that can be used to detect significant abiotic change, and to connect these findings with potential policy strategy.

Related Policies.

- **WFD 2000/60,** especially to the goal of achieving "good ecological and chemical status" by a target date (initially 2015, with possible extensions to 2027). For coastal waters, this means that the Ecological status is assessed based on biological elements (e.g., **phytoplankton),** and other elements. The development and use **of novel eDNA-based indicators** is currently under discussion in Eurostat.
- **MSFD 2008/56/EC**, and especially Descriptors D1 Biological Diversity, D4 Food webs, D5 Eutrofication, and the “emerging descriptors” or cross-cutting themes of Genetic Diversity (within species) and Marine Ecosystem Services that are not yet formally included but are gaining relevance due to environmental, technological, and policy developments. Especially for Marine Ecosystem Services (ES) these outputs will be combined with the advancements of the system dynamics modeling (lead by WP4 leader VITO and with the support of AUEB) to assess the impacts of stressors and human drivers (such as tourism) on biodiversity and ES endpoints (see more in sections ahead).

Visual-image.

Figure 5. Photos of field sampling, equipment and hydrothermal activity of the Hellenic Volcanic Arc of the Greek case study. Photo credits: NKUA.

Publications. Two master theses by NKUA - Terpsidou, 2025; Stranga, 2025.

Turkish Waters (Aegean Sea)

DiverSea's commitment to disseminating knowledge and integrating science into policy, is a very challenging task since the end users in each country regardless its status, *e.g.*, member, associate or neighbour, sharing coastal and marine ecosystems, have already organised the architectures of legislative, administrative and executive bodies according to the functional expectancies of their national perspectives. Moreover, their decision-making processes may include same or somewhat different phases in which similar or different actors take parts and/or hold and use initiatives, responsibilities and authority. Furthermore, the degree of stakeholders' involvement into the decision-making process also varies again with some similarities and differences.

All these similarities and differences inevitably influence the decision-making efforts in the national scale and thereby in the international scale which leads to additional efforts for seeking and reaching an agreed frame that is accepted by all relevant parties in a given issue on which a decision can be built. In addition, the very same approach is inherited for the implementation procedures, particularly for the distribution of responsibilities and authorities and the needs for data, information and knowledge.

Under such circumstances, integrating knowledge through science into policy can easily become a challenge that can be compared with curse of Sisyphus. Thus, DEU and AKD since they are able to observe during their efforts with WP 4 and WP 5 that the attitudes of decision makers in Turkey

on the issues related with the biodiversity in coastal marine ecosystems and their liaisons with the relevant stakeholders representing mainly the drivers and activities exploiting ecosystem goods and services. They are now focused on providing evidence-based information for developing MARBIOSE Dashboard as a decision support tool potentially capable to test various scenarios for end users' perspective based on the already established and ongoing dialogs among all parties, *i.e.,* decision makers, end users, stakeholders, scientists, whose efforts ultimately produces policies. The observations have been thrived to materialize via a series of workshops focused on the planned case study areas.

Publications. The overall evaluation will be presented in a paper to be published.

3.1.5 Northwestern Black Sea (case study 5, CS5)

Analysis by IMB of the specific situation in CS5 (Black Sea), which is exposed to the impact of military operations, provides the following priorities for research and environmental management in the region to be highlighted:

1. Environmental damage assessment and ecosystem restoration.
2. Status of war-affected vulnerable species, populations, and habitats.
3. Integration of military impact indicators into European environmental status assessment and monitoring.
4. Assessing the biota response to reduced civil impacts as a strategy for marine ecosystem restoration in the post-war period.
5. Post-war marine spatial planning and reorganization of marine reserve networks, N**atura 2000** and the **Emerald Network**.
6. Strengthening international environmental control, cooperation and research systems.
7. Environmentally-balanced post-war development and economy.

3.1.6 Genetic diversity & Sequencing

Sand eel and Kelp

Preliminary contributions from DiverSea partner UPF are the successful extraction of DNA from sand eel (*Ammodytes* spp.) and kelp (likely *Laminaria* or *Saccharina* spp.) samples collected through collaboration with Glenn Dunshea (NTNU) and Tom Gilbert (UPCH). These extractions are a key step in generating high-quality genomic data that will enable the assessment of genetic diversity, population structure, and potential adaptive responses in these ecologically significant species. Sequencing results are expected shortly.

Relevance for Policy and Marine Management. Sand eels and kelp are foundational species in coastal ecosystems. Sand eels are critical prey for many fish, seabirds, and marine mammals, while kelp forests support diverse benthic communities and contribute significantly to carbon sequestration.

Understanding the genetic diversity of these organisms provides a basis for:

-**Monitoring population health and resilience** in the face of environmental stressors such as climate change, pollution, and overexploitation.

-**Informing Marine Protected Area (MPA) design** by identifying distinct genetic populations or evolutionary significant units (ESUs).

-**Detecting biodiversity changes over time** at a molecular level, offering sensitive indicators for early ecological shifts.

-**Guiding restoration and conservation efforts**, especially for degraded kelp habitats or exploited sand eel populations.

This work contributes directly to biodiversity assessment efforts under the EU Biodiversity Strategy and supports evidence-based marine policy.

Visual material. Photographs of extracted DNA and lab workflow (Figure 5). Future figures will include population-level genetic diversity analyses.

Figure 6. Samples from kelp (Laminaria or Saccharina spp.) before being extracted by our laboratory technicians. Photo credits: UPF.

Publications and Outputs. Sequencing and analysis underway; a manuscript is anticipated in 2026. Data will be integrated into DiverSea's biodiversity mapping and MARBIOSE dashboard.

3.2 Data Space: Data integration, harmonization, cataloguing and compatibility with standards (WP2)

Contribution related to Data Management Policies. One of the key considerations in DiverSea which is relevant to many collaborative projects but especially for joint EU projects under the Horizon Programme is the decision concerning **Data Management Policy**. In principle, there are three possible designs of the data architecture that impact the policies

- Fully decentralized: This solution assumes local maintenance of the data by each participating partner and sharing of the data with other partners. It is based on the concept of a "data space", the work which is coordinated by the International Data Space Association (IDSA).
- Totally centralized: This solution is based on the classical concept of data warehousing, which requires concentration of all technical work for the collection, storing, and analysis of the data at the side of a dedicated hosting partner.
- Hybrid: This solution centralizes data management but decentralizes the use of data by establishing a protocol for sharing the data so that its processing can be organized locally by different partners. This is the solution implemented within DiverSea project, where the data management is concentrated in WP2. At the same time, the data are available for both internal use within other packages (WP1, WP3, WP4) and external use by the research community according to their profile.

Why is this relevant for policy or practice (e.g., biodiversity protection, MPA design, data gaps)? The above consideration is critical in all collaborative projects because of the significant consequences both for the project design and for the utilization of project results. On one side, the decentralized solution requires a higher level of local support, which also requires allocation of more technical and financial resources for each participant in the data space, which is important for the funding policy. On the other hand, such a solution makes it easier to network with other projects and publicly available resources, which is important for the projected impact.

Visually informing. Several DiverSea project data services are available for both internal and external use over the Internet using the following URLs
*https://datafiles-diversea.gate-ai.eu: Ra*w data from the project case studies (protected)
https://datasets-diversea.gate-ai.eu: Pre-processed data from a project relational database, structured according to a unified data model (protected)
https://datamap-diversea.gate-ai.eu: Live map of the locations of the available datasets, created within the project case studies (public)

These resources are maintained by Institute GATE of Sofia University, coordinating the work on data management within DiverSea project.

Publication links. Currently a paper is under preparation.

3.3 Knowledge integration & communication (WP4 & WP5)

This section refers to relevant information discussed and/or produced in WP4 (Knowledge integration: the MARBIOSE Dashboard for Biodiversity and Ecosystem Goods and Services) & WP5 (Consilience, Public Interface, Communication, Dissemination & Exploitation).

3.3.1 Toolbox for structural analysis of complex socio-environmental systems - application to marine biodiversity

The MARBIOSE dashboard will bridge the gap between scientific findings and policy making. A holistic perspective on the dependencies and system feedback between drivers of change, marine biodiversity and ecosystem services is essential for the protection of marine ecosystems and understanding their resilience.

Experts can work together with stakeholders and local authorities to develop co-designed causal loop diagrams (CLDs) - tailored conceptual models of the socio-environmental system. However, system feedback is often overlooked in the design of a CLD. Furthermore, deciding on what to include - and at what level of detail - can be challenging.

To facilitate the co-design of CLDs and simulation models, the VITO team developed a toolbox for structural analysis of systems. The toolbox is based on state-of-the-art graph theory and helps to:

1. identify feedback cycles;
2. prioritize variables and dependencies in a CLD; and
3. guide adaptations to the CLD structure to optimize the design.

This allows rapid co-design of models during workshops in a structured and more efficient manner. Meanwhile, the toolbox has been deployed to support the design of a holistic model for the interactions between climate change, pollution, tourism and seagrass health for the Hellenic Volcanic Arc case area of DiverSea (see Figure below).

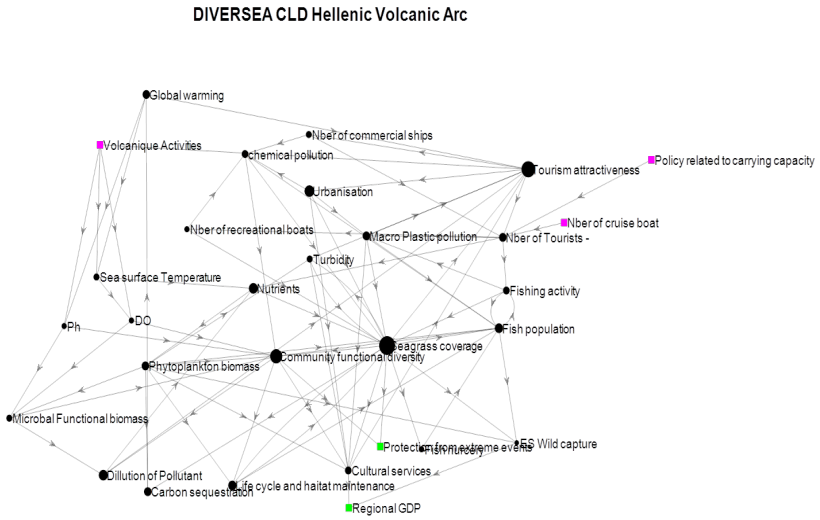

Figure 7. DiverSea Causal Loop Diagram (CLD) showing the social, environmental and economic interactions in the Hellenic Volcanic Arc near Santorini, Greece (DiverSea case study 4). Source: VITO.

This work was developed in WP4 and further applied to the Hellenic Volcanic Arc (HVA) case with the partners VITO, NKUA and AUEB. However, the potential for application is much broader.

Relationship with policy. Causal Loop Diagrams (CLDs) map feedback relationships between variables across domains—such as environmental, economic, and social systems—and reveal how policy levers can influence different parts of the system. By visualizing these interconnections, CLDs help identify where interventions may reinforce or balance complex dynamics.

Publication. A joint publication by the VITO, NKUA and AUEB partners on the methodology and application of the toolbox is currently in preparation.

3.3.2 Capacity building, citizen science and ocean literacy – communication & consilience

Work carried out under WP 5 Consilience, Public Interface, Communication, Dissemination & Exploitation by the various partners include capacity building and citizen science initiatives, with the elaboration of Deliverables such as D 5.9 (Fonseca, Kormaz et al., 2024a). Thus, policy relevant results include

- **implementation of training & protocols** for citizen science activities, and the **application of ECSA rules & DiverSea ethical rules,** such as the compliance of GDPR;
- **Recognition of the importance and Integration of citizen science into formal education** (national curriculum) (and not only). For example, in Turkey, citizen science is not mentioned in local regulations or policies, as the term is relatively new in this country.
  For the curriculum and activities, Turkish partner AKD followed the ECSA rules and DiverSea ethical rules.
- i**mprove knowledge and literacy of the Ocean, marine biodiversity & ecosystems,** for example, the importance in recognizing biodiversity and taxonomy (*Biodiversity & taxonomy recognition day Campaigns on social media).*
  Furthermore, the Portuguese partner LPN signed an Open Letter regarding the marine ecosystem and the Portuguese National Restoration Plan. This letter emphasized the need to improve national coordination of marine research, to integrate science-based marine biodiversity knowledge, and "promote public policies coherence in the field of marine biodiversity protection, coordinating the national restoration plan with related policy instruments, such as the National Strategy for Nature Conservation and Biodiversity for 2030, the National Strategy for the Sea 2021-2030, and European and global Strategies (LPN, 2024).

Collaborations with other projects (Task 5.7, SDG17) and communication initiatives within WP5 can also produce biodiversity policy-relevant information.

4. POLICY BRIEF I & FINAL CONSIDERATIONS

DiverSea is committed in producing clear, accessible, and policy-relevant syntheses (PrS) of its research outcomes. These syntheses will be made publicly available on the project website and through the MARBIOSE dashboard, ensuring broad access for stakeholders, policymakers, and the public.
While a comprehensive policy brief is still in development, it will be finalized and delivered by the end of the project. This brief will distill key scientific findings into practical, actionable recommendations to inform biodiversity policy and management. Upon completion, the brief will be formally submitted to the European Commission's Knowledge Centre for Biodiversity, contributing directly to the EU's evidence base for marine biodiversity governance.
All outputs will adhere to standardized metadata and quality control procedures and will be openly accessible via the MARBIOSE dashboard—an interactive platform hosting ecological syntheses, data visualizations, and policy analyses.
Furthermore, DiverSea plans to engage relevant stakeholders to gather feedback on Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs). Their critical input will support the review and refinement of these variables, ensuring better alignment with policy needs, incorporation of emerging technologies, and enhanced utility for environmental monitoring and

decision-making. We focused on identifying gaps and inconsistencies in current monitoring frameworks and emphasize the need for a standardized set of EOVs and EBVs by collaborating with various stakeholders.

The next Deliverable (D5.8 Policy relevant syntheses & Policy Brief II) is scheduled for the 48th month of the project, in other words August 2027.

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6. GLOSSARY, ACRONYMS AND ABBREVIATIONS

Short Name	Legal Name	Country
NTNU	NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET	NO
UCPH	KOBENHAVNS UNIVERSITET	DK
VITO	VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V.	BE
UNIVPM	UNIVERSITA POLITECNICA DELLE MARCHE	IT
LPN	LIGA PARA A PROTECÇÃO DA NATUREZA	PT
UPF	UNIVERSIDAD POMPEU FABRA	ES
AT	ASOCIACION TURSIOPS	ES
DEU	DOKUZ EYLUL UNIVERSITY OF IZMIR	TR
IMB	INSTITUTE OF MARINE BIOLOGY OF THE NAS OF UKRAINE	UA
UPORTO	UNIVERSIDADE DO PORTO	PT
GATE-SU	SOFIA UNIVERSITY ST KLIMENT OHRIDSKI	BG
AUEB	ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS - RESEARCH CENTER	EL
UGOT	GOETEBORGS UNIVERSITET	SE
VNNOR	VNNOR AS	NO
NKUA	ETHNIKO KAI KAPODISTRIAKO PANEPISTIMIO ATHINON	EL
AKD	AKDENIZ KORUMA DERNEGI	TR
UG	UNIVERSITY OF GHANA	GH
INEGI	INEGI - INSTITUTO DE CIENCIA E INOVACAO EM ENGENHARIA MECANICA E ENGENHARIA INDUSTRIAL	PT
IMS	Institute of Marine Science at University of Dar Es Salaam	TZ

Acronyms - Countries			
BE	Belgium	NO	Norway
BG	Bulgaria	PT	Portugal
DK	Denmark	SE	Sweden
EL	Greece	TR	Turkey
ES	Spain	UA	Ukraine
GH	Ghana	TZ	Tanzania
IT	Italy		

Table *DiverSea Project Terminology Abbreviation List*

Abbreviation	**Meaning**
AI-ML	Artificial Intelligence & Machine Learning
API	Application Programming Interface
BHD	Birds and Habitats Directive
BSTA	Beyond State of The Art
CAPED	Create Assess Protect Exploit and Disseminate
CDOM	Chromophoric/Colored Dissolved Organic Matter
Copernicus	European Union's Earth observation program
CTD	Conductivity, Temperature, Depth
DNA & RNA	Deoxy Ribonucleic Acid & Ribonucleic Acid
DOP & DEP	Dissemination and Outreach Plan & Dissemination and Exploitation Plan
EC centre for biodiversity	European Commission Knowledge Centre for Biodiversity
eDNA/eRNA	Environmental DNA/RNA
EGS	Ecosystem Goods & Services
ELTER	Integrated European Long-Term Ecosystem, critical zone and socio-ecological Research
EMODnet	European Marine Observation and Data Network
EOV/EBVs	Essential Ocean and Biodiversity Variables
ESA	European Space Agency
GBIF	Global Biodiversity Information Facility
GEOBON	The Group on Earth Observations Biodiversity Observation Network
GEOSS	Group on Earth Observations
GOOS	Global Ocean Observing System
GUI	Graphical User Interface
ICES	International Council for the Exploration of the Sea
IoT	Internet of Things
IUCN	International Union for Conservation of Nature
KERs	Key Exploitable Results
KPI	Key Performance Indicators
LSTS	Laboratório de Sistemas e Tecnologia Subaquática
MARBIOSE	European MARine BIOdiversity and ecosystem goods & Services
MOU	Memorandum of Understanding
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
NCA	New Concepts and Approaches
NGO & SME	Non-Governmental Organization & Small and Medium-sized Enterprises

O/Obj.	Objectives
OBIS	Ocean Biodiversity Information System
OMoMaP	Observation, Monitoring, Mapping and Prediction
R&D	Research and Development
S & SS	Scope & Specific Scope
SEWP	Spreading Excellence and Widening Participation
SSH	Social Sciences and Humanities
STEM	Science, Technology, Engineering, and Mathematics
SWAFS	Science with and for Society
TRL	Technology Readiness Level
WFD	Water Framework Directive
WP	Work Package
AUV	Autonomous Underwater Vehicle
CLD(s)	Causal Loop Diagram(s)
EU	European Union
PrS	Policy relevant Syntheses
OECM	Other Effective area-based Conservation Measures
UAV	Unmanned Aerial Vehicle