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1. Introduction

This report provides a synthesis of interlinkages between Ocean Health Index (OHI) elements and the EU strategies and directives. In particular, given the prominent role of the Marine Strategy Framework Directive regarding marine systems, a special look and interlinkages are analysed for this Directive in particular. Nevertheless, given that such Directives and approaches have international effects and linkages, this report contains a brief description of interlinkages and relevance of OHI in the context of the international conventions such as the Agreement under the United Nations Convention on the Law of the Sea and the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (BBNJ Agreement).

This report situates the analysis of the Ocean Health Index (OHI) within the broader landscape of European and international marine governance. By examining conceptual, methodological, and governance linkages between assessment frameworks and regulatory instruments, it contributes to ongoing efforts to enhance policy coherence and scientific integration in marine environmental management. In particular, the comparison between a legally binding directive such as the Marine Strategy Framework Directive (MSFD) and a voluntary, science-based framework such as the OHI allows for a critical reflection on how different tools address complexity, uncertainty, and cumulative impacts in marine systems. This perspective is especially relevant in a context of accelerating environmental change and increasing demands on ocean resources.

The work presents a brief description of EU strategies and directives considered (Section 2), then in two dedicated sections the main features of OHI (Section 3) and MSFD (Section 4) are analysed and distinguished in background, objectives, methodologies, use and applications. These parts serve as a basis for presenting linkages in the form of similarities and differences among OHI and MSFD in a fourth section (Section 5). Section 6 presents a case study mapping MSFD descriptors to cultural ecosystem services through the Ocean Health Index goals. Finally Section 7 is dedicated to highlight the linkages between international regulations such as the BBNJ and OHI. The report is based on analysis of scientific and policy literature increased by the experience carried out in AtlantEco through workshops, meetings and analyses that were carried in Task 3.1 and 3.2 of this Workpackage.

2. EU strategies and Directives for governing marine systems

The effectiveness of EU marine governance relies not only on the individual performance of sectoral directives but also on their degree of alignment and mutual reinforcement. Understanding how objectives, indicators, and monitoring requirements intersect across directives is therefore essential to avoid fragmentation and to maximize environmental outcomes.

The EU directives that were considered are the most important for governing marine systems with focus on environmental protection, safety, and sustainable management of sea resources. Although possibly many directives might be of concern, the ones considered key EU Marine Directives for marine systems that were considered in this work are:

- The **Marine Strategy Framework Directive (2008/56/EC) (MSFD)**, which is the cornerstone policy requiring member states to achieve or maintain good environmental status (GES) for marine waters through 11 descriptors, including biodiversity, marine litter, and noise (etc).
- The **Water Framework Directive (2000/60/EC) (WFD)** that focuses on coastal and inland water quality, set targets on nutrient river loads, identifies water bodies as a unit of monitoring, analysis and assessment, also for coastal environments (Anelli Monti et al., 2021). The WFD is connected with the Urban Waste Water Treatment Directive & Nitrates Directive that is considered crucial for managing nutrient runoff and pollution impacting marine ecosystems.
- The **Maritime Spatial Planning Directive (2014/89/EU) (MSP)** that requires the 22 coastal EU member countries to develop maritime spatial plans for the management of marine activities in a sustainable way. It aims to reduce conflicts by promoting coexistence of blue activities and sectors (energy, shipping, fisheries) while protecting the environment.
- The **Habitats (92/43/EEC) & Birds Directives (2009/147/EC)** are intended to map, monitor and protect key marine species and habitats.
- The **Common Fisheries Policy (CFP)**: Manages fish stocks, aiming to reduce seabed damage and bycatch. The latest European Union CFP reform (EC Regulation N° 1380/2013) aims at implementing a community system for conservation of marine fishery resources and for the management of fisheries exploitation in order to guarantee ecological, economic, and social sustainability (e.g., Libralato et al., 2019).

- The **Marine Equipment Directive (2014/90/EU) (MED)**: Ensures safety standards for equipment on EU-flagged ships, enhancing safety and reducing pollution risk.

Within this policy landscape, the MSFD plays a central coordinating role by providing an overarching ecosystem-based framework that connects sector-specific regulations, such as fisheries, water quality, and spatial planning, under a shared objective of Good Environmental Status (GES). This integrative role makes the MSFD particularly relevant for comparative analysis with holistic assessment tools such as the OHI. The **Marine Strategy Framework Directive (MSFD) (2008/56/EC)** has the goal of achieving "good environmental status" and has clear connections with other directives. For example, the WFD is complementing the MSFD and there are several potential connections between the objectives of the WFD and the indicators used to assess the GES in the MSFD descriptor 5 (Eutrophication), and the clear interlink between WFD and MSFD have been also analysed at level of EU seas (Piroddi et al, 2021). Moreover, according to Descriptor 3 (commercial fish and shellfish), the MSFD requires reaching a healthy stock status with fishing mortality (F) and spawning stock biomass (SSB) compatible with the CFP objectives of the respective MSY reference limits for all commercial species by 2020. Clearly, fisheries (regulated by CFP) are affecting biodiversity and other indicators measured in MSFD (see for example Agnetta et al., 2025) demonstrating clear linkages between the two directives. Therefore, although some regional criticalities emerged, MSFD and CFP are showing good alignment (Raicevich et al., 2019), and CFP might be seen as detailing one of the several aspects (descriptors) of the MSFD.

Overall, all key policies that include the Water Framework Directive (2000/60/EC), Maritime Spatial Planning Directive (2014/89/EU), and the Common Fisheries Policy (2013/1380/EU), has linkages with MSFD that therefore can be considered a cornerstone directive and was the target directive for analysing linkages with OHI framework. Moreover, the objectives of the EU Directives mentioned above and of MFSD in particular are also a high priority of many national and international regulations and initiatives such as the Convention of Biological Diversity (CBD), Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), United Nations Sustainable Development Goals (SDGs), which aim to promote the preservation of natural ecosystems and a sustainable use of fishery resources (Piroddi et al., 2017).

Therefore in the following special emphasis is given to explore the links between OHI and the MSFD and on the relevance of AtlantECO activities for this directive in particular.

3. Ocean Health Index (OHI): a brief description

3.1. OHI Background

The development of the OHI reflects a growing recognition that ocean sustainability cannot be evaluated solely through biophysical indicators, but must also account for the benefits ecosystems provide to human societies. This framing positions the OHI as a bridge between ecological science, socio-economic analysis, and governance. By conceptualizing ocean health as a balance between use and conservation, the OHI challenges traditional notions of pristine baselines and instead focuses on long-term sustainability under realistic management scenarios.

The Ocean Health Index (OHI) is a comprehensive framework designed to measure the health of the oceans by integrating ecological, social, and economic dimensions (Halpern et al., 2012). Launched in 2012 through a collaboration between Conservation International, the National Center for Ecological Analysis and Synthesis (NCEAS), and other academic and environmental institutions, the OHI was created to answer a fundamental question: How healthy is the ocean, and how can we manage it sustainably for future generations?

Unlike traditional environmental assessments that focus solely on ecological indicators (such as biodiversity or pollution levels), the OHI is intended to adopt a broader perspective by defining a “healthy” ocean as one that sustainably delivers a range of benefits to people now and in the future. Thus, ocean health is not viewed as the absence of human activity, but rather as the balance between ecosystem integrity and human well-being (Halpern et al., 2007).

The Ocean Health Index (OHI) is therefore an assessment used to evaluate ocean health by measuring the sustainable delivery of benefits and services that people rely on from healthy oceans, including food provision, cultural and social significance, and economic opportunities. Through the OHI toolbox the OHI group has produced since 2012 annual global assessments available at <https://oceanhealthindex.org/>. The OHI framework can be tailored to different spatial scales and can accommodate a range of contexts and values, these flexibilities allow for the index to be quite flexible in order to be adaptable to national and regional scales. This has been proven and applied in ATLANTECO as the OHI has been developed at two very contrasting scales: at the scale of the whole Atlantic, thus including also international high seas; at the level of coastal areas that has boundaries

defined by regional jurisdiction, such as for the coastal region of Galicia in Spain; at the scale of a sub-region within a country, determined on the basis of oceanographic conditions, i.e., the Southern Benguela. These different areas of application have been demonstrated in Deliverable 3.1.

Each coastal country receives a score between 0 and 100, reflecting how well its marine ecosystems are delivering long-term benefits relative to their potential.

3.2. Objectives of OHI

Beyond measurement, the OHI is explicitly designed to support learning and accountability by enabling comparison across regions and over time. This comparative capacity helps identify both systemic pressures and governance-related drivers of success or failure. The emphasis on communication and transparency further strengthens the OHI's relevance in policy contexts, where accessibility of information is critical for stakeholder engagement and informed decision-making.

The Ocean Health Index pursues four principal objectives that are i) the possibility to have a comprehensive measurement (such as cumulative impacts); ii) to support policy and decision making; iii) to perform continuous monitoring and accountability; iv) as a tool for communication and knowledge transfer.

In particular, i) the primary first objective of OHI approach is to develop a standardized, multidimensional metric of ocean health that integrates ecological condition with human use and governance capacity. By embedding ecosystem services within the assessment, the OHI bridges conservation biology and environmental economics.

Moreover, ii) the Index is explicitly designed to inform evidence-based marine governance. By identifying underperforming goals and quantifying drivers of decline, it enables policymakers to prioritize interventions such as fisheries reform, habitat restoration, or pollution mitigation. The OHI framework aligns conceptually with global sustainability initiatives, including the Sustainable Development Goals established by the United Nations, particularly SDG 14 ("Life Below Water").

Moreover, iii) annual updates of the OHI allow for analysis of national and regional performances. Trend metrics provide early-warning signals of declining ecosystem services and enable evaluation of policy effectiveness over time.

Finally, by synthesizing complex, multidimensional data into accessible indices, the OHI functions as a science–policy interface. The 0–100 scoring system facilitates communication among scientists, decision-makers, and the public without sacrificing methodological rigor.

3.3. Methodology and structure

The standardized yet flexible structure of the OHI allows it to be applied consistently across diverse ecological and governance contexts. This modularity supports adaptation to regional priorities while maintaining comparability at broader scales. By explicitly separating status, pressures, trends, and resilience, the OHI facilitates a clearer understanding of causal relationships and trade-offs, which is particularly valuable in complex social–ecological systems. Its open-access methodology also encourages iterative improvement, enabling continuous refinement as new data and scientific insights become available.

The OHI is composed of four dimensions (status, trend, pressures and resilience) which are derived from a wide range of data using tools that are also publicly available (see <https://github.com/OHI-Science/ohi-global/releases>). The combination of these dimensions indicates the current status and likely future condition for ten areas of evaluation called “goals”. This is possible because the core framework of how goals are scored does not change while the goal models can be adapted to accommodate the data available for the local assessment.

The OHI defines a “healthy” ocean as one that sustainably provides a suite of benefits to present and future generations. This definition is explicitly normative and anthropocentric, grounded in ecosystem service theory. It does not equate health with a pristine or pre-industrial ecological state; rather, it evaluates whether human uses are ecologically sustainable and socially equitable over the long term.

The core architecture of the OHI consists of ten societally derived goals, each representing a key category of ecosystem services:

1. Food Provision (wild fisheries and mariculture)
2. Artisanal Fishing Opportunities
3. Natural Products
4. Carbon Storage
5. Coastal Protection
6. Tourism and Recreation
7. Livelihoods and Economies
8. Sense of Place
9. Clean Waters
10. Biodiversity

This comprehensive overview of different goals allows for an evaluation of trade-offs, and of what stressors or enabling factors can be leveraged to drive change. Moreover, although this is a static indicator framework, it lends itself to explore future management scenarios by substituting chosen stressor and management layers, using the outputs of dynamic models (e.g., Longo et al 2017).

Each goal, in fact, is operationalized through a hierarchical set of indicators that quantify:

- **Current Status:** Present condition relative to a defined reference point.
- **Trend:** Recent rate of change in status.
- **Pressures:** Cumulative anthropogenic and environmental stressors (e.g., overfishing, nutrient loading, climate change).
- **Resilience:** Ecological and institutional capacity to mitigate pressures and support recovery (e.g., marine protected areas, governance quality, regulatory frameworks).

The integration of these components generates a goal-specific score ranging from 0 to 100, where 100 represents full sustainable delivery of benefits under existing ecological constraints.

3.4. Uses and applications of the OHI

The OHI has been widely used as both an assessment and exploratory tool, supporting scenario analysis and the evaluation of potential management interventions. This capacity enhances its usefulness in strategic planning and long-term policy development.

The OHI relies on harmonized datasets derived from the most various sources of data from fisheries statistics to remote sensing products, from biodiversity databases to socioeconomic indicators, and governance metrics. Data are normalized against ecologically and socially defined reference points to allow comparability across jurisdictions. A weighted aggregation method combines individual goal scores into a composite national score. Weighting schemes can be standardized (global assessments) or tailored (regional applications) to reflect stakeholder priorities.

Importantly, the Index incorporates future-oriented modeling by integrating trends and resilience metrics to estimate likely near-term trajectories. This dynamic component distinguishes the OHI from static environmental scorecards.

Although widely recognized for its global ranking of coastal nations, the OHI framework is explicitly modular and adaptable. Subnational assessments (e.g., for provinces, marine ecoregions, or exclusive economic zones) adjust reference points and indicators to local ecological baselines and policy

contexts (Efes et al., 2014). Methodological transparency and open-access documentation allow iterative refinement as improved datasets become available. This adaptive structure supports its long-term scientific credibility.

OHI assessments support marine spatial planning processes by identifying areas where ecosystem services are degraded or vulnerable. Spatially explicit indicators inform trade-off analyses among conservation, fisheries, energy development, and tourism sectors.

The Food Provision goal integrates stock sustainability metrics, enabling evaluation of national fisheries performance relative to maximum sustainable yield benchmarks and thus supporting reform of management regimes and monitoring of exploitation rates (Kleisner et al., 2013).

Indicators for carbon storage (e.g., blue carbon ecosystems) and coastal protection (e.g., coral reefs, mangroves, salt marshes) allow assessment of climate mitigation and adaptation functions. These metrics are increasingly relevant under accelerating sea-level rise and ocean warming scenarios.

The standardized methodology enables cross-country comparison of ocean management outcomes. While ecological and socioeconomic heterogeneity must be considered, comparative analysis can reveal structural drivers of success, such as governance quality or investment in conservation.

The OHI dataset has been widely used in interdisciplinary research examining linkages between environmental pressures, institutional capacity, and ecosystem service provision. Its integrated social–ecological approach contributes to advancing sustainability science.

OHI is an official indicator for tracking countries' achievement of Convention for Biological Diversity (CBD) Aichi target 10, as well as explicitly linked to several of the UN's Sustainable Development Goals (<https://www.bipindicators.net/indicators/ocean-health-index>).

3.5. General strengths and limitations

The Ocean Health Index represents a significant methodological advancement in marine environmental assessment. By operationalizing a social–ecological definition of ocean health and embedding ecosystem service sustainability within a quantitative framework, it transcends traditional sector-specific evaluations. The OHI framework represent an holistic integration of ecological, economic, and governance dimensions, which is quite unique and represent a clear strength. Its transparent, reproducible and freely available methodology represent an asset for large

application, improvement and reliability. These characteristics made the OHI of policy relevance, also at multiple scales.

An important consideration is represented by the fact that the index incorporates status, trends, pressures and resilience, making it considering explicitly future-oriented trend and resilience metrics. The integrative and communicative strengths of the OHI make it particularly effective for highlighting broad patterns and identifying priority areas for intervention. However, these strengths necessarily involve simplifications that must be carefully considered when interpreting results. Acknowledging these limitations is essential to ensure that OHI outputs are used as complementary evidence rather than as stand-alone decision criteria, especially in regulatory contexts.

One main limitation of the OHI is its dependence on datasets of information that span at global level: these inevitably may vary in quality and resolution, reducing possibilities to have uniformly accurate evaluations. For example there is a clear uneven data availability across developing and developed nations that makes assessment of different quality. Another weak point of OHI is the fact that the goal selection and reference point definition is pre-defined and based on existing legislations or agreements. This approach simplifies application and definition of reference but reduces objectivity and scientific determination of reference levels. A limitation inherent on the approach is represented by the potential oversimplification necessary for aggregating multiple aspects and complex dynamics into a composite score.

These limitations acknowledged within the framework, are partially mitigated through methodological updates, regional customization, recalculations and continuous adaptation. Its capacity for multi-scale implementation also demonstrated in AtlantECO, longitudinal monitoring, and policy integration makes it a valuable instrument in the context of intensifying anthropogenic pressures, climate change, and biodiversity decline and an approach that facilitate communication to policy makers of relevant gaps in data, unsustainability of sectors and thus areas for intervention. While methodological challenges remain, the OHI provides a scientifically grounded and policy-relevant benchmark for evaluating progress toward sustainable ocean governance.

4. The Marine Strategy Framework Directive (MSFD): a brief description

4.1. Background

The MSFD represents a significant evolution in European marine governance by institutionalizing an ecosystem-based approach through legally binding requirements. Its adoption marked a shift away from fragmented management toward integrated environmental stewardship of marine ecosystems.

The Marine Strategy Framework Directive (MSFD) is the principal legislative instrument of the European Union for the protection and sustainable management of the marine environment that has been adopted in 2008 (Directive 2008/56/EC). The MSFD establishes a comprehensive framework through which Member States are required to achieve or maintain Good Environmental Status (GES) of their marine waters. The MSFD constitutes the environmental pillar of the EU's Integrated Maritime Policy and complements the Water Framework Directive: while the Water Framework Directive (WFD) primarily addresses inland and coastal waters up to one nautical mile (for ecological status), the MSFD extends environmental governance to the broader marine environment, including offshore waters under Member State jurisdiction.

The Marine Strategy Framework Directive represents a landmark in European marine environmental governance. By operationalizing the ecosystem-based approach through legally binding obligations and harmonized descriptors of Good Environmental Status, it provides a structured pathway toward sustainable ocean management.

4.2. Objectives of the EU MSFD

The MSFD emerged in response to increasing scientific evidence of cumulative anthropogenic pressures on European seas, including overfishing, eutrophication, habitat degradation, pollution, introduction of non-indigenous species, underwater noise, and climate change. Recognizing the limitations of sectoral management approaches, the Directive adopts an ecosystem-based management framework and a regional coordination structure to address transboundary marine challenges. The MSFD is clearly emerging from a desire to set strategic visions and objectives, pushing the scientific community for large interactions in order to measure, assess and report the GES of EU Seas for the 11 descriptors (see for example: Borja et al., 2013; Tam et al., 2017; Boschetti et al., 2021).

By linking environmental protection with sustainable use, the MSFD explicitly recognizes that long-term socio-economic benefits depend on maintaining ecosystem structure and function. This dual focus aligns the Directive with broader sustainability agendas at both EU and global levels. The MSFD also acts as a necessary bridge for scientific collaboration, encouraging harmonized assessment methodologies and shared monitoring efforts across Member States. At the core of the MSFD lies the ecosystem-based approach to marine management. This approach seeks to ensure that the cumulative pressures of human activities remain within levels compatible with the achievement of Good Environmental Status, while allowing sustainable use of marine goods and services. The Directive explicitly integrates ecological structure and function, biodiversity conservation, and ecosystem service sustainability. Rather than focusing on single pollutants or species, it considers the marine environment as a complex socio-ecological system influenced by multiple interacting drivers.

The MSFD pursues three overarching objectives that are i) Achieving Good Environmental Status; ii) Ensuring Sustainable Use; iii) Contributing to Broader EU Environmental Policy.

The primary goal is to achieve or maintain GES in EU marine waters. This entails safeguarding biodiversity, restoring degraded ecosystems, and reducing anthropogenic pressures to ecologically sustainable levels. The Directive explicitly links environmental protection with sustainable use of marine resources. It aims to balance economic activities—such as fisheries, shipping, offshore energy, and tourism—with ecosystem resilience and long-term ecosystem service provision. The MSFD contributes to the objectives of the EU Biodiversity Strategy, the Common Fisheries Policy, and climate adaptation strategies. It aligns with international commitments, including the United Nations Sustainable Development Goal 14 (Life Below Water).

4.3 Good Environmental Status (GES) and Descriptors

The eleven descriptors of GES collectively provide a comprehensive framework for assessing marine ecosystem condition. However, their effective application depends critically on the availability of harmonized indicators and well-defined threshold values. The central operational objective of the MSFD is the attainment of Good Environmental Status. GES is defined through eleven qualitative descriptors (Annex I of the Directive), which collectively represent the ecological integrity of marine ecosystems:

1. Biological diversity is maintained.
2. Non-indigenous species do not adversely alter ecosystems.
3. Commercial fish and shellfish populations are within safe biological limits.
4. Marine food webs occur at normal abundance and diversity.
5. Human-induced eutrophication is minimized.
6. Seafloor integrity is maintained.
7. Hydrographical conditions do not adversely affect ecosystems.
8. Concentrations of contaminants are at safe levels.
9. Contaminants in seafood do not exceed standards.
10. Marine litter does not cause harm.
11. Introduction of energy, including underwater noise, does not adversely affect ecosystems.

These descriptors operationalize a holistic assessment framework covering biodiversity, fisheries, food webs, pollution, physical disturbance, and emerging pressures (e.g., marine litter and noise). Quantitative criteria and methodological standards for assessing GES have been further specified in subsequent Commission Decisions (e.g., Commission Decision (EU) 2017/848).

A fundamental part of the MSFD framework is the establishment of “threshold values” (TVs) — quantitative limits for indicators used to assess whether the marine environment meets the GES criteria (e.g., Palialexis et al., 2021). Without threshold values, policymakers and scientists cannot reliably determine if the marine environment is in good status or if actions are needed (Vasilakopoulos et al., 2022). Ongoing methodological refinement and scientific cooperation remain essential to improve consistency and comparability across regions.

4.4. Uses and applications of the MSFD

The MSFD functions not only as an assessment framework but also as a catalyst for management action through the implementation of Programmes of Measures. These measures link scientific assessment directly to policy intervention. The MSFD is mandatorily applied by all Member States of the EU. Implementation is coordinated through existing regional sea conventions, including the OSPAR Commission, the HELCOM, the Barcelona Convention, and the Bucharest Convention. Marine ecosystems transcend national boundaries; therefore, the MSFD requires Member States to cooperate at the level of marine regions and subregions. Four marine regions are defined:

- Baltic Sea
- North-East Atlantic Ocean
- Mediterranean Sea
- Black Sea

This regional dimension ensures methodological harmonization and addresses shared pressures such as fisheries exploitation, nutrient enrichment, and transboundary pollution.

Regular reporting to the European Commission ensures transparency and comparability. Scientific advisory bodies evaluate Member State progress and identify gaps in implementation. This reporting mechanism strengthens accountability and facilitates adaptive governance. The MSFD follows a six-year adaptive management cycle comprising: 1) a first step that represent the initial assessment of marine waters; 2) a second step that includes the determination of GES; 3) Establishment of environmental targets and indicators; 4) a successive step is based on the development of monitoring programmes; 5) the measures defined are adopted through a Programme of Measures (PoMs); 6) finally the MSFD foresee a periodic review and updating (see Figure 4.1).

Its adaptive six-year cycle provides a structured mechanism for incorporating new knowledge and adjusting management responses over time. This cyclical structure enables integration of new scientific knowledge and adaptive policy refinement. The first cycle (2012–2018) established baseline assessments; subsequent cycles focus on refining criteria, harmonizing monitoring methodologies, and enhancing coherence across Member States.

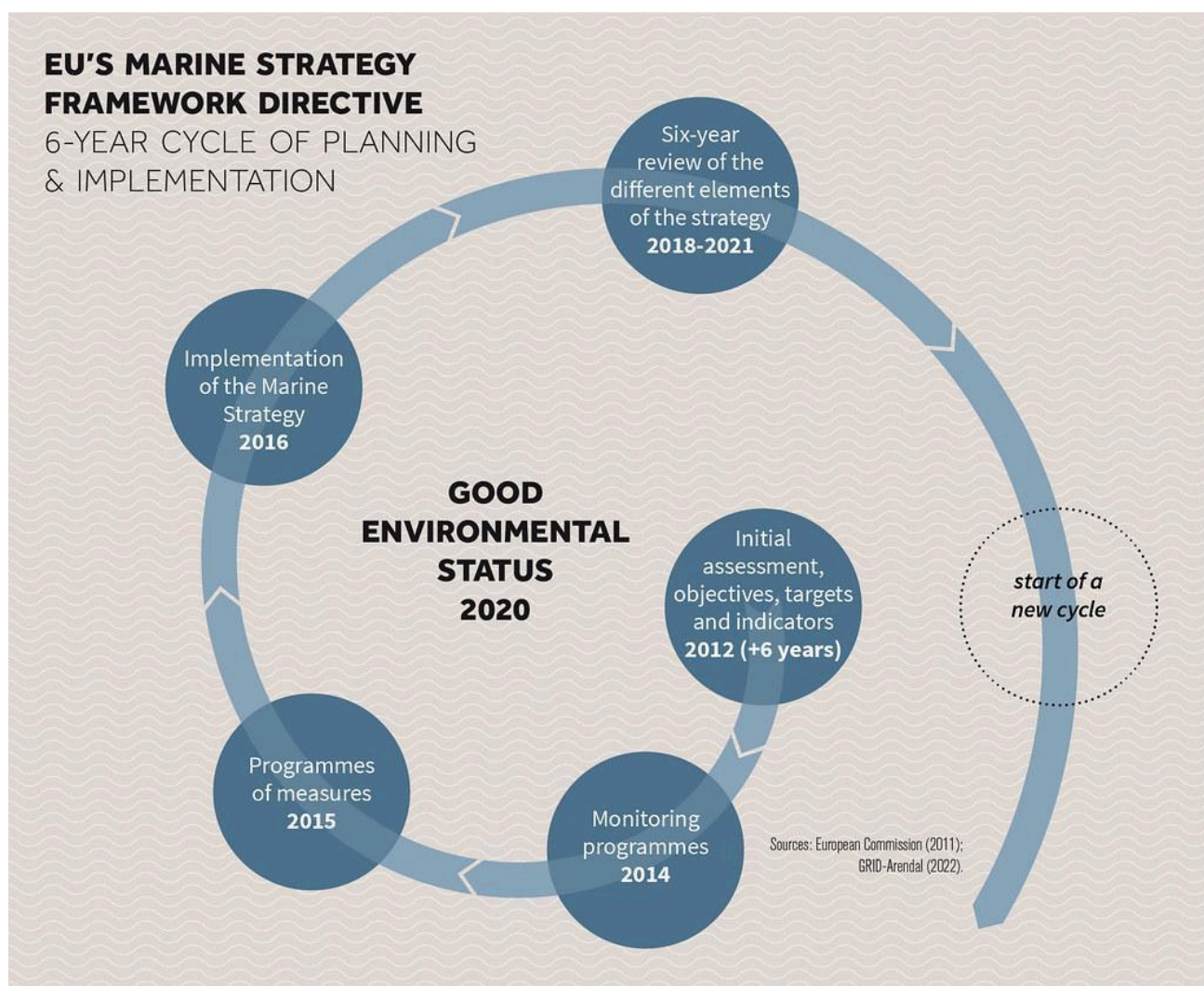


Figure 4.1 - The MSFD implementation cycle (Source: European Commission, 2011) .

The MSFD represents a fundamental tool for environmental assessment and monitoring, by establishing a harmonized monitoring systems across Member States. These systems generate standardized datasets on biodiversity, contaminants, eutrophication, hydrography, and marine litter that are of invaluable importance that goes beyond the MSFD application itself. The resulting assessments provide a comprehensive evidence base for marine policy evaluation.

Moreover, since member States must adopt Programmes of Measures to address identified pressures, the MSFD can result in effects and actions that goes beyond the monitoring and assessment tool by representing a tool for enhancing management of sea activities also in relation with other policies. For instance, MSFD results can trigger fisheries management restrictions

consistent with the Common Fisheries Policy, and MSFD results on descriptor 5 can facilitate adoption of nutrient reduction strategies linked to agricultural policy.

Results of MSFD for biodiversity descriptors (embedded in descriptor 4, food webs), might support designation and management of marine protected areas, while results for descriptors 10 and 11 (Marine litter and energy) might result in measures to reduce marine litter and underwater noise.

Marine Spatial Planning and Cross-Sectoral Integration is also possible, since the MSFD informs marine spatial planning by identifying ecologically sensitive areas and cumulative pressures. It complements the EU Maritime Spatial Planning Directive (2014/89/EU), promoting coherence between environmental protection and spatial allocation of maritime activities.

4.5. General strengths and limitations

The most relevant characteristic of the MSFD is that it is a legally binding framework, intended to be based on solid scientific knowledge, setting clear environmental objectives (Borja et al, 2013). The MSFD is solidly considering an ecosystem-based approach which is carried out by all coastal EU members that are regionally coordinated. Therefore as additional strength, the MSFD appears as a comprehensive descriptor of the marine system addressing traditional (e.g., fishing) and emerging (e.g. noise and plastics) pressures. One important strength of the MSFD approach and application is its adaptive management cycle that is programmed in 6 year cycles and that is strongly incorporating scientific updates. The legally binding nature of the MSFD ensures accountability and policy relevance, but also introduces challenges related to harmonization, data availability, and institutional capacity across Member States.

Limitations of the MSFD framework are mainly related to its flexible application within the different member states, which result in high variability in methodological interpretation of GES among Member States. The differences might be minimal for some descriptors that can have a high degree of uniformity of data and methods and for which the discussion is mainly based on the connection with pressures (e.g., Probst et al., 2016). However, applications are very different for descriptors like “food webs” (Descriptor 4) that result in very different applications across the Member states (Rombouts et al., 2013; Tam et al., 2017; Boschetti et al., 2021; Brito et al., 2024). Moreover, there are significant gaps in agreed threshold values methods and actual values, particularly for more complex ecological indicators (e.g., biological diversity descriptors; Vasilakopoulos et al., 2022).

Similarly to any other assessment approach, anyway, the MSFD is relying on data that are also collected on purpose by Member States. Therefore, uneven monitoring capacity and data gaps are important limitations of the MSFD (see Borja et al., 2013).

MSFD's great challenge is represented by the aim of addressing cumulative impacts and climate-driven changes affecting the GES: these, however, are still to be completely disentangled. Thus while significant progress exists for descriptors like eutrophication (D5) and litter (D10, e.g., 20 items per 100m coastline), many criteria still lack harmonized, quantitative, or specific thresholds (Vasilakopoulos et al., 2022).

Finally, the MSFD is seriously limited in the impacts on management and regulations, because of the limited direct regulatory authority that MSFD and the Ministries in charge of its application has over certain sectoral policies. A clear example is represented by fisheries, which is assessed also in D3 but it is necessarily managed under separate EU frameworks (such as the CFP).

Nevertheless, its regional coordination mechanisms, adaptive cycles, and integration with broader EU environmental policy enhance MSFD scientific and institutional robustness and represent an important setting for improving research (Vasilakopoulos et al., 2022). Despite ongoing challenges related to harmonization and cumulative impact assessment, the MSFD remains a cornerstone of European efforts to restore and maintain healthy marine ecosystems under increasing anthropogenic and climatic pressures.

5. Interlinkages between OHI and MSFD

The Ocean Health Index (OHI) and the Marine Strategy Framework Directive (MSFD) represent two influential yet structurally distinct frameworks for assessing and managing marine environmental sustainability. The OHI, developed as a global, science-based assessment tool, provides a quantitative evaluation of the capacity of marine ecosystems to sustainably deliver benefits to human societies. In contrast, the MSFD is a legally binding regulatory instrument of the European Union, designed to achieve or maintain Good Environmental Status (GES) in European marine waters through an ecosystem-based management approach.

Although conceived within different institutional contexts—one as a voluntary scientific index and the other as a regional regulatory directive—both **frameworks share a common conceptual foundation rooted in ecosystem-based management and sustainability science**. The interlinkages between OHI and MSFD are therefore methodological, conceptual, and operational. Examining these interconnections offers insights into how global assessment tools and regional legal frameworks can reinforce each other in advancing marine governance.

5.1 Broad Conceptual Convergence

Both frameworks share a common foundation in ecosystem-based management, emphasizing cumulative pressures, ecological integrity, and long-term sustainability. This shared vision creates opportunities for conceptual alignment despite differences in implementation. Both OHI and MSFD are grounded in the ecosystem-based approach (EBA). The MSFD explicitly mandates the application of EBA to ensure that anthropogenic pressures remain within levels compatible with ecosystem resilience (Brito et al., 2024). Similarly, the OHI conceptualizes ocean health as the sustainable provision of ecosystem services under cumulative pressures (Halpern et al., 2012).

The convergence lies in the recognition that marine ecosystems function as integrated social–ecological systems. Neither framework evaluates isolated variables; instead, they incorporate biodiversity, ecosystem structure, anthropogenic pressures, and governance capacity. However, while the MSFD defines EBA in regulatory terms linked to GES descriptors, the OHI operationalizes it through goal-based metrics centered on ecosystem services.

Conceptually, GES under the MSFD emphasizes ecological integrity as a prerequisite for sustainability, whereas the OHI integrates ecological integrity with explicit socioeconomic benefits

(Longo et al., 2017). Thus, the MSFD adopts an environmental quality objective framed primarily in ecological terms, while the OHI adopts a social–ecological performance metric.

In order to broaden the comparison we also included a scientific programme framework that was developed in purpose to assess the status of marine ecosystems, the IndiSeas framework (Shin and Shannon, 2010). Indiseas is a programme that relies on local expertise and data time series of ecosystem indicators, identified and filtered based on a well-defined process, quantified on the basis of ecosystem models developed and calibrated at a regional scale. IndiSseas has a focus on the impacts of fishing on marine ecosystems and the use of indicators for assessing marine populations and food web health. Human dimension indicators have also been developed to assess fisheries management effectiveness and governance quality and how those facets relate to ecosystem health and status. IndiSeas relies on research survey data rather than commercial catch data to assess fishing impacts. This has the benefit of data being less biased and more robust, but faces the challenge that these are national data, generated and owned by institutions. However, IndiSeas has engaged partner countries from the developed and developing world, their institutions and collaborators in a collective effort to leverage their expertise in individual systems. IndiSeas thus strengthens linkages between global and national indicator development and reporting, in line with the CBD Strategic Plan for Biodiversity or the European Union’s Management Strategy Framework Directive (MSFD).

OHI, MSFD and Indiseas are mapped in a coherent way in Table 5.1 and Table 5.2.

As shown in Table 5.1, IndiSeas ecological indicators measure key elements identified in MSFD as measures of Good Environmental Status (GES). Namely, the IndiSeas indicators can be used to measure specific attributes or ‘criteria’, that the Directive requires to measure to assess status of biodiversity, commercially exploited species and marine food webs (i.e., descriptors 1, 3 and 4, respectively). The same table also shows correspondence between these IndiSeas indicators and OHI Biodiversity goals (both Habitats and Species preservation subgoals) and Food Provision ‘wild capture fisheries’ subgoal. In addition, fishing pressure and biodiversity declines in OHI are used to calculate stressors that affect the delivery of other goals, e.g., Natural products, Artisanal opportunities, Livelihoods & economies. The OHI framework, separating overall goal delivery into ‘dimensions’

capturing status, trend, pressures or enabling factors (or ‘resilience’), helps explicitly distinguish drivers from outcomes, and identify trade-offs, such as delivery of fishery productivity that provides livelihoods and food, but might threaten biodiversity, or regulations that might protect species, but reduce tourism benefits, etc. When compared side by side with GES descriptors, it shows which elements of the OHI framework are relevant to MSFD, but also helps classify the descriptors as outcomes, stressors, or enabling factors, thus explicitly showing how they contribute to the delivery of the relevant ecosystem services. An example of how these different schemes might be related is shown in Table 2. The table also shows how IndiSeas can be used to estimate a specific subset of the OHI data layers through its 8 ecological and 6 biodiversity and conservation indicators.

Table 5.1 – Mapping MSFD descriptors, IndiSeas and OHI with AtlantECO ecosystem services and data

MSFD-descriptors	MSFD – criteria	IndiSeas – Ecological indicators	OHI Dimensions	AtlantECO Ecosystem service	AtlantECO data
D1 Biological diversity	1.2 Population size	tot B survey; trend flagship spp	Biodiversity – Species subgoal Status/Trend	Biodiversity & bioproducts	
	1.3 Population condition	mean L, mean lifespan			
	1.6 Habitat condition	MTL at sea, mean vuln., tot B survey			
	1.7 Ecosystem structure	prop. pred., prop. exploited, MTL landings, trophic level of the community			Richness from omics
D2: Non-indigenous species			Genetic pollution	Healthy planet, healthy people	HAB from genetic data (WP2)
D3 Commercial species	3.1 Level of pressure of the fishing activity	MTL landings, B/catch, mean vuln., discards; proportion of under to moderately exploited species	Fishing Pressure	Food security	
	3.2 Reproductive capacity of the stock	B stability, prop. declining fished	Food Provision – Fisheries subgoal Status/trend		Larvae/juveniles from genetic data
	3.3 Population age and size distribution	mean L			

MSFD -descriptors	MSFD – criteria	IndiSeas – Ecological indicators	OHI Dimensions	AtlantECO Ecosystem service	AtlantECO data
D4 Marine foodwebs	4.2 Proportion of selected species at the top of the foodweb	mean L, prop. Predators, trophic level of the community, Mean trophic index (TL>3.25)		Climate support system	
	4.3 Abundance/distribution of key trophic groups/species	Prop. exploited, trend flagship spp, mean lifespan, prop predators	Biodiversity – Species & Habitats subgoals Status/Trend		Plankton Key species from networks based on omics (WP5)
D5: Eutrophication	5.1 Eutrophication		Eutrophication Pressure; Clean waters pressure	Healthy planet, healthy people	NPP (Wp6) Indicator of recycling
D6: Sea floor integrity			Biodiversity - Habitats subgoal Status/Trend; Fishing pressure	Deep ocean life support system	Organic matter accumulation (WP2?)
D10: Marine litter			Clean Waters Status; Marine Debris Pressure	Healthy planet, healthy people	Microplastics

Table 5.2 – Complete description of MSFD descriptors, IndiSeas and OHI dimensions

MSFD – Descriptors	IndiSeas – Ecological Indicators (MSFD criteria)	OHI – Dimensions
D1: Biological diversity	Population size and conditions, Habitat condition, Ecosystem structure	<u>Biodiversity – Species</u> subgoal Status/Trend; <u>Habitat destruction</u> Pressure
D2: Non-indigenous species		<u>Genetic Pollution</u> Pressure
D3: Population of commercial fish	Fishing pressure, Stock reproductive capacity, Population age/size distribution	<u>Food Provision – Fisheries</u> subgoal Status/Trend ; <u>Fishing</u> Pressure
D4: Elements of marine food webs	Proportion of selected species at the top of the foodweb ; Abundance/distribution of key trophic groups/species	<u>Biodiversity Resilience</u> ; <u>Sense of place – Iconic species</u> subgoal Status/Trend
D5: Eutrophication		<u>Eutrophication</u> Pressure
D6: Sea floor integrity		<u>Biodiversity - Habitats</u> subgoal Status/Trend; <u>Fishing</u> Pressure
D7: Alteration of hydrographical conditions		
D8: Contaminants		<u>Clean Waters</u> goal Status/Trend; <u>Pollution</u> Pressure
D9: Contaminants in fish and seafood for human consumption		
D10: Marine litter		<u>Clean Waters</u> Status; <u>Marine Debris</u> Pressure
D11: Introduction of energy, including underwater noise		<u>Noise Pollution</u> Pressure

MSFD – Descriptors	IndiSeas – Ecological Indicators (MSFD criteria)	OHI – Dimensions
		<u>Carbon Storage</u> Status/Trend (in coastal habitats: blue carbon)
		<u>Natural Products</u> Status/Trend
		<u>Coastal protection</u> Status/Trend (by naturally-occurring habitats)
		<u>Sense of place – Lasting special places</u> Status/Trend
		<u>Artisanal Opportunities</u> Status/Trend
		<u>Livelihoods & Economies</u> Status/Trend
		<u>Tourism & Recreation</u> Status/Trend
		<u>Tourism</u> Pressure
		<u>Climate change</u> Pressure
		<u>Fisheries</u> Management
		<u>Artisanal fishing</u> Management
		<u>Climate change</u> mitigation Regulations
		<u>Pollution</u> Regulations
		<u>Biodiversity protection</u> Regulations

5.2 Methodological Interlinkages: correspondences

The substantial overlap between MSFD descriptors and OHI goals highlights the potential for methodological complementarity, particularly in areas such as biodiversity, fisheries, and pollution. Both frameworks are indicator-based assessments that have foundation in the quantitative evaluation of objectives on the basis of set criteria. The MSFD defines Good Environmental Status through eleven qualitative descriptors encompassing biodiversity, food webs, seafloor integrity, eutrophication, contaminants, marine litter, and underwater noise. The OHI, in contrast, defines ocean health as the sustainable delivery of ten societal goals, including food provision, biodiversity, clean waters, carbon storage, coastal protection, and livelihoods. There is a great similarity among the structure and a substantial overlap among MSFD descriptors and OHI goals (Table 5.3).

Table 5.3 – Most relevant examples of correspondence between MSFD descriptors and OHI goals

MSFD Descriptors	link	OHI goals
Descriptor 1 – Biodiversity	aligns	Biodiversity goal
Descriptor 3 - Commercial fish stocks	aligns	Food Provision
Descriptor 5 – Eutrophication	corresponds	Clean Waters
Descriptor 6 - Seafloor integrity	relates	Habitat condition within multiple goals
Descriptor 10 - Marine litter	affects	Tourism and Clean Waters goals

This functional correspondence indicates that OHI indicators can, in principle, complement MSFD assessments. OHI indicators may therefore provide additional context or comparative insight for MSFD assessments, especially at broader spatial scales.

The MSFD operationalizes its descriptors through quantitative criteria and threshold values established in Commission Decision (EU) 2017/848. Similarly, the OHI aggregates standardized indicators normalized against reference points to generate goal-specific and composite scores.

5.3 Methodological Interlinkages: differences

Key methodological differences reflect the distinct purposes of each framework: regulatory compliance versus comparative assessment. These differences should be seen as complementary rather than contradictory. Some methodological differences are notable to highlight (Table 5.4).

- 1) The MSFD evaluates compliance with predefined GES thresholds, while the OHI assesses performance relative to ecological and socioeconomic potential on a 0–100 scale. Although the scale range definition in OHI is defined on data available, which is highly questionable this approach helps more to give a comparative orientation which can be useful in non binding approaches. Conversely the strictly regulatory nature of the MSFD requires as much as possible well determined thresholds to be used in case of controversy or regulations.
- 2) MSFD assessments often rely on achieving or failing specific criteria, whereas the OHI provides continuous performance gradients: again the fact that the Directive is a legislative act requires threshold-based approach, whereas the voluntary OHI approach benefit from the continuous scoring because it can show progressions of effects of measures, differences across countries or regions in a more comparative way and not necessarily distinguishing in good or bad.
- 3) MSFD outcomes entail legal obligations for Member States because of the legislative nature of the Directive, while the OHI results are advisory and comparative because of the voluntary nature of the framework. The legal enforceability therefore is quite different and this explain the main differences among MSFD and OHI.

Despite these differences, OHI datasets can inform MSFD reporting by providing harmonized, large-scale indicators, especially for transboundary pressures such as fisheries exploitation or climate-driven impacts.

Both frameworks incorporate anthropogenic pressures, though with different emphases. In particular, the MSFD requires explicit identification of a set of predefined pressures (e.g., nutrient enrichment, physical disturbance, contaminants, noise) which are at the base of some descriptors. However, there are other pressures (e.g., fishing effort) which are not the target of a descriptor but influence it (e.g., D3- fisheries resources and D4 – Food webs). Member States must develop Programmes of Measures to mitigate these pressures. Conversely, the OHI integrates explicitly pressures into all its goals and the pressures are included in the OHI scoring algorithm.

Notably OHI incorporates resilience indicators (e.g., governance effectiveness, marine protected areas; see Table 5.4) connected to pressure to project near-term trajectories. This resilience dimension is not formally embedded in MSFD descriptors, although it is indirectly addressed through the analysis of GES (e.g., through formal statistical causal analysis) and can be incorporated during the monitoring and the adaptive cycles: the integration of the OHI resilience metrics would provide added analytical value for MSFD implementation, particularly in evaluating adaptive capacity and governance effectiveness.

Table 5.4 summarizes the principal structural, methodological, and governance-level interconnections between the two frameworks, highlighting both convergence and complementarity.

Table 5.4. Key Interlinkages between the Ocean Health Index (OHI) and the Marine Strategy Framework Directive (MSFD)

Dimension	OHI	MSFD	Interlinkage / Complementarity
Conceptual basis	Ecosystem services and social–ecological systems approach	Ecosystem-based management and ecological integrity	Shared ecosystem-based perspective integrating human pressures and ecological function
Primary objective	Sustainable delivery of marine ecosystem benefits	Achievement of Good Environmental Status (GES)	Both aim at long-term marine sustainability
Structure	10 societal goals (e.g., food provision, biodiversity, clean waters)	11 GES descriptors (e.g., biodiversity, eutrophication, contaminants, litter)	Substantial thematic overlap (biodiversity, fisheries, pollution, habitats)
Methodology	Combining status, pressure, trend and resilience	Assessment of the status, although pressure and climate change are required	OHI implement, although in a standardized and liner way way, a more complex framework than MSFD
Assessment	Continuous scoring (0–100), reference-point normalization	Threshold-based criteria and regulatory standards	OHI provides performance gradients; MSFD provides compliance benchmarks
Quantification	Although using a large set of data, the quantification is simplistic (linear, expert based weights)	Approach is data intensive, strongly scientific-based and typically considering the complexity of dynamics	OHI simplistic but high efficacy; MSFD scientifically robust but not always feasible
Pressures	Integrated into scoring model (cumulative pressures)	Explicit identification of anthropogenic pressures	Shared focus on cumulative human impacts
Resilience	Explicit resilience indicators (e.g., management effectiveness, MPAs)	Indirectly addressed via Programmes of Measures	OHI can complement MSFD by quantifying adaptive capacity
Spatial scale	Global, national, subnational	EU marine regions (Baltic, NE Atlantic, Mediterranean, Black Sea)	OHI enables cross-regional comparison; MSFD ensures regional coordination
Legal status	Voluntary scientific index	Legally binding EU directive	OHI supports benchmarking; MSFD ensures enforceability
Policy use	Communication, benchmarking, evaluation of cumulative impacts	Regulatory compliance, marine policy implementation	OHI enhances transparency and policy communication under MSFD
Alignment with SDG 14	Global benchmarking of ocean sustainability	Regional implementation within EU waters	Joint contribution to international ocean governance objectives

5.4 Governance and Institutional Dimensions: convergences

Together, the MSFD and OHI illustrate how regulatory instruments and voluntary assessment tools can reinforce one another by combining enforceability with transparency and communicative clarity. Both frameworks depend heavily on monitoring infrastructures and standardized data. The MSFD requires Member States to develop coordinated monitoring programmes, while the OHI relies on globally harmonized datasets (Tam et al., 2017). The heavy dependence on data implies that both frameworks rely on monitoring and data harmonization that also represent broad scientific challenges. Key shared challenges include the presence of large data gaps in deep-sea and offshore ecosystems which are less monitored than coastal areas, and the fact that available data might result from inconsistent methodological applications across jurisdictions (see AtlantEco D. 3.1).

Moreover, both OHI and MSFD have limited integration of climate change projections, mainly because of an inherent complexity in disentangling all sources of variability (and thus of climate change) and difficulties in assessing cumulative impacts in the assessed indicators and goals. Nevertheless, the OHI's standardized global datasets can promote comparability, whereas the MSFD's legally mandated monitoring improves data quality at regional scales. Together, they offer complementary strengths: global comparability (OHI) and regulatory precision (MSFD).

Regarding the policy application, both frameworks are supporting adaptive management: the MSFD operates on six-year adaptive cycles, OHI trend and resilience metrics can inform adaptive revisions by identifying emerging declines before threshold breaches occur.

Enhancing Communication is a common characteristic of both OHI and MSFD. OHI's composite scoring system enhances communication of complex environmental data to policymakers and the public. MSFD reporting, often technically detailed, may benefit from complementary summary indicators for broader stakeholder engagement.

Finally both frameworks are aligning with Global Sustainability Goals., and in particular to Sustainable Development Goal 14 (Life Below Water). The MSFD operationalizes SDG 14 regionally within the EU, while the OHI provides a global comparative context. Together, they bridge regional implementation and global benchmarking.

5.5 Governance and Institutional Dimensions: differences

In governance and institutional dimensions OHI and MSFD appear different in many aspects, but these differences permit interlinkages and interrelations between the two frameworks resulting also in potential complementarities. Selective integration of OHI elements—particularly in communication, benchmarking, and resilience assessment—could enhance MSFD implementation without compromising its legal robustness.

For instance, the spatial scale at which the two frameworks operate are quite different. The MSFD operates at regional sea scales (Baltic, North-East Atlantic, Mediterranean, Black Sea) and mandates coordination through regional sea conventions such as the OSPAR Commission, HELCOM, and the Barcelona Convention. The OHI, by contrast, is globally standardized but adaptable to national and subnational contexts as it was also demonstrated in AtlantEco WP3 activities (see Deliverable 3.1). The flexibility of OHI, anyway, enables regional customization that can be consistent with MSFD marine regions. An important interlinkage that emerges is that the OHI regional assessments could serve as complementary benchmarking tools within MSFD marine regions, facilitating cross-country comparison beyond minimum compliance. An example of such MSFD and OHI interlinkage is reported in Nikolaou et al., (2025), where assessments obtained with MSFD are weighted by homogeneous regions in a way very similar to the OHI approach, thus resulting in the possibility to carry out cross-areas comparisons.

Another important difference is that MSFD represents a legal obligation while the OHI is a voluntary benchmarking. Therefore, while MSFD imposes binding obligations on EU Member States to achieve GES and report progress (Borja et al., 2013), the OHI has no regulatory authority and its influence derives from scientific credibility and transparency (Halpern et al., 2012). Nevertheless, voluntary benchmarking mechanisms like the OHI can enhance accountability by enabling public comparison of national performances and in this case the OHI can act as an external evaluative lens on MSFD implementation similarly to what Nikolaou et al., (2025) has done.

One of the most significant distinctions between OHI and MSFD lies in their treatment of ecosystem services. The MSFD implicitly protects ecosystem services by safeguarding ecological integrity (Borja et al., 2013) but does not explicitly quantify benefits such as livelihoods, tourism revenue, or carbon sequestration values. Its primary orientation is therefore to simply quantify the environmental status with respect to a threshold level. Instead, the OHI explicitly measures some provisioning services, i.e., Food provision, Coastal protection, carbon storage (blue carbon ecosystems), Tourism and recreation

and Coastal Livelihoods and economies (see AtlantEco Deliverable 3.1). This explicit ecosystem service framing complements the MSFD by translating ecological improvements into socio-economic outcomes. Integrating OHI-style service metrics into MSFD assessments could strengthen cost–benefit analyses of Programmes of Measures and improve policy communication.

5.6 Limitations of the integration of the two frameworks

Despite complementarities, several constraints limit direct integration of OHI and MSFD. The first and most pervasive hamper for direct integration is related to the differences in normative framing: the binding characteristics of MSFD requires legal requirements for the assessments that may not align with OHI methodologies that are strongly defined on expert-based information. For example the aggregation biases in composite indices for OHI that hold for voluntary approach, may not work or might seem as oversimplify the reality, thus hampering the regulatory complexity that MSFD requires.

The differences in indicator definitions and especially in the reference points represent a cascading effects of previous limitation: while OHI relies on a ranking of capabilities to provide services, MSFD requires definition of GES with thresholds on ecological status

Therefore a careful methodological harmonization would be required to formally integrate OHI metrics into MSFD reporting processes.

5.7 Way forward for the integration of the two frameworks

These limitations represent challenges for integration of the two frameworks in a unique approach. Nevertheless there are opportunities for using the peculiar features of each framework to complete or improve the other.

For instance, the OHI approach can help improve some weak areas of MSFD. While the MSFD itself is a scientific state-of-play review, it implicitly suggests that achieving full GES assessment under the MSFD requires more coordinated threshold-setting work across Member States and regions which can be improved by considering the OHI weighted approach of the different elements of the goals (see Nikolaou et al., 2025).

OHI approach can also inspire harmonization of methodologies for defining the thresholds in MSFD: although apparently simplistic (assuming linear additive effects with expert-based weights) the OHI

represent a fundamentally simple approach to rank capacities of the ecosystem to provide services (see AtlantEco Deliverable 3.1).

OHI communicative power can be implemented in the MSFD permitting a wider adoption and consistency of threshold values for all MSFD criteria across countries.

Both MSFD and OHI approaches provide grounds for further research and data sharing to fill gaps for layers of information and indicators that currently lack solid thresholds. Because threshold values are the numerical backbone of environmental assessment under binding legislation such as the MSFD and without reliable threshold values marine environmental status cannot be robustly measured, targets for environmental improvements are harder to set and European policy action is less evidence-based. While the OHI approach for calculating each single Goal score might be less robust than what MSFD requires, the way OHI is aggregating the scores, communicating them and weighting them might represent an inspiration for MSFD to enhance its potential, challenging scientifically and operationally its effort to protect marine ecosystems.

6. Mapping MSFD descriptors to cultural ecosystem services through the Ocean Health Index goals

6.1 Introduction

Incorporating cultural ecosystem services into marine assessments is essential for capturing dimensions of human well-being that are not reflected in traditional biophysical indicators. These services play a critical role in shaping public perceptions and support for conservation measures. While provisioning and regulation & maintenance services are relatively straightforward to quantify, cultural ecosystem services (CES) present a much greater challenge, as they are deeply rooted in human perceptions, experiences, and regional contexts. Understanding CES is therefore crucial for capturing how human stressors and environmental pressures influence not only the ecological components of an ecosystem but also the social and cultural benefits derived from them. It is essential to distinguish between the ecosystem's capacity to supply services—a function of ecological processes—and the actual societal benefits that emerge when people invest effort, knowledge, and resources to access or appreciate those services. Confusing these two dimensions can obscure how stressors on ecosystems ultimately affect human well-being, particularly in the cultural domain (ICES 2023).

For cultural services, only in-situ forms of engagement (e.g., direct experiences such as recreation or nature-based tourism) can be directly linked to the ecological state of an area. In this sense, the presence of species provides a more meaningful indicator than biomass for evaluating these connections. Evaluating CES requires a context-specific approach, as the relevance and interpretation of indicators vary across regions and cultures (e.g., recreational diving holds very different significance in the Mediterranean compared to the Baltic Sea). Incorporating social science perspectives is therefore vital—not only to refine and contextualize metrics but also to better understand the complex linkages between biotic groups and cultural values. Such interdisciplinary input can help prioritize or weight key relationships, identify culturally significant (iconic) species, and ultimately enrich assessments of how human activities and ecological pressures interact to shape cultural benefits derived from nature (ICES 2023).

Socio-cultural values reflect the diverse ways in which communities—across different regions, societies, and sectors—perceive and value nature and its role in human well-being, including aspects such as aesthetic appreciation, cultural identity, and social relationships (Garcia Rodrigues et al.,

2024). Growing attention is being paid to understanding how various groups value nature's contributions to people (NCP), as this knowledge can support fair and effective management of Marine Protected Areas (MPAs). Consequently, more pluralistic and socially equitable valuation frameworks are being integrated into resource management to help address disparities in access to and use of marine ecosystems (Villasante et al., 2023). Acknowledging and incorporating socio-cultural values is now a key component of inclusive marine spatial planning (MSP) and ocean governance systems, which seek to recognize the diverse ways people connect with, depend on, and interpret nature (Ainsworth et al., 2019; Villasante et al., 2023). Tourism in MPAs can deliver numerous benefits—for instance, raising awareness about marine conservation—but may also lead to negative impacts such as disturbing wildlife (Pham, 2020). The overall outcome largely depends on how well these areas are managed, the strength of regulatory compliance, and the behaviour of visitors. Thus, assessing visitors' socio-cultural values and their perceptions of NCP is crucial to designing effective management strategies and ensuring the long-term conservation of MPAs (Garcia Rodrigues et al., 2024). Studying people's perceptions about the quality of cultural ecosystem services provided by marine and coastal sites can support understandings of the quality of associated ecosystem components. The application of OHI goals to socio-cultural data demonstrates a promising pathway for linking qualitative social values with quantitative assessment frameworks, thereby enriching ecosystem-based management approaches.

6.2 Methods

A social science study carried out by the University of Santiago de Compostela (USC), described in D3.2 Pluralistic Valuation of Ecosystem Services (Villasante et al., 2025), investigated how visitors to 23 diverse iconic marine sites—including protected and tourist areas—around the Atlantic Ocean culturally interact with the sea. This was achieved by analysing Google Maps reviews left by visitors. These online reviews represent spontaneous data, as users shared their comments voluntarily rather than through a structured survey. This indicates that the topics mentioned were particularly meaningful to certain visitors, though they may reflect only a fraction of the broader range of visitor experiences and opinions.

To identify key themes, the data was first coded to reveal the variety of cultural activities (or pursuits) available at each site. Approximately 80 pursuits were classified into 18 broader categories of cultural practices (Fish et al., 2016). The dataset was then further analysed to determine the

cultural ecosystem services offered across sites. A novel analytical approach was developed by coding the content using the ten goals (and corresponding sub-goals) of the Ocean Health Index (OHI) (<https://oceanhealthindex.org/goals/>). Each review remark was linked—positively or negatively depending on the emotional intent of the review—to one or more of these OHI goals. For instance, comments addressing the cleanliness of the ocean at a site were coded according to the Clean Waters goal. We also created a separate code ‘clean site’ under the Sense of Place - Lasting Special Places Sub-Goal to capture remarks pertaining to plastics on land (e.g. on beaches, in coastal villages).

6.3 Results

6.3.1 Case study characteristics

We collected a total of 6,319 reviews from 23 case study locations distributed across coastal, island, and open ocean sites throughout the Atlantic Ocean. An average of 44% of ratings were submitted without accompanying written comments. Consequently, the remaining 3,541 reviews (56%) were manually analysed for content.

The study locations encompassed eight marine provinces, 20 ecoregions, 19 countries, and six types of designations. Five of these designations corresponded to different forms of protected areas—World Heritage Area/UNESCO Man and Biosphere Reserve, Marine Protected Area, Ramsar Site, Natural Park, and National Park—while the sixth was classified as a “tourism area” (Figure 6.1).



Figure 6.1: Map of 23 case study sites. Dark blue icon = National Park; green = UNESCO World Heritage Site; brown = Ramsar site; orange = tourism site; teal = national natural park; yellow = other type of protected area. Numbers refer to site names.

Visitor ratings, based on a five-point scale where one indicated “very poor” and five indicated “very good,” ranged from a low of 4.2 (at Bojo Beach and Cayos Miskitos y Franja Costera Inmediata) to a perfect score of 5.0 (at Parque Nacional Marinho de Abrolhos and Skomer Island). The content of the reviews demonstrated a correlation between satisfaction with the site and the cultural services provided by different sites.

Visitors most frequently made comments relating to the following OHI Goals and our code:

- Sense of Place – places and iconic species (e.g. references to the characteristics of a site that make it special to individuals, groups or communities;
- Tourism & Recreation (e.g. references to participation in tourism or recreational activities based on availability or quality of the site or services provided);
- Livelihoods & Economies (e.g. references to availability and quality of local businesses of interest to tourists or investment in site management or infrastructure);

- Biodiversity – species and habitats (e.g. references to the perceived health of habitats based on quality, extent or abundance);
- Clean Waters (e.g. references to the perceived cleanliness of the ocean based on clarity or presence of non-natural items);
- Clean site (e.g. references to the perceived cleanliness of coastal land or presence of non-natural items).

Biodiversity was especially important to reviewers as seen from the frequency of positive reviews relating to iconic species, species in general and to habitats (Figure 6.2).

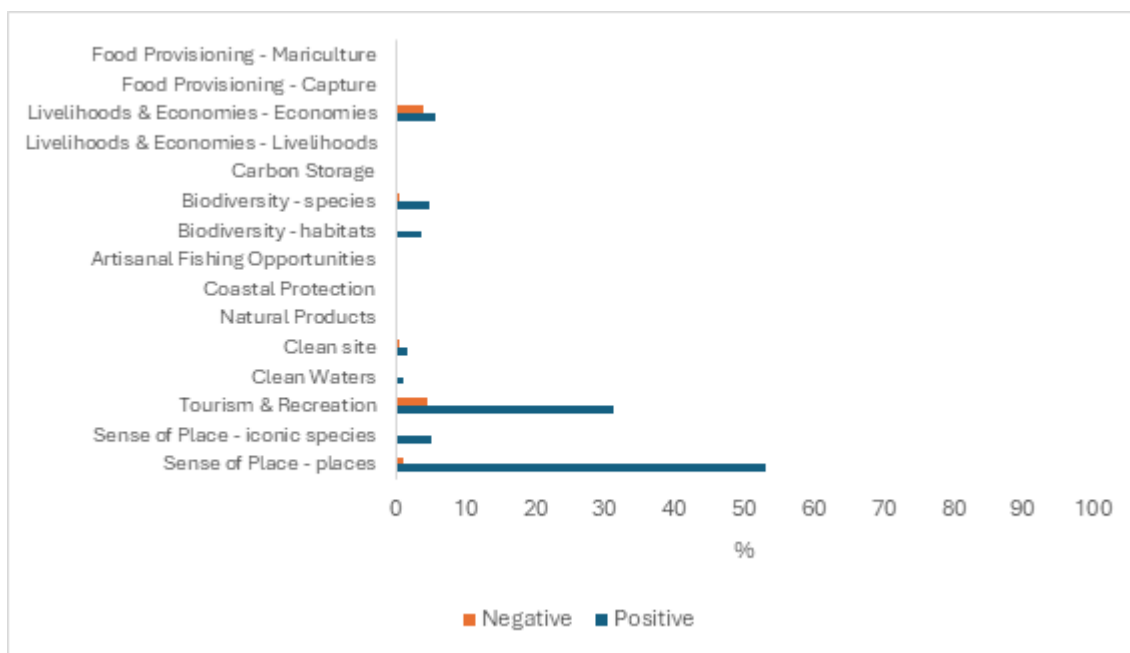


Figure 6.2: Proportion of comments from all 23 sites combined coded according to the 10 OHI Goals/Sub-Goals and 'clean site'. Negative reviews = disbenefits received; positive reviews = benefits.

6.3.2 D1: Biological Diversity – Biodiversity – Species subgoal

Top five activities related to biodiversity

Demonstrating the importance of biodiversity to satisfactory visitor experiences in marine iconic sites, reviewers most frequently reported 'playing and exercising' (Fish et al. 2016) while immersed in nature and engaging with biodiversity. These include interacting with wildlife, enjoying the physical characteristics and aesthetics of the sites, and exploring the environment on land and in the water (Figure 6.3).

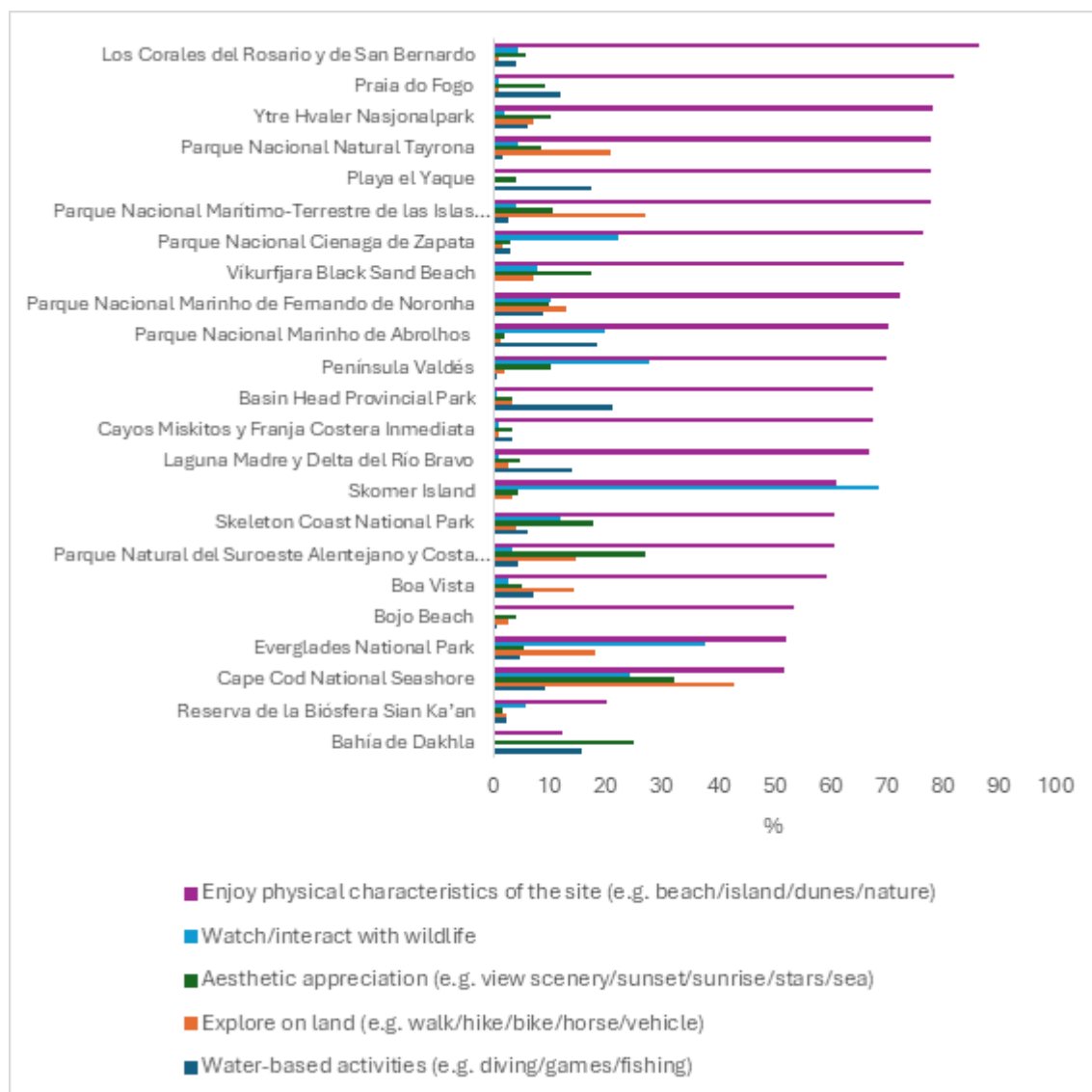


Figure 6.3: The top five activities most frequently reported by reviewers.

The top five most frequently mentioned cultural practices (out of 18) involve biodiversity, including habitats and wildlife for example:

OHI Biodiversity – habitats:

- enjoying the physical characteristics of the site (e.g. beach/island/dunes/nature),
- aesthetic appreciation (e.g. viewing scenery/sunset/sunrise/stars/sea)
- exploring on land (e.g. walk/hike/bike/horse/vehicle)

OHI Biodiversity – species:

- watching/interacting with wildlife,
- water-based activities (e.g. diving/games/fishing)

This is important to know because understanding the major values for conservation of nature associated with ecosystem services and NCP provides a benchmark for the sound design and planning of site conservation management. Demonstrated conservation of natural and cultural values and ecosystem services/NCP are considered criteria for achieving successful long-term conservation outcomes. Socio-cultural benefits associated with charismatic marine life and biodiversity have been shown to contribute to a ‘fulfilled human life’ and social wellbeing (Ainsworth et al. 2019). Overall, reviewers mentioned connecting with habitats and land/seascapes more frequently than they mentioned engaging with wildlife, apart from in Skomer Island which is a wildlife sanctuary providing opportunities for visitors to directly interact with colonies of iconic seabirds.

Biodiversity hotspots

Examining which sites received the highest proportions of reviews relating to biodiversity identified 9 biodiversity hotspots. These were distributed around the ocean but were found particularly on the eastern Atlantic (Figure 6.4).

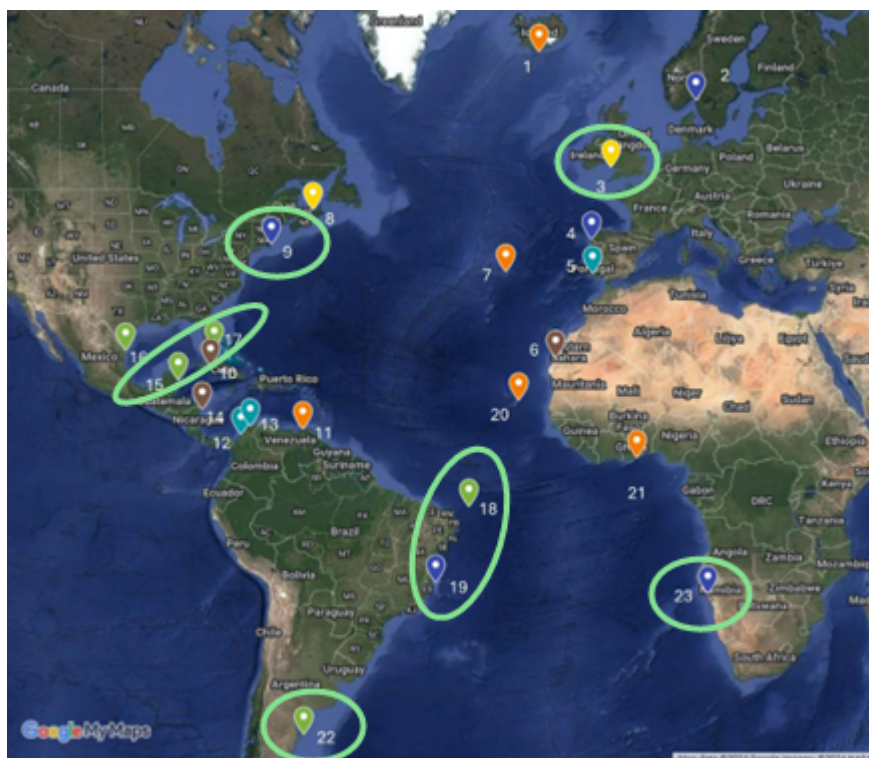


Figure 6.4: Map of 23 case study sites distributed around the Atlantic Ocean. Dark blue icon = National Park; green = UNESCO World Heritage Site; brown = Ramsar site; orange = tourism site; teal = national natural park; yellow = other type of protected area. Numbers refer to site names. Green circles indicate biodiversity hotspots.

6.3.3 D1: Biological diversity – Sense of Place - Iconic species subgoal

The reviews demonstrated important differences in the ecosystem services provided by biodiversity at different sites, reflecting the capacity for individual sites to supply cultural services (Figure 4.5). For example, reviewers of Skomer Island (United Kingdom), Everglades National Park (USA), Cape Cod National Seashore (USA), Parque Nacional Ciénega de Zapata (Cuba) and Peninsula Valdés (Argentina) highlighted the presence of iconic species (e.g. seabirds, alligators, white sharks, orcas) and wildlife in general. Other sites, such as Parque Nacional Marinho de Fernando de Noronha (Brazil), Parque Natural del Suroeste Alentejano y Costa (Portugal) received more comments about their sea/landscapes and habitats than about fauna. Reviewers of Parque Nacional Marinho de Abrolhos (Brazil) and Reserva de la Biósfera Sian Ka'an (Mexico) commented almost equally about species and habitats.

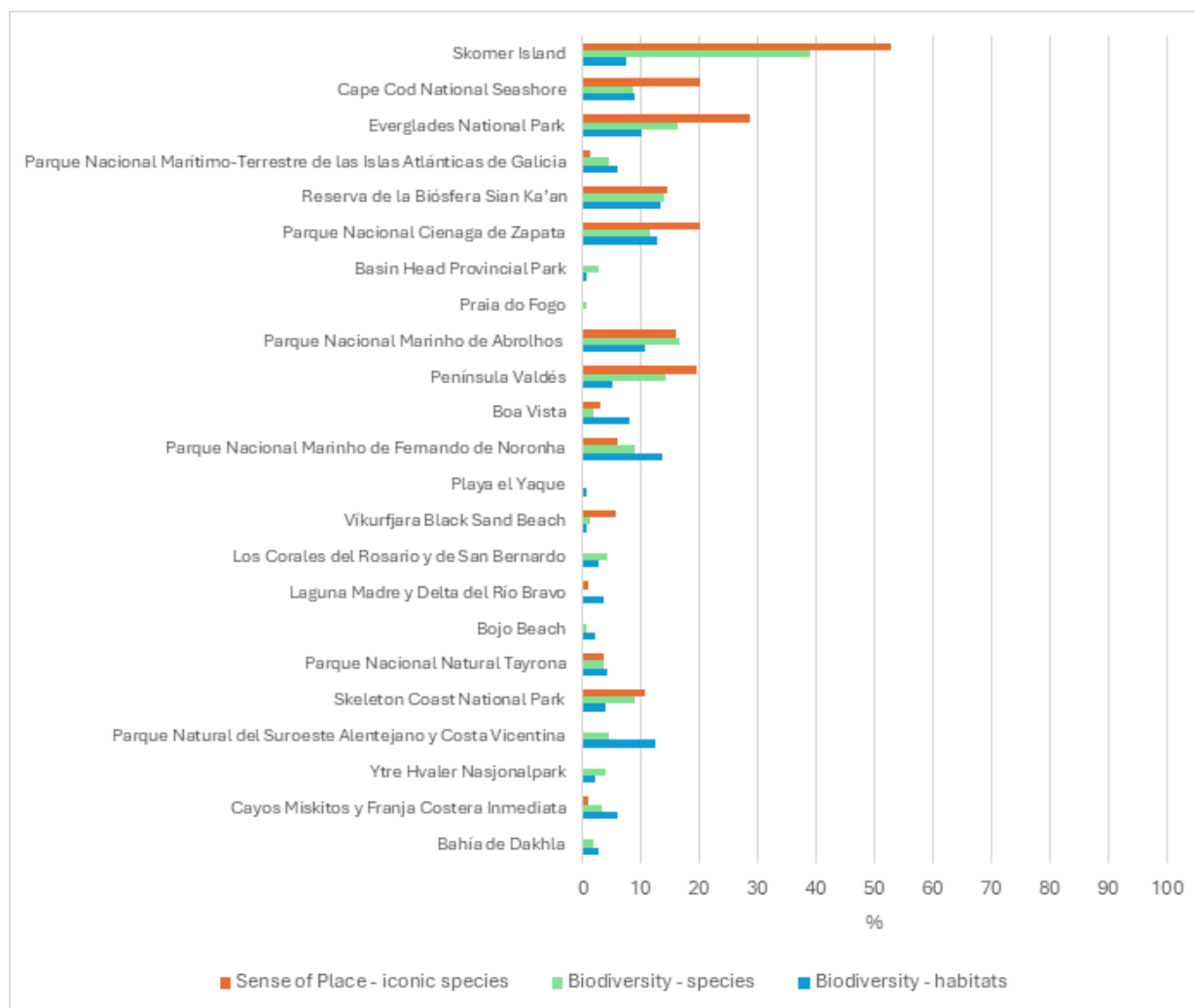


Figure 6.5: Proportion of positive reviews for each of 23 iconic marine sites relating to OHI biodiversity goals. N=3,541

6.3.4 Cumulative pressures

Sites at risk from climate, local human activity or anthropogenic impacts

Our findings showed that 18 out of the 23 iconic sites examined were experiencing socio-environmental threats at the time of analysis—threats significant enough to be noticed and reported by multiple reviewers. These 18 sites were distributed across several biogeographic provinces of the Atlantic Ocean: Lusitanian (4 sites), Cold Temperate Northwest Atlantic (2), Tropical Northwestern Atlantic (7), Tropical Southwestern Atlantic (1), West African Transition (1), Gulf of Guinea (1), and Magellanic (1) (Figure 14). The remaining five sites where such threats were not mentioned were located in the Northern European Seas (3 sites), the Tropical Northwestern Atlantic (1), and the Benguela region (1).

The identified threats were largely linked to local human activities—such as overcrowding, insufficient investment in site infrastructure, and the accumulation of plastics or other types of litter on land. However, additional threats were noted that extend beyond local causes. These included broader anthropogenic impacts, such as marine plastics and debris brought in from the ocean, as well as climate-related changes, including the potential proliferation of undesirable species like jellyfish or mosquitoes.

More than half of the sites (13) were perceived as being affected by multiple threats, with Playa el Yaque (Venezuela), Parque Nacional Marinho de Fernando de Noronha, and Reserva de la Biósfera Sian Ka'an particularly impacted—each facing six or more types of pressures. Reviews for the remaining sites—Parque Nacional Marinho de Abrolhos, Parque Natural del Suroeste Alentejano y Costa, Basin Head Provincial Park (Canada), Boa Vista (Cabo Verde), Bojo Beach (Ghana), Cape Cod National Seashore, Praia do Fogo (The Azores), Parque Nacional Marítimo-Terrestre das Ilhas Atlánticas de Galicia (Spain), Cayos Miskitos y Franja Costera Inmediata (Nicaragua), Laguna Madre y Delta del Rio Bravo (Mexico), Parque Nacional Natural Tayrona (Colombia), and Península Valdés—mentioned fewer individual threats, though these were still considered locally significant (Table 6.1). Overall, our analysis indicates that up to 20 of these sites may currently represent—or are likely to become—vulnerable or high-risk hotspots.

Table 6.1: Key threats mentioned by reviewers.

Site	Key threats										
	Local human activities								Anthropogenic impacts	Climate impacts	
	Overcrowding of people in the site	Lack of investment in site infrastructure	Presence of plastics and other litter on land	Site not contributing effectively to social equity in local community	Site not adequately managed for biodiversity	Site is not adequately managed for tourism	Biodiversity negatively affected by tourism	Biodiversity negatively affected by plastics	Presence of plastics and other litter arriving from / in ocean	Potential blooms in undesirable species	Biodiversity affected by climate change events
Parque Nacional Marinho de Abrolhos		Yes									
Parque Natural do Sudoeste Alentejano y Costa Vicentina		Yes			Yes						
Basin Head Provincial Park	Yes									Yes	
Boa Vista				Yes							

Site	Key threats										
	Local human activities								Anthropogenic impacts	Climate impacts	
	Overcrowding of people in the site	Lack of investment in site infrastructure	Presence of plastics and other litter on land	Site not contributing effectively to social equity in local community	Site not adequately managed for biodiversity	Site is not adequately managed for tourism	Biodiversity negatively affected by tourism	Biodiversity negatively affected by plastics	Presence of plastics and other litter arriving from / in ocean	Potential blooms in undesirable species	Biodiversity affected by climate change events
Bojo Beach		Yes	Yes	Yes							
Cape Cod National Seashore	Yes		Yes			Yes					
Bahía de Dakhla	Yes	Yes	Yes		Yes						
Playa el Yaque	Yes	Yes		Yes		Yes			Yes	Yes	
Everglades National Park					Yes	Yes	Yes			Yes	Yes

Site	Key threats										
	Local human activities								Anthropogenic impacts	Climate impacts	
	Overcrowding of people in the site	Lack of investment in site infrastructure	Presence of plastics and other litter on land	Site not contributing effectively to social equity in local community	Site not adequately managed for biodiversity	Site is not adequately managed for tourism	Biodiversity negatively affected by tourism	Biodiversity negatively affected by plastics	Presence of plastics and other litter arriving from / in ocean	Potential blooms in undesirable species	Biodiversity affected by climate change events
Parque Nacional Marinho de Fernando de Noronha	Yes	Yes	Yes	Yes		Yes			Yes	Yes	
Praia do Fogo										Yes	
Parque Nacional Marítimo-Terrestre de las Islas Atlánticas de Galicia	Yes									Yes	

Site	Key threats										
	Local human activities								Anthropogenic impacts	Climate impacts	
	Overcrowding of people in the site	Lack of investment in site infrastructure	Presence of plastics and other litter on land	Site not contributing effectively to social equity in local community	Site not adequately managed for biodiversity	Site is not adequately managed for tourism	Biodiversity negatively affected by tourism	Biodiversity negatively affected by plastics	Presence of plastics and other litter arriving from / in ocean	Potential blooms in undesirable species	Biodiversity affected by climate change events
Cayos Miskitos y Franja Costera Inmediata					Yes						
Laguna Madre y Delta del Río Bravo		Yes	Yes								
Los Corales del Rosario y de San Bernardo	Yes	Yes	Yes		Yes	Yes					
Reserva de la Biósfera Sian Ka'an		Yes	Yes		Yes		Yes	Yes		Yes	Yes

Site	Key threats										
	Local human activities								Anthropogenic impacts	Climate impacts	
	Overcrowding of people in the site	Lack of investment in site infrastructure	Presence of plastics and other litter on land	Site not contributing effectively to social equity in local community	Site not adequately managed for biodiversity	Site is not adequately managed for tourism	Biodiversity negatively affected by tourism	Biodiversity negatively affected by plastics	Presence of plastics and other litter arriving from / in ocean	Potential blooms in undesirable species	Biodiversity affected by climate change events
Parque Nacional Natural Tayrona	Yes					Yes					
Península Valdés	Yes										
TOTAL number of sites affected	9	9	7	4	6	6	2	1	2	7	2

6.3.5 D10: Marine Litter

Clean Waters

Three reviewers gave Bojo Beach specific negative comments regarding the impact of ocean plastics (Figure 4). Their observations suggested that the plastic waste was visible from land, implying that it was concentrated near the shoreline. The reviewers noted that the presence of plastics diminished the site's visual appeal, expressed reluctance to swim or enter the polluted water, and criticized the site's management for not adequately addressing the plastic problem.

Clean site

Ten locations received negative feedback concerning the effects of plastic waste on land areas (such as beaches or nearby terrain): Reserva de la Biósfera Sian Ka'an (14), Bojo Beach (8), Boa Vista (2), Bahía de Dakhla (Morocco; 2), Los Corales del Rosario y de San Bernardo (2), Parque Nacional Natural Tayrona (2), Cape Cod National Seashore (1), Parque Nacional Marinho de Fernando de Noronha (1), Laguna Madre y Delta del Rio Bravo (1), and Península Valdés (1) (Figure 6.6).

Reviewers of these sites reported finding various types of plastic debris scattered along walking paths, across beaches, on fences bordering private properties near the sites, and even within wildlife breeding zones. Their comments often conveyed feelings of disgust, sadness, frustration, or anger at encountering plastic waste in these natural environments, a reaction seemingly intensified by the stark contrast between the pollution and the area's natural beauty.

In several cases—particularly on beaches—reviewers attributed the litter to local sources, such as nearby communities or fishing activities (as noted in Boa Vista, Bojo Beach, Cape Cod National Seashore, Bahía de Dakhla, Laguna Madre y Delta del Rio Bravo, Reserva de la Biósfera Sian Ka'an, and Península Valdés). In other instances, they blamed tourists for discarding waste along walking trails (as observed in Parque Nacional Marinho de Fernando de Noronha and Parque Nacional Natural Tayrona). Ten reviewers of Reserva de la Biósfera Sian Ka'an complained about having paid a substantial amount of money either to enter the biosphere reserve or for a guided tour but after experiencing the amount of litter in the area they described feeling that the revenue derived from these fees was not being invested by local authorities to manage the litter problem.

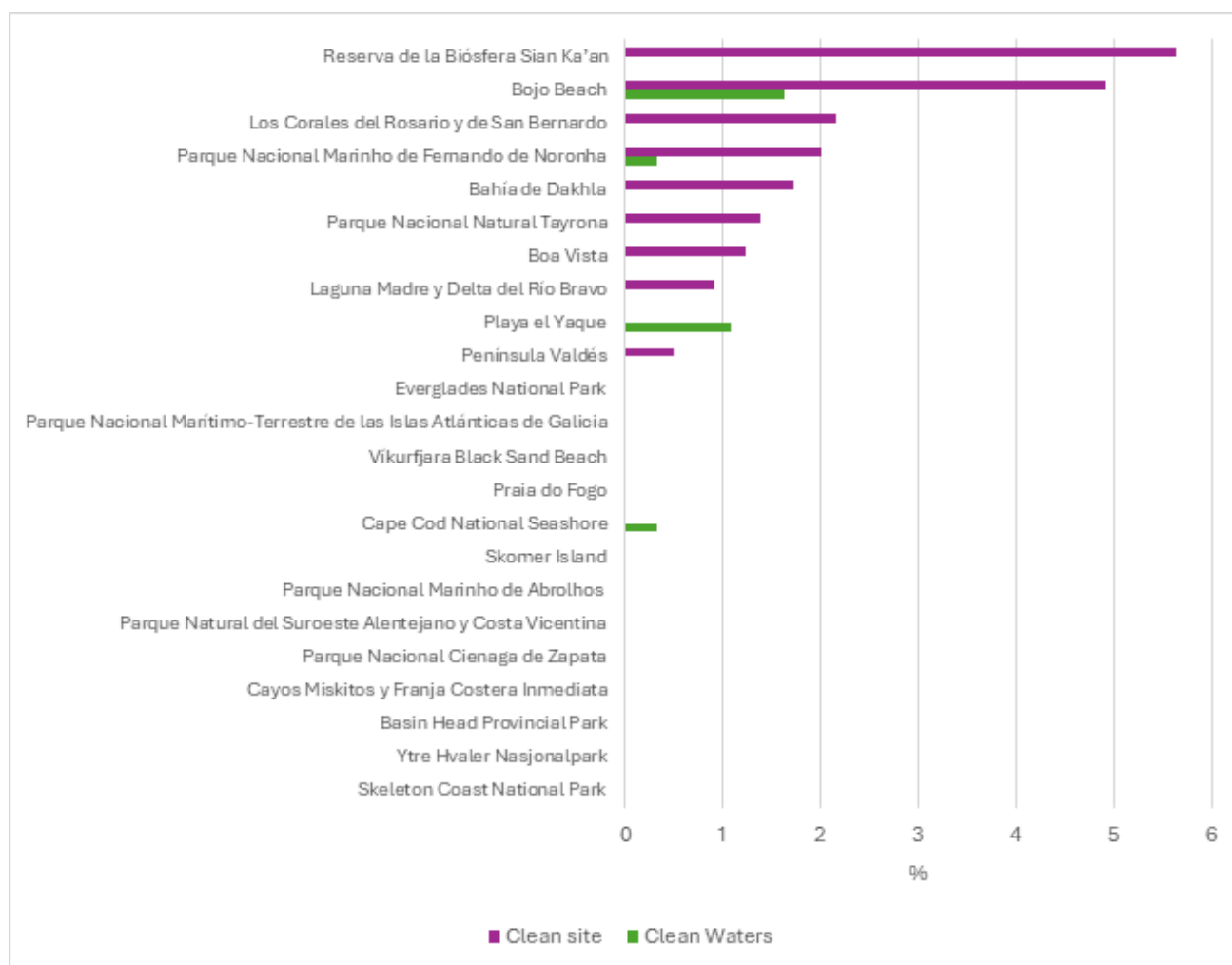


Figure 6.6: Proportion of negative reviews for each of 23 iconic marine sites relating to Clean site and Clean Waters. N=3,541

6.3.6 Marine litter hotspots

Regarding the impacts of marine litter on coastal ecosystem health, it is recommended that transboundary effects should be considered when defining overall and intermediate measurable targets. Combining in-situ observations with modelling approaches can help trace and identify the sources of litter that are transported across regions by ocean currents (Macias et al., 2019; 2022). Our data reveals that seven of the 10 iconic marine sites said to be affected by marine litter correspond closely to the passage of the Gulf Stream which is part of the clockwise rotating currents of the North Atlantic Gyre. The Gulf Stream begins flowing off the west coast of North Africa, travelling towards the Caribbean Sea, through the Gulf of America and the Straits of Florida, up the

east coast of the United States and back into the open Atlantic in a northeastern direction (European Space Agency 2015) (Figure 6.7).

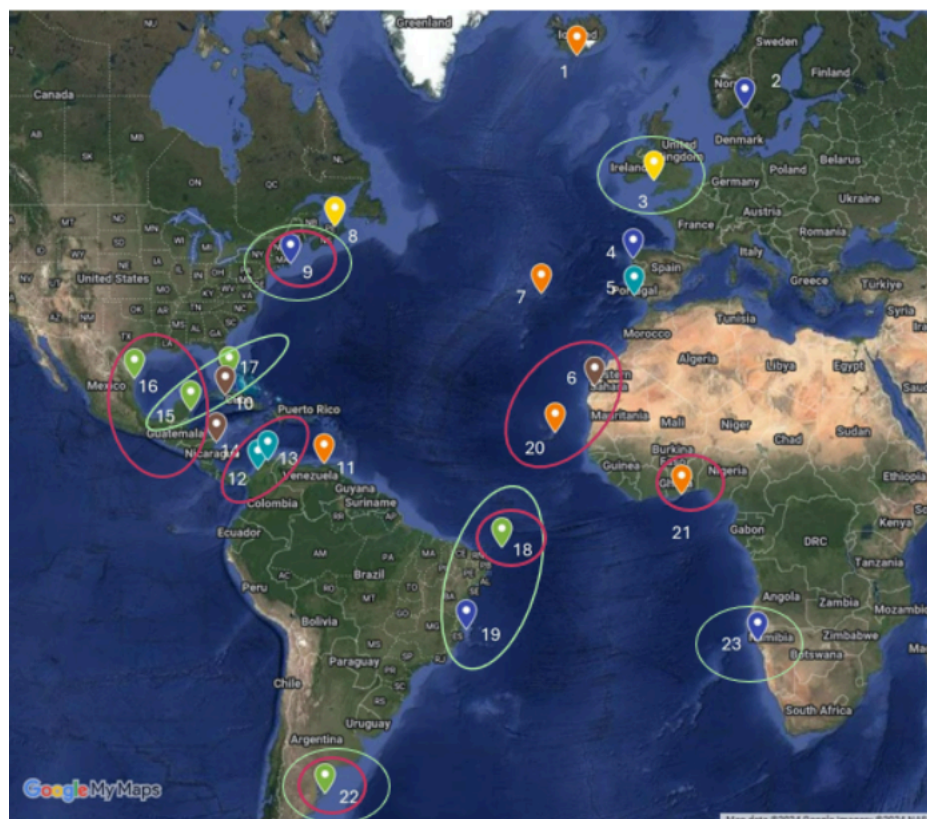


Figure 6.7: Map of 23 case study sites. Dark blue icon = National Park; green = UNESCO World Heritage Site; brown = Ramsar site; orange = tourism site; teal = national natural park; yellow = other type of protected area. Numbers refer to site names. Green circles indicate biodiversity hotspots. Red circles indicate marine litter hotspots.

6.3.7 Tourism & Recreation

Several tourism pressures were identified in numerous sites including overcrowding of people in sites (9 sites), sites not being adequately managed for biodiversity (6) or tourism (6), biodiversity being negatively affected by tourism (2) (Table 4.1). Some sites suffered from multiple pressures, e.g. Cape Cod National Seashore, Bahía de Dakhla, Everglades National Park, Parque Nacional Natural Tayrona, Los Corales del Rosario y de San Bernardo and Reserva de la Biósfera Sian Ka'an. Visitors to several of these sites also complained about a lack of investment in infrastructure, and the presence of plastics and other litter on land.

7. Interlinkages between OHI and BBNJ

The OHI provides a methodological foundation that can support the implementation of the BBNJ Agreement by offering tools for baseline assessment, monitoring, and performance evaluation in areas beyond national jurisdiction.

The adoption of the BBNJ Agreement under the auspices of the United Nations in 2023 marks a significant milestone in the evolution of international ocean governance. Formally titled the Agreement on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction, it establishes a legal framework to address long-standing governance gaps in the high seas and the deep seabed beyond national jurisdictions (ABNJ). Its core pillars—marine genetic resources (including benefit-sharing), area-based management tools (ABMTs) such as marine protected areas (MPAs), environmental impact assessments (EIAs), and capacity-building and technology transfer—aim to reconcile conservation objectives with equitable and sustainable use.

In parallel, the Ocean Health Index (OHI) has emerged as a comprehensive, science-based framework for assessing the condition of marine ecosystems and their capacity to sustainably deliver benefits to people. Rather than focusing exclusively on ecological integrity, OHI integrates ecological, social, and economic dimensions into a composite index structured around clearly defined goals, such as biodiversity, food provision, carbon storage, coastal protection, and livelihoods.

Although OHI and BBNJ differ in nature—one being a quantitative assessment tool and the other a binding international legal instrument—they are conceptually and operationally complementary. The BBNJ Agreement creates governance mechanisms and obligations, while OHI provides an integrated methodology capable of evaluating outcomes and tracking progress. Their interlinkage is particularly relevant in ABNJ, where data scarcity, fragmented governance, and cumulative pressures have historically hindered effective conservation and sustainable management. By translating complex ecological and governance dynamics into integrated indicators, OHI can enhance transparency and accountability in emerging high-seas governance mechanisms.

7.1 Conceptual convergence between OHI and BBNJ

Both frameworks are grounded in the dual objective of conserving biodiversity while ensuring sustainable use. The BBNJ Agreement explicitly frames conservation and sustainable use as mutually

reinforcing goals. Similarly, OHI is built upon the principle that a healthy ocean is one that can sustainably provide benefits to present and future generations.

OHI operationalizes this concept through a goal-based structure. For example, its biodiversity goal evaluates species status and habitat condition, while other goals assess fisheries sustainability, natural products, and ecosystem services such as carbon sequestration. This integrated perspective aligns closely with BBNJ's systemic approach, particularly its emphasis on ecosystem-based management and precaution.

The Agreement's provisions on ABMTs, including high seas MPAs, directly intersect with OHI's biodiversity and habitat protection components. OHI indicators could serve as a scientific basis for establishing ecological baselines prior to the designation of protected areas and for monitoring ecological recovery or degradation over time. In this sense, OHI provides a quantitative articulation of what "good status" or "effective protection" might look like under BBNJ implementation.

7.2. Monitoring, Indicators, and Performance Evaluation

A central challenge in implementing the BBNJ Agreement lies in translating legal commitments into measurable environmental outcomes. The effectiveness of ABMTs, EIAs, and benefit-sharing arrangements will depend on robust monitoring and reporting systems. Here, the OHI offers methodological insights.

OHI relies on transparent indicator selection, reference points, and trend analysis. Each goal is scored relative to defined benchmarks representing sustainable performance. This structure parallels the need under BBNJ for measurable conservation outcomes and periodic review mechanisms. While the Agreement does not prescribe specific global indicators, it establishes institutional processes that will require scientific input for monitoring biodiversity status and assessing cumulative impacts.

The OHI framework could inform these processes in three main ways:

1. **Baseline Establishment:** OHI methodologies for setting reference conditions and sustainability targets can guide the establishment of ecological baselines in ABNJ, where historical data are often limited.
2. **Integrated Assessment:** OHI's multi-dimensional structure allows for simultaneous consideration of ecological condition and human use, supporting holistic evaluation of ABMT effectiveness.

3. **Trend Analysis and Adaptive Management:** By incorporating temporal trends into its scoring system, OHI supports adaptive governance, a principle embedded in BBNJ through periodic review and scientific advice mechanisms.

Importantly, ABNJ governance requires cooperation across regional fisheries management organizations (RFMOs), the International Seabed Authority, and other sectoral bodies. OHI's integrative logic may help bridge sectoral fragmentation by providing a unified assessment framework that synthesizes disparate data streams.

7.3 Area-Based Management Tools and Marine Protected Areas

One of the most transformative elements of the BBNJ Agreement is the global mechanism for establishing MPAs and other ABMTs in ABNJ. Historically, the high seas have lacked comprehensive spatial protection, resulting in regulatory gaps and ecological vulnerability.

The OHI includes explicit components related to habitat conditions and biodiversity protection. These components can be spatially disaggregated and adapted to evaluate conditions in ABNJ. By integrating data on fishing pressure, habitat disturbance, pollution, and species trends, OHI-type assessments could contribute to identifying ecologically significant areas suitable for protection.

Moreover, once MPAs are established under BBNJ, OHI indicators could support effectiveness evaluation. For instance, improvements in species status, reductions in cumulative pressures, or stabilization of ecosystem services could be quantitatively tracked. This would enhance transparency and accountability, reinforcing the legitimacy of BBNJ governance structures.

7.4 Marine Genetic Resources and Equity Considerations

The BBNJ Agreement introduces a novel framework for the fair and equitable sharing of benefits derived from marine genetic resources (MGRs) in ABNJ. This reflects broader commitments to global equity and capacity-building.

While OHI does not directly assess genetic resource utilization, it incorporates dimensions of livelihoods, food provision, and economic opportunity. These goals align with the normative underpinning of equitable benefit-sharing. Furthermore, OHI's emphasis on linking ecosystem health with human well-being underscores the principle that conservation and sustainable use are interconnected with social justice.

Enhanced scientific cooperation and technology transfer under BBNJ could improve data availability and modeling capacity, particularly for developing states. This would indirectly strengthen global OHI assessments, which depend on comprehensive and spatially resolved datasets. Thus, BBNJ's capacity-building pillar may contribute to reducing knowledge asymmetries that currently limit global-scale assessments.

7.5 Data Gaps and Scientific Infrastructure

Both frameworks confront significant data limitations in ABNJ. Deep-sea ecosystems, pelagic biodiversity, and cumulative anthropogenic pressures remain incompletely understood. Effective BBNJ implementation will require expanded ocean observation systems, standardized reporting, and interoperable data platforms.

OHI's methodological transparency highlights the importance of data quality and comparability. As BBNJ institutions develop scientific advisory bodies and clearing-house mechanisms, alignment with standardized assessment frameworks such as OHI could promote methodological coherence and comparability across regions.

In this sense, the interlinkage between OHI and BBNJ is not merely conceptual but infrastructural: improvements in global ocean data governance under BBNJ would directly enhance the reliability of ocean health assessments, while OHI provides a ready-made integrative framework capable of synthesizing such data into policy-relevant indicators.

8. Conclusions

Overall, this report demonstrates that meaningful progress toward sustainable ocean governance requires both robust regulatory frameworks and integrative assessment tools. The complementarities identified between MSFD, OHI, and international agreements such as BBNJ highlight pathways for more coherent, adaptive, and inclusive marine management. Strengthening synergies between science and policy through transparent, interdisciplinary approaches will be critical for addressing the escalating challenges facing marine ecosystems in the coming decades.

The Ocean Health Index and the Marine Strategy Framework Directive represent complementary approaches to marine sustainability assessment. Both are grounded in ecosystem-based management and indicator-driven methodologies, yet they differ in institutional mandate, normative emphasis, and analytical design. The MSFD provides a legally binding framework for achieving Good Environmental Status in European seas, emphasizing ecological integrity and regulatory accountability. The OHI offers a globally standardized, ecosystem service-oriented performance metric that integrates ecological condition, socioeconomic benefits, pressures, and resilience.

Their interlinkages are evident in overlapping thematic domains (biodiversity, fisheries, pollution, habitat integrity), shared reliance on monitoring data, and alignment with sustainability objectives. Synergistic application of OHI benchmarking within the MSFD context could enhance transparency, adaptive management, and communication of marine policy outcomes.

Mapping MSFD descriptors to cultural ecosystem services through the Ocean Health Index goals provides a powerful, integrative lens on how ecological condition translates into lived human experiences. By coding spontaneous visitor reviews to OHI goals and sub-goals, this study shows that MSFD-relevant pressures (e.g. biodiversity loss, marine litter, cumulative human impacts) can be detected and interpreted in terms of the benefits and disbenefits people actually perceive at iconic marine sites. This approach reveals where and how specific MSFD descriptors—particularly those related to biodiversity (D1), marine litter (D10), and human pressures—shape key cultural values such as sense of place, tourism and recreation, and livelihoods. It highlights biodiversity hotspots where species and habitats underpin high cultural benefits, as well as litter and tourism-pressure hotspots where those benefits are undermined. In doing so, it makes visible the alignment or

mismatch between an ecosystem's capacity to provide services and the realised socio-cultural outcomes experienced by visitors.

The OHI framework offers a common language for linking MSFD implementation, ecosystem service assessments, and pluralistic socio-cultural valuations. Using OHI goals to organise visitor perceptions helps identify which ecosystem attributes matter most to people, how pressures erode those values, and where management or investment is likely to yield the greatest gains for both ecological status and human well-being. This demonstrates that routine monitoring of cultural ecosystem services, structured through the OHI–MSFD linkage, can provide actionable evidence to support more socially responsive MPAs, marine spatial planning, and ocean governance.

In the context of accelerating climate change, biodiversity loss, and cumulative anthropogenic pressures, integrating global assessment tools with regional legal frameworks represents a promising pathway toward more coherent and effective ocean governance.

The Ocean Health Index and the BBNJ Agreement represent complementary pillars of contemporary ocean governance. The BBNJ Agreement establishes a long-awaited legal architecture for the conservation and sustainable use of biodiversity in areas beyond national jurisdiction. The Ocean Health Index, in turn, provides a scientifically grounded methodology to measure ecosystem condition and the sustainable delivery of marine ecosystem services.

Their interlinkage lies in the translation of governance commitments into measurable outcomes. OHI-type frameworks can support baseline establishment, performance monitoring, and adaptive management under BBNJ. Conversely, the implementation of BBNJ—particularly through enhanced scientific cooperation and capacity-building—can strengthen the empirical foundations upon which integrated ocean health assessments depend.

Together, they illustrate the convergence of law, science, and policy in addressing the global commons. Effective alignment between assessment frameworks and governance mechanisms will be essential for ensuring that conservation objectives in BBNJ are not only legally articulated but demonstrably achieved.

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