MSP-OR
Advancing Maritime Spatial Planning in Outermost Regions

D.3.3. MSP ZONING EVALUATION EXAMPLE: AN INTEGRATED ASSESSMENT OF ECOSYSTEM SERVICES FOR OFFSHORE WIND FARMS

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ABSTRACT

This report presents a practical example focusing on the monitoring and evaluation of zoning within the national Marine Spatial Planning (MSP) process for Marine Demarcation of the Canary Islands. The main objective is to provide a practical example of how MSP zoning for offshore wind energy can be evaluated and revised through an integrated socio-ecological assessment. This process incorporates environmental, social, and economic aspects into planning while considering both the Marine Strategies and MSP Plans.

The report builds upon knowledge gathered from previous projects, like MarSP, and provides a case study on the development of offshore wind energy (OWE) in the Canary Islands. Offshore wind energy has been identified as a key area of interest for renewable energy production, given the region's favorable oceanographic and wind conditions. Floating wind turbines are particularly well-suited for the deeper waters around the Canary Islands, and the report aims to assess how the designated areas for these wind farms—created in previous MSP processes—can be re-evaluated using new data and methodologies.

One of the critical aspects addressed in this report is how to structure and use data for MSP processes effectively. The MSP Data Framework (MSPdF) is highlighted as a crucial tool in organizing and standardizing the input data needed for making informed decisions. This structured approach ensures that zoning decisions, such as those for OWE, are based on reliable, up-to-date information that considers technical, environmental, and legal considerations.

The document details three key assessments:

1. Viable zoning assessment focusing on identifying technically feasible areas for OWE development by evaluating oceanographic potential, seabed conditions, legal restrictions, and conflicts with other maritime activities, such as fisheries and maritime traffic.
2. Environmental effects assessment, of the resulting suitable zoning, estimating the effects of OWE and derive pressures on marine ecosystems and their potential to alter the natural state.
3. Ecosystem services assessment, estimating how OWE benefits in providing clean energy, can disrupt ecosystem functions, particularly benthic habitats.

Note that governance related aspects (e.g. goals, objectives and scenarios development, etc.) are not covered in this report, as these aspects will need, among other, stakeholders derived data inputs which are out of the scope of the present case-study.

In summary, this report demonstrates the practical application of monitoring and adaptive evaluation methods in the context of OWE zoning. It presents a clear framework for how MSP zoning can evolve through structured and transparent data collection (including stakeholder involvement, which is not address here) to assess tecnhical and legal viability, environmental negative effects and impacts on the well-being through the consideration of ecosystem services to achieve sustainable maritime development.

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Advancing Maritime Spatial Planning in Outermost Regions

SUMMARY

Co-funded by the European Union

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1.4. ABBREVIATIONS AND ACRONYMS

AHP	Analytical Hierarchy Process
CEA	Cumulative Effect Assessment
CEDEX	Centre for Public Works Studies and Experimentation
CICES	Common International Classification of Ecosystem Services
DAPSI(W)R(M)	Driver-Pressure-State-Impact-(Welfare)-Response-(Management)
DPSIR	Driver-Pressure-State-Impact-Response
DPSWR	Drivers-Pressures-State-Welfare-Response
EES	Ecosystem Services Supply
EIA	Environmental Impact Assessment
EMFF	European Maritime and Fisheries Fund
FAIR	Findable, Accessible, Interoperable, Reusable
FBIO	Spanish Biodiversity Foundation
FRCT	Regional Fund for Science and Technology
GES	Good Environmental Status
GIS	Geographic Information System
HDD	Horizontal Directional Drilling
HELCOM	Baltic Marine Environment Protection Commission (Helsinki Commission)
IEO (CSIC)	Spanish Institute of Oceanography – State Agency of the Spanish National Research Council
INDIMAR	Decision Support System for maritime activities
JNCC	Joint Nature Conservation Committee (UK)
MITERD-DGCM	Ministry for the Ecological Transition and the Demographic Challenge – Directorate General for the Coast and the Sea
MPA	Marine Protected Area
MSP	Maritime Spatial Planning
MSFD	Marine Strategy Framework Directive
MSPdF	Maritime Spatial Planning Data Framework
NGO	Non-Governmental Organization
OWE	Offshore Wind Energy
PAD	Pressures Activities Database (UK)
POEM	Maritime Spatial Plans of Spain
SLD	Styled Layer Descriptor
SPU	Service Providing Unit
SRMP-DRAM	Regional Secretariat for the Sea and Fisheries – Regional Directorate of Maritime Affairs
TEEB	The Economics of Ecosystems and Biodiversity
ULPGC	University of Las Palmas de Gran Canaria
ZAPER	High Potential Areas for Renewable Energy

1. INTRODUCTION

This report is built on top of 'the shoulders of giants', i.e. capitalizing the knowledge gathered through the previous MarSP project and the MSP-OR. It is not intended here to thoroughly explain all useful outcomes or results achieved since the beginning of the MarSP project in 2018, but the reader can consult more details regarding useful reports in the Deliverable 3.1. MarSP legacy matrix report (Cordero-Penín et al., 2022).

From the identification of potentially useful results from the previous MarSP project, a series of workshops were held. The first one, held on March 2022, aimed to provide an in-depth hands-on session on the MSP tools and products identified as more relevant for the MSP-OR partners and competent authorities for their MSP processes. The "ready to use" products (MS11) presented were:

- The MSP INSPIRE data model, which aims to organize in a structured and harmonized way the output resulting from the different spatial analyses needed for MSP. This enables to have coherent MSP plans at a European scale across borders and favors dissemination and working with different data sets. Besides, a legend that was specifically developed (within the MarSP project) to visualize the spatial distribution of multiple maritime activities at the same time was presented. This SLD visual legend was built by combining different colors, transparency levels, and patterns to clearly differentiate each maritime sector regardless of possible spatial overlaps. All information on the reviewed MSP INSPIRE data model can be consulted in the Deliverable 3.2. of the MSP-OR project in Abramic et al. (2024).
- the INDIMAR decision support system, developed within a MarSP sister project named PLASMAR to map the most suitable locations for the development of the various maritime activities promoting clarity in:
    - What are the constraints arising from sectoral legislation, such as marine protected areas?
    - What are the conflicts between sectors and the synergies and incompatibilities between them?
    - What are the oceanographic conditions suitable for the development of maritime activities?
    - What is the effect on the good environmental status?
    - What are the land-sea/sea-land interactions depending on the land uses on the coast?

The first workshop targeted the project's partners i.e., technical representatives, but it was also open to the external participation of other MSP actors and relevant stakeholders resulting in a mix of participants ranging from research institutes, MSP technical representatives, and PhD and Master students. All in all, this workshop resulted in an interactive space to exchange and build capacities handy for MSP processes.

The second workshop was held in May 2024 aiming to present internally to the MSP-OR partners, three preliminary ideas that could be further elaborated in the present report. These ideas were:

1. MSP Input data auto-assessment, that would have been designed to analyze the data required Vs the one used during the regions' MSP processes, under the FAIR principles — Findable, Accessible, Interoperable, and Reusable.
2. MSP Output data assessment, that would have been designed to analyze how suitability of the designated areas (i.e. zoning) in the regions' MSP Plans would vary according to the data used.
3. An Integrated Ecosystem Service assessment, that could serve as an evaluation exercise in future MSP Plans cycles.

As a result of the workshop, the third option was considered the most appropriate alternative based on the current needs. Thus, this report its intended to present a practical example, using as case study one maritime sector in the waters surrounding the Canary Islands, of how the designated areas (or zoning) from the marine plans could be revised during the monitoring and evaluation phase of the Marine Spatial Planning (MSP) process. Thus, the potential improvements of the planning process itself (i.e. governance aspects) are not addressed here, but rather how the resulting zoning of previous planning process could be revised in the light of new data and information derived from the monitoring efforts in an adaptive and iterative process to achieve the corresponding social, economic and environmental objectives of the MSP Plan.

For this aim, the Offshore Wind Energy (OWE) zoning has been selected to show case the evaluation exercise following the MSP data Framework (MSPdF) recommendations on how to structure input data for MSP process, monitoring & evaluation (Abramic et al., 2023) to achieve the main goal in marine management: "how to maintain and protect ecological structure and functioning while at the same time, allowing the system to produce ecosystem services from which we derive societal benefits" (Elliott & O'Higgins, 2020). The latter quote implies the relationship between MSP and the Marine Strategy Framework Directive (MSFD) to achieve the Good Environmental Status (GES) and maintain the life supporting systems upon which our society and economy depends on.

1.1. LINKS BETWEEN MSP AND MSFD

MSP and MSFD Directives are interdependent and complementary. Connecting MSP and MSFD to achieve comprehensive integrated socio-ecological assessments could be done using the **D**rivers-**A**ctivities-**P**ressures-**S**tate change-**I**mpacts (on human **W**elfare)-**R**esponse (as **M**easures) conceptual framework (Elliott et al., 2017; Elliott & O'Higgins, 2020), as represented in Figure 1. Here, MSP is identified as a tool for rationalizing the spatial distribution of maritime activities, thus reducing conflicts among different uses and promoting sustainable development. The MSFD provides the environmental criteria for achieving GES, which MSP must support. However, while the MSFD outlines what should be achieved (GES), it does not specify how to manage human activities in maritime areas, a gap MSP can fill.

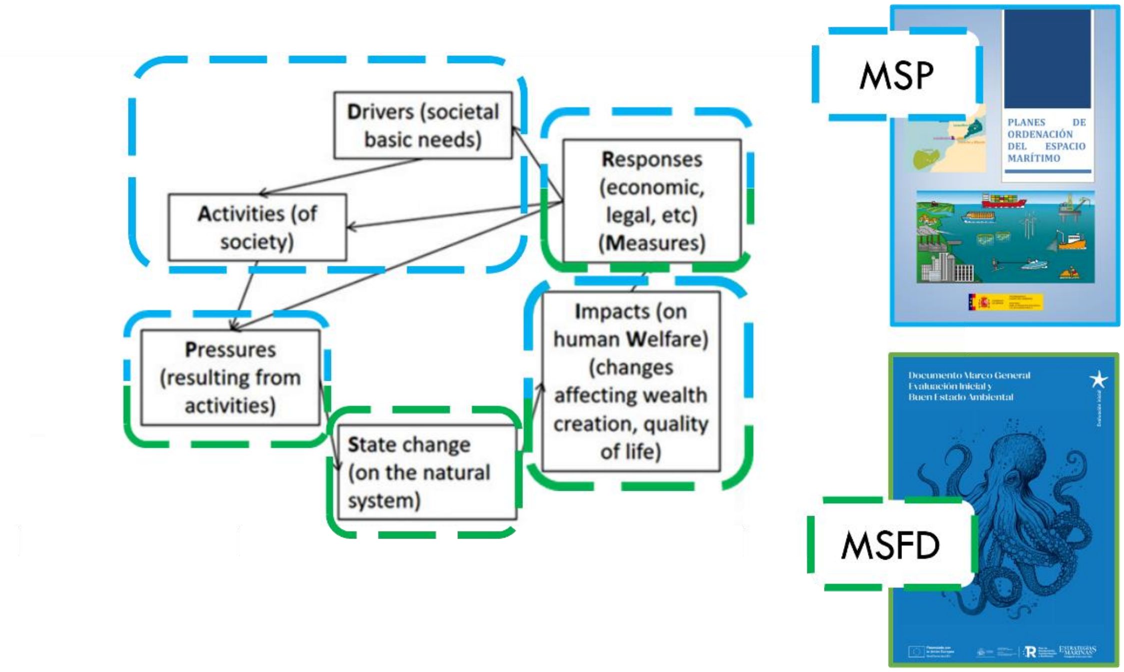

Figure 1. Representation of the DAPSI(W)R(M) conceptual framework highlighting the type of assessments that fall under the Marine Spatial Planning Directive (MSP, in blue) and the Marine Strategy Framework Directive (MSFD, in green) respectively and thus the technical connections between them.

Crucial assessments to undertake when aligning MSP and MSFD include (only the first three are addressed in this report):

1. Multiuse areas assessment, identifying the spatial and temporal needs of each maritime activity as well as conflicts and synergies between them and coastal activities.
2. Cumulative impact assessment, estimating the cumulative effects of multiple activities and pressures on marine ecosystems and their potential to alter the natural state of the ecosystems.
3. Ecosystem services assessments, understanding all the ecological supply-side, the socio-economic demand-side and the social value-side of the multiple ecosystem services underpinned by marine ecosystems that sustains the development of human activities.
4. Governance assessments, identifying the main legal constrains for the activity's development given by their corresponding sectoral and environmental legislation, and structuring stakeholder participation processes to define goals and objectives, select desired scenarios and gather other social preferences and data.

The necessary assessments for MSP are logically related to the aspects required to be covered by monitoring and evaluation efforts to gradually improve them during future planning cycles, as reflected in the Spanish MSP Plans (POEM[1] by its Spanish acronym) for its monitoring and evaluation. These are (see also Figure 10 for the original scheme in the POEM):

1. How does the presence and intensity of human activities in the sea evolve?
2. How does the environmental state of the marine environment, including climate change, evolve?
3. How does the social and economic context of each maritime sector evolve?
4. Are the objectives of the Marine Spatial Plans (POEM) being achieved? and, are the POEM effective?

Note that the **fourth aspect is not covered** (i.e. governance assessments and strategic aspects of the Marine Plans) in this report's monitoring and evaluation exercise as this will need stakeholders derived data inputs which are out of the scope of the present case-study demonstrator.

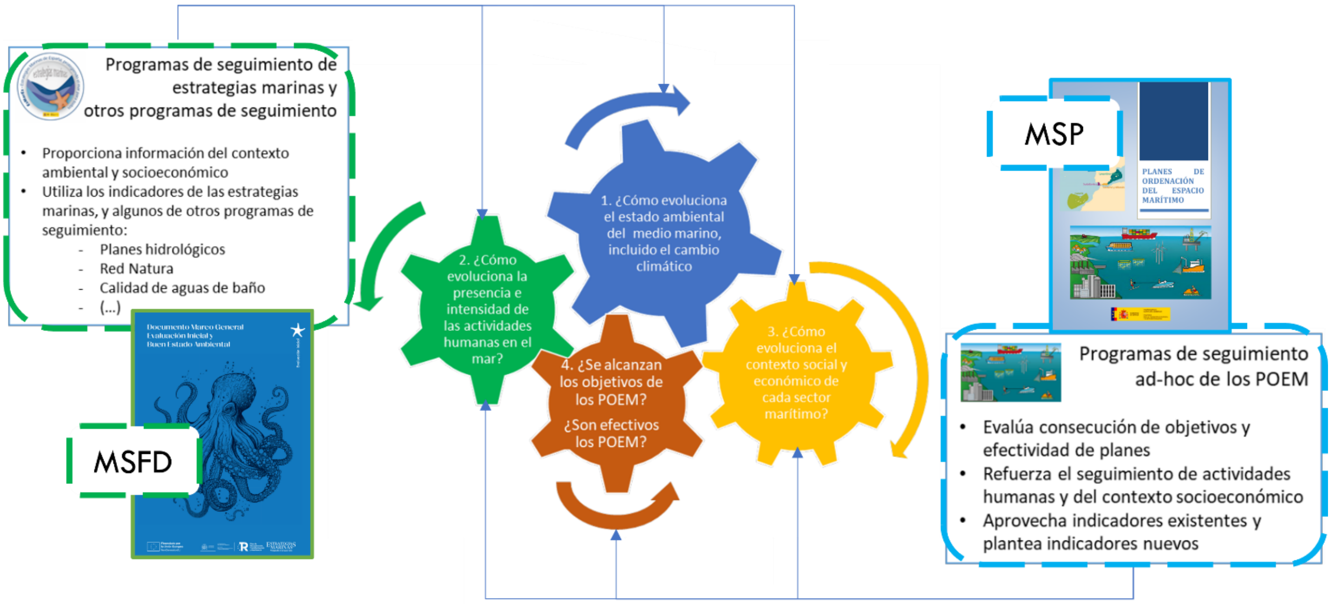

Figure 2. Represents Figure 10 in the Spanish MSP Plans (POEM page 196) highlighting the information to be covered by the monitoring programs that will produce the information derived from the Marine Strategies (MSFD) and the Marine Spatial Plan itself (MSP). Source: (MITECO, 2023).

1.2. DATA RELATED CHALLENGES TO ACHIEVE INTEGRATED SOCIO-ECOLOGICAL ASSESSMENTS

Undertaking integrated socio-ecological assessments is not straightforward and its complexity will depend on their scope and level of detail, which in practice (i.e. operational terms) may translate, among other challenges, in:

- Gathering a **wide range of data types** to understand both the social and ecological dimensions in their own units. This is explaining how ecological components, processes and functions work in a 'healthy' environment through biophysical units from the International System while social values, practices, preferences and economic goods and services are explained through social units, e.g. monetization, criteria or narratives. In practice, this translates in dealing with both quantitative and qualitative data at the same time and thus the complex process of linking them coherently to success in capturing the dynamic interactions between human and environmental factors.

[1] In Spain, due to the transposition process of both the MSP and MSFD Directives, the integration of both technical assessments are, at least in theory, favored as the same compentent authority is in charge of both processes, they use the same conceptual framework (i.e. DPSIR), and the POEM are conceived as a meassure to ensure the Good Environmental Status (GES).

- **Spatial and temporal mismatch** between the scales of human activities in MSP and the broader ecological processes necessary for achieving GES. In practice, this translates in dealing with models' outputs at different scales at the same time and thus the complex process of linking and weighing, not all relevant variables in a giant very complex model, but the outputs directly being able to configure the bigger picture based on smaller interconnected pieces of information.
- Using the **best available (spatial) information** to promote effective MSP. This entails managing the absence of reliable data, disparity in the level of detail and accuracy of spatial data that may not always be harmonized across scales. In practice, this translates in the need of developing specific systems (e.g. based on the level of agreement of experts, and the strength of the evidence) to track the various sources of uncertainty to evaluate the applicability of the socio-ecological analysis and facilitate the operationalization of the precautionary approach.

1.3. MARITIME SPATIAL PLANNING DATA FRAMEWORK (MSPDF)

How to structure input data for MSP process, monitoring & evaluation is the main focus of the MSPdF technical report (Abramic et al., 2023). It provides a structured framework for maritime spatial planning (MSP) processes, offering a methodology for collecting, organizing, and using data effectively throughout the MSP lifecycle, including monitoring and evaluation. It emphasizes how data collection can enhance decision-making and ensure that maritime and coastal plans are developed using relevant and comprehensive spatial information. This report is particularly useful for several aspects of marine spatial planning processes:

- **Data Structuring for MSP**: The framework organizes data into seven clusters structuring the data necessary for the development and evaluation of MSP (Figure 3). Despite this data lists may not be exhaustive and ultimately the MSP competent authorities will decide on the data usage, it provides a checklist to support the collection, usage and addressing data gaps for informed decision-making.
- **Monitoring and Evaluation**: It offers guidelines for ongoing data collection and evaluation to ensure plans remain relevant and effective.
- **Interoperability**: By promoting standardization and harmonization of data models, it helps in improving comparability across different regions and projects, while facilitating cross-border collaboration.

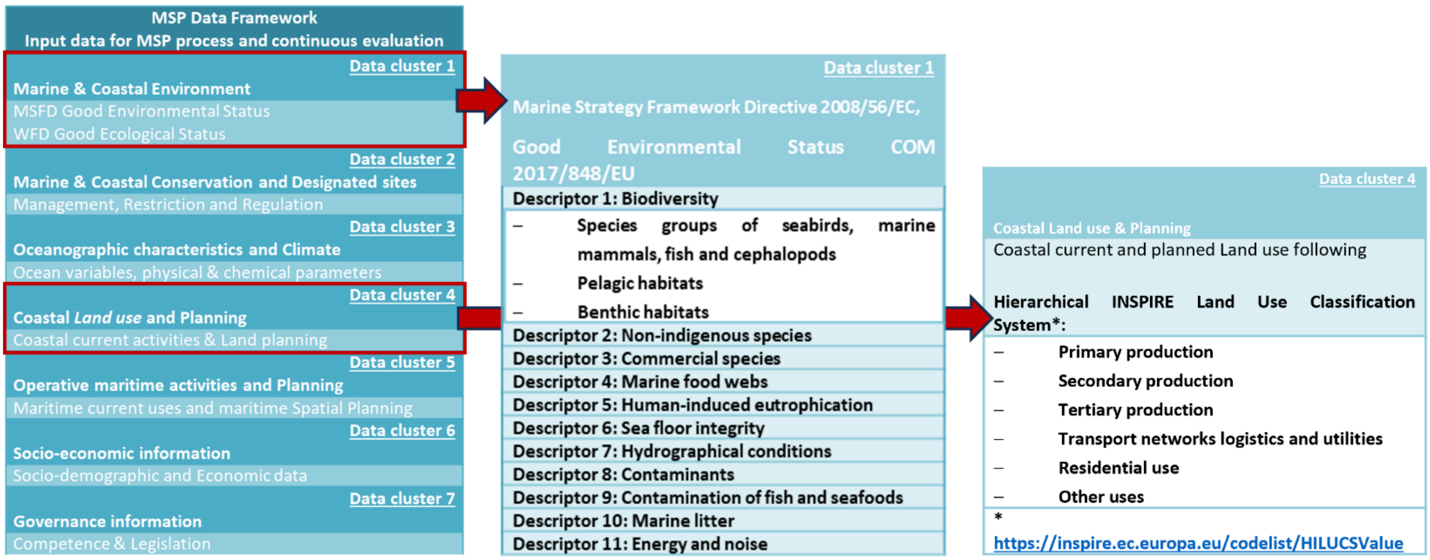

Figure 3. The seven clusters structuring the data necessary for the development and evaluation of MSP (on the left) and two examples of some of the spatial data contained in the Marine & Coastal Environment (cluster 1) and Coastal Land use & Planning spatial data (cluster 4) on the right. Source: Abramic et al., 2023.

1.4. OBJECTIVES OF THE REPORT

Thus, **the objective** of the present report is to exemplify how MSPdF may be useful for structuring data needed to develop suitability zoning in MSP processes. This is exemplified through an integrated socio-ecological assessment to spatially designate zones for offshore wind energy (OWE) development connecting both MSP and MSFD derived outputs. Following this objective, the OWE sector will be used to demonstrate the interconnection of the following assessments:

4. Viable or suitable areas identification for the development of OWE as well as conflicts and synergies between OWE and other maritime and coastal activities.
5. Environmental effects assessment of the resulting suitable zoning, estimating the effects of OWE and derive pressures on marine ecosystems and their potential to alter the natural state of the ecosystems.
6. Ecosystem services impact assessment, estimating how the affected benthic habitats may alter their potential to supply multiple ecosystem services.

In theory, following an ecosystem-based approach (EBA) for suitable zoning for any human activity should consider all relevant information derived from the rest of required assessments such as hotspots of ecological value for biodiversity and ecosystem functioning, usage of ecosystem services and cumulative effects assessments. Thus, the EBA suitable zoning will be the result of integrating all these necessary assessments outputs together, which will not be the case of the present report demonstrator.

Here, a rather linear approach will be followed, i.e. showing the data required for each assessment without the final integration of the three above mentioned assessments outputs. This is justified as the present report is not addressing other necessary governance analysis to be EBA compliance, such as engaging stakeholders to define the sectorial objectives and gather social preferences for OWE development and evaluate what may be consider as acceptable environmental risks and trade-offs among other activities.

Besides, it must be noted that this report contains several key MSP assessments in relation to OWE zoning as an example of the monitoring data and evaluation needed for adaptative MSP processes. In order to progress towards consistent EBA suitability zoning, the present example/demonstrator will have to be repeated for each of the coastal and maritime activities under planning and merge accordingly to analyze cumulative environmental effects, synergies and conflicts among activities and trade-offs between different stakeholders, being all this out of the scope of this report.

2. MONITORING AND EVALUATING OWE ZONING

Hereunder, the reader will find three sections explaining the methodological approaches that can be followed, the main data to be considered and the assumptions that can be made for each of the assessments that are proposed to evaluate the suitability of the different zoning designated by an MSP plan, which may also be framed (only) within the risk identification and risk analysis phases (Figure 4) of a risk-based management process applied to MSP suitability zoning (Stelzenmüller et al., 2018, 2020).

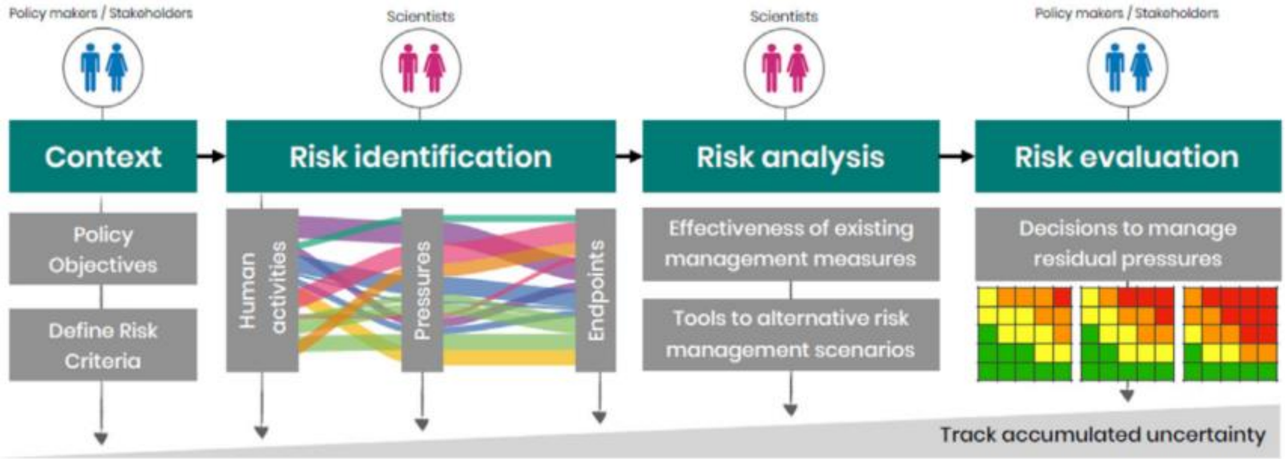

Figure 4. Shows the phases to operationalize risk-based cumulative effect assessments in the marine environment highlighting the main technical tasks to be done within each phase as well as which type of stakeholders should be involved during each phase. Source: graphical abstract of Stelzenmüller et al. (2020).

In the present demonstrator, it has been considered the zoning proposed for the development of the offshore wind energy (OWE) exemplifying the following assessments:

1. Requirements and constraints for the development of OWE, i.e. viable zoning assessment (section 2.1).
2. Environmental effects produced by OWE in marine ecological components, i.e. environmental effects assessment (section 2.2).
3. Ecosystem services that may be produced and affected by OWE, i.e. ecosystem services assessment (section 2.3).

In each case, data used to inform the analysis has been identified with the help of the MSP data framework (MSPdF, Abramic et al., 2023). Note that data identified in this report should, ideally, be derived from the monitoring efforts done during the application cycle of both the MSFD and the MSP processes. Note as well, that **the presented results here** are only to exemplify the outputs of the before-mentioned assessments, and they **are not rigorous enough to be used in any formal exercise of MSP planning**. Among other analysis (including governance-type and participatory-derived data), some deficiencies that should be address for official planning efforts should:

- Use the best available data, i.e. official data that competent authorities and official technical-scientific supporting bodies may have.
- Include exhaustive literature reviews and the knowledge from other experts besides this report's authors (e.g. NGOs, universities and other stakeholders/actors) relevant to understand the complex interconnections across the DAPSI(W)R elements and assess their relative contribution in each case.
- Define the new MSP cycle context and evaluate the associated risks (see Figure 4) through extensive participation processes to define the new objectives, risk criteria, define acceptable trade-offs among socio-economic actors (i.e. winners and losers) and the level of risk that organized civil society and policy makers are willing to tolerate. All of which should result on evaluating the different management options, i.e. the most suitable zoning for human activities.

2.1. VIABLE ZONING ASSESSMENT

In this analysis, the considered guiding questions have been:

1. What biophysical and technical requirements need OWE to be successfully developed?
2. What are the legal considerations that may limit OWE development?
3. What are the (positive and negative) interactions between OWE and the rest of coastal and maritime activities?

These questions have been answered assuming that the type of OWE technology that will be deployed in the Canary Islands are floating wind turbines systems. The literature sources used to answer the above guiding questions are described in Table 1 and presented in the results section 3.1.

Table 1. Literature sources consulted to gather relevant data and information guided by the relevant questions for the viable zoning assessment of OWF.

Study	Description	Main results
(MITECO, 2023; MITERD, 2023)	The official MSP Spanish Plan (i.e. POEM) approved by the Royal Decree 150/2023, of February 28, for the first planning cycle (2022-2027) has been consulted. In particular, the “common part” and the diagnosis for the Canary Islands.	The POEM contains all relevant information used for the identification of the High Potential Areas for the Development of Offshore Wind Energy (ZAPER), which have been selected based on technical feasibility, environmental protection, and coexistence with other maritime activities.
(Abramic et al., 2021)	The study focuses on identifying suitable areas for OWE development in the Canary Islands gathering relevant spatial data, applying the Analytical Hierarchy Process (AHP) multicriteria analysis based on experts judgement through a decission support system called INDIMAR.	The study’s results are structured following five out of the seven data clusters proposed by the MSPdF. It describes all relevant information used for the suitability zoning of OWE in the Canary Islands, such as technical requirements or conflicting activities.

According to the information provided by the energy company Iberdrola[2], a major OWE promoter worldwide, there are different types of floating wind turbines platforms (Figure 5), that can use different mooring systems (i.e. cables, chains or other elements that fixes and connects the floating platform to the anchorage point), and anchoring points that connect the mooring lines to the seabed, depending on factors such as depth, slope, type of seabed or oceanographic conditions (e.g. waves, currents, wind, etc.) that cause dynamic movements of the platforms (Table 2).

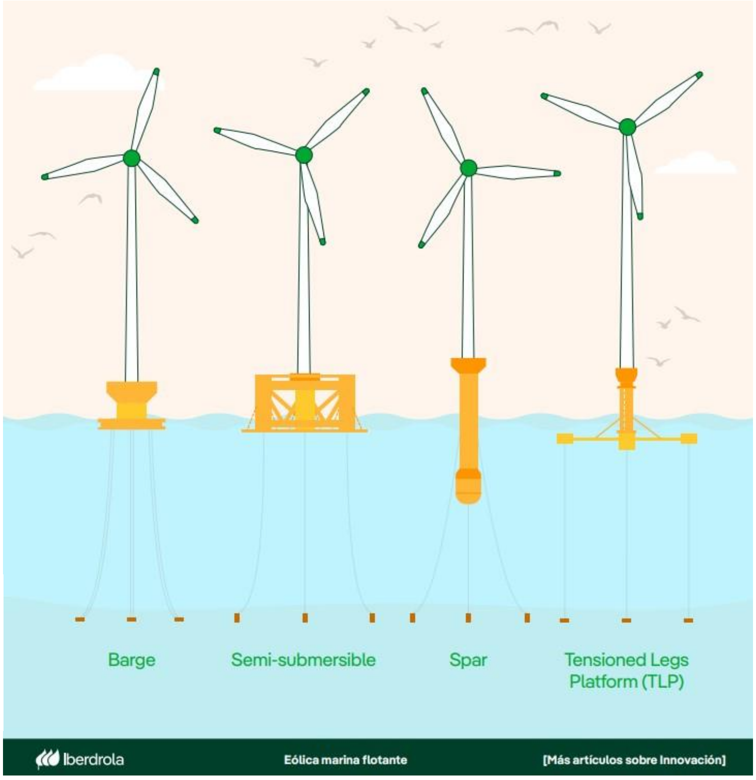

Figure 5. Infographic of the main OWE types of platforms that can be used to deploy offshore wind floating turbines. Source: Iberdrola S.A., https://www.iberdrola.com/innovacion/eolica-marina-flotante

The choice of mooring system depends on the depth, type of floating platform, and ocean conditions (waves, currents, winds):

- **Catenary mooring**: This is the shape the mooring cable takes when not tensioned, primarily influenced by its own weight. It is the most common type. Floats and weights can be added to modify its shape, such as forming an "S" (lazy-wave) to adjust for water depth and platform movement restrictions.
- **Taut mooring**: This system involves mechanically tensioning a catenary mooring to reduce its footprint (the affected seabed area), minimize cable length, and restrict platform movement.
- **Tensioned Leg Platforms (TLPs)**: The moorings in TLPs are tendons that operate differently from tensioned catenary systems. They are suited for great depths due to the material savings they offer.

The anchoring systems can be:

- **Dragging Anchors**: These are similar to those used by ships. This type of system supports tension in one direction (with a certain tolerance angle).
- **Suction Anchors** (Suction Buckets): These are steel structures, usually cylindrical, open at the bottom end. They rest on the seabed and create suction to generate pressure differences (vacuum), which secures the anchor.
- **Driven or Drilled Piles**: These are the same structures used in fixed foundations to anchor the substructure to the seabed. Typically, they are large hollow metal cylinders driven (hammered) into the seabed. In rocky or hard soils, drilling is required for installation. These piles require special vessels for installation, which can cause noise and suspended sediments.
- **Deadweights or Gravity Anchors**: These are massive concrete structures placed on the seabed. They typically have a large footprint on the seabed.

[2] https://www.iberdrola.com/innovacion/eolica-marina-flotante

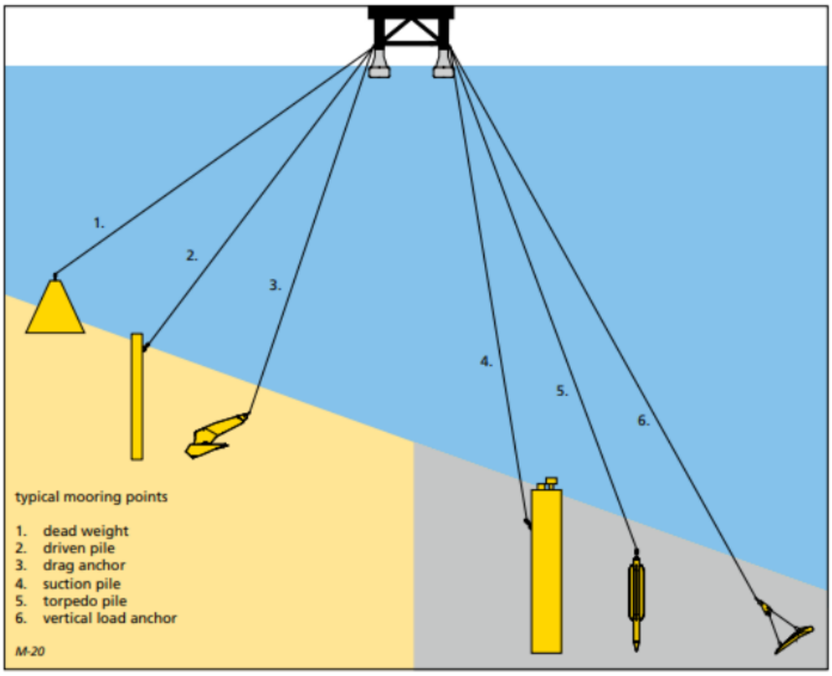

Figure 6. Examples of different types of anchoring systems for shallow and deep waters. Source: designed by Vryhof Anchor in Ikhennicheu et al. (2020)

Table 2. Main OWE floating platforms anchoring systems and their suitability for seabed type and slope, depth and oceanographic conditions (e.g. waves, currents, wind, etc.) that generate dynamic movements of the platforms. Source: information summarized from Cerfontaine et al. (2023) and Ikhennicheu et al. (2020)

Type of Anchor	**Advantages**	**Disadvantages**	**Suitability for Seabed Slope**	**Type of Seabed**	**Depth**	**Dynamic Movements**
Dragging Anchors	Simple and proven technology; cost-effective.	Limited to supporting tension in one direction; not suitable for all seabeds.	Best for flat or gentle slopes.	Best for sandy or soft seabed.	Effective at moderate depths.	Good for platforms with minimal movement; tension in one direction
Suction Anchors (Suction Buckets)	Strong and secure anchorage; works in various conditions.	Requires balanced seabed texture (not rocky); difficult in coarse materials.	Works well in moderate slopes.	Sandy or sandy-silt seabed; unsuitable for rocky or coarse beds.	Best in moderate to deep waters.	Provides good dynamic stability due to suction effect

Driven or Drilled Piles	Very strong in hard/rocky seabeds; widely used in fixed foundations.	Noisy and environmentally impactful during installation; requires specialized vessels. Difficult to remove upon decommissioning	Suitable for steep slopes if drilled.	Suitable for hard or rocky seabeds.	Works in various depths, including deep waters	Highly stable in dynamic environments, especially with tension piles
Deadweights or Gravity Anchors	Stable and reliable anchorage through mass alone; simple design.	Massive structures, large seabed footprint, limited to specific cases. Difficult to remove upon decommissioning	Requires flat or gentle slopes due to large footprint	Works on most seabeds, but less suitable for rocky ones.	Best for shallow to moderate depths.	Highly stable but cna be affected by strong currents or dynamic conditions.

The Canary Islands are identified as highly economically favorable for the development of offshore wind (floating) energy according to the Catalonia Institute for Energy Research (IREC) in their global viability map for areas of interest in offshore wind installation (Figure 7). This analysis considers variable cost factors such as bathymetry, ocean conditions, distance from the coast, and distance to port.

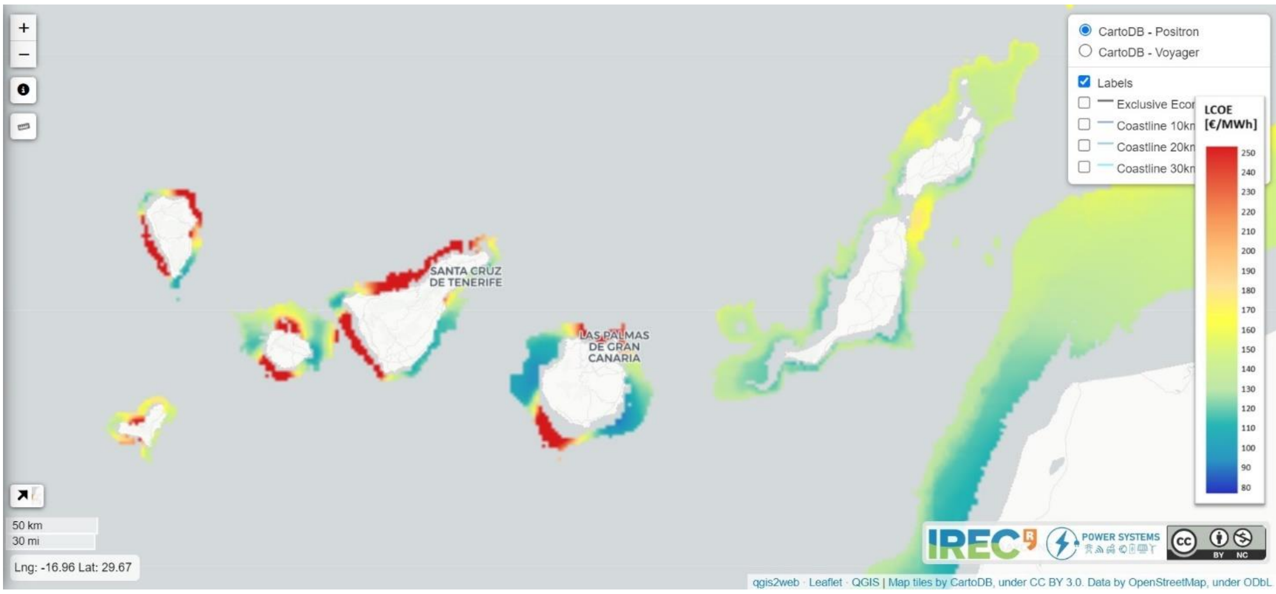

Figure 7. Economic feasibility and areas of interest for the installation of floating offshore wind farms. Source: IREC, https://floatingwindmap.energysmartlab.com/#2.2/16.76/-0.01

According to the Spanish MSP Plan (POEM), the High Potential Zones for Offshore Wind Energy Development (ZAPER, Figure 8) are defined based on technical and environmental criteria that ensure their suitability for commercial projects. The main factors considered include:

1. Wind Resource: ZAPER are in areas with wind speeds exceeding 7.5 m/s at140 meters height.
2. Depth: These zones are in waters with depths less than 1000 meters. However, other criteria such as the type or slope of the sea bottoms have not been considered (MSP-OR report D.3.10, *Moreno et al., 2024*).

3. Proximity to Electrical Infrastructure: They are positioned near onshore facilities that enable the transmission of the generated energy.
4. Environmental Compatibility: ZAPER avoid protected areas, such as Special Protection Areas for Birds (ZEPA), important seabird habitats, or Habitats of Community Interest, ensuring biodiversity conservation (Figure 9).
5. Interaction with Other Activities: They do not obstruct port approach routes or maneuverability, including waters in the service area. They are not located in areas with high traffic density, confirmed by AIS data. Besides, aeronautical restrictions are considered.

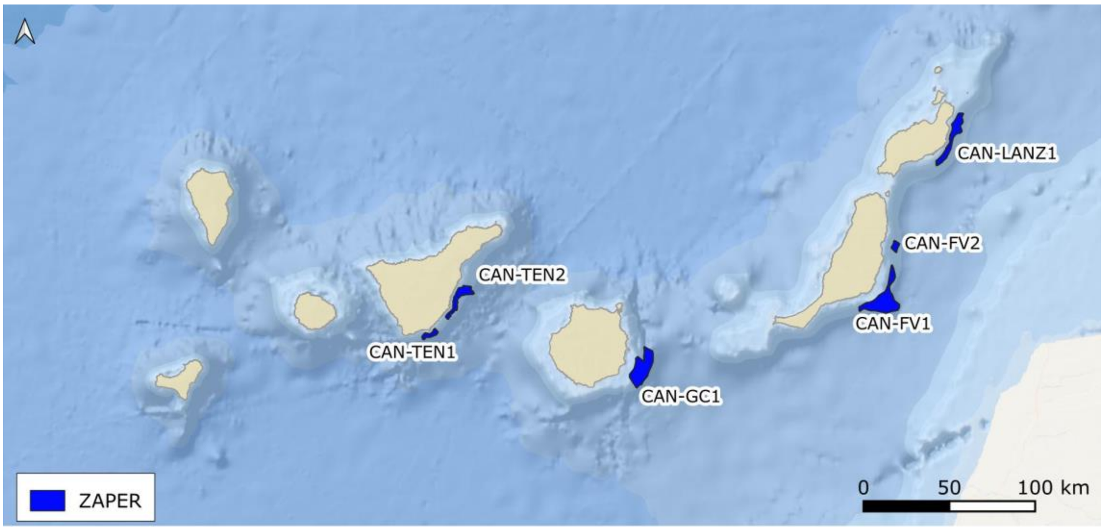

Figure 8. High potential areas for offshore wind development (ZAPER) as definded in the Spanish MSP Plan. Source: figure elaborated by CEDEX in the MSP-OR report D.3.10 (Moreno et al., 2024) *from data of the Spanish MSP Plan (MITECO, 2023).*

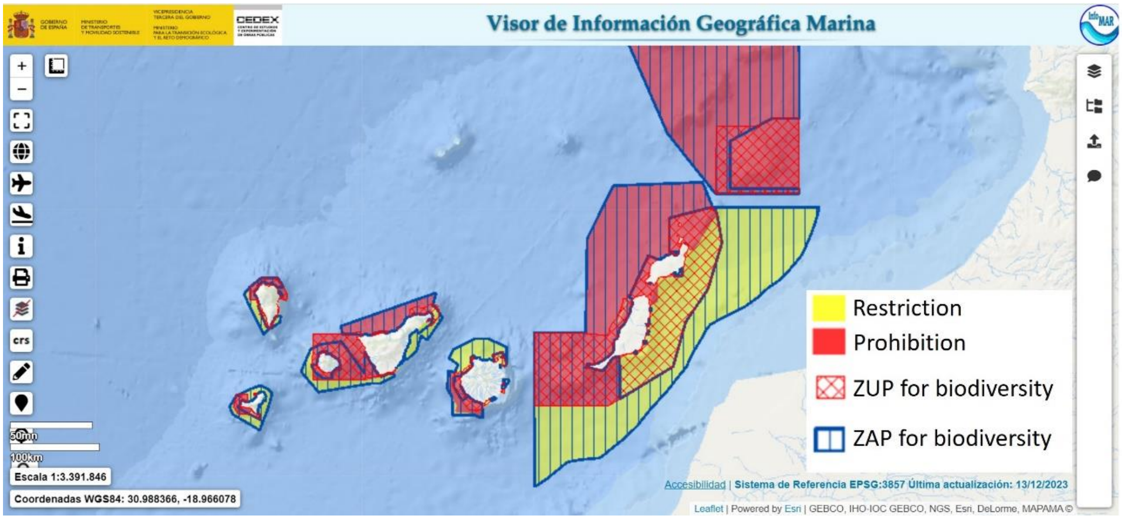

Figure 9. Offshore wind energy zoning considering limitations derived from environmental legislation between the OWE and already existing special protection zones for birds, special areas of conservation or sites of community interest (i.e. priority use areas for biodiversity, ZUP for biodiversity), and areas identified for ther ecological values for future protected areas (i.e. areas of high biodiversity potential, ZAP for biodiversity). Source: INFOMAR, https://infomar.miteco.es/visor.html.

In this section's assessment (i.e. the viability zoning) the focus has been placed on analysing the technical viability aspects, the environmental legislation compliance (Figure 9) resulting in official zoning for OWE development (i.e. ZAPERs in Figure 8), as well as how the synergies and conflicts between OWE and other coastal and maritime activities could be considered during the viability zoning (Table 3). Besides, the Spanish MSP plan (POEM) describes a series of (non-spatial) criteria to guide overlapping cases between OWE and the rest of coastal and maritime activities. However, the zoning approach followed in the POEM lacks an effects assessment of the main environmental components (i.e. benthic habitats and mobile species), which is address in the following section 2.2. Overall, the suitability zoning for OWE should encompass all key assessments' results. An example of this can be found in the study done by Abramic et al. (2021) in which suitable locations for OWE installations in the Canary Islands were identified (Figure 10) applying a Decision Support System (DSS) called INDIMAR, which uses an Analytical Hierarchy Process (AHP) to evaluate five key clusters: oceanographic potential, environmental sensitivity, marine conservation restrictions, land-sea interactions, and conflicts with existing maritime and coastal activities. These parameters were weighted and integrated into spatial analyses to produce suitability maps for OWE development. This study exemplifies the importance to focus on the spatial data used for the zoning exercise highlighting how the overall suitability zoning will depend ultimately on both the considered weighting or accepted trade-offs among key clusters (e.g. prioritizing environmental effects minimization over economic viability) and the quality and availability of spatial data. As a first step to this in order to help track the spatial data used, we have followed the MSPdF as a checklist for the different analysis undertaken in the present report (see MSP data Framework checklist).

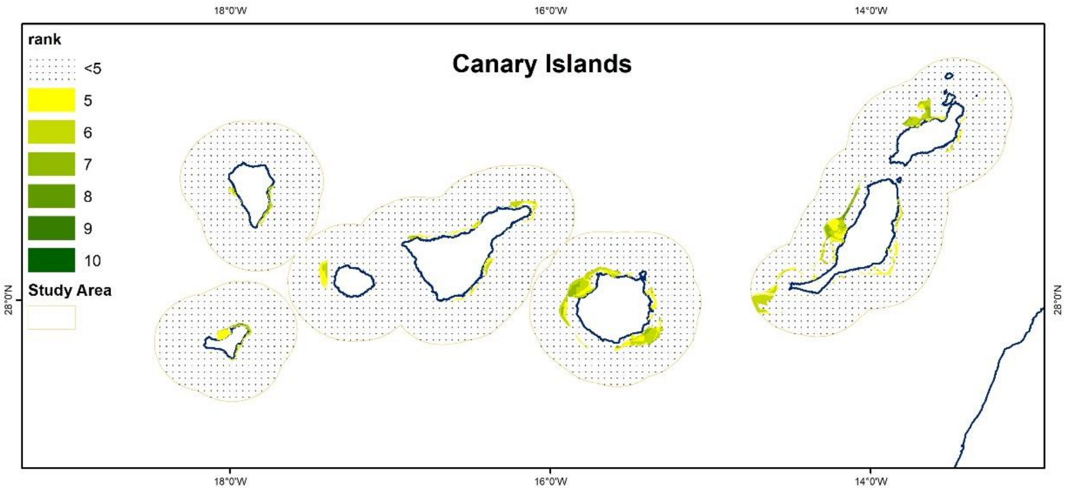

Figure 10. OWE suitability analysis for Canary Islands done using the DSS INDIMAR within the PLASMAR project (MAC/1.1a/030). Source: Abramic et al. (2021).

Table 3. Examples of synergies and conflicts between OWE and other coastal and maritime activities including the level of conflict and spatial ranges used to identify suitability zoning for OWE in Abramic et al. (2021).

Type of relationship	Activities	Compatibility level and spatial ranges used in Abramic et al. (2021)
Synergies	Offshore aquaculture	
	Electrical Infrastructure on the coast	
Conflicts	Maritime traffic[3]	N° of vessels per year: **Low** (0-3000) **Medium** (3000-10000) **High** (10000-25000)
	Aquaculture close to the coast	Spatial designated areas for this activity: **High** (overlapping with areas of high potential for aquaculture) **Incompatible** if overlap occurs with existing areas for aquaculture.
	Telecommunication cables	Spatial areas of development: **Incompatible** if overlap occurs.
	Fisheries	N° of vessels per year: **High** conflict if overlap occurs.
	Maritime tourism	Spatial areas of development: **High** conflict if overlap occurs.

[3] For a more detailed analysis on the interactions between OWE and maritime traffic, please consult MSP-OR report D.3.10 (Moreno et al., 2024).

	Nautical sports	Spatial areas of development: **High** conflict if overlap occurs.
	Wrecks	Spatial areas of development: **Incompatible** if overlap occurs.
	Urban (touristic) Areas	Distance (m) to urban areas in the coast: **Negligible** (10000-50000) **Medium** (5000-10000) **High** (2000-5000) **Incompatible** (0-2000)
	Industrial areas	Distance (m) to urban areas in the coast: **Negligible** (0-5000) **Medium** (5000-50000)
	Port Areas	Distance (m) to urban areas in the coast: **Negligible** (>10000) **Medium** (5000-10000) **High** (1500-5000) **Incompatible** (0-1500)
	Sites of cultural interest	
	Aeronautical manoeuvres	**Incompatible** with aeronautical easements (POEM)

2.2. ENVIRONMENTAL EFFECTS ASSESSMENT

For this analysis, it has been assumed that the type of OWE technology that will be deployed in the Canary Islands are floating wind turbines systems, for which the guiding questions have been:

1. What are the main pressures derived from OWE development and to which extension they may have an effect (i.e. pressures-footprints)?
2. What are the main ecological components (as receptors of pressures) and how sensitive might they be to pressures derived from OWE?

These questions have been answered assuming that the type of OWE technology that will be deployed in the Canary Islands are floating wind turbines systems. Both pressures-related (i.e. the likelihood of exposure) and sensitivity-related (i.e. the likelihood of effect or affection) analysis are related to vulnerability assessments

Conceptually, **vulnerability** is a measure of the likelihood of exposure of an environmental component to a pressure to which it is sensitive (Tyler-Walters et al., 2023). Thus, vulnerability closely relates to the concept of "**risk**," which involves both the likelihood of encountering a hazard (chance of exposure) and the potential consequences (chance of effect or sensitivity). Besides, Tyler-Walters et al. (2023) further extend or express these as:

- "**sensitivity** as a product of
  - the likelihood of damage (termed resistance, tolerance, or intolerance) due to a pressure and;
  - the rate of (or time taken for) recovery (termed resilience, or recoverability) once the pressure has abated or been removed".
- "**exposure** as a product of
  - the magnitude/intensity and;
  - extent, duration and frequency of the pressure.

OWE Pressure Index

To assess the probability of exposure, or the OWE **Pressure Index (PI)**, a simplifyed version of the equation used by Menegon et al. (2018) could be applied here:

$$PI = \sum_{i=1}^{n} \sum_{j=1}^{m} p_{i,j} (w_{i,j} U_i)\, d_{i,j}$$

Where:

$p_{i,j}$ = represents the contribution of the i-th human use/activity to the j-th (MSFD) pressure
U_i = is the spatial distribution of the i-th human use/activity
$w_{i,j}$ = is a "weight" factor describing each activity-pressure connection. In practical applications, this can be used as a dimensional factor (e.g. Kg of fish landings, marine litter, liters of an oil spill, sound exposure levels of underwater noise, etc.), or it can serve as an a-dimensional factor expressing the relative contribution of each activity generating a certain pressure (see example of Table 4).
$d_{i,j}$= distance (or spatial buffer) representing the radius of influence (in meters) of a j-th (MSFD) pressure from the location of its source, i.e. the i-th use/activity. Here, the different pressure's attenuation gradients may be considered (see Figure 11).

Simpler assessments may not consider weights, thus, $w_{i,j} = 1$ for all activity-pressure relationships. This implies all pressure sources (i.e. activities) are considered equally and the overall PI will depend on the number of overlapping pressures in space and time. However, weighting factors could be applied to acknowledge for different activities' magnitudes or intensities when producing the aggregated pressure layers, for example see Table 4.

Table 4. Weighting factors, based on information from a literature review, applied by HELCOM in the Baltic Sea when producing the aggregated pressure layer of physical disturbance based on spatial data sets on human activities. Source: (HELCOM, 2018).

Rank	Human activity	Weight
High pressure intensity and/or slow recovery	Coastal defense, Deposit of dredged material, Dredging, Extraction of sand and gravel, Trawling	1
Moderate to high	Pipelines, Shipping	0,8
Moderate	Finfish mariculture, Shellfish mariculture, **Wind farms (under construction)**	0,6
Low to moderate	Cables (under construction)	0,4
Low	Furcellaria harvesting, Recreational boating and sports, **Wind farms (operational)**	0,2
No pressure		0

Pressures derived from OWE have been identified (Table 5) based on the "UK marine pressures-activities Database (PAD[4])" (Robson et al., 2018) from the Joint Nature Conservation Committee (JNCC) of the UK and structured following the MSFD in physical, and biological pressures and inputs of substances, waste, energy, and noise (MITECO, 2024a). All details for the OWE Pressure Index development can be consulted in Table 6.

Human activities in marine environments frequently exert pressure that extends beyond the immediate area of operation. The spatial distribution and the gradient of attenuation from the core zone vary depending on the specific activity and the associated pressure. To assess each pressure's footprint (with the help of a geographic information system, GIS) buffers were taken from the pressure's spatial data and layers used in the second cycle of the Marine Stragies in the Canary Islands (MITECO, 2019) and, when absent, complemented with the"Spatial distribution of pressures and impacts" thematic assessment of the third HELCOM holistic assessment of the Baltic Sea (HELCOM, 2023) and other spatial impact assessment studies (Batista et al., 2014).

As for the gradient of attenuation from the source (i.e. the activity), the third HELCOM holistic assessment of the Baltic Sea for example, classified pressure's attenuation patterns into four distinct scenarios (Types A, B, C, and D, in Figure 11), each representing a unique relationship between activity and pressure. In their analysis, different buffer zones were established for each scenario type, and these types were linked to specific activity-pressure pairings. However, for the example presented in this report, all pressures have been spatialized through different buffers depending on each pressure type, but always assuming a linear attenuation gradient (i.e. type B in Figure 11).

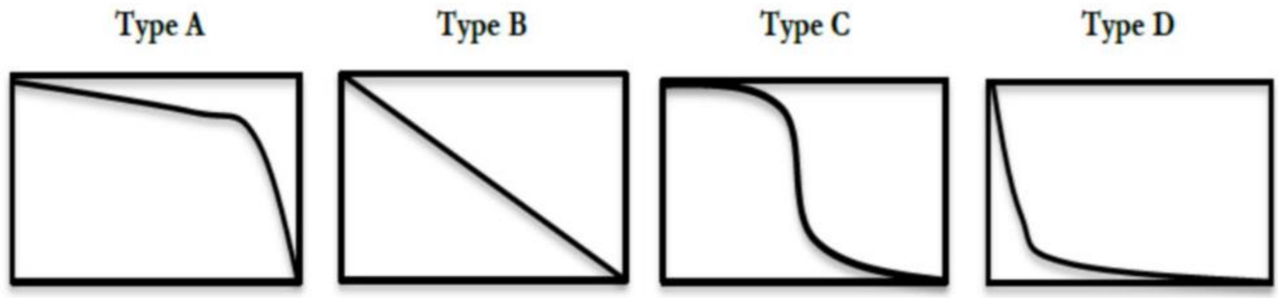

Figure 11. The assessment employs various attenuation gradients to characterize pressure distribution. Type A represents a pressure that maintains a relatively consistent impact over most of its range, followed by a rapid decline. Type B describes a pressure that diminishes gradually and continuously from the source. Type C reflects a pressure that experiences a moderate decline over a certain distance, after which it sharply decreases. Lastly, Type D characterizes a pressure that predominantly exerts a strong impact within its immediate vicinity. Source: figure taken from the "Spatial distribution of pressures and impacts" thematic assessment of the third HELCOM holistic assessment of the Baltic Sea (HELCOM, 2023).

[4] Accessible at: https://jncc.gov.uk/our-work/marine-activities-and-pressures-evidence/#jncc-pressures-activities-database

Table 5. Lists the main pressures derived from offshore wind energy (floating) and the installation of cables. Source: UK Marine Pressures-Activities Database (Robson et al., 2018).

Type	Pressure	Underlying spatial datasets	Description
Physical	Physical disturbance to seabed by abrasion	Offshore wind	Damage to the seabed occurs from the deployment and recovery of anchors from ships, as well as from the dragging of chains, which causes abrasion and erosion. During the decommissioning phase, temporary excavations may also be required to remove buried cables or foundations, increasing the impacts on the seabed.
		Cables (HDD[5])	The laying of cables will lead to seabed abrasion and disturbance of the substrate on the surface of the seabed in any circumstance, either if the cable is buried, protected or not. Ploughing, trenching, rock placement, anchor placement and pre-sweep dredging will all result in abrasion and disturbance. Depending on the installation method used, the footprint of the cable installation machinery could be up to 20 m wide where pre-sweep dredging is required, or between 5-10m wide per cable trench for ploughing, and trenching. Cables laid at the surface can result in some degree of abrasion mainly where there is high wave activity (in shallow waters of <20 m marks ranged from 6-45cm wide)
	Physical disturbance to seabed below its surface	Offshore wind	Seabed damage may occur from anchor deployment, dragging, and anchor chains causing abrasion and scour. Large vessel anchors can penetrate up to 1 m into soft sediments. Decommissioning may also involve temporary excavation pits to access buried cables or remove foundations below seabed level.
		Cables (HDD)	Direct penetration and habitat disturbance will result from the punch out of the HDD process, excavation of exit pits, installation of cofferdams (approximately 3 m x 10 m and a depth of up to around 4 m), use of jack-up rigs, rock placement, or other cable pipeline protection and anchor placement. Additionally, survey work prior to HDD may require borehole surveys that penetrate the sediment.
	Physical disturbance to seabed due to smothering and siltation	Offshore wind	Dredging for seabed preparation to install gravity base foundations can lead to localized and temporary increases in siltation rates. The level of impact depends on factors such as local hydrodynamics, foundation type, and seabed substrate.
		Cables (HDD)	During HDD punch out and excavation of exit pits where required, sediment re-suspension will occur and subsequent re-deposition on the seabed. The siltation rates will depend on the hydrological conditions and the sediment particle size distribution.

[5] HDD stands for Horizontal Directional Drilling, which is necessary to install the electrical evacuation cables.

Type	Pressure	Underlying spatial datasets	Description
	Physical loss due to permanent change of seabed substrate	Offshore wind	The seabed habitat may shift to materials like steel, concrete, or rock, depending on the type of foundation or scour protection used.
		Cables (HDD)	This pressure must be screened in where cable or scour protection material is used. Rock dumping, rock bags, concrete mattresses or other forms of protection may be used to stabilize pipe ends following completion of the HDD process and duct installation and prior to cable installation.
	Physical loss due to extraction of seabed substrate	Offshore wind	The extent of the impact depends on factors such as local hydrodynamics, foundation type, and seabed substrate. Maintenance may also involve dredging or extraction, exerting pressure on the environment. During decommissioning, all structures, including foundations and cables, are likely to be removed, possibly requiring dredging and the removal of habitats that developed over the project's lifespan.
		Cables (HDD)	Material can be removed using a dredger, mechanical excavator, or mass flow excavator to create exit pits (ranging from 5-30 m wide) in the intertidal zone for cable installation and related marine works.
	Changes to hydrological conditions including sediment transport considerations	Offshore wind	Structures placed in the marine environment immediately interact with the local current regime. The physical presence of a wind turbine could lead to diffraction or funneling of waves and currents between the turbines, reductions in the wave energy reaching the coast and changes in local wave patterns. This may lead to scour pits adjacent to turbine foundations or secondary scour around scour protection. Artificial reefs may have direct negative impacts through changes in current velocities and direction. Structures added to the coastal environment because of coastal defense schemes, coastal developments, artificial reefs, etc., can change local flow conditions. In particular, cross shore structures such as groins and harbour arms can intercept flow paths, causing flows to divert around or across the structures
		Cables (HDD)	External cable protection above the seabed, can cause localized water flow changes, leading to turbulence and the possible formation of scour pits. These effects are expected to be limited and confined to specific areas. Similarly, seabed excavation for exit pits or cable protection can alter wave propagation, affecting wave height and direction, but these changes are likely to be localized and temporary.
	Changes to hydrological conditions including tidal level change considerations	Cables (HDD)	Excavation of exit pits can lower the seabed in the intertidal or sub tidal in the short term. Changes in seabed/estuary profile due to the removal of substrate (dredging) can alter seabed/estuary profile resulting in changes in tidal flows, propagation altering the tidal curve and tidal in an area/estuary.
Biological	Input or spread of non-indigenous species	Offshore wind	Wind turbines create new opportunities for non-indigenous species, including those introduced and those expanding their range. These artificial hard substrates may also help existing species increase their

Type	Pressure	Underlying spatial datasets	Description
			population, strengthening their presence
		Cables (HDD)	This pressure is potentially associated with the need for very specific machinery and vessels to perform the necessary work for cable deployment, which may come from distant locations carrying non-native species as biofouling or in their ballast water
	Disturbance to species movement (e.g. where they breed, rest and feed)	Offshore wind	Obstructions to species movement can be caused by physical barriers or prolonged exposure to factors such as noise, light, visual disturbances, or changes in water quality. Offshore wind farms can have visual effects on birds, causing them to avoid the area around the turbines in response to visual stimuli.
		Cables (HDD)	This pressure is only relevant to cables carrying electricity. Electromagnetic fields have the potential to disrupt migratory routes of species that use earth magnetic field to navigate (e.g. elasmobranchs, Atlantic salmon, European eel).
	Extraction of, or mortality/injury due to ABOVE water collision of wild species	Offshore wind	Offshore wind farms pose a recognized collision risk for seabirds, particularly in migratory "bottleneck" areas, which may require mitigation measures. Although the collision risk is considered higher at night, it remains low due to the high visibility of the birds, even in low light conditions.
	Extraction of, or mortality/injury due to BELOW water collision of wild species	Offshore wind	Although it does not pose a high collision risk due to the additional maritime traffic that may occur around offshore wind farms, the anchoring and electrical evacuation cables of each floating turbine may present an entanglement risk for marine organisms.
Substances, litter and energy	Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides)	Offshore wind Cables (HDD)	Although wind farm operations do not typically involve significant discharges, lubricants, oils, and greases are required for maintenance, and accidental spills of these materials may occur. Turbine coatings may also be a source of antifouling compounds, such as TBT, released into the environment.
	Input of other forms of energy (light)	Offshore wind	Lighting associated with construction, maintenance, and operation, including that on vessels and structures, can potentially cause disorientation or displacement of sensitive species. Offshore wind turbines, illuminated by navigational lights, may also attract birds, increasing the risk of collision.
		Cables (HDD)	The pressure is potentially associated with construction, maintenance, operational lighting, plus navigation and operational lighting on vessels and structures.
	Input of litter (solid waste	Offshore wind	Marine litter can be released into the marine environment associated with vessels carrying out the

Type	Pressure	Underlying spatial datasets	Description
	matter, including micro-sized litter)	Cables (HDD)	construction, maintenance or decommissioning operations.
	Input of ABOVE water anthropogenic sound (impulsive, continuous)	Offshore wind	Without piling, the noise levels would be significantly lower compared to fixed-bottom turbines, as piling is one of the most intensive sources of underwater noise during construction. However, wind turbines generate two types of noise: aerodynamic noise from blades and mechanical noise from machinery in the nacelle, with mechanical vibrations in the drive train being a significant source during their lengthy operational phase. The magnitude of noise depends on the scale, intensity, and duration of activities.
		Cables (HDD)	Noise can arise from many activities in the associated with cable laying and operation. The use of machinery, vessels, and people will result in an increase of above water noise.
	Input of UNDERwater anthropogenic sound (impulsive, continuous)	Offshore wind	Ambient noise in the marine environment averages around 70 dB. During wind farm operations, noise mainly arises from mechanical vibrations in turbines, potentially causing behavioral changes in marine species. Decommissioning activities generate noise primarily from vessels, including propeller cavitation, machinery, hull turbulence, and cutting and lifting operations. This low-frequency noise can travel over large areas, impacting marine life. Key factors affecting noise impact include peak pressure, sound pressure levels, signal duration, frequency range, and propagation characteristics.
		Cables (HDD)	Construction, maintenance and decommissioning associated vessels are an important source of underwater noise. Although the majority of this will come from the propeller cavitation, on-board machinery and turbulence around the hull can also result in underwater noise being transmitted underwater.

Table 6. Details on how each pressure spatial footprint have been calculated from the underlaying spatial datasets (i.e. activities distribution or footprint).

Type	Pressure	Underlying spatial datasets	Spatial extent	Data processing	Aggregation method
Physical	Physical disturbance to seabed by abrasion (PF-01)	Offshore wind	20m buffer around each turbine with operational status.	Buffered point data, values given over linear decline.	Spatial extents and potential attenuation gradients are assigned to the specific pressure layers. They are merged (by affected area, km^2) to avoid overlapping areas. Intersected with 1 km grid to calculate % of area affected within a cell. Normalized. (HELCOM, 2023)
		Cables (HDD[6])	20m buffer around cables with operational status (Robson et al., 2018)	Buffered line data, values given over linear decline.	
	Physical disturbance to seabed due to smothering and siltation (PF-02)	Offshore wind	500m due to dredging (MAPAMA[7])	Buffered point data, values given over linear decline.	
		Cables (HDD)	500m due to dredging (MAPAMA[6])	Buffered line data, values given over linear decline.	
	Physical loss due to permanent change of seabed substrate (PF-03)	Offshore wind	30m buffer around each turbine with operational status (HELCOM, 2023)	Buffered point data, equals lost area (HELCOM, 2023)	Activities are combined and potentially overlapping areas are removed. Dataset is clipped with coastline. Combined layer is intersected with 1 km grid to calculate % of area lost within a cell. (HELCOM, 2023)
		Cables (HDD)	1.5m buffer around cables with operational status (HELCOM, 2023)	Buffered point data, equals lost area (HELCOM, 2023)	
	Physical loss due to extraction of seabed substrate (PF-04)	Offshore wind	30m buffer around each turbine with operational status (HELCOM, 2023)	Buffered point data, equals lost area (HELCOM, 2023)	
		Cables (HDD)	1.5m buffer around cables with operational status (HELCOM, 2023)	Buffered point data, equals lost area (HELCOM, 2023)	
	Changes to hydrological conditions including	Offshore wind	300m buffer around each turbine classified as operational, with linear	Location of operational turbines as points were buffered and values given	Spatial extents and potential attenuation gradients are assigned to the specific pressure layers. They are merged (by affected

[6] HDD stands for Horizontal Directional Drilling, which is necessary to install the electrical evacuation cables.
[7] https://remro.cedex.es/WebCepyc/Canaria.html

Type	Pressure	Underlying spatial datasets	Spatial extent	Data processing	Aggregation method
	sediment transport considerations (PF-05)		decline (Type B decline), composed of 3 rings. (HELCOM, 2023)	over linear decline. (HELCOM, 2023)	area, km^2) to avoid overlapping areas. Intersected with 1 km grid to calculate % of area affected within a cell. Normalized. (HELCOM, 2023)
		Cables (HDD)	Unknown	Unknown	
	Changes to hydrological conditions including tidal level change considerations	Cables (HDD)	Unknown	Unknown	
Biological	Input or spread of non-indigenous species (PB-01)	Offshore wind	5000m (MAPAMA[8])	Buffered point data, equals affected area	Each of them is considered as of equal importance (same weight), except for ports of general interest, which are scored double, with the exception of the Port of Santa Cruz de Tenerife, which is scored quadruple due to the high volume of bulk cargo it handles. Calculate the sum of the pressure in a cell. Classified as: Very High: 5 / High: 4 / Medium: 3 to 2 / Low: 1 / Very Low: 0. (MAPAMA[6])
		Cables (HDD)	5000m (MAPAMA[7])	Buffered line data, equals affected area	
	Disturbance to species movement (e.g. where they breed, rest and feed) (PB-02)	Offshore wind	10000m buffer around each turbine with operational status (Garthe et al., 2023)	Buffered point data, equals affection area	Specific pressure layers first modified by spatial extents of influence. Each of them is considered as of equal importance (same weight). Calculate the sum of the pressure in a cell. Normalized.
		Cables (HDD)	10m buffer around cables with operational status.	Buffered point data, equals electromagnetic field	
	Extraction of, or mortality/injury due to ABOVE water collision of wild species	Offshore wind	300m buffer around each turbine with operational status	Buffered point data, equals affection area	Specific pressure layers first modified by spatial extents of influence. Each of them is considered as of equal importance (same weight). Calculate the sum of the pressure in

[8] https://remro.cedex.es/WebCepyc/Canaria.html

Type	Pressure	Underlying spatial datasets	Spatial extent	Data processing	Aggregation method
	(PB-03)				a cell. Normalized.
	Extraction of, or mortality/injury due to BELOW water collision of wild species (PB-04)	Offshore wind	300 m buffer around each turbine with operational status.	Buffered point data, equals affection area	Specific pressure layers first modified by spatial extents of influence. Each of them is considered as of equal importance (same weight). Calculate the sum of the pressure in a cell. Normalized.
Substances, litter and energy	Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides)	Offshore wind	Not considered	Not considered	Not considered
		Cables (HDD)	Not considered	Not considered	Not considered
	Input of other forms of energy (light)	Offshore wind	Not considered	Not considered	Not considered
		Cables (HDD)	Not considered	Not considered	Not considered
	Input of litter (solid waste matter, including micro-sized litter)	Offshore wind	Not considered	Not considered	Not considered
		Cables (HDD)	Not considered	Not considered	Not considered
	Input of ABOVE water anthropogenic sound (impulsive, continuous)	Offshore wind	Not considered	Not considered	Not considered
		Cables (HDD)	Not considered	Not considered	Not considered
	Input of UNDERwater anthropogenic sound (impulsive, continuous)	Offshore wind	Not considered	Not considered	Not considered
		Cables (HDD)	Not considered	Not considered	Not considered

OWE Effect Index

The risk associated with the above-described pressures will escalate based on the spatial and temporal scope, as well as the intensity or magnitude of the activity. Additionally, the risk is influenced by the activity's proximity to the ecological feature (i.e. exposure), both in terms of space and time, and the sensitivity of that feature or ecological component to the pressure. Thus, the cumulative and combined effects of multiple activities may further heighten the risk.

In other words, there would be a risk of ecological degradation if the environmental component is exposed (according to the pressure index) to a pressure to which it is sensitive, i.e. to which it is easily adversely affected (e.g. low resistance) and recovery is only achieved (if at all) after a long period (e.g. low resilience or recoverability (Tyler-Walters et al., 2023).

To develop the OWE **Effect[9] Index** associated to OWE and their electrical evacuation cables' system, a simplifyed version of the CEA equation used by Menegon et al. (2018) could be applied here:

$$CEA = \sum_{k=1}^{p} d(E_k) \sum_{j=1}^{m} s_{j,k}(P_j, E_k)$$

Where:

$d(E_k)$ = Abundance or presence/absence of the k-th environmental component (E_k) on the cell (x, y), which is 1 for fixed E (benthic habitats), and varies from 0 to 1 for mobile special features (turtles, marine mammals and seabirds).

$s_{j,k}(P_j, E_k)$ = Sensitivity of the environmental component (E_k) to the j-th (MSFD) pressure (P_j) considered for the assessment.

Sensitivity to environmental components should be assessed to a defined intensity of pressure or 'benchmark' designed to provide a standard level of pressure against which to assess resistance and resilience. In simple CEA a relatively high-pressure intensity (enough to create a significant detrimental effect on the environmental components) can be assumed together with a linear ecological response of these to the pressures.

To identify the environmental components susceptible to be affected (either positive or negatively) by pressures described in the pressures index, literature reviewing the ecological impacts of offshore wind farms have been selected (Table 7). Then, their ecological sensitivity could have been evaluated applying a set of criteria to assess both their resistance (tolerance or level of impact) and resilience (recovery) (Table 8 and 9). This criteria are based on the Marine Life Information Network[10] of the UK (Tyler-Walters et al., 2023), and their different scales have been assigned through expert judgment/interpretation of the literature (i.e. studies presented in Table 7) to each environmental component identified. Here, the strength of the evidence could be incorporated to the analysis (being the expert judgement the lowest strength), as well as applying the precautionary approach in such a way that whenever the evidence is low or absence, greater sensitivity weights could be applied to the CEA similar to (see Figure 46 in MITECO, 2024b).

Note that environmental components' sensitivities have not been assessed here due to the impossibility of configuring an expert panel.

[9] The terms "effect" and "impact" are often used interchangeably as synonyms in the literature. However, in the present demonstrator, the term "effect" is preferred in the cumulative effect assessment to refer later to impacts on human well-being in the ecosystem services assessment.
[10] https://www.marlin.ac.uk/sensitivity/sensitivity_rationale

Specifically, to identify potentially affected benthic habitats, the geometry intersection between the official ZAPER in the Spanish MSP Plan (POEM) and the eco-cartography of benthic habitats[11] for the Canary Islands was done resulting in a list of habitats under the area of the ZAPER (including a 500m buffer due to physical disturbance to seabed, see Table 6).

Overall, potentially affected environmental components to OWE-derived pressures can be consulted in Table 10. Once more, the reader should note that ecological components' sensitivity (not assessed here due to the impossibility of configuring an expert panel) parameters could have been evaluated at a general level, not site-specific (therefore assuming relatively high pressure intensity always) nor species-specific, thus assuming the same ecological traits across all MSFD species groups (European Commission, 2017). This implies, for example, assuming the same sensitivity and range of disturbance to movements for all seabirds, based on evidence from the North Sea by Garthe et al. (2023). These authors observed a decline in abundance of the family Gaviidae (loons; known for their high sensitivity to human-induced disturbances, especially light and noise) "by 94% within the OWF + 1 km zone and by 52% within the OWF + 10 km zone".

Table 7. List of studies selected to identify the potential environmental components affected by OWE development and assess their sensitivity to the resulting OWE pressures.

Study	Structure of results	Main conclusions	Main recommendations
(Abramic et al., 2022)	The 11 GES descriptors of the MSFD are used to structure the environmental impacts related to the construction, operation and decommissioning phases, the mitigation measures and the spatial data required for environmental monitoring.	The GES descriptors offer a comprehensive framework to assess the multiple environmental, social, and economic impacts that OWFs present.	The study advocates for improving collaboration between EIA and MSFD authorities to narrow the information gaps in assessing before and monitoring after to ensure that OWF developments are environmentally responsible.
(Lloret et al., 2022)	The 11 GES descriptors of the MSFD are used to structure the environmental effects due to the construction, operation and decommissioning stages of OWF.	OWFs have significant and varied impacts on marine ecosystems necessitating further research to understand long-term ecological consequences.	Continuous monitoring and adaptive management are needed integrating long-term ecological monitoring programs and mitigation strategies to reduce impacts
(Galparsoro et al., 2022)	The information is classified according to studied pressure category and type, ecosystem elements, and indicators assessed in scientific research	OWFs are crucial for renewable energy transition, but significant knowledge gaps exist regarding the long-term effects on some ecological components.	Emphasis on more comprehensive research and integration of ecological considerations in OWF projects to ensure their alignment with marine conservation goals.
(Rodríguez-Juncá et al., 2023)	Impacts of offshore wind energy (OWE) on cetaceans structured by different phases (pre-construction, construction, operation, and decommissioning).	Cetaceans are highly vulnerable to OWE development, especially due to acoustic pollution and habitat disruption, especially during the construction phase.	More specific studies adapted to the Canary Islands' environment are needed. Long-term monitoring and regulation of noise impacts, and site selection based on minimizing impacts on sensitive cetacean populations are recommended.

[11] Based on the eco-cartography (up to 50m depth) of the Canary Islands harmonized together with the Broad Habitats Types of EMODnet. Access here: http://www.geoportal.ulpgc.es/geonetwork/srv/spa/catalog.search#/metadata/ES_ECOAQUA_MSPMD_DATASET10400-20191001

Study	Structure of results	Main conclusions	Main recommendations
(García-Suárez et al., 2024)	Analysis of potential impacts of offshore wind energy on fisheries and related habitats, structured by stages (pre-construction, construction, operation, and decommissioning).	OWFs can modify marine habitats and species behavior, especially during the construction phase, leading to disruptions in fishing activities and ecological processes, with possible long-term impacts on commercial species.	Detailed planning and strategic siting are essential to minimize conflicts between OWFs and fisheries. Adaptive management, including fishing exclusion zones and monitoring of habitat changes, should be integrated into the development processes.
(Atienza et al., 2024)	Structured based on bird species' vulnerability in ZAPER (areas with high wind energy potential). Criteria include biodiversity, protection levels, and seasonal distribution of marine birds.	In most of the ZAPER the vulnerability value of seabirds to wind infrastructures is very high. Potential impacts include collisions with turbines and habitat fragmentation	The precautionary principle should be applied. ZAPERs should be revised to avoid critical areas for marine birds. Conservation measures, such as strategic siting and the development of species-specific impact assessments, are necessary to mitigate negative effects on bird populations.
(Causon & Gill, 2018)	Structures the information to link benthic habitats and biodiversity changes to impacts on their associated processes and functions and related ecosystem services.	Understanding how OWFs affect functional diversity is crucial for developing effective environmental monitoring programs that can predict both positive and negative impacts on ecosystem services.	They call for improved impact assessments and regulatory frameworks to assess the effects on functional diversity in areas affected by OWF developments.

Table 8. Assessment scales for resistance (tolerance) and resilience (recovery) of a given environmental component to a defined intensity of pressure. Note that lower levels of resistance/resilience of an environmental component implies greater sensitivity and oveall risk of degradation if exposure to the pressure is also met. Source: The Marine Life Information Network of the UK (Tyler-Walters et al., 2023).

Level	Description	Weight
Resistance		
None	Key functional, structural, characterizing species severely decline and/or physicochemical parameters are also affected e.g. removal of habitats causing a change in habitat type. A severe decline/reduction relates to the loss of 75% of the extent, density or abundance of the selected species or habitat component e.g. loss of 75% of substratum (where this can be sensibly applied).	3
Low	Significant mortality of key and characterizing species with some effects on the physicochemical character of habitat. A significant decline/reduction relates to the loss of 25-75% of the extent, density, or abundance of the selected species or habitat component e.g. loss of 25-75% of the substratum.	2
Medium	Some mortality of species (can be significant where these are not keystone structural/functional and characterizing species) without change to habitats relates to the loss of <25% of the species or habitat component.	1
High	No significant effects on the physicochemical character of the habitat and no effect on the population viability of key/characterizing species but may affect feeding, respiration and reproduction rates.	0

Resilience		
Very Low	Negligible or prolonged recovery possible; at least 25 years to recover structure and function	3
Low	Full recovery within 10-25 years	2
Medium	Full recovery within 2-10 years	1
High	Full recovery within 2 years	0

Table 9. Categorization of sensitivity based on the combination of resistance and resilience. Source: The Marine Life Information Network of the UK (Tyler-Walters et al., 2023).

	Resistance			
Resilience	None	Low	Medium	High
Very low	High	High	Medium	Low
Low	High	High	Medium	Low
Medium	Medium	Medium	Medium	Low
High	Medium	Low	Low	Not sensitive

Table 10. Identification of environmental components proposed to develop the sensitivity matrix together with pressures described in Table 6.

Environmental components	**Species groups and benthic communities**	**Sensitivity**
Mobile species		
Birds	Further specification is needed	Not assessed
Mammals	Further specification is needed	Not assessed
Turtles	Further specification is needed	Not assessed
Fish	Further specification is needed	Not assessed
Cephalopods	Further specification is needed	Not assessed
Broad habitat types (BHT) (EUNIS 2012 codes and names)		
A3 - Infralittoral rock and other hard substrata	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A3.2 - Atlantic moderate energy infralittoral rock	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A4 - Circalittoral rock and other hard substrata	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A4.12 - Sponge communities on deep circalittoral rock	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A5.13 - Infralittoral coarse sediment	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A5.14 - Circalittoral coarse sediment	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A5.15 - Deep circalittoral coarse sediment	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A5.23 - Infralittoral fine sand	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed

A5.25 - Circalittoral fine sand	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A5.27 - Deep circalittoral sand	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A5.37 - Deep circalittoral mud	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A5.52 - Kelp and seaweed communities on sublittoral sediment	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A6 - Deep-sea bed	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A6.11 - Deep-sea bedrock	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A6.3 - Deep-sea sand	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed
A6.4 - Deep-sea muddy sand	BHT crosswalk and further specification of benthic communities could be based on (MITECO, 2024b)	Not assessed

Note that the environmental components identified above may as well be consider as the Ecosystem Services Supply Units to understand how human activities might ‘backfire’ altering the capacity of nature to contribute to our well-being. For further details, see section 2.3 of this report.

2.3. ECOSYSTEM SERVICES ASSESSMENT

For this analysis, only benthic habitats will be considered as a further literature review and experts' involvement would be required to include mobile species. The guiding question to be answered has been:

1. Which benthic habitats have the potential to underpin which ecosystem service?

Ecosystem services (ES) may be understood as the goods and benefits provided by human activities and underpinned by the overall functioning of ecosystems (Marion Potschin-Young et al., 2017). Thus, the recognition that ES is an anthropogenic concept (i.e. only exist in reference to human beneficiaries (Armstrong et al., 2012)) necessarily results in the consideration of cultural values and human-made or built capital (M. Elliott et al., 2017) for their flow from nature to society (Burkhard et al., 2014). In turn, this flow depend on the governance system (Spangenberg et al., 2014), the society's consumption habits, and perceptions and values around ES, all of which may change over time (Hebel, 1999; Klain & Chan, 2012) altering the ES mapping efforts. Quoting Elliott (2023) "the natural system can produce a blue whale but human capital is required for society to confer a greater value to that animal than just if it was yet another animal. Indeed, it can be argued that nature itself would not confer a greater value on the whale than it would a polychaete worm!".

In other words, MSP should ensure a reasonable use of the marine space to prevent the deterioration of the ecological components that underpins the provision of ES (i.e. the "service providing units"; Kremen, 2005; Luck et al., 2009). Therefore, maintaining ES supply in the long-term. Additionally, ES assessments, comprising both environmental and socio-economic information, can contribute to the transparency of MSP processes. They may provide a baseline to evaluate existing trade-offs between different economic, ecological and social objectives while measuring their success (Elliott et al., 2020; García-Onetti et al., 202). In this sense, Tallis et al. (2012) recommends in order to promote the implementation of ES into MSP processes to clearly differentiate between:

1. the potential and further capacity of ecosystems to provide ES (i.e. supply metrics);
2. the flow of ES used or enjoyed by users (i.e. service metrics); and
3. the benefits that are perceived by society (i.e. value metrics).

Nevertheless, it should be noted that this section 2.3 only comprises the first step in mapping the supply of ES, already done in the Canary Islands Cordero-Penín et al. (2023), and does not include either the demand or value side of ES, which will require acknowledging for the economic benefits and jobs (i.e. instrumental values) derived from (a yet inexistent) OWE in the Canary Islands, the social preferences and perceptions (i.e. relational values) in relation to the marine ecosystems and the social willingness to conserve them (i.e. the perceived intrinsic value).

Commonly, ES supply is assessed through the ES-matrix approach, which explores the linkages between the service providing units (SPU, i.e. Table 10) and the different ES they are able to underpinn (Campagne et al., 2020; Jacobs et al., 2015). Then, from all possible SPU with the potential to provide ES, critical ones are identified based on their supply capacity (Culhane et al., 2020), which in turn will depend on their ecological state or condition. For example, Teixeira et al. (2019) score the overall ecosystem services supply of the SPU by distinguishing between three dimensions:

1. The supply potential, which is the "full potential of a SPU to provide a potential ecosystem service, irrespective of whether humans actually use or value that function or element currently" (Tallis et al., 2012). For example, a whale is a potential source of food, but in general it would only be a food source if their hunt is legalized.
2. The supply capacity, which is the 'weight' or how relatively efficient or capable a SPU is of contributing to a service it has potential to underpin. In simple terms, capacity may only refer to the habitats' "true spatial representativeness" (Teixeira et al., 2019) meaning the contributing area to a given ES.
3. The supply condition, which refers to the general descriptors of the status of the SPU. This may be derived from SPU meeting (or not) their Good Environmental Status (GES) according to the Spanish MSFD as proposed in (F. Culhane et al., 2019).

In the present example, the benthic habitats' condition is assumed to meet their GES, thus condition is equal to 1, and their capacity has been considered the area corresponding to each habitat, calculating their ES supply (ESS) as:

$$aESS_{ijk} = \sum_{h=1}^{n} a_{ijk}$$

Where,

a is the area, h is habitat type, i is the service potentially provided.
No weights have been considered through a ranking scale (i.e., j), due to the difficulty in harmonizing these semi-quantitative scores from the various literature sources.
Habitat condition or quality (i.e., k) is assumed to meet their GES, thus $k = 1$

Responding to which ecosystems provide which ES is a complex task, which has been identified as a particular need for European Atlantic Ocean archipelagos (Galparsoro et al., 2014). ES are context-dependent and their analysis has not always followed a uniform terminology across literature hindering the compilation of empirical data about their supply (Bordt & Saner, 2019; M. Potschin-Young et al., 2018). Nonetheless, the work "spatial distribution of marine ecosystem service capacity [i.e. potential] in the European seas" (Tempera et al., 2016) has cross-referenced the different ES terminologies from various reviews (Table 11) into the Common International Classification of Ecosystem Services (CICES) (Haines-Young & Potschin, 2018) enabling ES mapping in areas where detailed benthic habitats cartography is available.

The identification of the multiple ES potentially provided by the marine habitats in the Canary Islands was done based on Cordero-Penín et al. (2023) (Table 12). These authors used Tempera et al. (2016) cross-reference tables to translate the ES terminology presented by the consulted literature reviews (Table 11) into the latest CICES version 5.1. following the guidance on the application of the revised structure and its corresponding equivalence table (Haines-Young & Potschin, 2018). Note that ES may be used as a narrative instrument to understand and explain, in simpler terms to stakeholders, how OWE may affect their well-being and, thus, be used in participatory processes to promote deciding on trade-offs among human activities, guiding zoning exercises and help define the desire scenario within the MSP process, as well as for the identification of the Green Infrastructure (see for example the D.4.1 of the MSP-OR project, Campillos-Llanos et al., 2024).

Table 11. Literature reviewed to assess ecosystem services potential of benthic habitats in the Canary Islands.

Source	Description	Source upon which is based	Capacity scoring method	Confidence/ Quality of evidence	ES classification	Habitat classification
Tempera et al. 2016	Spatial Distribution of Marine Ecosystem Service Capacity in the European Seas	Agardy et al. 2005; Millennium Ecosystem Assessment 2005; Armstrong et al. 2012; Salomidi et al. 2012; Potts et al. 2014; Galparsoro et al. 2014	"Based on information from scientific literature evidence and expert judgement classified in: presence, absence and no data.	A quality score of the individual ecosystem services assessment was established directly from the percentage of mapped EUNIS habitats for which presence/absence of a certain service could be established from the literature review.	CICES	EUNIS
Salomidi et al. 2012	Assessment of goods and services, vulnerability, and conservation status of European seabed biotopes	Literature review	Based on expert judgement classified as High; Low; Negligible/Irrelevant/Unknown	n/a	Millenium Ecosystem Assessment and Beaumont et al. (2007)	EUNIS
Galparsoro et al. 2014	Mapping ecosystem services provided by benthic habitats in the European North Atlantic Ocean	Salomidi et al. 2012	Based on expert judgement classified as High; Low; Negligible/Irrelevant/Unknown	n/a	Millenium Ecosystem Assessment and Beaumont et al. (2007)	EUNIS
Potts et al. 2014	Examines the potential relationships between the ecosystem services provided by the coastal and marine environment and the designation of marine protected areas in the UK	Fletcher et al. 2012	Based on the relative importance of each habitat and species in providing ES, classified as: Significant contribution; moderate contribution; Low contribution; No or negligible; Not assessed)	Based on the source of information (UK-related, peer reviewed; grey or overseas literature; expert judgement)	TEEB	EUNIS
Fletcher et al. 2012	Description of the ES provided by broad-scale habitats and features of conservation importance that are likely to be protected by MPAs in the UK	Literature review & expert judgement	Only descriptive	Based on the source of information (peer reviewed, grey literature or expert judgement)	TEEB	EUNIS

Table 12. ES-matrix either confirming the presence (coded as 1) or absence (coded as 0) of ES potential of benthic habitats (see Table 10 for interpreting habitats' codes). Cells in blank are left due the lack of information to confirm either the presence/absence of potential. To consult ES potential of more habitats, see supplementary tables of Cordero-Penín et al. (2023).

	Provisioning services											**Regulation and maintenance services**																	**Cultural services**													
	Provisioning	Biomass	Wild plants	Wild animals	Fibres & materials (plants)	Wild animals (nutrition)	Fibres & materials (animals)	New genetic strains (plants)	New biological entities (plants)	New genetic strains (animals)	New biological entities (animals)	Regulation & Maintenance	Transformation of inputs	Regulation of conditions	Extreme events	Lifecycle maintenance	Disease control	Soil quality	Water quality	Atmospheric composition	Filtration/sequestration	Erosion	flood control	Nursery populations and habitats	Disease control	Decomposition and fixation	Chemical condition (water)	Chemical condition (atmosphere)	Cultural	Direct outdoor interactions	Indirect indoor interactions	Physical interactions	Intellectual interactions	Spiritual and symbolic	Non-use values	Recreation (immersive)	Recreation (observational)	Research	Education	Aesthetic	Existence	Bequest
A3	1	1	1	1	0		0	0	0	0	0	1	1	1	1	1	1	0	1	1		0	1		1		1		1	1	1	1	1	1	1	1	0	1	1	0	1	1
A3.2	1	1	1	1								1	1	1	1	1			1	1			1				1		1	1	1	1	1		1	1		1	1		1	1
A4	1	1	1	1	0		0	0	0	0	0	1	1	1	1	1	1	0	1	1		0	1		1		1		1	1	1	1	1	1	1	1	0	1	1	0	1	1
A4.12	1	1	1	1								1	1	1	1	1	1		1	0							1		1	1	1	1	1		1			1	1		1	1
A5.13	1	1	1	1	1		1					1	1	1		1			1	0							1		1	1	1	1	1		1	1		1	1		1	1
A5.14	1	1	1	1								1	0	1		1			1	0							1		1		1		1		1			1			1	1
A5.15	1	1	1	1								1	0	1		1			1	0							1		1		1		1		1			1			1	1
A5.23	1	1	1	1								1	0	1		1			1	0							1		1	1	1	1	1		1	1		1			1	1
A5.25	1	1	1	1								1	0	1		1			1	0							1		1		1		1					1			1	1
A5.27	1	1	1	1								1	1	1	1	1			1	0							1		1	1	1		1		1			1			1	1
A5.37	1	1	1	1								1	1	1		1			1	0							1		1		1		1		1			1			1	1
A5.52	1	1	1	1								1	1	1	1	1	1		1	1			1				1	1	1	1	1	1	1			1		1		1	1	1
A6	1	1	1	1		1						1	0	1	1	1			1	0			1				1		1	1	1		1		1			1	1		1	1
A6.11	1		0	0								1	0	1		1				0							0		1	1			1		1			1			1	1
A6.3	1	1	1	1		1						1	0	1	1	1			1	0			1				1		1	1			1		1			1	1		1	1
A6.4	1	1	1	1		1						1	0	1	1	1			1	0			1				1		1	1			1		1			1	1		1	1

MSP DATA FRAMEWORK CHECKLIST

If the three main assessments proposed in the present report (i.e. section 2.1, 2.2 and 2.3) could be iteratively to guide the evaluation of the maritime activities' designated areas (i.e. zoning) in future MSP cycles, spatial data needed for each of them may be identified and structured following the MSP data Framework (MSPdF) (Abramic et al., 2023). This is proposed here as a common glossary to promote transparency and the registration of the relevant data that ideally would be needed versus the ones available at the present planning cycle for:

1. Viability (technical and legal) for OWE development as well as for conflict minimization with other coastal and maritime activities, that could use already ad-hoc monitoring efforts in the MSP plans.
2. Environmental effects assessment, that could use already existing monitoring efforts in the MSFD and WFD reporting exercises.
3. Ecosystem services assessments, that could use already existing monitoring efforts in the MSFD as well as ad-hoc accounting exercises for the blue economy within MSP plans.

Thus, MSPdF provides a framework for organizing spatial information and data that must be considered throughout the entire MSP process including, for OWE development, technical and legal viability, EIA, and ES assessments. Table 13 includes a checklist for the seven MSP-relevant clusters proposed in the MSPdF, outlining the information that should be considered in the MSP process. The required data is organized into seven thematic clusters, covering: the marine environment, marine conservation, oceanographic characteristics, coastal land use, maritime operations, socio-economic developments, and governance themes. Note that datasets listed in Table 13 are only the ones considered necessary by the authors for the present demonstrator for the evaluation exercise of the OWE zoning. To see all datasets included in the cluster, please see Abramic et al. (2023). Note that for official MSP processes application, all the proposed assessments in this report, as well as the development of the MSPdF checklist (i.e. Table 13) should be done by the competent authorities handling the official information.

This analysis is expected to structure the data collection process for OWE zoning, EIA, and ES studies, but results also can be applied for evaluation of already finalized processes, evaluating the data collection applied and identifying information that previously was not considered but relevant.

Note that **Table 13 has been included ONLY as an example**. However, it is intended to exemplify that each data within MSPdF may lay within the monitoring of a different legal instrument, e.g. MSFD, WFD, Habitats and Birds' directives, the Network of Marine Protected Areas of Spain (RAMPE), Flood Risk Management Plans, Climate Change Adaptation Plans, Master Plans for the Use and Management of MPAs, etc.

Furthermore, the MSPdF may serve as a checklist or a registry of the spatial data needed and/or used for the different assessments needed to evaluate (and amend them if needed) previous maritime activities' zoning and thus, could also guide the evaluation of some of the monitoring indicators. For example:

- Considering the Spanish POEM objective "MA.2. Ensure that vulnerable and/or protected habitats and species are not affected by the location of human activities that require the use of marine space.", the proposed indicators (as in D.5.2 report of the MSP-OR Project) are:
  - "MA.CAN.IN.03. Surface area and percentage of the marine demarcation for which updated mapping of benthic habitats, and vulnerable and/or protected species is available."
    - Which is an important input as a dataset needed for CEA and ES assessments.
  - "MA.CAN.IN.04. Surface area and percentage of the marine demarcation susceptible to being affected by a high or very high level of cumulative impacts according to the cumulative impacts study conducted in the marine demarcation."
    - Which would be derived from the degree that CEA assessment outputs are considered in the final zoning.

Table 13. MSPdF checklist filled only as an example highlighting all datasets ideally needed for the different assessments to evaluate the suitability zoning of OWE in future polici cycles. Source: Abramic et al., (2023)

Data clusters within the MSPdF	Suitability zoning evaluation			Primary data source
	Viability Asessment	Environmental effects assessment	Ecosystem services assessment	
MSFD				
(QD1) Sea birds		x	x	MSFD monitoring
(QD1) Marine mammals		x	x	MSFD monitoring
(QD1) Marine reptiles		x	x	MSFD monitoring
(QD1) Benthic habitats		x	x	MSFD monitoring
(QD2) Non-indigenous species		x		MSFD monitoring
(QD3) Commercial species		x	x	MSFD monitoring
(QD4) Marine food webs		x	x	MSFD monitoring
(QD6) Sea floor integrity		x		MSFD monitoring
(QD7) Hydrographical conditions		x		MSFD monitoring
(QD10) Marine litter		x		MSFD monitoring
(QD11) Energy and noise		x		MSFD monitoring
WFD				
Benthic Invertebrates		x		WFD monitoring
Macrophytes		x	x	WFD monitoring
Organic pollutions		x		WFD monitoring
Specific pollution		x		WFD monitoring
Hydrology		x		WFD monitoring
Morphology		x		WFD monitoring
Marine Protected Sites	x			Other
Marine Protected Areas	x			Other
Designeted sites on conservation	x			Other
Designeted sites on safety	x			Other
Oceanographic Characteristics				
Waves	x			Copernicus
Currents	x			Copernicus
Winds	x			Copernicus
Bathymetry	x			Copernicus
Coastal Land Use				
Fossil Fuel Based Energy	x			Land planning
Renewable Energy	x			Land planning

Water Transport	x			Land planning
Electricity Gas And Thermal Power	x			Land planning
Residential Use	x			Land planning
Permanent Residential Use	x			Land planning
Residential Use With Other Compatible Uses	x			Land planning
Other Residential Use	x			Land planning
Other Uses	x			Land planning
Maritime activities				
Aquaculture and fishing	x			MSP monitoring
Aquaculture	x		x	MSP monitoring
Finfish Aquaculture	x			MSP monitoring
Professional Fishing	x		x	MSP monitoring
Recreational Fishing	x		x	MSP monitoring
Renewable Energy Production	x		x	MSP monitoring
Renewable Energy (Wind)	x		x	MSP monitoring
Other industry	x			MSP monitoring
Desalination	x			MSP monitoring
Maritime Services	x			MSP monitoring
Nautical Sports	x		x	MSP monitoring
Surf	x		x	MSP monitoring
Windsurf	x		x	MSP monitoring
Kitesurf	x		x	MSP monitoring
Beaches	x		x	MSP monitoring
Coastal Tourism	x		x	MSP monitoring
Whale Watching	x		x	MSP monitoring
Scuba Diving	x		x	MSP monitoring
Underwater Cultural Heritage	x		x	MSP monitoring
Wreck	x		x	MSP monitoring
Archeological	x		x	MSP monitoring
Harbors	x			MSP monitoring
Port	x			MSP monitoring
Fish Port	x			MSP monitoring
Commercial Port	x			MSP monitoring
Cruises Ferries Port	x			MSP monitoring
Recreational Port	x			MSP monitoring
Anchorage Area	x			MSP monitoring
Maritime Traffic Lanes	x			MSP monitoring

Marine Traffic Safety Zone	x			MSP monitoring
Other Transport Network	x			MSP monitoring
Electricity Gas And Thermal Power Distribution	x			MSP monitoring
Submarine Cable Power	x		x	MSP monitoring
Areas Where Any Use Allowed	x			MSP monitoring
Marine Protected Area	x			Other
No Take Zone	x			MSP monitoring
Species Corridor		x	x	MSFD monitoring
Birds Migration Corridor		x	x	MSFD monitoring
Ecological Protection	x			MSFD monitoring
Coastal Protection	x			Other
Navigation Protection	x			Other
Heritage Protection	x			Other
Militar Area	x			Other
Socio-economic Information				
Coastal sectors jobs			x	MSP monitoring
Coastal sectors income			x	MSP monitoring
Maritime sectors jobs			x	MSP monitoring
Maritime sectors income			x	MSP monitoring
Governance				
Administrative competence:	x	x	x	MSP monitoring
Area of planning	x	x	x	MSP monitoring

CONCLUSION

The present report underscores the critical role of adaptive zoning in Marine Spatial Planning (MSP), particularly when dealing with complex, multi-sectoral activities like Offshore Wind Energy (OWE) development. By integrating new data derived from monitoring efforts, MSP processes can continuously evolve to better align with both environmental (i.e. MSFD) and socio-economic objectives (i.e. MSP). The case study of the Canary Islands highlights how zoning decisions made during the initial phases of MSP can be re-evaluated to ensure they remain relevant in the face of emerging challenges and opportunities, particularly as we strive to balance ecological protection with renewable energy needs.

The assessments presented in this report—viable zoning, environmental effects, and ecosystem services—demonstrate the importance of a holistic approach to MSP incorporating data from the monitoring reports of the MSFD. Through structured data frameworks, such as the MSPdF, the evaluation of suitable areas for OWE development can incorporate technical feasibility, environmental impact, and socio-economic trade-offs. However, zoning decisions must be flexible and iterative, incorporating feedback from environmental monitoring, stakeholder engagement, and new scientific research. This ensures that MSP processes are responsive to changing conditions and can better mitigate potential conflicts between conservation and human activities.

Ultimatelyc cumulative effect assessments and ecosystem services are integral components of the planning cycle. By consistently refining zoning and management strategies based on real-world data, MSP can support sustainable marine development that meets the needs of both present and future generations.

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