NESBp
Northern European Sea Basins project

D4.3 Towards Mariparks: Environmental Baseline Study data framework for Ocean Multi-Use

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List of acronyms

CC	Climate Change
DTO	Digital Twin of the Ocean
EBA	Ecosystem-Based Approach
EBS	Environmental Baseline Study
EC	European Commission
EEA	European Environmental Agency
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMFAF	European Maritime, Fisheries and Aquaculture Fund
EMODnet	European Maritime Observation and Data network
EMP	Environmental Monitoring Plan
eMSP-NBSR	Emerging ecosystem-based Maritime Spatial Planning topics in North and Baltic Sea Regions
ENC	Electronic Navigational Charts
ESA	European Spatial Agency
EU	European Union
FAIR	Findable, Accessible, Interoperable, Reusable
GNSBI	Greater North Sea Basin Initiative
HELCOM	Helsinki Commission
IHO	International Hydrographic Organization
INSPIRE	Infrastructure for Spatial Information in Europe
IPCC	Intergovernmental Panel on Climate Change
MPA	Marine Protected Area
MS	Member State(s)
MSFD	Marine Strategy Framework Directive
MSP	Maritime Spatial Planning
MSPD	Maritime Spatial Planning Directive
MSPdF	Maritime Spatial Planning Data Framework from TEG on data for MSP
MU	Multi-Use(s)
MUS	Multi-Use Setting
NESBp	Northern European Sea Basins project
NID	Nature-Inclusive Design
OGC	Open Geospatial Consortium
OWF	Offshore Wind Farm
R&D	Research and Development
ReMAP	Reviewing and Evaluating the Monitoring and Assessment of Maritime Spatial Planning

SBE	Sustainable Blue Economy
SEA	Strategic Environnemental impact Assissent
Shom	French Hydrographic and Oceanographic Service – *Service Hydrographique et Océanographique de la Marine*
SSP	Shared Socioeconomic Pathways
TEG on data for MSP	Technical Expert Group on Data for MSP
TRACC	Trajectoires d'Adaptation au Changement Climatique
VASAB	Vision and Strategies around the Baltic Sea
WFD	Water Framework Directive
WFS	Web Feature Service
WMS	Web Mapping Service
WP	Work Package(s)

I. Introduction

1.1. WP4 description

The WP4 "*Multi-use in practice: From mariparks to basin-scale Multi-Use*" aims to assess the challenges and opportunities associated with Ocean Multi-Use (MU) development, through the tool of Maripark. The North Sea and Baltic Sea are among the most intensively used sea basins in Europe, with certain areas in a "spatial squeeze" situation. In this context, Mariparks underline (i) the potential for reducing space demand for different activities (ii) and the socio-economic possibility to share infrastructure and reduce overhead costs of offshore operations [1] [2].

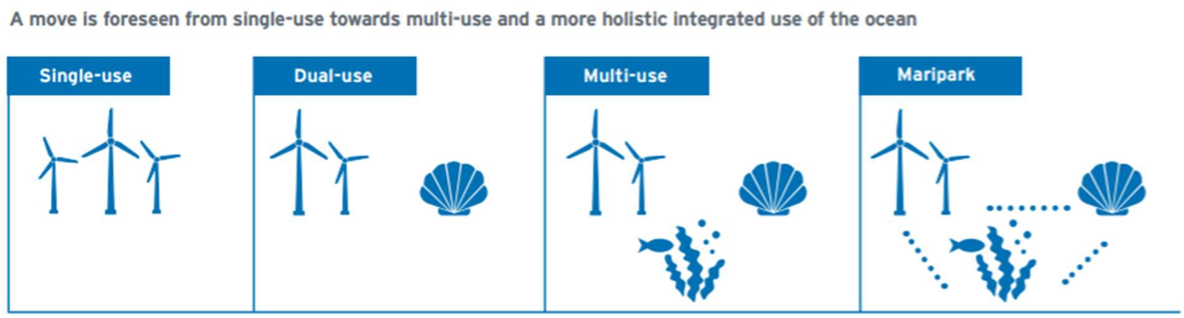

Figure 1: Understanding Ocean MU: from single use to Maripark tool [3]

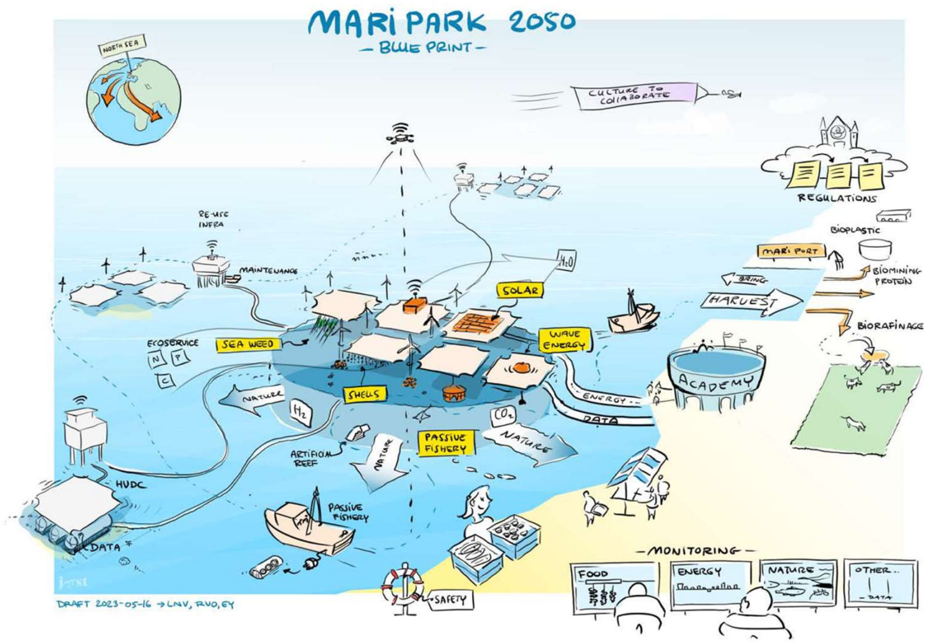

Figure 2: Maripark tool overview [4]

The Maripark tool was conceptually designed during the eMSP NBSR project[1], as one of the pillars of Sustainable Blue Economy[2]. This WP therefore uses the Maripark as the central theme to integrate on concrete working level the following aspects:

- **Governance**: permitting and setting up a coherent and holistic legal and administrative context (T4.1);
- **Ecosystem Based Approach (EBA)**: ensuring that Mariparks operate in a genuine EBA (T4.1);
- **Sustainable blue economy**: making all included activities sustainable, maximizing synergies between uses (T4.2);
- **Monitoring and evaluation**: integration of smart monitoring techniques to implement adaptive management and use of an environmental monitoring plan (EMP) (T4.3);
- **Sharing data**: smart use and collection of data supporting the different objectives (T4.3);
- **Climate change**: preparing future proof Mariparks regarding climate change (WP4);
- **EU Green deal**: turn climate and environmental challenges into opportunities (WP4).

[1] https://www.emspproject.eu/wp-content/uploads/2023/10/Report-CoP-6-MULTI-USE-and-policy-advice-September-2023.pdf

[2] https://storymaps.arcgis.com/stories/e39d73286c124cdeb26a23c19598437e

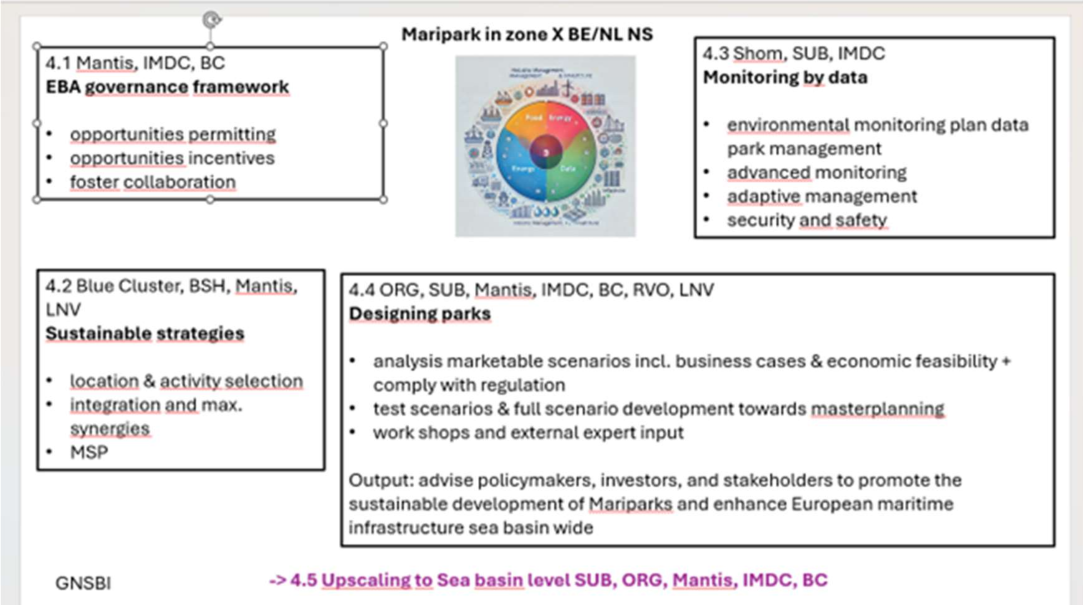

Figure 3: WP4 overview

Ultimately, the goal of this WP is to use the Maripark as a "diagnostic tool" to provide policymakers, investors, and stakeholders with actionable insights that promote sustainable development, enhance European maritime infrastructure at the sea-basin scale, and support the wider adoption of MU practices. By doing so, Mariparks can catalyse policy innovation, attract investment, and contribute to the long-term health of marine ecosystems and coastal communities.

Into the WP4; three Multi-Use Settings (MUS) will be studied across different scenarios and cases (locations) to explore their environmental, socio-economic, and governance implications.

❑ *Key findings*

- In WP4, a Maripark is considered **as a valuable tool** for identifying the limitations within current governance and policy systems, and so ultimately guiding the establishment of sustainable MUS area[3].

[3] MUS is considered an innovative approach to promoting efficiency in space and resource use whilst contributing global policy priorities [8].

- A Maripark can be understood as **a holistic multi-functional and symbiotic MU combination** with socio-economic and environmental interplays [3] [4].

1.2. T4.3 scope and objectives

The aim of T4.3 is to provide a methodological foundation to frame and describe the data framework need[4], during the spatial planning and monitoring phases of Ocean MU projects, according to their potential environmental interaction.

As this task is being developed ahead of the definition of the scenarios (T4.4), it cannot prejudge of those ones selected within WP4. It will therefore focus its study on the environmental dimension of the baseline study, in complementary of the EBA framework developed (T4.1). In this view, this exploratory study follows a logic approach: first develop guidelines for an Environmental Baseline Study (EBS) and the data framework linked (D4.3), then produce an Environmental Monitoring Plan (EMP) (D4.6), integrating the Environmental Impact Assessment (EIA) stage.

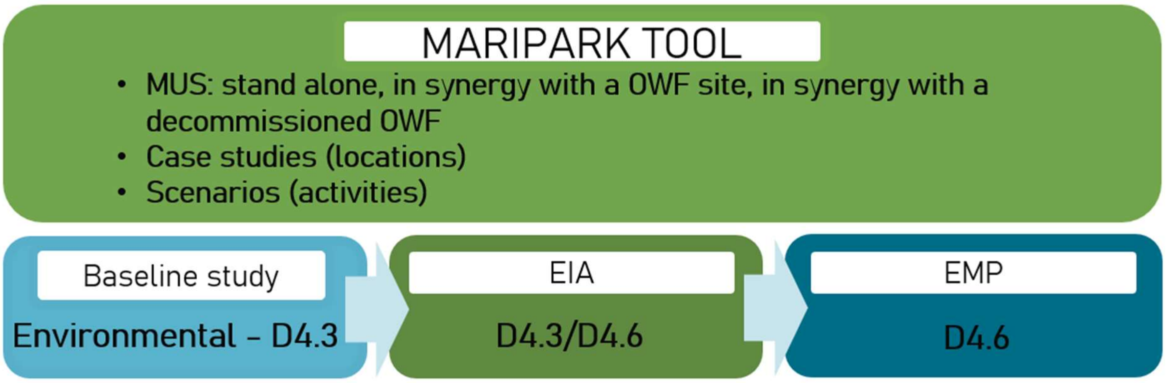

Figure 4: T4.3 logic approach

About the definition of terms

- EBS: a baseline study is an analysis of the current situation that establishes reference conditions for a programme or project[5]. An EBS determines the

[4] Terms like data, datasets, data layers are here interchangeable.

[5] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Baseline_study

characterization of an area prior to the development of a project and establishes the initial environmental status. This requires a high degree of understanding of both the impact of the receiving environment and the process that produces it. It is a core element of national EIAs, but it can also be carried out independently, for example in forward-looking MUS scenarios where no specific project or EIA has yet been defined. In D4.3, the EBA focuses on the environmental dimension of MU projects, including the integration and management of relevant datasets.

- EIA: a legally required process that evaluates (meaning predict, minimize, measure and, if necessary, correct and compensate) the direct and indirect significant environmental impacts of a proposed project before implementation, usually at national level. It includes stakeholder consultation and typically results in mitigation or compensation measures (European Commission, Environmental Impact Assessment - European Commission).

Objectives of D4.3

- Define the methodological scope of an EBS data framework for Mariparks project perspective as preparation for EIA and EMP;
- Describe the three MUS selected through existing MU projects and Belgian cases to highlight key outputs;
- Provide general recommendation about the data framework need in considering MU projects feedback.

Public targeted

- Public authorities, policy makers and agencies involved in national MSP strategy, sectoral planning as aquaculture and ORE, MU developments;
- MU project developers and EIA consultants.

1.3. T4.3 methodology and synergies

Ocean MU has already been trialed through several EU-funded projects, such as UNITED and ULTFARMS. These project pilots provide valuable insights, particularly through the Belgian pilot site *Belwind*, where extensive bibliographic material and stakeholder feedback are available. Drawing on this knowledge base, the current study outlines the theoretical scope of an EBA in a Mariparks context, including an indicative list of required datasets and complementary field studies. Particular attention is given to the integration of future-oriented data, especially climate projections, which remain underutilised in long-term spatial planning.

In a second step, the proposed data framework is applied to three Belgian case studies to assess its robustness and adaptability. These case studies, developed within WP4, were selected to test the three settings mentioned above: stand-alone (MUS-1), operational OWF (MUS-2), decommissioned OWF (MUS-3).

MU Settings	Cases
MUS-1	Belgium case 1: Zone A
MUS-2	Belgium case 2: Princess Elisabeth Zone
MUS-3	Belgium case 3: C Power Zone, Thornton Bank

Table 1: WP4 MUS

Finally, the report provides a set of recommendations addressing the potential adjustments required to apply the proposed methodology in other contexts. The synergies within WP4 are as follows:

- T4.1: developing governance framework in relation to EBA: governance and permitting process will be introduced in this report and developed in T4.1. It will also explore cumulative assessment to ensure EBA approach for Mariparks.
- T4.2: sustainable activities: will provide social and economic assessment of the Mariparks relying on data. The task provided the initial settings and cases (locations).
- T4.4: more likely further elaboration or assessments of Mariparks scenarios with external expert input and case studies: the scenarios and activities will be developed in the EMP report.
- T4.5: upscaling – diffusion of data frameworks for Maripark recommendations, adaptation at governance and basin scale level

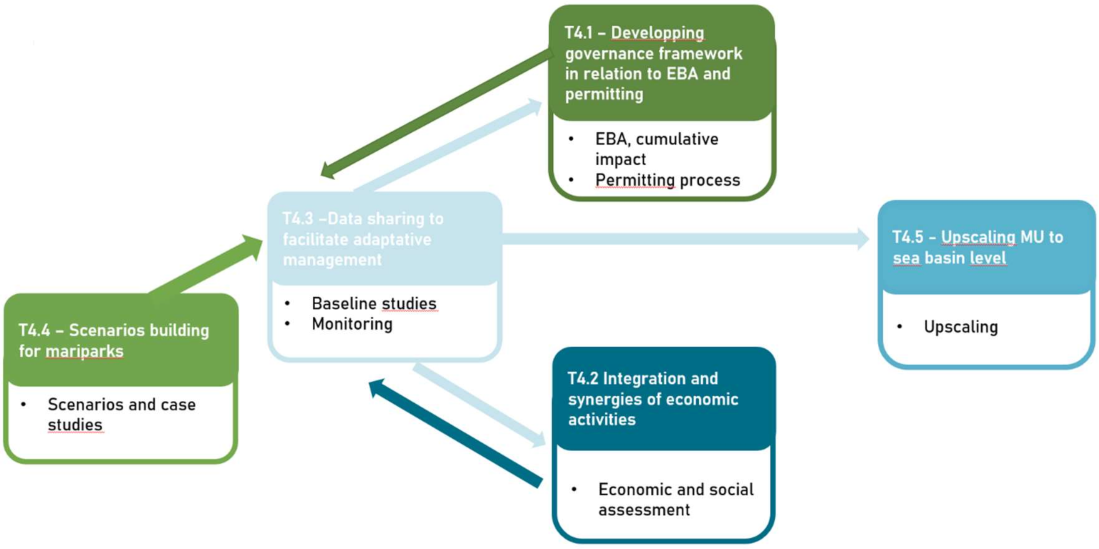

Figure 5: T4.3 synergies

II. Data frameworks for Mariparks

2.1. Ocean MU tool: Mariparks in progress

Consideration of a sustainable exploitation of ocean resources and use of sea space has increased the popularity of the MU concept, especially in the context of crowded seas and MSP initiatives as the pragmatic solution to solve it [5]. If pressures on the environment are building and space is at a premium[6], MU could potentially reduce it. As a result, the European Commission (EC) formally recognized MU as a legitimate field of study and integrated it into its political agenda, primarily through the European Union Blue Growth Strategy [6], the EU Offshore Renewable Energy Strategy [7], and the Strategic Guidelines for Sustainable and Competitive EU Aquaculture [8]. As a first definition step, the Horizon 2020 Multi-Use of European Seas (MUSES) project defined the following definition:

❑ *Key findings*

- *Ocean multi-use is* ***the joint use of resources in close geographic proximity by either a single user or multiple users****. It is an umbrella term that covers a multitude of use combinations in the marine realm and represents a radical change from the concept of exclusive resource rights to the inclusive sharing of resources and space by one or more users.*

[6] https://maritime-forum.ec.europa.eu/contents/multi-use-ocean-platforms-emerging-concept_en


Figure 6: Example of multi-use management of a wind farm [11]

So, for the same space or platform, a MU is a way of operating which can reduce the demand for space and offer significant socio-economic and environmental benefits for different marine users and sectors [9]. It can take many forms, ranging from the co-location of two activities to a fully integrated, multi-use business infrastructure or a shared sea space [10].

In this way Mariparks tool could potentially create synergies by enabling industries to share and pool infrastructure, governance, security, monitoring, and smart services, reducing costs and risks for offshore operations [12].

In the North Sea, Mariparks open new opportunities aligned with the EU Sustainable Blue Economy and Green Deal objectives, making a sustainable blue economy more collaborative, secure, and cost-effective. They can enhance efficiency and support solutions for[7]:

- The protein transition and food security remain relevant drivers, especially in a geopolitical landscape where conflict has highlighted the importance of local production. However, the business case for marine protein still lacks solid evidence. It's important to note that policy decisions are not solely based on economic return — agriculture, for instance, has long received support simply to stay viable. These are governmental choices.
- Energy diversification, particularly in times of global uncertainty. Offshore zones can play a key role in increasing resilience.

[7] https://www.bluecluster.be/news/mariparks-in-the-spotlight-during-multi-use-at-sea-design-workshop-in-venice

- Nature restoration is distinct goals and should be assessed and treated as such in design processes. Mariparks can contribute meaningfully by offering foraging and breeding grounds, as well as steppingstones that enhance ecological connectivity. This way, they can contribute to Biodiversity goals.
- A shift toward smart aquaculture is crucial to enable integration and scaling within Mariparks. At the same time, less intensive approaches like sea ranching are already feasible and urgently needed. Both forms of aquaculture are considered, separated in timing of implementation.

2.2. EBS for Ocean MU in Mariparks context

A baseline study forms the cornerstone of spatial planning and assessing Ocean MU developments. It provides a comprehensive reference point on environmental, socio-economic, and governance conditions prior to the implementation of activities such as offshore wind combined with aquaculture, or tourism combined with conservation. In the EU, baseline assessments are a prerequisite for informed Maritime Spatial Planning (MSP), Environmental Impact Assessments (EIA), and compliance with the Marine Strategy Framework Directive (MSFD). For MU initiatives, they are particularly important in identifying potential synergies and conflicts between uses, ensuring that new solutions contribute to both the Blue Economy and biodiversity goals.

2.2.1. Baseline study definition to EBS

In the context of MU, baseline studies are systematic evaluations of the physical, biological, socio-economic, and governance characteristics of a marine area. Their purpose is not only to describe the "status quo" but to identify ecological sensitivities, user interactions, and governance gaps that will shape MU feasibility. Unlike monitoring, which tracks changes over time, baseline studies provide the benchmark against which impacts and added value of MU configurations can be measured.

EBS is the environmental dimension of a baseline study, so closely linked to established assessment frameworks such as EIAs, Strategic Environmental Assessments (SEA), and EBA approaches. In MU projects, an EBS focus in abiotic and biotic components, ensuring that potential MU project is feasible, sustainable, and resilient regarding the existing and future environmental condition.

According to multiple studies, a baseline study data framework preparation follows widely used approaches in MSP (MU can be considered a micro-scale MSP project) and multi-use assessments [13, 14, 15, 16, 17]:

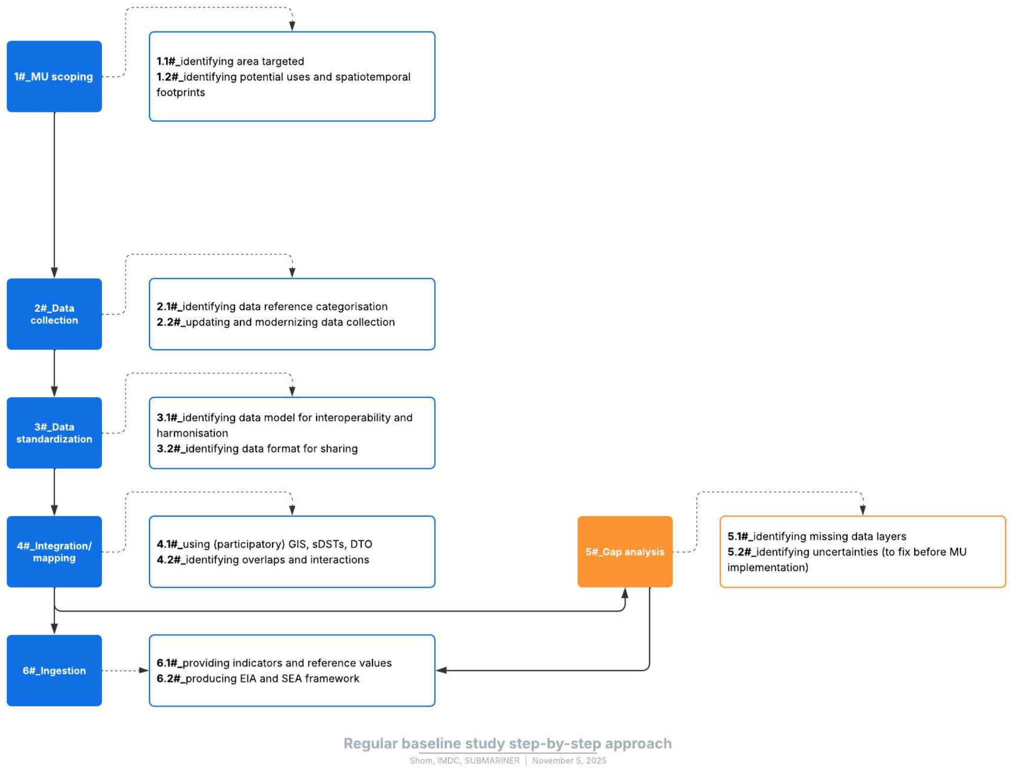

Figure 7: Regular baseline study step-by-step approach

Several European projects on multi-use (MU) at sea have already generated substantial knowledge and methodological insights, which provide a strong foundation for this work.

The following section highlights key examples of relevant integrated baseline studies from recent EU initiatives, notably the UNITED and ULTFARMS projects. Both advanced the operationalization of MU concepts in real-world settings in the Baltic and North Seas. Importantly, both projects included the Belwind pilot site in Belgium, which has been selected as a reference case for the Belgian case studies presented in Part III of this report. These projects tested MU integration within an existing offshore wind farm (OWF), providing concrete lessons for the development of Mariparks.

2.2.2. Examples of relevant baseline studies on Ocean MU

Baseline assessment methodologies from the UNITED Project

The UNITED (Multi-Use offshore platforms demoNstrators for boostIng cost-effecTive and Eco-friendly proDuction in sustainable marine activities) project, funded by the Horizon 2020 programme, aimed to demonstrate the technical, economic, social, and environmental feasibility of ocean multi-use across five European pilot sites, including Belwin. These pilots tested different combinations of offshore wind and solar energy, aquaculture (including bivalves, seaweed, and finfish), nature restoration, and maritime tourism.

Within the project, WP4 focused on evaluating the environmental added value of multi-use by developing structured assessment methods and testing them through real-world applications and upscaled scenarios. These efforts generated valuable insights for baseline data collection, cumulative impact assessment, and environmental monitoring, directly relevant to future multi-use initiatives such as the Maripark tool.

For the conducted baseline study, UNITED used the following datasets as key indicators to inform the baseline study ([8][18]):

Data category	Datasets collected
Abiotic environment	✓ Seabed: morphology and substrate ✓ Seawater properties: oxygen concentration, temperature, salinity, turbidity, and nutrient levels (nitrite and nitrate), as well as hydrodynamic conditions: current, swell ✓ *Optional: atmospheric and climatic conditions, seascape features, underwater cultural heritage*
Biotic environment (fauna & flora)	✓ Plankton and zooplankton communities, fish species, benthic organisms, marine mammals, and seabirds ✓ Important for ecological status and potential stress: nonindigenous species, eutrophisation in water column ★ Critical point: presence of vulnerable animals and plants species (EU legislation/ Birds and habitats Directives)
Habitat types/structures	✓ Structure, distribution, and ecological value of benthic and pelagic habitats (spawning grounds, reefs, or vegetated seabed)
Anthropic pressures	

[8]https://www.h2020united.eu/images/PDF_Reports/D41_current_environmental_assessment_and_status_of_the_pilots_revised_dec2021_220207.pdf

	✓ Commercial and recreational fishing, maritime transport, industrial discharges, tourism, and other sectoral activities

Table 2: United indicators for baseline study conducted

Potential positive and/or negative environmental impacts of the proposed MU combination were also considered, although this step goes beyond the baseline description itself. Nevertheless, it provided important context and helped to highlight indicators that may require specific attention in future monitoring and planning stages.

The indicators were applied flexibly at each pilot site using a combination of in situ measurements, sensor deployments, remote sensing, literature review, and stakeholder engagement. For example, the Belgian pilot, Belwind which integrated offshore wind infrastructure with flat oyster cultivation, seaweed farming, and reef restoration, placed particular emphasis on benthic habitat conditions and biodiversity. In contrast, the Greek pilot, which focused on combining finfish aquaculture with tourism, gave greater weight to indicators related to water quality, eutrophication, and human activity.

❑ *Key findings*

- EBS requires coverage of abiotic, biotic, habitat types and anthropogenic pressures datasets.
- Site-specific differences emerge at later stages, allowing prioritisation of certain datasets depending on the context.

Baseline assessment methodologies from the ULTFARMS Project

ULTFARMS, a Horizon Europe Ocean Mission project (2023–2026), pioneers low-trophic aquaculture (LTA) integration within offshore wind farms (OWFs) across six pilot sites in the North and Baltic Seas, including Belwind (Belgium). A key element of its strategy is to develop baseline assessments, which underpin effective design, monitoring, and management of LTA in challenging offshore conditions. The baseline assessment in ULTFARMS includes the same category than the UNITED project for the environmental dimension. Another interesting aspect was that ULTFARMS aims to transform offshore aquaculture by developing innovative engineering, ecological, and biological processes tailored to challenging conditions, including harsh offshore environments and low-salinity waters. By combining aquaculture with renewable energy infrastructure, ULTFARMS exemplifies the potential of multi-use platforms to deliver both economic value and ecosystem benefits, positioning the project as a key step toward the sustainable blue economy in Europe.

A key cross-cutting resource in ULTFARMS is the HiSea platform, which integrates multi-source datasets—satellite imagery, in situ sensors, and forecast models—into a single decision-support interface. This tool enables environmental monitoring, planning of offshore operations, and visualization of conditions in near real-time.

For Mariparks, HiSea demonstrates how baseline datasets can be aggregated, standardized, and shared among multiple stakeholders, helping to overcome sectoral silos and reduce data fragmentation. Beyond data integration, ULTFARMS also highlights the importance of collaborative governance, showing that multi-use requires coordination across diverse actors and governance levels. Together, these elements illustrate how digital tools and inclusive governance can make baseline information more actionable and future-oriented.

- *Key findings*

  - Spatially explicit environmental datasets remain central, as they determine the compatibility of co-located uses and provide the basis for cumulative impact assessments.
  - Early-stage stakeholder engagement is a prerequisite for defining acceptable multi-use configurations and reducing potential conflicts.
  - Integrated modelling approaches (e.g., coupled bio-physical-economic) are already used at the baseline stage to establish reference conditions and test scenarios. This forward-looking approach strengthens adaptive management and reduces uncertainty.
  - Digital tools such as the HiSea platform demonstrate the potential of shared, multi-source data layers to reduce fragmentation and make baseline study information actionable in real time.

2.2.3. Focus on Belwind OWF site

The Belwind Offshore Wind Farm, located 49 km off Zeebrugge in the Belgian Part of the North Sea (BPNS), exemplifies some of the characteristics that define a Maripark. It was using as pilot site of two European projects, UNITED and ULTFARMS on Ocean MU.

Belwind was built in 2010, the UNITED project, to develop MU at sea, was carried on from 2020 to 2023 and the ULTFARMS project, to improve the combination of the MU, from 2023 to 2026 (see the table 2)

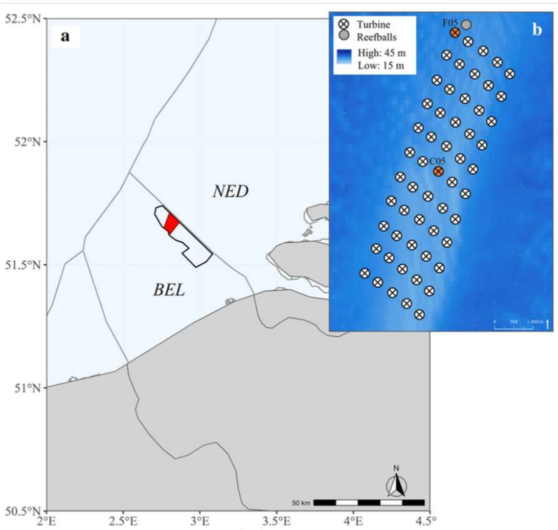

Figure 8: Belwind location [19]

Country	Belgium
Depth	Average of around 40 m deep
Area	Around 17 km²
Distance from coast	49 km from Zeebrugge
Number of turbines	55 Vestas turbines (Phase I) + 1 demonstration Haliade turbine = 56 turbines (operational configuration often reported as 56 units). Installed capacity reported as ~171 MW (55×3 MW + 1 demo)
Foundation types	Steel monopiles
Existing biodiversity	

	Monitoring shows rapid colonisation of hard substrata (monopiles + scour beds) by fouling communities (mussels, barnacles, sponges, algae and other epifauna), changes in macrobenthic communities near turbines, and evidence that turbines/scour act as artificial reef / fish aggregation sites; seabird use/monitoring indicates some displacement and small predicted collision risk for certain gull species. (Many Belgian monitoring reports and peer-reviewed studies document these patterns.) Vlaams Instituut voor de Zee
List of current activities	✓ Operation & maintenance (O&M); ✓ Electrical export cables & grid connection; ✓ Environmental monitoring (benthic, fish, seabirds, noise); ✓ R&D / demonstration projects (e.g., testing a large Haliade turbine); ✓ Vessel transit and servicing; ✓ Regulated restrictions for fishing/anchoring in the concession

Table 3: Belwind project parameters

EBS for Belwind installation (operational OWF)

At the time of implemenation, EBS focused mainly on physical conditions (bathymetry, sediment types, hydrodynamics, wave regime) and ecological receptors (benthic habitats, fish, seabirds, marine mammals). These environmental datasets served primarily to assess the operation impacts of construction phase.

However, MU potential, biodiversity enhancement, and climate change projections were not included. Datasets were not directly accessible on site and required an inventory of existing databases and, where gaps remain, complementary field studies.

Environmental baseline study for UNITED / ULTFARMS (MU OWF)

In contrast, long-term monitoring under EIA and MSFD obligations has since built a robust ecological baseline: seabird and marine mammal surveys, benthic community monitoring, fish assessments, and hydrodynamic data.

For MU pilots (oyster introduction, reef restoration, aquaculture), EBS requirements were extended to include:

- Habitat suitability for aquaculture (plankton dynamics, carrying capacity, disease vectors);
- Long-term ecological monitoring of benthic colonisation and reef development;

- Cumulative impact assessments (OWF + aquaculture + biodiversity enhancement).

These datasets directly support the integration of ecological enhancement and low-trophic aquaculture into OWFs, a central aspect of the Maripark concept. Climate Change projections remain absent, representing a critical knowledge gap.

Post-construction monitoring at the Belwind offshore wind farm revealed rapid colonisation of turbine foundations and rock armour by hard-substrate indigenious species such as *Mytilus edulis and Semibalanus balanoides as well as un-indigenious species as Jassa marmorata, Elminius modestus and Telmatogeton japonicus*, resulting in artificial reef effects and increased benthic biomass [20]. These ecological changes, while creating new habitats and enhancing local biodiversity, also led to shifts in benthic community composition. In parallel, localised seabird displacement were observe [21]. Overall, these findings illustrate that operational offshore wind farms induce both ecological opportunities and constraints, emphasising the need for adaptive management within future Mariparks.

However, while Belwind showcases the functional and experimental aspects of a Maripark, it also highlights the gaps that prevent full realization: co-uses remain project-based and temporary, governance and licensing frameworks are not yet structured to integrate multi-use systematically, and future-oriented assessments for climate change, cumulative impacts, or navigation risk are limited.

In summary, Belwind functions as a proof-of-concept Maripark: it embodies operational multi-use, ecological opportunities and constraints, and stakeholder engagement, while emphasizing that structural governance, socio-economic integration, and forward-looking monitoring are critical to evolving OWF-based sites into fully operational Mariparks.

❑ *Key findings*

- Belwind demonstrates that OWF can host complementary activities such as biodiversity enhancement and low-trophic aquaculture;
- **Extensive long-term monitoring** provides a robust baseline for ecological, hydrodynamic, and socio-economic assessments;
- **Co-uses remain temporary and project-based**; governance, licensing integration, and future-oriented assessments (climate, cumulative impacts, navigation risks) are limited;
- **Belwind functions as a proof-of-concept Maripark**, showing both potential and structural gaps;

- **Climate change considerations were not undertaken**; long-term, future-oriented projections are required.

As comparative perspective, UNITED and ULTFARMS projects highlight:

- The 2010 baseline situation at Belwind reflects the challenges of **MUS-1 (stand-alone)**: reliance on external databases, complemented by field studies to build a basic site description;
- The UNITED and ULTFARMS monitoring aligns with **MUS-2 (operational OWF)**: systematic monitoring already in place under EU legislation, expanded with additional indicators for aquaculture and biodiversity enhancement.
- Although not yet decommissioned, Belwind's long-term monitoring and post-construction ecological findings anticipate the requirements of **MUS-3 (decommissioned OWF)**, where recovery trajectories, navigation safety, and alternative uses become central.

2.3. Data reference for EBS in Mariparks context

The previous MU projects highlighted common datasets targeted to inform the EBS, whatever the MU site and combination. It should be noted that these prerequisites are already widely shared and known in the field of offshore energy planning [22].

Data category	Datasets identified
Abiotic environment	✓ High-resolution bathymetry and seabed morphology (slope, substrate maps) ✓ Sediment characteristics (grain size, sorting, carbonate content) ✓ Hydrodynamics (tidal range, current velocity, residual flow patterns) ✓ Wave climate (significant wave height, period, direction) ✓ Temperature and salinity cycles, long-term trends, anomalies ✓ Suspended sediment concentrations
Biotic environment (fauna & flora)	✓ Pelagic species surveys (fish, plankton abundance and diversity) ✓ Marine mammal sightings and acoustic detections

	✓ Seabird colony locations and tracking data ✓ Diseases vectors ✓ Non-indigenous/invasive species ★ Critical point: presence of vulnerable animals and plants species (EU legislation/ Birds and habitats Directives)
Habitat types/structures	✓ Benthic habitats and species distributions ✓ Protected areas: Natura 2000 sites, MPAs
Anthropogenic pressures	✓ Underwater noise baselines and activity ✓ human activities: fisheries, shipping, renewable energy, recreation ✓ Related footprints /zoning/regulation area ✓ Pollution (chemical contaminants, nutrients) ✓ Marine litter (macro- and microplastics) ✓ Defence and aerospatial pressures (drones…)
Climatic / Long-term change	✓ Temperature/salinity anomalies and long-term trends ✓ Wind force/orientation ✓ Precipitation levels ✓ Climate change drivers (sea level rise, marine heatwaves…)

Table 3: Data reference for EBS in Maripark context

The dataset categories listed above form a common baseline reference for all Maripark settings. However, the prioritization and treatment of datasets differ depending on the site context and development stage.

MUS-1 – stand-alone

- No systematic monitoring is yet in place. Data must therefore be compiled from regional and European databases (e.g. EMODnet, Copernicus Marine Service, ICES, OSPAR Data & Information Management System, HELCOM Map and data service, Wise Marine), complemented by targeted field surveys (e.g. sediment sampling, habitat mapping).
- A key challenge is the selection of the most appropriate reference datasets, ensuring that spatial resolution, temporal coverage, and methodological consistency are sufficient to support reliable baselines and future monitoring.
- Priority is given to establishing a basic physical and ecological description of the site (bathymetry, sediments, hydrodynamics, key habitats and species).

MUS-2 – operational OWF

- Extensive monitoring already exists under EU legislation (EIA, MSFD, Natura 2000), providing access to long-term datasets.
- For multi-use pilots such as oyster introduction, reef restoration, or aquaculture, the baseline must be extended beyond the original EIA to include:
  - ✓ Habitat suitability for aquaculture (plankton dynamics, carrying capacity, disease vectors);
  - ✓ Long-term ecological monitoring of benthic colonisation and reef development;
  - ✓ Cumulative impact assessments (OWF + aquaculture + biodiversity enhancement).

MUS-3 – decommissioned OWF

- Decades of monitoring usually exist, covering benthic habitats, fish, seabirds, and physical processes.
- Baseline requirements must expand to address transition scenarios, including:
  - ✓ Habitat recovery trajectories (benthic recolonisation, reef persistence);
  - ✓ Navigation and safety risk assessments;
  - ✓ Evaluation of alternative use scenarios (reef conservation, aquaculture-only, biodiversity park);
  - ✓ Future-oriented datasets on CC resilience and extreme events.

❑ *Key findings*

- The EBS data reference is universal, but its application varies: in standalone sites the challenge is to build a baseline from databases and new surveys, while in operational and decommissioned OWFs the EBA can rely on existing long-term monitoring, complemented with new indicators aligned with MU and Maripark objectives.
- Importantly, across all settings, there is a systematic gap in climate/long-term change datasets (marine heatwaves, sea-level rise, storm patterns…).
- Addressing this gap is essential to ensure that Maripark EBS are not only descriptive of current conditions, but also future-oriented and resilient to CC.

2.4. Future-oriented data in Mariparks context

In a context of accelerating CC, rapid technological development, and growing spatial competition in marine areas, long-term maritime projects such as Maripark must be grounded in predictive (future-oriented), high-resolution data reference.

In Belgium, recent legislation (Royal Decree of 3 June 2024) defines a maximum concession period of 40 years for offshore renewable energy infrastructures, typically including 35 years of operation and up to 5 years for construction and decommissioning. This means that infrastructures approved today will be operational until at least the 2070s, under environmental and socio-economic conditions that may differ radically from the present.

The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) confirms that global warming is likely to exceed 1.5 °C in the coming decades, potentially reaching +4 °C by 2100 under high-emission scenarios [23]. In the North Sea, sea surface temperatures (SST) have risen by an average of +0.38 °C per decade between 1982 and 2024 and marine heatwaves occur about 1.04 times more often per decade. This sea surface warming trend has doubled since 2013 [24].

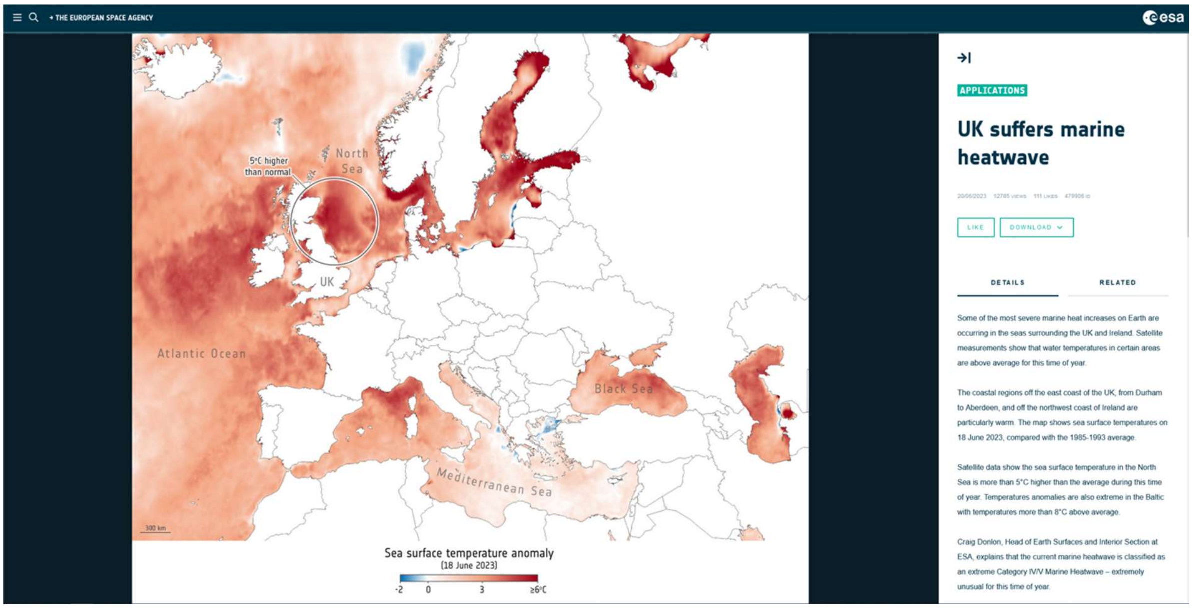

Figure 9: ESA - UK suffers marine heatwave

In July 2025, the southern North Sea recorded anomalies of +1.5 to +3 °C, with risks of harmful algal blooms and stress on commercial species such as mussels and oysters [24]. This is also a concern for seaweed aquaculture which is a promising emerging sector of the EU Blue Bioeconomy [25]. Indeed, key species, as Saccharina latissima (the most produced species [26]), face reduced growth and mortality risks at around 20°C during heatwaves [27]. Looking ahead, some areas may function as climate refuges, while others could shift into ecological dead zones, with significant implications for site selection.

For Maripark, whose lifecycles span several decades, the integration of predictive datasets on climate and environment is a foundational requirement for resilient and future-proof planning. However, as illustrated by the UNITED and ULTFARMS projects, CC considerations were largely absent. Within the NESBp EBS data framework, this section adopts an exploratory perspective: mapping available datasets, identifying emerging predictive tools, and outlining methodological options, while acknowledging that many of these tools remain at a developmental stage and are not yet fully operational.

2.4.1. Climate projections

Any long-term offshore infrastructure must be designed in alignment with scientifically validated climate scenarios. For instance, in Belgium, the maximum concession period is 40 years for offshore renewable energy infrastructures. This regulatory horizon implies that any site approved today will still be active under radically different climate conditions, potentially beyond +2.5 °C average global warming by mid-to-late century. For Maripark, which may remain operational into the 2070s, this means changes would affect both infrastructures and associated ecosystem-based planning on future-oriented climate projections and incorporating scenario-based uncertainties into both spatial design and risk mitigation strategies.

Sources and data availability

The IPCC's Shared Socioeconomic Pathways (SSPs) provide a robust framework for climate scenario planning. However, choosing the most relevant pathway depends on the purpose (mitigation planning, adaptation design) and spatial scale (regional, local). For instance:

- SSP2–4.5: a stabilisation scenario
- SSP3–7.0: a high-emission scenario
- SSP5–8.5: an extreme high-emissions scenario

While some NESBp countries do not yet provide official recommendations on which SSP to adopt, two examples could be mentionned: France's TRACC framework (*Trajectoire de Réchauffement de référence pour l'Adaptation au Changement Climatique*) [28], which sets legally recognised climate trajectories for regional and coastal planning, and Belgium's National Adaptation Plan (2020) [29], which outlines a first step towards high-resolution national scenarios (though marine-specific pathways are still under development).

TRACC framework:

- Legally binds climate adaptation trajectory framework;
- Is developed by the French Ministry for Ecological Transition and the French National Observatory on the Effects of Global Warming (ONERC);
- Sets differentiated climate scenarios for coastal, marine, and terrestrial planning, aligning with national commitments under the Paris Agreement;
- recommends regionalised projections from CMIP5 and EURO-CORDEX (sea surface temperature, sea level rise, and extreme event frequency) for marine domains [28];
- Advise to use provided climate data projection TRACC, SSP5-8.5[9];
- Scenarios should be applied for 2030, 2050 and 2100.

TRACC key data sources include:

- CMIP6 projections via the Copernicus platform: global baseline climate simulations[10];
- Copernicus Marine Service (CMEMS), model available at regional scale[11];
- EURO-CORDEX[12] – high-resolution regional climate projections for Europe (typically 0.11° or ~12 km grid), available under multiple RCP/SSP scenarios.

For operational MSP and MU projects such as Maripark, high-resolution regional downscaling is essential. However, many regional climate models are still run without dynamic ocean–atmosphere coupling, which can lead to underestimation of key marine extremes [30].

[9] https://www.drias-climat.fr/accompagnement/sections/401

[10] https://cds.climate.copernicus.eu/datasets/projections-cmip6?tab=download

[11] https://data.marine.copernicus.eu

[12] https://www.euro-cordex.net/

Application to Mariparks

Integrating climate projections into Maripark design enables:

- Strategic site selection: avoiding areas with high future exposure to extreme events;
- Infrastructure resilience: adapting mooring systems, platform design and energy systems;
- For MU project including aquaculture, projections of seasonal sea surface temperature are essential to ensure long-term viability of cultivated species.

❑ *Recommendations*

- MSP and public authorities:
  - Harmonise climate scenario selection at sea-basin scale to ensure interoperability across states.
  - Invest in the development and maintenance of regional coupled ocean–atmosphere models for more accurate marine projections.
- MU/Maripark developers:
  - Apply multiple SSP scenarios, including at least one high-emission pathway, to test infrastructure and environment resilience.
  - Use the most accurate, high-resolution marine-specific datasets available for the site.
  - Integrate adaptive design features (flexible layouts, phased infrastructure deployment) to accommodate evolving environmental conditions.
  - Apply the scenarios for 2030, 2050 and 2070.

2.4.2. MSP-Climate refugia area and "dead zones" projections

MSP-climate refugia area as designed by Sweden MSP process[13], is area that may need special protection to preserve keystone species as the climate changes and their distribution grows smaller or changes in the future. This kind of pioneering zoning are relatively buffered from contemporary CC impacts, providing stable environmental conditions that allow vulnerable species and ecosystems to persist despite broader regional or global changes. According to the IPCC AR6 (2023) as well, refugia serve as critical habitats supporting biodiversity conservation under shifting climatic conditions

[13] https://helcom.fi/wp-content/uploads/2023/10/Country-fiche_SE_MSP.pdf

[23]. The MSFD also highlights the importance of identifying and protecting such areas to maintain ecosystem resilience.

On the contrary, “dead zones”, also known as hypoxic or risk-intensive zones, refer to marine areas characterized by severely depleted oxygen levels (hypoxia), often caused by nutrient enrichment, stratification, and compounded environmental stressors. These zones lead to biodiversity loss, trophic disruptions, and ecosystem collapse. “Dead zones” indicate marine ecosystem degradation linked often to the combination of CC and anthropogenic pressures [31].

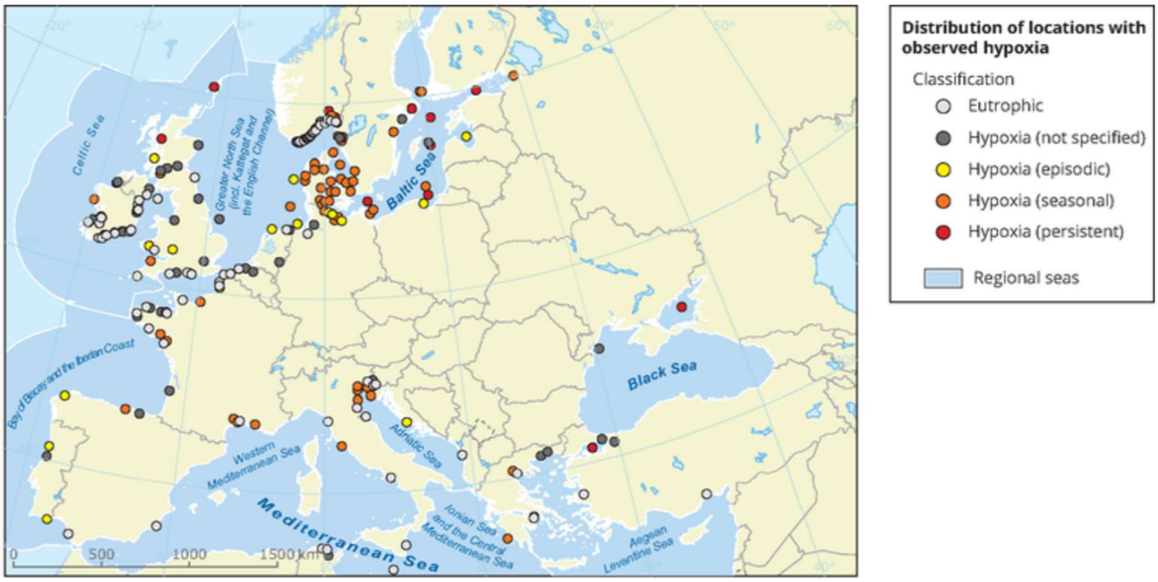

Figure 10: EEA - Distribution of oxygen-depleted 'dead zones' in European seas

These concepts are fundamental in MSP for providing new zoning methodology and improve the current ones, as they inform where conservation efforts must focus and where certain developments should be restricted.

Sources and data availability

Two european initiatives demonstrate the application of “climate-smart” spatial planning through zoning climate refugia areas and “dead zones”:

- Sweden’s climate refugia zoning: Sweden has incorporated climate projections into spatial planning by adapting the Symphony cumulative-impact tool within the ClimeMarine project. The work produced and tested spatial data layers (future sea-surface and bottom temperature, salinity, ice cover and nutrient-related biogeochemical projections) and explored complementary habitat and species distribution modelling to identify potentially resilient habitat patches and corridors that could function as climate refugia[14]. These outputs are intended to inform MSP and the designation or justification of restrictive zones for sensitive habitats [32].

- EU MSP MEDIGREEN project WP2/T2.2: Shom in MEDIGREEN project applies the *dynamic coastal-shelf seascape* approach, as developed by Tew-Kai et al. (2020) [33], to model marine physical seascapes in the Mediterranean under climate change scenarios. This methodology classifies seascapes from a combination of bathymetry, substrate type, and key oceanographic parameters, enabling the identification of spatially and temporally variable marine habitats. For MEDIGREEN, these seascapes will be cross-referenced with marine heatwave datasets and climate projections to produce future-oriented maps of potential climate refugia and dead zones in the Mediterranean. This integrated approach will provide a robust basis for prioritising conservation areas, defining exclusion zones for multi-use developments, and guiding regenerative use strategies within an ecosystem-based spatial planning framework.

Integration for Maripark design

Maripark promotes a long-term MU combination of offshore infrastructures. In this view, integrating projections of climate refugia and "dead zones "is critical to ensuring ecological sustainability and infrastructure resilience over their operational lifespan:

- Restricted zone: avoid siting infrastructures in identified climate refugia area to preserve critical habitats that provide biodiversity stability under future climate conditions.
- Development zone: target degraded or hypoxic zones for ecological restoration initiatives, potentially enhancing ecosystem services and contributing to the regeneration of marine environments alongside infrastructure deployment.
- Development zone: consider degraded or hypoxic areas as potential sites for multi-use infrastructures that can contribute to local environmental improvement while mitigating potential negative impacts on the surrounding ecosystem. These areas could become ecological opportunities, for example, by enhancing water

[14] https://maritime-spatial-planning.ec.europa.eu/practices/symphony-tool-ecosystem-based-marine-spatial-planning

circulation, providing artificial habitats, or integrating nature-based restoration features alongside industrial functions.

❑ *Recommendations*

❖ MSP and public authorities:
- ♦ Enhance the initiatives as climate refugia area and modelling marine physical seascapes to identify future restricted zone and development zone.
- ♦ Support decision process for MU locations on MSP-climate refugia areas zoning and "dead zones" projections.

❖ MU/Maripark developers:
- ♦ Use new zoning methodology to justify the relevancy of the choice for Maripark location and the economic cost-benefit ratio of the MU combination project.

EBS data reference must include future-oriented data as CC projections, with the relevant regional model regarding the next Maripark location. Into his framework, to address realistic outputs for the EIA, SIA and EMP implementation, it is crucial to frame it through data management guidelines.

Recent international guidance, such as the MSPglobal International Guide on Marine/Maritime Spatial Planning, Volume 3: Climate-smart Principle [34], further outlines how multi-use and climate adaptation can be jointly embedded into MSP processes.

2.5. Data management in Mariparks context

Ocean MU development offers both opportunities (e.g. cost sharing for hosting a shared platform between multiple investors) and challenges (e.g. harmonised spatially and administratively fragmented datasets) for data management. In the Maripark perspective, regarding the "Regular baseline study step-by-step approach", step 3#_Data collection and step 4#_Data standardization concentrate the main challenges:

2.5.1. Data collection

Data reference categorisation (repository)

The Maritime Spatial Planning data Framework (MSPdF) from the TEG on Data for MSP emphasises the importance of aligning datasets to facilitate interoperability [35]. MSPdF provides the architecture for organising spatial data and the resulting geographic information into a logical structure composed by seven thematic groups (or data clusters) covering rationally and exhaustively marine/maritime analytical thematics:

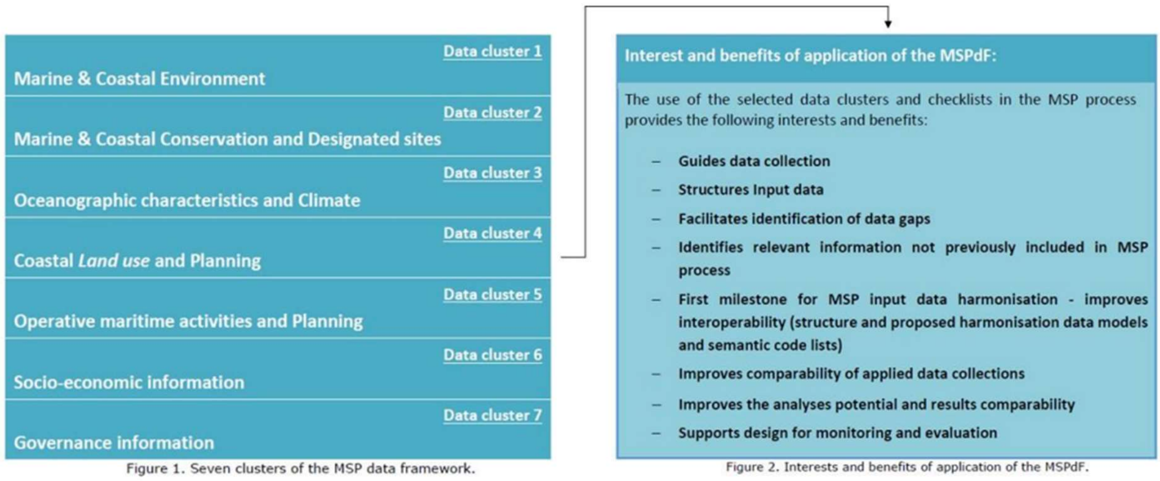

Figure 11: MSPdF structure [35]

Based on the MSPdF[15], Shom in MSP-OR and ReMAP projects have proposed a detailed repository with a standard architecture composed by a hierarchy of five scalable strata as an "umbrella" (here with the data cluster 1 example):

CATp.1.1	Parent category - 1st level	= MARINE BIODIVERSITY
CATp1.2	Parent category - 2nd level	= Flora life
CATc1.3	Child category	= Phytoplankton
CLAc1.3.1	CLAss child - 1st rank	= Phytobenthos
CLAc1.3.2	CLAss child - 2nd rank	= Specific species

Table 4: MSPdF completed by Shom

[15] Each MSPdF data cluster is structured by a categorisation, at a first level, and mainly based on already established frameworks, the digital resources available for managing the lifecycle of input data, as well as potential sources of data. However, the MSPdF does not provide a detailed categorisation architecture for each data cluster, i.e. all the sub-categories attached and a classification system, or an inventory of the reference data to be considered.

Under this "umbrella", from the 3rd strata (here CATc1.3), it is possible to identify potential datasets for the data collection step to implement an Ocean MU project. In this way, it ensures to collect all relevant datasets by category to feed the EBS and the integration process.

Updating and modernizing data collection

Regular update of data used in Ocean MU project should be prioritized. Currently, many datasets are often outdated, which affects the quality and relevance of the analysis. National authorities and data providers should be encouraged to invest in technologies that enable real-time data collection and automated data systems, such as remote sensing and satellite-based technologies. Moreover, EU funding programs should be directed towards the development of state-of-the-art technologies for continuous monitoring and the generation of up-to-date environmental and socio-economic datasets. Specifically, climate-related data such as sea surface temperatures, ocean salinity, currents and atmospheric pressure are essential for assessing the impacts of climate change on marine ecosystems and can be found in EU database (e.g. Copernicus data base, EEA, ESA). Furthermore, incorporating data on extreme weather events, such as storms and heatwaves, as well as long-term trends like sea-level rise, will enable more effective decision-making in Ocean MU project.

2.5.3. Data standardization

Interoperability/harmonisation

To address the fragmentation of datasets, the adoption of standardized data formats and frameworks across Member States (MS) should be promoted. This includes the widespread implementation of the INSPIRE directive [36] for spatial data interoperability and FAIR principles (Findable, Accessible, Interoperable, Reusable) [37] for data management[16]. A harmonized approach to data model (common and specific attributes) and formats will reduce processing time, improve data comparability and foster seamless cross-border collaboration into Ocean MU field. These efforts could be strengthened by setting mandatory guidelines for data standards, as outlined in this report, ensuring all Mariparks developers follow uniform protocols for data collection, standardization and sharing during the EBS process.

[16] https://www.emspproject.eu/wp-content/uploads/2024/01/Data-Sharing-Policy-Brief-eMSP-NBSR-January-2024.pdf

Data harmonization is not only about standardizing spatial data attributes and formats but also ensuring consistency across countries in case of MU project location is close to EEZ. For example, the Baltic Sea2Land European project [38] has provided key guidelines for harmonizing data across regions, especially for critical Ocean MU data such as OWF, cultural heritage sites and subsea cables.

Data sharing

Given the liquid and transboundary nature of marine environments, fostering data-sharing agreements between potential Mariparks developers is crucial. A comprehensive framework that facilitates the seamless exchange of data reference for EBS should be push forward with the implementation of all data harmonized in a common datasets catalogue[17]. This should include better integration of cross-thematic data and simplification of data sharing process in the platform where public and private stakeholders, including national authorities, researchers and NGOs, can access relevant datasets.

❑ *Recommendations*

❖ MSP and public authorities:

- Strengthen international data standards such as ISO, INSPIRE, International Hydrographic Organization (S-57 or S-100) and apply TEG recommendations to increase the FAIR principles [39] [40] [41].
- Strengthen the integration of Reference Lists developed by the eMSP data CoP into planning processes, to increase data coherence and harmonization approach, data classification and categorization (e.g. MSPdF) into relevant and consistent categories and subcategories [35] [42].
- Encourage "MSP Data Quality Label" to certify relevant datasets for supporting Ocean MU data framework.

❖ MU/Maripark developers:

- Establish a centralised data repository accessible to project partners and, where possible, MSP authorities (e.g. MSP4BIO database).
- Document data lineage (sources, processing steps, quality checks, data prioritisation) for avoiding "black box".
- Aligning data attributes and format with existing EU data models (e.g. EMODnet data model, Copernicus Marine Services).

[17] Based on the MSPdF categorisation, the MSP4BIO database is a relevant exemple to consider: https://msp4bio.vliz.be/

- Use geospatial visualisation resources and future-oriented data.

The way Ocean MU EBS could be informed differs depending on the regional context and site conditions. The following case studies (Part III) illustrate how this framework is operationalised in practice, mainly for here general baseline study approach (integrating EBS), with a focus on the Belgian Part of the North Sea (BPNS), where national and European platforms provide concrete examples of data availability, monitoring practices, and gaps to be addressed.

III. Belgian case studies

The Belgian Part of the North Sea (BPNS) is one of the most intensively used marine areas in Europe, supporting a dense mix of economic activities that require careful spatial and environmental management.

Key sectors relevant to the Maripark tool include:

- Offshore Wind Farms (OWF): As of 2025, Belgium has 2.26 GW of installed offshore wind capacity from 399 turbines, with expansion underway in the Princess Elisabeth Zone. These installations transform the seascape and contribute significantly to renewable energy targets. OWFs present opportunities for Maripark co-location, where recreational, educational, and biodiversity enhancement functions can be integrated with energy production.

- Nature restoration and biodiversity initiatives: The BPNS contains five Natura 2000 sites, covering ~37% of its surface. Restoration projects target sandbanks, gravel beds, and reefs formed by tube worms (*Lanice conchilega, Sabellaria spinulosa*), providing habitat for fish, seabirds, and marine mammals. Such sites are relevant for Maripark designs aiming to deliver ecosystem services such as carbon sequestration, fish nursery habitat, and coastal protection.

- Military use: Certain zones are designated for defence purposes, including live-fire exercises and training. These areas are generally excluded from civilian use but may influence adjacent site planning through safety zones or seasonal restrictions.

- Shipping: The BPNS lies at the crossroads of major North Sea traffic lanes, with ~60,000 ship movements annually, including routes into Antwerp, Zeebrugge, and Ostend. AIS-based shipping density maps highlight high-intensity corridors where Maripark placement could conflict with navigation safety, requiring predictive modelling of traffic flows and risk corridors.

- Fisheries: Belgian and foreign fleets target flatfish, crustaceans, and pelagic species. Vessel Monitoring System (VMS) data reveal seasonal activity peaks in shallow nearshore areas and along sandbanks. This information is vital for assessing potential conflicts and identifying opportunities for joint management, such as gear-restricted biodiversity enhancement zones.

By linking each sector to EBA needs, we ensure that Maripark site selection aligns with existing uses while maximising synergies.

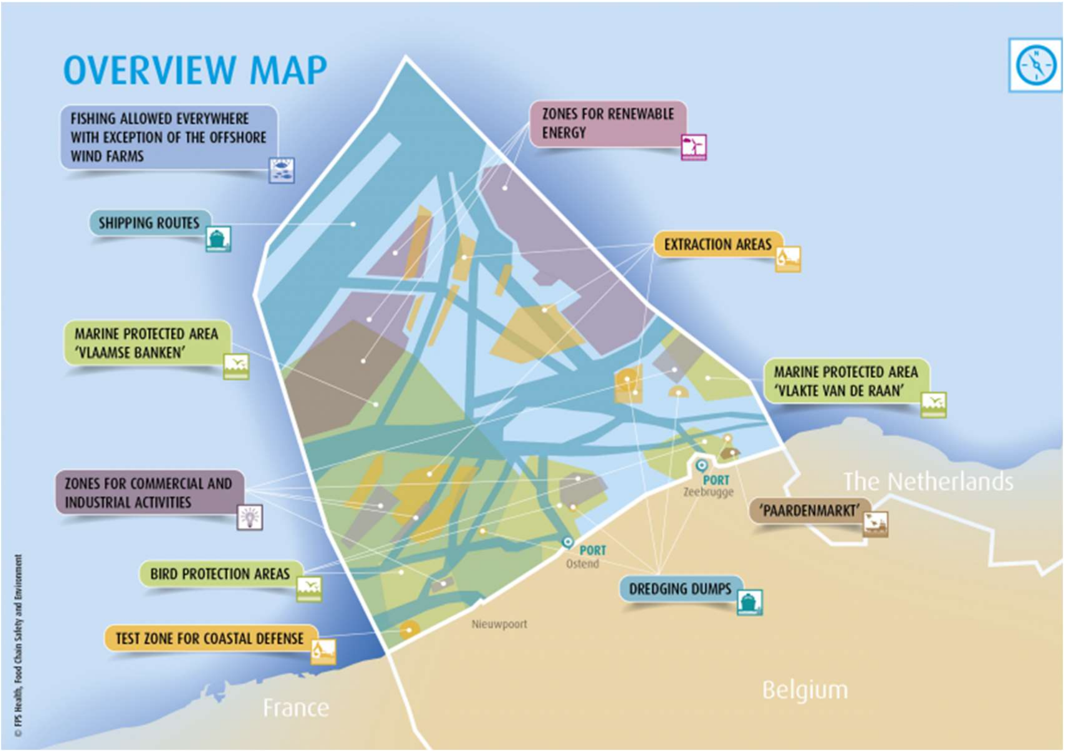

Figure 12: Current MSP of the Belgian part of the North Sea

3.1. MU scoping

The Belgian Part of the North Sea (BPNS) is located in the southern part of the North Sea and covers an area of approximately 3,454 km². It stretches along a 67 km coastline and extends up to 87 km seawards. The area features a diverse underwater landscape shaped by water depths ranging from less than 20 m nearshore to around 45 m offshore, with sandbanks as a defining feature. The BPNS is influenced by strong tidal and wind-driven currents, high turbidity, and a distinct salinity gradient from coast to open sea. Water masses in the region originate from the English Channel and several rivers, including the Scheldt, the Rhine-Meuse system, and to a lesser extent the Seine-Somme, which can occasionally exert even greater influence depending on weather and hydrological conditions[18] (Belgische Staat, 2025).

The three case studies are compared in the synthesis table below, while detailed descriptions are provided in Appendix 1.

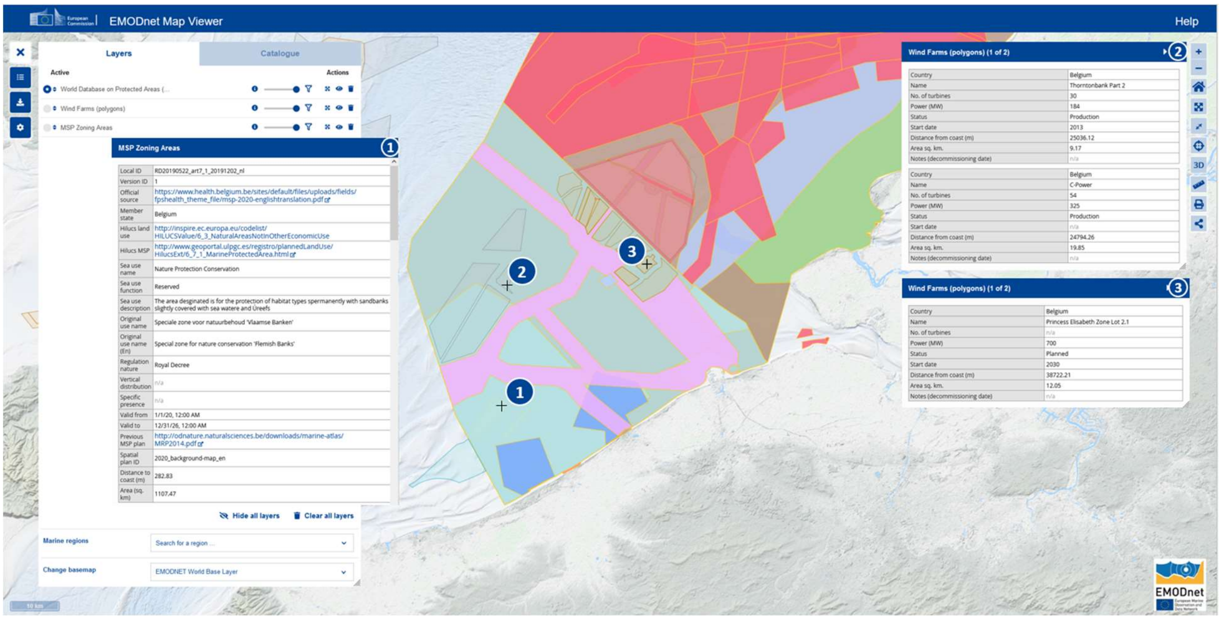

Figure 1:: Proposed Belgian WP4 case studies

	MUS-1 – Zone A	MUS-2 – Princess Elizabeth	MUS-3 - Thornton Bank
Country	Belgium	Belgium	Belgium
Depth	12m	25 – 30 m	18 – 24 m
Area	TBD with ORG (T4.4)	TBD with ORG (T4.4)	TBD with ORG (T4.4)
Distance from coast	~20 km	~45 km	~30km
Number of turbines	[redacted]	TBD	Formerly 54 (6 gravity base, 48 jacket),
Foundation types	[redacted]	Monopiles	Gravity based and jackets

18 https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/2025_ontwerp_evaluatieherzieningihds.pdf

Existing biodiver-sity	Sandy seabed with fine to medium sands, occasional gravel patches	Medium coarse sands with benthic communities typical of offshore wind farm zones	Well-sorted coarse sands with biogenic colonisation from 15 years of turbine operation
List of current activities	Shipping lane nearby, reserved for commercial & industrial marine uses (CIA zone as defined within MSP)	Offshore wind energy generation, cable corridor maintenance, vessel access to Princess Elisabeth Island	Decommissioning activities, low vessel traffic, possible ecological enhancement
Conclusion	High sediment stability and proximity to shore make this zone well suited to MUS-1 with minimal interference from heavy offshore infrastructure.	Integration within the Princess Elisabeth Zone offers synergies with existing offshore energy infrastructure, enabling efficient maintenance access and power export.	A decommissioned wind farm site provides cleared cable routes, reduced vessel traffic, and opportunities to build on established benthic communities for ecological enhancement.

Table 5: Belgian case studies synthesis

The next step of the baseline study is a systematic search across existing databases and catalogues.

3.2. Data collection

3.2.1. Databases for EBS in the PBNS

At the PBNS scale, various catalog can be used to find the adequate datasets to compl. They can be national or regional: RBINS Metadata Catalog (GeoNetwork).

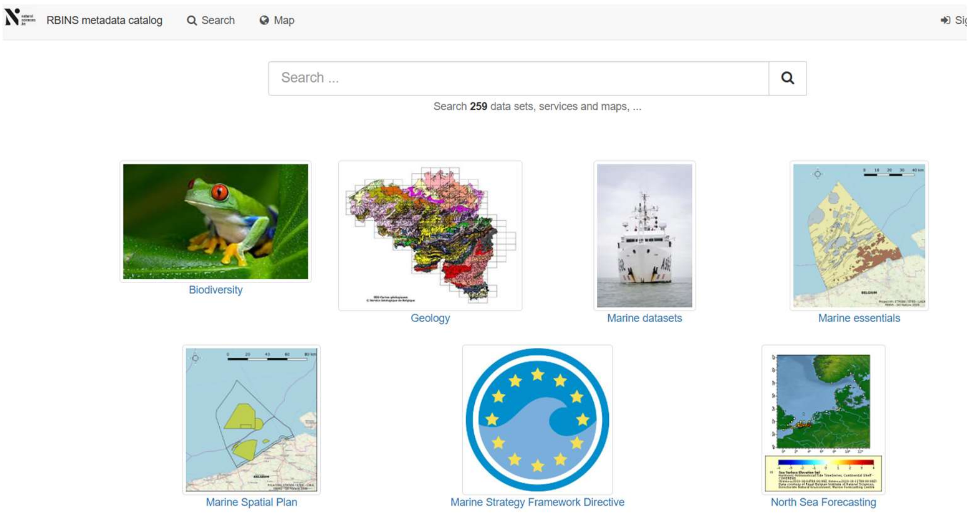

Figure 14: Metadata Catalog RBINS

The table below provide comparison of these sources while Appendix 2 allowed an exhaustive presentation of all the sources.

Data platform	Focus Areas	Main Features / Tools
RBINS Metadata Catalog (GeoNetwork)	Marine ecosystems, human activities, environmental pressures in Belgian waters	Searchable geospatial datasets, standardized metadata, interactive map viewer, GIS downloads
VLIZ Marine Data Center (VMDC & IMIS)	Biodiversity, monitoring, field surveys, taxonomic data	Data discovery and visualization, Marine Data Archive, World Register of Marine Species (WoRMS), Marine Regions for georeferenced boundaries
EMODnet Map Viewer	Bathymetry, seabed habitats, chemistry, biology, human activities across Europe	Interactive map viewer, harmonized datasets, GIS-compatible downloads, layer filtering and comparison
INSPIRE Geoportal	European geospatial datasets including environmental monitoring, protected sites, maritime boundaries	Harmonized geospatial data, metadata standards, GIS interoperability
MarineTraffic / AIS Data	Vessel traffic, shipping lanes, human activity pressures	Near real-time spatial data on ship movements, route visualization, pressure mapping

Table 6: Comparison of data sources for Belgian cases

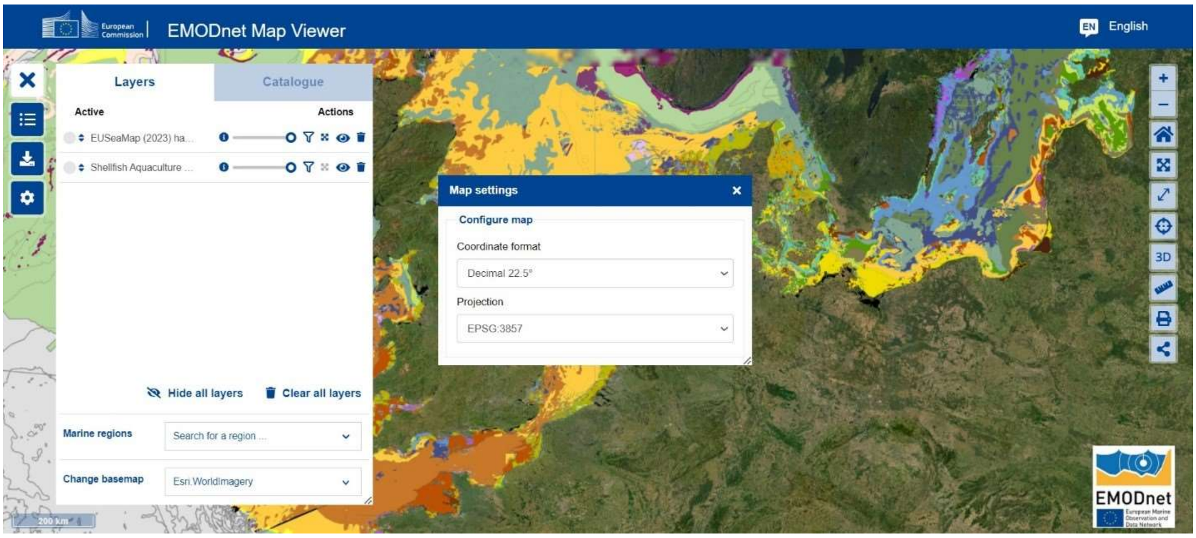

Figure 15: EMODnet Map Viewer – EUSeaMap (2023) datalyer

By combining these resources, researchers and Maripark developers can establish a detailed and reliable baseline study (including EBS) for Maripark project. Regular consultation of these databanks ensures that new monitoring campaigns complement existing datasets, that metadata are systematically recorded, and that management decisions are informed by the most comprehensive and spatially explicit information available. Integrating national, regional, and European data sources into baseline studies enhances data quality, supports collaboration across institutions, and provides a strong foundation for sustainable marine park management.

❑ *Recommendations*

- Establish a **centralized data management system** building on existing infrastructures (RBINS, VLIZ, EMODnet), a centralized management system could studied at basin level.
- Ensure all datasets follow **FAIR principles** (Findable, Accessible, Interoperable, Reusable) and include standardized metadata.
- Prioritize monitoring of **key ecosystem components** (habitats, species, water/sediment quality, physical processes) and **key human activities** (fisheries, shipping, renewable energy, recreation, etc.).
- Integrate **existing datasets** before commissioning new surveys to maximize efficiency and avoid duplication.
- Facilitate **data access and visualization** through user-friendly map viewers to support decision-making.

- Embed monitoring in a **long-term adaptive framework**, with periodic reviews, identification of data gaps, and incorporation of new technologies (e.g. satellites, eDNA, automated sensors).

3.2.2. Available environmental datasets

For baseline descriptions of offshore locations in the BPNS, including physical, ecological, socio-economic, and legal aspects, there are several national and international data sources.

List of the available sources of data for the Belgium cases:

Categories	Source	Resolution / Scope	Use in Baseline study
Bathymetry & Seabed	EMODnet, Flemish Hydrography	~100 m grid	Habitat & hydrodynamic modelling
Hydro-dynamics	OD Nature, HNSO	Hourly / regional	Input for TELEMAC, XBeach
Biodiversity	Lifewatch, RBINS monitoring	Species-specific	Baseline ecological mapping
Fisheries	VMS, ICES	Seasonal / annual	Activity overlap & planning
Shipping	EMODnet Human Activities, AIS	Hourly / seasonal	Navigation safety analysis
MPA	Natura 2000 database	Spatial polygons	Constraint mapping

Table 7: Available data sources list for Belgium cases

For baseline monitoring studies in the BPNS, it is recommended to apply a suite of numerical models to complement field data and provide future-oriented insights into key environmental parameters.

Hydrodynamic–ecological models, such as **TELEMAC with AED2**, should be used to simulate nutrients, phytoplankton, zooplankton, detritus, oxygen, suspended sediment, and temperature. These outputs help establish the biochemical and physical context relevant for ecosystem health.

To address specific pressures, additional models are advised. Plastic transport models can identify hotspots of floating and submerged plastic accumulation, supporting targeted mitigation. Underwater noise models should be applied to predict propagation of noise from pile driving, vessel traffic, or other human activities, enabling assessments of potential impacts on sensitive fauna. Near-field and mixing zone models, coupled with three-dimensional hydrodynamic frameworks, are recommended for simulating dispersion of dredging plumes, sediment spills, or other discharges, providing critical insight into turbidity and water quality impacts.

In the coastal zone, shoreline resilience models such as XBeach are particularly useful for assessing dune and beach system responses to waves, overtopping, and storm surges. These models can support the design of nature-based solutions and long-term climate adaptation strategies.

By integrating these modelling approaches into baseline studies, Maripark planning can be informed by robust predictions of physical, chemical, and biological processes. This ensures that cumulative pressures are properly assessed and that site design and monitoring frameworks are guided by evidence-based decision-making.

3.2.3. Existing monitoring datasets

For MUS-2 (operational OWF) and MUS-3 (decommissioned OWF), a significant amount of data is already available through EIA, long-term monitoring programmes, and EU legislative requirements (e.g., MSFD, Natura 2000 reporting). These datasets typically cover hydrodynamics, benthic communities, fish populations, seabirds, marine mammals, and underwater noise.

Access to these datasets should be formally requested from the OWF management companies and relevant authorities, ensuring compliance with data-sharing obligations under national and EU frameworks. Where possible, data should also be cross-checked with public repositories (e.g., RBINS Metadata Catalog, VLIZ, EMODnet) to ensure consistency and completeness.

3.3. Gap analysis: complementary field studies

While substantial baseline data exists from Marine Spatial Planning (MSP) processes and offshore wind farm (OWF) Environmental Impact Assessments (EIAs), targeted field studies are recommended to strengthen site-specific assessments for the three proposed Maripark settings. These suggestions build on monitoring approaches commonly applied in European offshore wind contexts (Y;Z).

MUS-1 – stand-alone in Zone A

Additional benthic grab samples and sediment profiling would help verify habitat suitability and map small-scale variability in sediment types, following methodologies outlined in Belgian monitoring programmes [43]. Water quality measurements (nutrients, suspended matter, oxygen) should be collected to ground-truth model simulations [44]. Opportunistic surveys of seabirds and marine mammals in the area would provide information on potential ecological interactions with new installations [45].

MUS-2 - embedded in an operational OWF (Princess Elisabeth Zone)

Underwater noise measurements during routine maintenance or new co-location works would help assess cumulative acoustic impacts in line with MSFD Descriptor 11 requirements [46]. Dedicated seabird and marine mammal surveys should be undertaken to evaluate habitat use in and around turbine arrays, as recommended in long-term monitoring programmes in the BPNS [47]. Benthic surveys using video transects or grabs would confirm colonisation patterns on scour protection and natural habitats [48], providing insights into biodiversity co-benefits.

MUS-3 - decommissioned OWF (Thornton Bank)

Drop-camera or ROV surveys of remaining scour protection and foundation footprints would document colonisation and reef development [49]. Sediment chemistry analyses could assess potential release of trace metals or hydrocarbons following decommissioning [50]. Complementary fish surveys (e.g. acoustic or net sampling) would help determine whether the site functions as a refuge or nursery ground after turbine removal [51].

Remote sensing technologies offer valuable support for Maripark baseline studies and monitoring. Satellite observations (e.g. Sentinel-2, Sentinel-3, Landsat) provide consistent time-series on sea surface temperature, chlorophyll-a, turbidity, and sediment plumes, which are particularly useful for tracking seasonal variability and cumulative pressures across the BPNS [52]. High-resolution aerial or drone imagery can complement field surveys by mapping shoreline dynamics, dune systems, and surface debris accumulation. Remote sensing data also play a role in validating numerical models, offering large-scale context for site-specific measurements.

3.4. Synthesis

The Belgian Part of the North Sea (BPNS) provides a highly dynamic testbed for developing the Maripark tool, with its dense overlap of economic activities and ecological values. The three MUS, Zone A (stand-alone), Princess Elisabeth Zone (embedded in operational OWF), and the decommissioned Thornton Bank (repurposed), illustrate a gradient of opportunities and challenges:

- Standalone in Zone A offers flexibility and minimal interference from existing infrastructure but faces navigational safety risks and requires detailed seabed characterisation.
- Embedded in an active OWF enables strong synergies through shared infrastructure and maintenance logistics, yet regulatory restrictions and cumulative pressures (noise, biodiversity impacts) must be carefully managed.
- A decommissioned OWF site provides an experimental ground for adaptive reuse, with ecological enhancement potential from existing reef-like structures, though uncertainties remain around residual contaminants and structural safety.

Parameters	MUS 1 – stand-alone in Zone A	MUS 2 – operational OWF (Princess Elisabeth Zone)	MUS 3 – Decommissioned OWF (Thornton Bank)
Depth	6–12 m	25–30 m	18–24 m
Seabed type	Fine to medium sands, occasional gravel patches	Medium-coarse sands	Well-sorted coarse sands with biogenic colonisation
Currents	Low to moderate (~0.5–0.7 m/s)	Strong, predictable (~1.0–1.2 m/s)	Moderate (~0.8–1.0 m/s)
Distance from coast	~25 km	~45 km	~27 km
Existing uses	Near shipping lane, industrial/marine commercial activities	Offshore wind energy production, cable corridor maintenance, vessel access to energy island	Post-decommissioning works, reduced vessel traffic
Ecological context	Sandy benthic habitats; limited structural complexity	OWF-associated benthic and reef-like habitats; high pelagic activity	Mature biogenic colonisation on scour protection; potential artificial reef functions
Potential synergies for Maripark	Minimal interference; flexible design potential for recreation and research	Shared infrastructure, maintenance routes, and export capacity; potential for biodiversity co-management	Ecological restoration and adaptive reuse of foundations; tourism/education potential

Main constraints	Proximity to navigation routes; sediment mobility in shallow areas	Navigation safety within OWF; regulatory restrictions on access	Possible residual contaminants; physical hazards from remaining structures
Baseline data availability	MSP bathymetry, AIS shipping density, VMS fisheries; limited benthic species surveys	Extensive OWF EIA datasets (hydrodynamics, biodiversity, noise)	Historical OWF monitoring data; some gaps post-decommissioning
Data gaps / complementary studies	Benthic grabs & sediment profiling	Underwater noise surveys during co-location activities; seabird/mammal monitoring	Drop-camera habitat mapping; sediment chemistry for pollutant risk
Modelling priorities	Nearfield & Mixing Zone (turbidity); Water Quality	Underwater Noise; Water Quality; Plastics transport	Benthic habitat modelling; Water Quality; Plastics transport
Climate change considerations	Shallow water SST rise and storm surge exposure	Offshore marine heatwave frequency; current strength variability	Mid-depth SST trends; potential as climate refuge or restoration site
Navigation safety needs	AIS-based traffic simulation; corridor definition	IWRAP/Navisafe collision risk modelling	Risk mapping for residual structures; integration into route planning

Table 7: Parameters to inform Belgium cases by MUS

Together, these case studies highlight the importance of coupling spatial planning layers (MSP, AIS, VMS, Natura 2000) with site-specific monitoring (benthic, pelagic, noise, contaminants), and predictive modelling tools (hydrodynamics, turbidity, plastics, shoreline resilience). The integration of ecological restoration, co-location synergies, and stakeholder acceptance will ultimately determine the feasibility of Maripark designs in Belgium.

❑ *Recommendations*

- **Adopt a tiered monitoring approach:** combine MSP baseline data with complementary benthic, noise, and water quality and **remote sensing datasets** (e.g. Sentinel, drone imagery) to fill spatial and temporal gaps.
- **Integrate advanced modelling tools:** apply coupled hydrodynamic–ecological models and nearfield dispersion simulations to anticipate cumulative pressures.
- Leverage synergies with existing OWFs: explore co-management of biodiversity monitoring, logistics, and infrastructure access within active wind farms.
- **Prioritise ecological enhancement at decommissioned sites:** use reef colonisation data to guide restoration strategies and assess climate refuge potential.
- **Ensure navigation safety and stakeholder buy-in:** apply AIS/VMS-based risk modelling and engage fisheries, shipping, and defence authorities early in site planning.
- **Embed climate resilience:** test Maripark functions against scenarios of rising sea temperature, marine heatwaves, and storm surge impacts.
- Promote multifunctionality: design Mariparks to integrate recreation, education, and ecosystem services alongside energy and biodiversity goals.
- **Use a harmonised data management, shared access tools, and cross-sectoral governance to transform baselines into actionable planning instruments**

In conclusion, the Belgian case studies illustrate how Mariparks can be adapted to a wide gradient of site conditions, from standalone to operational and decommissioned OWFs. They highlight that while dataset categories are common, their prioritisation, accessibility, and governance needs vary significantly across contexts. These lessons provide a concrete basis for formulating cross-cutting recommendations on EBS, data management, and multi-use integration, which are presented in the following section.

IV. Recommendations and next steps

4.1. General recommendations

The analysis of EBS requirements across European multi-use projects and within the Belgian case study demonstrates that Maripark development requires a rigorous, step-wise data framework to select relevant datasets, ensure standardisation, and integrate complementary information, including climate-projection data, to support subsequent EIA and SEA processes.

A key contribution of this report is the identification of two hidden additional steps in the EBS pathway that should to highlighted: 2#_Initialisation and 7#_Data_completion

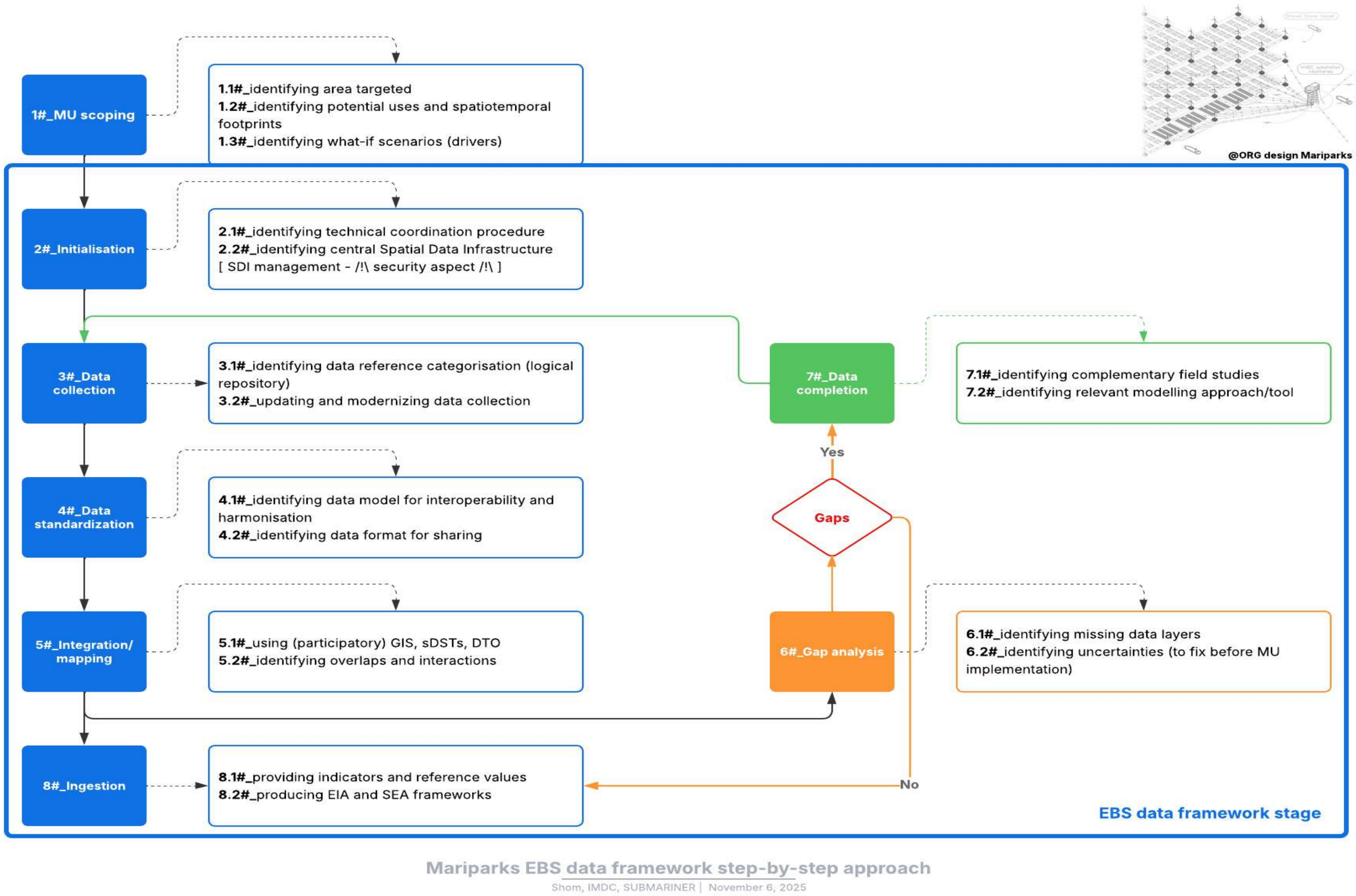

Figure 16: Mariparks EBS data framework step-by-step approach

2#_Intialisation

Into a higher level of possible interplays between different uses, it seems crucial to identify before the data collection step itself, the technical coordination procedure, including what-if scenarios as drivers in order to anticipate various conditions for the development of Mariparks, for which an EBS (and integrated baseline study) must provide as much detail as possible. Directly linked, the conception of technical platform as Spatial Data Infrastructure (SDI) to centralise the data-information-knowledge must be considered by Maripark developers at a key element. Recently, the second phase of MSPglobal (MSPglobal 2.0) published online the *Data Toolbox: Volume 1 – How to develop a Spatial Data Infrastructure for Marine Spatial Planning*. It provides robust guidelines for Ocean MU project scale too, as the key cross-cutting resource in ULTFARMS project with the HiSea platform example, which demonstrates the potential of shared, multi-source data layers to reduce fragmentation and make baseline study information actionable in real time.

7#_Data_completion

To update data collection according to the gap analysis, it requires a completion step with complementary fields studies or modelling of the missing values. This step prepares the evidence base for subsequent long-term monitoring.

Looking ahead, this modelling could be integrated to the European Digital Twin of the Ocean (EDiTO). This initiative, announced under the Ocean Pact and planned for full implementation by 2030, will go beyond modelling to provide a comprehensive, interoperable platform integrating observation, modelling, and decision-support tools across European seas. This evolution will further enable real-time integration of baseline information and foster the transition towards fully connected, adaptive Maripark management systems.

About data management, full compliance with standards remains rare in practice [53], particularly for multidisciplinary projects such as Mariparks, where data comes from diverse sources, scales, and timeframes. For the EBS, two types of data must be distinguished: (i) existing datasets and (ii) datasets that need to be produced through fieldwork or new modelling tools. The main recommendations for dataset management are summarised:

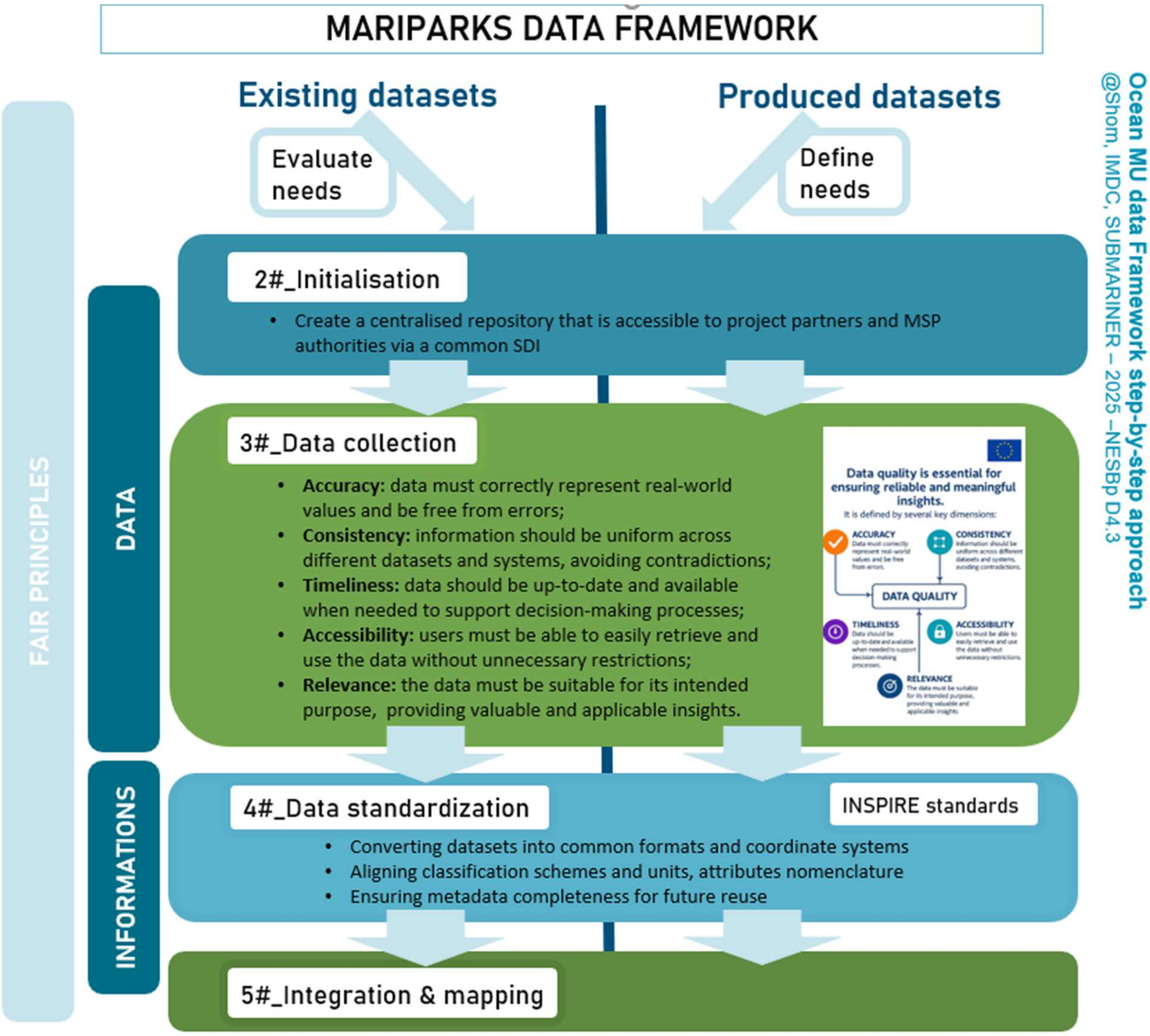

Figure 17: Datasets management framework

A list of recommendations emerges from this report:

EBS step-by-step	MSP and public authorities	MU/Maripark developers
1#_MU Scoping	✓ Base decision-making on spatially explicit datasets and climate refugia projections. ✓ Harmonise permitting frameworks across sectors (energy, aquaculture, environment, tourism).	✓ Define project objectives in line with site-specific environmental and socio-economic priorities.
2#_Initialisation (including stake-holders engagement)	✓ Institutionalise multi-stakeholder platforms for continuous engagement. ✓ Embed stakeholder knowledge in MSP processes and adaptive cycles.	✓ Engage industries peers, fishers, aquaculture, shipping, NGOs, and local communities from EBS. ✓ Promote co-ownership and conflict minimisation in design choices. ✓ Establish a centralised repository accessible to partners and authorities.
3#_Data collection	✓ Support and maintain national, regional and European data catalogue/repositories.	✓ Apply datasets universal framework, identify gaps and complete with modelling. ✓ Document data lineage (sources, quality checks, metadata)
4#_Data standardi-zation	✓ Enforce international data standards (ISO, INSPIRE, IHO). ✓ Integrate eMSP CoP Reference Lists, TEG Categorization and ReMAP guidelines for dataset	✓ Ensure compliance with FAIR principles (Findable, Accessible, Interoperable, Reusable). ✓ Integrate eMSP CoP Reference Lists, TEG Categorization and ReMAP guidelines for dataset classification.

	categorisation/classification. ✓ Promote an "MSP Data Quality Label".	
5#_Integration/mapping (& scaling up)	✓ Integrate baseline frameworks systematically into MSP decision-making. ✓ Scale up to a North Sea basin approach (T4.5) harmonising scenarios, standards, and monitoring.	✓ Leverage synergies with OWF infrastructures and monitoring where available. ✓ Promote multifunctionality: biodiversity, recreation, education, energy.
6#_Gap analysis	✓ CC gap: adopt high-emission climate scenario as reference for long-term risks. ✓ Enhance regional coupled model for climate change.	✓ Complete gap with modelling or field studies. ✓ Use predictive coupled models (hydrodynamics, ecological carrying capacity, socio-economic trade-offs) to guide adaptive Maripark design. ✓ Stress-test designs under multiple climate scenarios (2030, 2050, 2070)

Table 8: Mariparks EBS data framework step-by-step approach: key recommendations

Embedding Maripark development within a structured EBS framework ensures that site selection, design, and governance are transparent, harmonised, and resilient. By aligning datasets, standards, and stakeholder processes at both national and basin scales, Mariparks can evolve into replicable models for sustainable multi-use planning in European seas.

While this deliverable focuses on project-level baseline studies to support Maripark development, it is recognised that future Maritime Spatial Plans could benefit from integrating baseline assessments directly into their Strategic Environmental Assessment (SEA) processes. This would strengthen a "multi-use-by-design" approach at planning scale, particularly in spatially constrained sea basins.

Additionally, given the strategic role of GNSBI in supporting coordinated basin-level planning, the integration of baseline information into SEA processes at MSP level should also be discussed within this platform.

Finally, climate change considerations will need to be consistently embedded across baseline, monitoring, and planning phases. Recent guidance such as the MSPglobal International Guide – Volume 3: Climate-Smart Principle [34] provides useful additionnal methodological direction to integrate climate-resilience pathways and future-conditions scenarios within multi-use planning frameworks.

4.2 EIA outlook

Environmental Impact Assessments (EIAs) in the marine domain have traditionally been designed for single-use projects, focusing on compliance and on evaluating direct environmental effects over relatively short timeframes. For Mariparks, whose lifecycles extend across several decades and combine multiple activities, such approaches are no longer sufficient. EIAs must evolve into integrated and forward-looking tools that capture not only risks, but also opportunities, synergies, and long-term resilience.

A Maripark-oriented EIA should therefore assess cumulative economic, social, and environmental impacts in combination, rather than treating each activity in isolation. Where data is lacking, the precautionary principle must guide decision-making. At present, there is no dedicated legal framework for multi-use EIAs, although conducting such assessments is strongly recommended to better understand the implications of multi-use projects. This regulatory gap will be further explored in Task 4.1.

The transition from single-activity to integrated assessments also requires new methods. Workflows developed in recent projects, such as UNITED's OMAF/CIA, demonstrate how interactions, risks, and benefits can be captured across different activities. Scenario-based approaches comparing single-use, current practice, and optimised multi-use, combined with spatial optimisation analyses, provide additional evidence for planning. However, regulatory and technical barriers still limit integration in practice, even if future developments in permitting, insurance models, technology, and business practices may gradually reduce these constraints.

At the same time, EIAs for Mariparks should not focus only on negative impacts but also identify the potential for positive outcomes. Concepts such as nature-inclusive design (NID) show how multi-use infrastructure can actively contribute to ecosystem restoration and generate ecosystem services. To be effective, these approaches require active involvement of industry actors in co-designing pilots, sharing datasets, and testing combined uses. Equally important is the integration of monitoring and modelling into the EIA framework, enabling adaptive management, early-warning systems, and threshold-based mitigation across the full lifecycle of a Maripark.

Finally, effective multi-use EIAs depend on stronger regulatory guidance and governance frameworks that explicitly recognise multi-use configurations and support cross-sectoral coordination. This should go hand in hand with continuous stakeholder involvement: fishers, developers, aquaculture operators, NGOs, and authorities must be engaged from the earliest design stages through to long-term monitoring. Establishing institutionalised platforms for dialogue and co-decision will be essential to anchor Maripark EIAs within adaptive governance structures.

V. Conclusion

The D4.3 defines the methodological scope of an EBS data framework for Mariparks perspective as preparation for EIA and EMP. The MU projects and Belgian cases adapted to the three MUS defined enables the identification of strengths and gaps to establish a robust Mariparks EBS process.

❑ *3 Key messages*

- A universal dataset framework is essential; differences lie in availability and prioritisation.
- Climate change is the critical gap, scenarios must be embedded.
- Governance and stakeholder integration in early stage determine feasibility (harmonised standards, shared repositories, and inclusive platforms)

For WP4, the added value of this work is threefold:

- T4.1 (Governance and policy): provides evidence of fragmentation and need for harmonised permitting and a structured EBS framework transferable to EBA approach.
- T4.2 (Sustainable Mariparks): delivers a methodology to integrate to socio-economic and cumulative impact assessment into Mariparks design.
- T4.4: identifies future-oriented scenarios as a common gap in Ocean MU and stresses the need to embed climate projections supported by adequate datasets to define Maripark scenarios. T4.5 (Scaling-up): emphasises the need for basin-scale harmonisation (North Sea), explore the potential integration of this baseline approach into basin-scale MSP/SEA processes, in collaboration with GNSBI.

The next deliverable (D4.6) will build on this work by developing a methodology for Mariparks Environmental Monitoring Plan (EMP), exploring smart monitoring and digital twin integration.

Bibliography

[1] Przedrzymirska, J., Zaucha, J., Calado, H., Lukic, I., Bocci, M., Ramieri, E., Varona, M.C., Barbanti, A., Depellegrin, D., de Sousa Vergílio, M. *et al.* (2021). Multi-Use of the Sea as a Sustainable Development Instrument in Five EU Sea Basins. Sustainability 2021, 13, 8159. https://doi.org/10.3390/su13158159

[2] O'Shea, R., Capuzzo, E., Hemming, V., Grebe, G., Stafford, R., van den Burg, S W.K., Wood, D., Watson, G., Wells, V., Johnson, T., Erbs, S., van Hal, J.W., Bas Binnerts, B., Collins, A.M., Howe, C. (2024) Managing offshore multi-use settings: Use of conceptual mapping to reduce uncertainty of co-locating seaweed aquaculture and wind farms, Journal of Environmental Management, Volume 358, 2024, 120696, https://doi.org/10.1016/j.jenvman.2024.120696

[3] Maripark Blueprint (2024). Ernst & Young Global Limited, Netherlands. Commissioned by Ministry of Agriculture, Fisheries, Food Security and Nature (MINLNV)

[4] RVO, (2023). Maripark Connecting Multi Use, power point presentation

[5] Schupp, MF., Bocci, M., Depellegrin, D., Kafas, A., Kyriazi, Z., Lukic, I., Schultz-Zehden ,A., Krause, G., Onyango, V., Buck BH. (2019). Toward a Common Understanding of Ocean Multi-Use. Front. Mar. Sci. 6:165. https://doi.org/10.3389/fmars.2019.00165

[6] European Commission. Blue Growth: Opportunities for marine and maritime sustainable growth. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Commitee and the Committee of the Regions Com (2012) 494, European Commission, Brussels (2012).

[7] European Commission (2020). *EU Strategy on Offshore Renewable Energy.* COM(2020) 741 final. Brussels. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:741:FIN&qid=1605792629666

[8] European Commission (2021). Strategic Guidelines for a More Sustainable and Competitive EU Aquaculture for the Period 2021–2030. COM(2021) 236 final. Brussels. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:236:FIN

[9] Stancheva, M., Stanchev, H., Zaucha, J., Ramieri, E., Roberts, T. (2022). Supporting multi-use of the sea with maritime spatial planning. The case of a multi-use opportunity development - Bulgaria, Black Sea, Marine Policy, Volume 136, 2022, 104927, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2021.104927.

[10] Guyot-Téphany, J., Trouillet, B., Diederichsen, S. *et al.* (2024). Two decades of research on ocean multi-use: achievements, challenges and the need for transdisciplinarity. *npj Ocean Sustain* 3, 8. https://doi.org/10.1038/s44183-024-00043-z

[11] van den Burg, S.W.K., Aguilar-Manjarrez J., Jenness, J., Torrie, M. (2019). Assessment of the geographical potential for co-use of marine space, based on operational boundaries for Blue Growth sectors, Marine Policy, Volume 100, Pages 43-57, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2018.10.050

[12] Lacroix, D. et S, Pioch. (2011). The multi-use in wind farm projects: more conflicts or a win-win opportunity? Aquat. Living Resour. 24, 129–135 (2011) c EDP Sciences, IFREMER, IRD 2011 DOI: 10.1051/alr/201113

[13] Lazar Luminita, Spanu Alina, Boicenco Laura, Oros Andra, Damir Nicoleta, Bisinicu Elena, Abaza Valeria, Filimon Adrian, Harcota George, Marin Oana,

[14] Pantea Elena, Timofte Florin, Vlas Oana, Korpinen Samuli (2024). Methodology for prioritizing marine environmental pressures under various management scenarios in the Black Sea. Frontiers in Marine Science, Volume 11 – 2024. DOI=10.3389/fmars.2024.1388877, ISSN=2296-7745.

Bosso, L., Saviano, S., Abagnale, M. *et al.* GIS-based integration of marine data for assessment and management of a highly anthropized coastal area. *Sci Rep* **15**,

[15] 16200 (2025). https://doi.org/10.1038/s41598-025-00206-z.

Gov.Scot (2012). Socio-economic Baseline Review Methodology and Data Gap Analysis for Offshore Renewables in Scottish Waters. https://www.gov.scot/publications/socio-economic-baseline-review-methodology-data-gap-analysis-offshore-renewables/pages/10/. ISBN 9781782561996.

[16] Flynn, S., Meaney, W., Leadbetter, A. M., Fisher, J. P., & Nic Aonghusa, C. (2020). Lessons from a Marine Spatial Planning data management process for Ireland. *International Journal of Digital Earth*, *14*(2), 139–157. https://doi.org/10.1080/17538947.2020.1808720.

[17] Kemal Pınarbaşı, Ibon Galparsoro, Neil Alloncle, Frédéric Quemmerais, Ángel Borja (2020). Key issues for a transboundary and ecosystem-based maritime spatial planning in the Bay of Biscay, Marine Policy, Volume 120, 104131, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2020.104131.

[18] Lukic I et al (2020). D4.1 Revision of the current environmental assessment and status of pilots. UNITED Project

[19] van der Knaap, I., Slabbekoorn, H., Winter, H.V. et al. Evaluating receiver contributions to acoustic positional telemetry: a case study on Atlantic cod

around wind turbines in the North Sea. Anim Biotelemetry 9, 14 (2021). https://doi.org/10.1186/s40317-021-00238-y

[20] F. Kerckhof, S. Degraer, A. Norro & B. Rumes ,Offshore intertidal hard substrata: a new habitat promoting non-indigenous species in the Southern North Sea: an exploratory study, Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models (MUMM), Marine Ecosystem Management Section

[21] Degraer, S., Brabant, R., Rumes, B. & Vigin, L. (eds). 2021. Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Attraction, avoidance and habitat use at various spatial scales. Memoirs on the Marine Environment. Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management, 104 pp

[22] Riclet, E. Herpers, F. Le Visage, C. (2021). Best Practice Guidance in Multi-Use Issues and Licensing Procedures Short Background Study, ISBN 978-92-95225-07-7, doi: 10.2926/015669, HZ-02-21-805-EN-N

[23] IPCC, (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland. https://doi.org/10.59327/IPCC/AR6-9789291691647

[24] Mohamed, B. Barth, A. van der Zande, D. Alvera-Azcárate, A. (2025). Amplified Warming and Marine Heatwaves in the North Sea Under a Warming Climate, EGUsphere preprint repository https://doi.org/10.5194/egusphere-2025-1578

[25] Met Office, Press office, Waters surrounding UK experiencing significant marine heatwave. (2025) Waters surrounding UK experiencing significant marine heatwave - Met Office

[26] Araújo, R. Vázquez Calderón, F. Sánchez López, J. Costa Azevedo, I. Bruhn, A. Fluch, S. Garcia Tasende, M. Ghaderiardakani, F. Ilmjärv, T. Laurans, M. Mac Monagail, M. Mangini, S. Peteiro, C. Rebours, C. Stefansson, T. Ullmann. J. (2025). Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy, Frontiers in Marine Science. https://doi.org/10.3389/fmars.2020.626389

[27] Sogn Andersen, G. Pedersen, M. Nielsen S. (2013). Temperature acclimation and heat tolerance of photosynthesis in Norwegian *Saccharina latissima* (*Laminariales, Phaeophyceae*), Journal of Phycology, Volume 49, https://doi.org/10.1111/jpy.12077

[28] Ministère de la Transition Ecologique et de la Cohésion des Territoires. Rapport de référence. La Trajectoire de réchauffement de référence pour l'adaptation au changement climatique (TRACC), (2025).

https://www.ecologie.gouv.fr/sites/default/files/documents/document-reference-TRACC.pdf

[29] National Climate Commission. Belgium. Belgian National Adaptation Plan 2017-2020. (2017). https://www.cnc-nkc.be/sites/default/files/report/file/nap_en.pdf

[30] Gröger, M., Dieterich, C. & Meier, H.E.M. Is interactive air sea coupling relevant for simulating the future climate of Europe?. *Clim Dyn* 56, 491–514 (2021). https://doi.org/10.1007/s00382-020-05489-8

[31] Diaz, J. et Rosenberg, R. (2008). Spreading Dead Zones and Consequences for Marine Ecosystems, Robert Science (2008), Vol 321, Issue 5891, pp. 926-929 https://doi.org/10.1126/science.1156401

[32] Wåhlström, I. Pålsson, J. Törnqvist, O. Jonsson, P. Gröger, M. Almroth-Rosel, E. (2020). Bringing climate change into ecosystem based management of the sea: Data and methods for the Symphony framework, SMHI, report oceanography 68

[33] Tew-Kai, E. Quilfen, V. Cachera, M. Boutet. M. (2020). Dynamic Coastal-Shelf Seascapes to Support Marine Policies Using Operational Coastal Oceanography: The French Example. J. Mar. Sci. Eng. 2020, 8(8), 585; https://doi.org/10.3390/jmse8080585

[34] UNESCO-IOC and European Commission. 2025. MSPglobal International Guide on Marine/Maritime Spatial Planning: Volume 3 – Climate-smart Principle. Paris, UNESCO. (IOC Manuals and Guides No. 89, Volume

[35] Abramic, A., Norton, D., Sarretta, A., Menegon, S., Katsika, M., Gekas, V., Rybka, K., Fernández-Palacios, Y. (2023). Maritime Spatial Planning Data Framework (MSPdF). How to structure input data for MSP process, monitoring & evaluation. Produced by Technical Expert Group (TEG) on Data for MSP. Supported by CINEA and DG MARE (EC). 45p. Doi: 10.2926/440667

[36] European Parliament and Council of the European Union. (2007). Directive 2007/2/EC of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). Official Journal L 108, 25 April 2007, 1–14. Retrieved from https://data.europa.eu/eli/dir/2007/2/oj

[37] Wilkinson, M., Dumontier, M., Aalbersberg, I. et al. (2016). The FAIR Guiding Principles for scientific data management and stewardship. Sci Data 3, 160018, https://doi.org/10.1038/sdata.2016.18

[38] Baltic Sea2Land Project. (2023). MSP input data harmonisation recommendations. VASAB Secretariat. (Baltic Sea2Land project deliverable)

[39] Temporary MIWP 2021-2024 sub-group 2.3.1. INSPIRE Data Specification on Sea Regions – Technical Guidelines (2024) https://inspire-mif.github.io/technical-guidelines/data/sr/dataspecification_sr.pdf

[40] https://iho.int/fr/s100-project
[41] Technical Expert Group on MSP Data. (2021). Proposal for making harmonized MSP plan data available
across Europe: Results of the work of the Technical Expert Group (TEG) on MSP data.
[42] B. Lequesne, A. Souf. 2023. Policy Brief on Strengthening Data sharing for informed decision-making in Maritime Spatial Planning. Policy brief of the eMSP NSBR Data Sharing, Information & Communication Technologies Serving MSP Learning Strand, download from https://www.emspproject.eu/results
[43] Marine Biology Section, Ugent. Belgium. INRAM. Benthic fauna monitoring- SSD - Belgian Science Policy. Available online http://www.vliz.be/projects/inram/imers.php.
[44] OSPAR (2017). *Guidelines for monitoring and assessment of marine litter and eutrophication.*
[45] ICES (2024). Working Group on Marine Mammal Ecology (WGMME). ICES Scientific Reports. Report. https://doi.org/10.17895/ices.pub.26997367.v3
[46] Dekeling, R. et al. (2014). Monitoring guidance for underwater noise in European seas. JRC Scientific and Policy Reports.
[47] Degraer, S. et al. (2020). *Environmental impacts of offshore wind farms in the Belgian part of the North Sea: Fifteen years of monitoring.* RBINS.
[48] Coolen, J. W. P. et al. (2020). Reefs, sand and reef-like sand: Benthic biodiversity of hard substrates on the BPNS. *Frontiers in Marine Science.*
[49] Dannheim, J. et al. (2019). Benthic effects of offshore renewables: identification of knowledge gaps and urgently needed research. *ICES Journal of Marine Science, 76(2).*
[50] European Commission (2018). *Environmental Impact Assessment. https://environment.ec.europa.eu/law-and-governance/environmental-assessments/environmental-impact-assessment_en*
[51] Reubens, J.T., Degraer, S. & Vincx, M. The ecology of benthopelagic fishes at offshore wind farms: a synthesis of 4 years of research. *Hydrobiologia* **727**, 121–136 (2014). https://doi.org/10.1007/s10750-013-1793-1
[52] OD Nature, RBINS. (2025). *REMSEM – Remote Sensing Services*. Royal Belgian Institute of Natural Sciences. Retrieved September 22, 2025, from https://odnature.naturalsciences.be/remsem/remote-sensing
[53] E. Delaroche, A. Souf, I. M. Moreno, A. Abramic, A. Sarretta, Y. Leroy. D3.4 Best practice based on data analysis completeness and quality needed for MSP. ReMAP project

Appendix

Appendix 1: Exhaustive description of BNPS and case studies location

Despite its modest size, the BPNS is one of the most intensively used marine areas in Europe, hosting a wide array of economic activities such as shipping, port operations, offshore wind energy, fisheries, sand and gravel extraction, dredging and disposal of dredged material, military exercises, and recreational boating. This multifunctional use requires integrated spatial planning to ensure a sustainable balance between economic development and marine ecosystem protection (Belgische Staat, 2025).

The BPNS also holds significant ecological value. It contains five designated marine protected areas under the EU Habitats and Birds Directives, forming part of the Natura 2000 network that aims to safeguard and connect nature across Europe. In the west lies the "Vlaamse Banken" (Flemish Banks), Belgium's largest nature reserve, designated to protect sandbanks, gravel beds, and reefs built by tube-forming worms. This area, along with the wider BPNS, provides important habitat for species such as harbour porpoises, and common and grey seals. The "Vlakte van de Raan," located in the eastern BPNS, is a second Habitats Directive site established to protect sandbanks and biogenic reefs formed by aggregations of reef-building worms. It also lies alongthe migratory path of the twaite shad. In addition, three Birds Directive sites are located near the ports of Nieuwpoort, Ostend, and Zeebrugge, offering essential feeding and resting grounds for seabirds and partially safeguarding their migratory routes along the coast (Belgische Staat, 2025).

In the upcoming third Marine Spatial Plan (2026–2034), three additional marine nature reserves have been proposed. Two are situated within the Flemish Banks, one nearshore and another on the distant gravel beds of the Hinder Banks, while the third lies in the far north of the BPNS between major international shipping lanes (Belgische Staat, 2025).

MUS-1 - Maripark stand-alone in commercial & industrial Zone A
This location lies within the Marine Spatial Plan's "Zone A" for commercial and industrial activities, a shallow water shelf area off the Belgian coast between Ostend and Nieuwpoort at around 25 km from the coast. Water depths here generally range from 6 m nearshore to about 12 m further out, over a seabed of fine to medium sand with occasional gravel patches. The site sits just north of the main navigation route into Ostend port. Sediment stability is high, with negligible tidal scouring, making it suited to standalone installations such as Maripark platforms.

MUS-2 - Maripark embedded in an operational OWF (Princess Elisabeth Zone)
Situated approximately 45 km off the Belgian coast in the central sector of the Princess Elisabeth offshore wind zone, this location falls amidst a cluster of wind farms and the developing artificial energy island. Water depths here deepen to 25–30 m, and the seabed consists of mediumcoarse sands. Strong but predictable tidal currents (up to

1.2 m/s) prevail, and the area is crisscrossed by exportcable corridors radiating toward the Princess Elisabeth Island hub. Integrating Maripark modules here leverages existing offshoreelectrical infrastructure and maintenance access routes.

MUS-3 - Maripark in a decommissioned OWF (CPower Zone, Thornton Bank) This site occupies part of the former CPower concession on Thornton Bank, about 27 km north of the coast. Initially home to 54 turbines (6 gravitybase foundations and 48 jackettype), water depths are 18–24 m over wellsorted coarse sands. After turbine removal began, the area can feature remaining scour protection layers and access tracks. However, there is no certainty yet on whether the scour protection will have to be removed.

Currents here are moderate (0.8–1.0 m/s), and the seabed bears biogenic colonization from 15 years of turbine runtime. A standalone Maripark unit in this decommissione zone would benefit from cleared cable routes and reduced vessel traffic, while providing an opportunity for ecological enhancement on the former turbine footprints.

- Marine Atlas (Beheerplan voor de BPNS) (https://www.marinemaps.be) Interactive map viewer maintained by the FPS Public Health (DG Environment) with zoning, concessions, shipping lanes, Natura 2000 areas, etc.
- Royal Decree on the MSP: legal zoning and activities (consult the latest version via FPS Environment)
- Kaderrichtlijn mariene strategie Deel 1 voor de Belgische mariene wateren – Staat van Belgische mariene wateren, goede milieutoestand en milieudoelen (version 2025).

Bathymetry and Seabed Substrate

- Coastal Portal (Kustportaal) (https://www.kustportaal.be): Hosted by the Flemish Government, provides seabed maps, sediment data, and bathymetric information.
- Flemish Hydrography (https://www.afdelingkust.be) Publishes hydrographic charts and depth soundings, including nautical maps.
- RBINS–Operational Directorate Natural Environment (OD Nature) – (https://odnature.naturalsciences.be): Datasets on bathymetry, seabed classification (e.g. grain size), and geological history.

Oceanographic and Hydrodynamic Data

- Coastal Ocean Observing System (COOS) (https://coos.be): Real-time and historical data on currents, waves, temperature, salinity, turbidity, and wind conditions.
- MUMM/OD Nature (RBINS): oceanographic measurements and model outputs for the BPNS.

Ecology and Nature

- Marine biodiversity monitoring – LifeWatch.be (https://lifewatch.be) Species occurrence data, habitat maps, bird and mammal observations (RBINS).
- INBO – Research Institute for Nature and Forest (https://inbo.be): Data on seabird distribution, marine protected areas, and ecological indicators.
- Seabirds@Risk - Sensitivity mapping to anthropogenic disturbance of seabirds at sea (INBO -2023)
- Natura 2000 data via EEA (European Environment Agency) or national platforms.

Offshore Wind Energy

- MarineSpatialPlanning.be: concession maps and wind farm status updates.
- Elia (https://www.elia.be): Information about offshore grid infrastructure and Princess Elisabeth Island.
- MUMM/OD Nature: environmental impact monitoring reports for wind farms (e.g. C-Power, Norther).

Human Activities and Use

- CIRB/CIBG Belgian Marine Cadastre: Coordinates sea use, permits, and infrastructure.
- ILVO Flanders Research Institute for Agriculture, Fisheries and Food (https://www.ilvo.vlaanderen.be): Data on fisheries activity, vessel monitoring (VMS), and socio-economic assessments.
- FPS Economy – DG Statistics (https://statbel.fgov.be): Statistics on shipping, ports, and maritime economy.

Environmental Impact Assessments and Studies

- Environmental Impact Assessment (EIA) reports published via FPS: Environment or project-specific websites (e.g. C-Power, Seamade)
- BELSPO (Belgian Science Policy Office): research project outputs (e.g. TILES, ZAGRI, WinMon.BE).

Appendix 2: Databases and catalogues exhaustive presentation

The RBINS Metadata Catalog, accessible at metadata.naturalsciences.be, is a spatial data management platform developed by the Royal Belgian Institute of Natural Sciences

(RBINS). It employs GeoNetwork Opensource to facilitate the sharing and discovery of geographically referenced data, maps, and services across various organizations.

GeoNetwork is a catalog application designed to manage spatially referenced resources. It provides powerful metadata editing and search functions, as well as an interactive web map viewer. The platform is utilized in numerous Spatial Data Infrastructure initiatives worldwide (https://github.com/geonetwork/core-geonetwork)

The RBINS Metadata Catalog serves as a centralized repository for datasets related to marine and environmental sciences. For baseline studies in multi-use marine parks, the catalog serves as a critical tool for identifying existing data, including information on habitat distribution, species occurrence, water quality, hydrodynamics, and human activities. Each dataset is accompanied by standardized metadata describing its origin, scale, temporal coverage, format, and quality, which ensures consistency and interoperability when integrating data from multiple sources. Users can navigate the platform through its search and filtering functions, explore datasets using the interactive map viewer, and download or link data directly to GIS platforms for spatial analysis and mapping. By consulting the catalog, researchers and park managers can avoid duplication of effort, align their monitoring protocols with regional and national initiatives, and ensure that baseline studies are spatially explicit and compatible with existing knowledge. Furthermore, the catalog supports multi-use assessments by providing access to thematic datasets such as shipping routes, fishing grounds, renewable energy installations, and protected areas, enabling a comprehensive evaluation of potential interactions between different uses. Incorporating the RBINS Metadata Catalog into baseline monitoring workflows enhances data quality, promotes collaboration, and facilitates evidence-based decision-making for sustainable management of multi-use marine parks.

In addition to RBINS, the Flanders Marine Institute (VLIZ) offers several specialized databanks and tools for marine research. The VLIZ Marine Data Center (https://www.vliz.be/en/what-we-do/data-information/data) provides services for archiving, accessing, and managing marine data under FAIR principles, ensuring that data are findable, accessible, interoperable, and reusable.

VLIZ provides a secure, online system for archiving data files in a well-documented manner through the Marine Data Archive (MDA). The MDA (https://marinedataarchive.org/) allows sustainable long-term storage of research datasets, while Marine Regions (https://www.marineregions.org/) delivers a standardized list of marine georeferenced place names, boundaries, and regions for GIS applications.

VLIZ also maintains the Integrated Marine Information System (IMIS), which aggregates biodiversity, monitoring, and field survey data, as well as the World Register of Marine Species (WoRMS), a taxonomic reference widely used in marine biodiversity studies. Together, these platforms provide a comprehensive framework for locating, integrating, and analyzing ecological and environmental information.

Beyond national platforms, European and global initiatives offer valuable data for the North Sea. EMODnet (European Marine Observation and Data Network) provides standardized datasets on bathymetry, seabed habitats, chemistry, biology, human activities, and geology, accessible through interactive map viewers and GIS-compatible downloads.

The INSPIRE Geoportal facilitates access to harmonized geospatial data across Europe, including environmental monitoring, maritime boundaries, protected sites, and human activities, ensuring interoperability with other GIS tools. For monitoring human pressures, platforms such as MarineTraffic provide vessel traffic and shipping lane information, allowing users to assess potential impacts on marine ecosystems.

D4.3 Executive summary

Deliverable D4.3 provides a methodological foundation for establishing environmental data frameworks supporting Maripark development within the Northern European Sea Basins project (NESBp).
It outlines a eight-step EBS framework integrating best practices from UNITED and ULTFARMS and applies them to three Belgian case studies representing different multi-use settings.
The report identifies core environmental data categories, promotes data harmonisation under EU standards (INSPIRE, FAIR, MSPdF), and introduces the use of climate projection datasets (including concepts of climate refugia and dead zones) for future-proof marine planning.
It highlights the need for improved data interoperability, the mutualisation of monitoring approaches from early project stages, and climate-smart spatial design.
D4.3 thus serves as a conceptual and operational baseline for the forthcoming Environmental Monitoring Plan (D4.6), contributing to a coherent, data-driven, and resilient approach to multi-use maritime spatial planning across European sea basins.

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