D2.1 Development of ENHANCE One Health Framework for Coastal Management

WP2: ENHANCE requirements, co-creation, services co-design

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Date: 30/05/2025

ENHANCE

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Title of Deliverable	Development of ENHANCE One Health Framework for Coastal Management
Type of Deliverable	R (Report)
Dissemination Level	PU – Public
Work Package	WP2 – ENHANCE requirements, co-creation, services co-design
Lead Beneficiary	UTH
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Date Due.	31/05/2025
Date Submitted	30/05/2025
Status (In progress / Draft / Completed)	Completed
Reviewed by (if applicable)	Tijs Maes (NAZKA) and Giannis Adamos (AMRN)
Suggested Citation	Ioannou et al. (2025) Development of ENHANCE One Health Framework for Coastal Management. ENHANCE Deliverable 2.1, Horizon Europe grant no. 10113447

Date	Version	Contributors	Comments
14/04/2025	v0.1	Alexandra Ioannou (UTH)	Draft Version of D2.1
14/05/2025	v0.2	Alexandra Ioannou (UTH), Evmorfia Bataka (UTH), Nikolaos Kokosis (UTH), Georgia Patsioura (UTH), Chrysi Laspidou (UTH), Antonia Vronti (SLG), Georgia Tseva (AMRN), Argyrios Balatsoukas (AMRN), Ioanna Tyligada (AMRN), Giannis Adamos (AMRN), and Jaume Piera (CSIC)	Contributions from UTH to Sections 1, 2, 4, 5, and subsection 3.1, SLG to Sections 3.3 and 3.4, AMRN to Section 3.2 and Annexes, and CSIC to subsections 1.2 and 3.5
16/05/2025	v0.3	Alexandra Ioannou (UTH)	First Draft Consolidation of D2.1
28/05/2025	v0.4	Tijs Maes (NAZKA), Giannis Adamos (AMRN)	Internal review
30/05/2025	v0.5	Alexandra Ioannou (UTH)	Final Consolidation

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Table of Abbreviations

Abbreviations	Explanation
AAHR	Aquatic Animal Health Risk Index
AHP	Analytic Hierarchy Process
AMR	Antimicrobial Resistance
CS	Case Study
D	Deliverable
DPSIR	Driver–Pressure–State–Impact–Response
EEQI	Environmental Ecosystem Quality Index
EGNSS	European Global Navigation Satellite System
EU	European Union
FAIR	Findable, Accessible, Interoperable, and Reusable
GIS	Geographical Information Systems

GOHI	Global One Health Index
HAS	High Accuracy Service
IDI	Intrinsic Drivers Index
IoT	Internet of Things
KPIs	Key Performance Indicators
LAU	Local Administrative Unit
MCDA	Multi-Criteria Decision Analysis
MoSCoW	Must, Should, Could or Won't have
MSP	Multistakeholder Platform
NOAA	National Oceanic and Atmospheric Administration
OH	One Health
OP	Open Platform
SEQI	Sanitary Environmental Quality Indicator
WP	Work Package

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Executive summary

This deliverable outlines the co-creative development of the ENHANCE One Health (OH) Framework for Coastal Management. It reflects inputs from literature, stakeholder engagement, and participatory workshops conducted in the two pilot Case Studies (CSs): the Barcelona–Ebro Delta region (Spain) and the Pagasitikos Gulf (Greece).

The framework is structured around three core domains of OH approach—human, animal, and environmental health—guided by the DPSIR model. It introduces three composite indicators (SEQI, AAHRI, EEQI) to support integrated monitoring and risk assessment.

Key outcomes inform the upcoming digital services of the ENHANCE platform, aligning OH principles with real-world coastal management needs. This document sets the foundation for further technical implementation under WP3.

1. Introduction

This deliverable (D2.1) presents the foundational design of the ENHANCE OH Framework for Coastal Management. Developed under WP2, the framework introduces an interdisciplinary structure for integrating human, animal, and environmental health into coastal governance strategies. It builds upon the core principles of the One Health paradigm, which emphasize multisectoral collaboration and the interdependence of human, animal, and ecosystem health (FAO, OIE, & WHO, 2019; Destoumieux-Garzón et al., 2018). This deliverable establishes the conceptual and methodological groundwork for the digital tools and indicators to be developed under WP3.

The ENHANCE OH Framework is structured around the DPSIR model (Driver–Pressure–State–Impact–Response), enabling a causal understanding of how anthropogenic and environmental dynamics shape health risks and ecosystem resilience (Smeets & Weterings, 1999). The framework is built upon three pillars: human and socio-economic well-being, aquatic animal health, and environmental ecosystem quality. This structure supports integrated monitoring, risk prediction, and adaptive decision-making through the development of thematic indicators—namely the Sanitary Environmental Quality Indicator (SEQI), the Aquatic Animal Health Risk Index (AAHRI), and the Environmental Ecosystem Quality Index (EEQI). These indicators to be developed within ENHANCE will be informed by international frameworks and scientific literature. The SEQI will integrate parameters on microbial contamination, nutrient levels, and microplastics based on the WHO Guidelines for Recreational Water (WHO, 2003) and EU Directives (2006/7/EC; 2008/56/EC). The AAHRI will follow risk analysis principles for aquatic animal health management as described by Peeler et al. (2007), incorporating pathogen surveillance, environmental stressors and biosecurity measures, in alignment with the WOAH Aquatic Animal Health Code (WOAH, 2019). The EEQI will apply the DPSIR framework extensively used in European environmental policies, integrating remote sensing, in-situ observations and citizen science data for coastal ecosystem assessment, following Borja et al. (2006).

To inform the development of the framework, WP2 implemented a co-creation process involving literature review, identifying and developing user personas, representing the diverse range of stakeholders, who will engage with the tools of stakeholder mapping, expert consultations, and participatory workshops. These activities were carried out in the project’s two CS areas: the Barcelona-Ebro Delta in Spain and the Pagasitikos Gulf in Greece. Participants from sectors including public health, marine science, aquaculture, and local governance helped define local needs, validate assumptions, and shape the indicator selection.

The insights gathered culminated in a set of clearly defined user requirements, which will serve as a critical input for WP3. These requirements will guide and inform the design and technical development phases, ensuring the resulting tools are both user-aligned and fit for purpose. Figure 1.1 presents the connection of the ENHANCE OH framework with WP2, WP3 and WP4. Specifically, WP2 has a two-way interconnection (feeds and receives data from and to the framework) with ENHANCE OH framework as it assists its development using information from living labs, stakeholders' needs and expertise and user personas. WP3 receives inputs from ENHANCE OH framework since it serves as the cornerstone of ENHANCE OH platform by receiving the indicators, parameters for the tools, services, datasets etc. WP4 has a two-way interconnection (feeds and receives data from and to the framework) since it feeds ENHANCE OH framework with in-situ data, satellite data and citizen science data (MINKA) from the pilots.

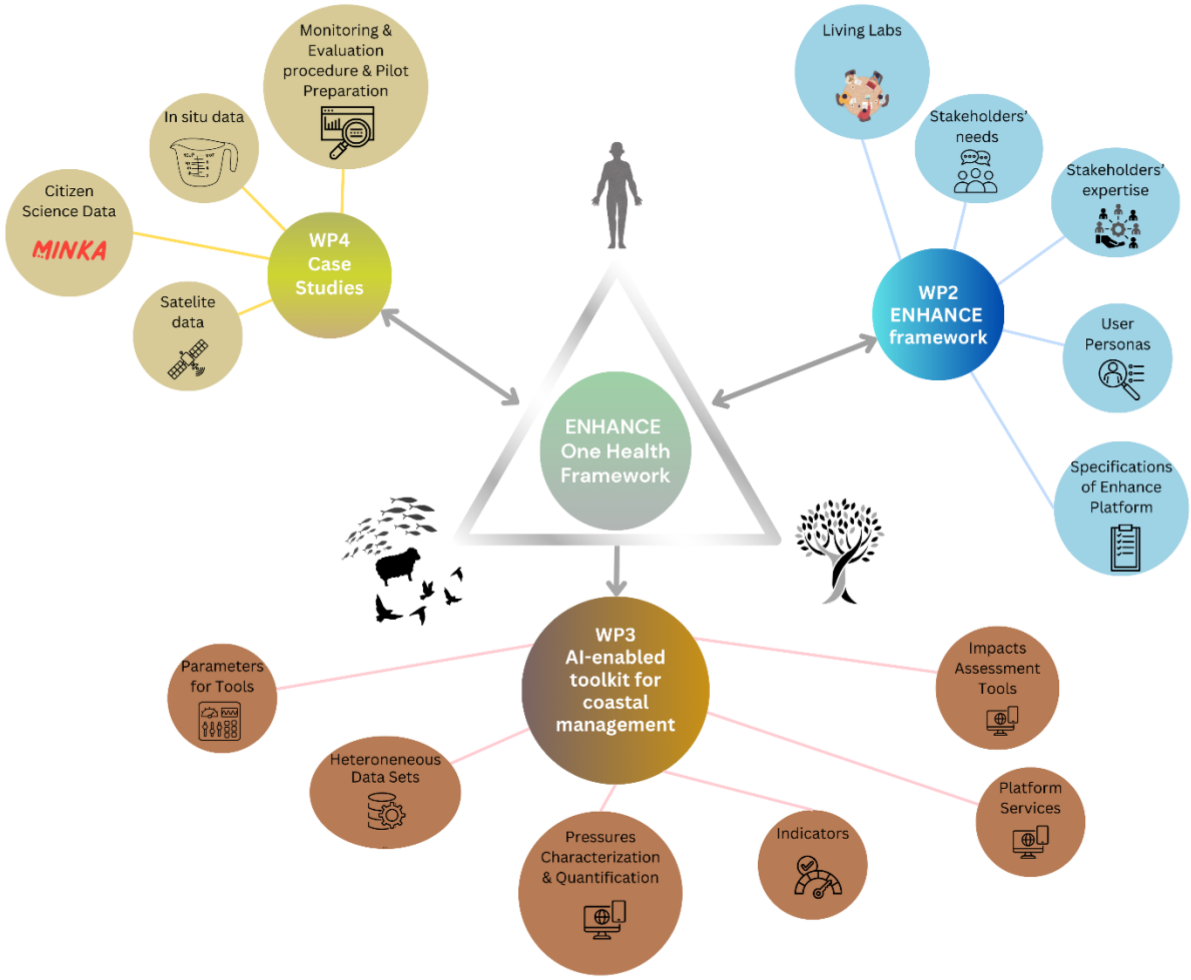

Figure 1. The interconnections between WP2, WP3 and WP4 with the ENHANCE OH framework.

This Deliverable serves both strategic and operational purposes. It lays the foundation for the implementation of OH principles within coastal management and sets the basis for the digital services and decision-support tools to be developed in subsequent phases of ENHANCE. Table 1.1 summarizes the key actions implemented to assist the ENHANCE OH framework development along with the corresponding Key Performance Indicators (KPIs). The document is organized as follows: Section 2 outlines the conceptual foundations of the OH approach and its relevance to coastal and marine environments. Section 3 presents the methodological approach, including the literature review, stakeholder mapping, and co-creation activities. Section 4 introduces the ENHANCE OH Framework, built on three core pillars and supported by key indicators. Section 5 summarizes the insights gained from co-creation processes and discusses the framework's applicability and future implementation steps.

Table 1. Objectives and corresponding KPIs for D2.1

Objective	*KPI*
Identify and document local needs and expectations for One Health-based coastal management	*9 experts interviews conducted (CS2--Greece); 2 stakeholders workshops held in pilot regions (Spain and Greece)*
Establish a structured, participatory co-creation methodology	*Co-creation process defined and applied; multi-actor participation covering 5 core stakeholder categories*
Develop the conceptual One Health Framework based on an adapted DPSIR model	*One integrated framework finalized, combining DPSIR structure with One Health pillars (human, animal, environment)*
Define preliminary structure of composite indicators (SEQI, AAHRI, EEQI)	*Initial structure and definitions drafted for 3 indicators, validated through expert feedback*
Capture user requirements for future digital services and platform features	*Functional and usability needs recorded in co-creation documentation and synthesized as input to WP3*
Define baseline engagement and participation indicators for use in platform co-design and testing	*Stakeholder typologies and inclusion criteria defined; participation KPIs prepared for WP3/WP4*

2. Conceptual Foundation: Current state-of-the-art

One Health (OH) is a collaborative, multisectoral, and transdisciplinary approach that aims to achieve optimal health outcomes by recognizing the interconnection between people, animals, and their shared environment (FAO, OIE, & WHO, 2019). Rooted in the idea that human, animal, and environmental health are deeply interdependent, the OH approach promotes integrated responses to complex health challenges such as zoonotic diseases, antimicrobial resistance, and ecosystem degradation (Zinsstag et al., 2011; Mackenzie & Jeggo, 2019).

While traditionally applied to zoonoses and food safety, the OH approach is gaining increasing relevance in coastal and marine environments, where human activity, ecological diversity, and climate-related stressors intersect (Destoumieux-Garzón et al., 2018). Coastal zones are highly dynamic systems that support livelihoods, biodiversity, tourism, aquaculture, and public health, but they are also increasingly vulnerable to cumulative pressures such as pollution, habitat loss, and sea-level rise. These overlapping drivers demand holistic and inclusive governance strategies, which the OH model supports (Hitziger et al., 2018).

In the ENHANCE project, the OH concept is applied not only to improve intersectoral coordination but also to guide the design of a functional, scalable framework that supports evidence-based coastal management. This includes advancing beyond the conventional zoonotic disease framing to include broader elements such as human well-being, aquatic animal health, environmental quality, and digital governance tools.

The ENHANCE OH Framework emphasizes the need for systems thinking and integrated monitoring approaches that capture the full spectrum of interactions across sectors. Literature shows that the implementation of OH in coastal contexts benefits from transdisciplinary partnerships, knowledge integration, and participatory processes (Norman et al., 2023; Selbach et al., 2022). However, challenges remain, including fragmented policy landscapes, limited data sharing, and difficulties in translating OH principles into practical tools (Adisasmito et al., 2022; Boudreau LeBlanc et al., 2025). These insights informed the design of the framework developed in D2.1, which aligns OH logic with existing coastal governance structures and digital infrastructures.

By combining scientific research with stakeholder input from the project's pilot regions, the ENHANCE framework lays a strong conceptual foundation for the subsequent development of risk indicators and digital services. In this way, it contributes to the operationalization of OH in real-world coastal systems.

3. Integrating Participatory Practices into the One Health Approach for Coastal Ecosystem Management

3.1 Stakeholder mapping analysis

Stakeholder mapping was a core activity under Task 2.2, with the overall aim of establishing a transparent and inclusive process for identifying, recording, and analyzing stakeholders. This process serves as a decision-making tool to support both the launch of living labs in the CSs (Task 4.4) and the implementation of all co-creation activities across the project.

To implement the stakeholder mapping activity within the ENHANCE project, analytical guidelines were developed for all partners. These guidelines defined a three-step process designed to ensure a comprehensive, inclusive, and actionable mapping of stakeholders relevant to marine and coastal ecosystems. Step 1 included the initial identification and description of stakeholders across the Quadruple/Quintuple Helix. As part of this step, partners were asked to think openly about relevant stakeholders and provide information reflecting descriptive, normative, and instrumental dimensions (Figure 3.1). An online form was used to collect and organize stakeholder group data in a consistent and structured way. Step 2 was dedicated to the analysis of the provided input about stakeholders, taking into consideration power/interest and connection levels based on established literature (Petrescu-Mag et al., 2025; Scrich et al., 2024; Awa et al., 2024; Zakaria et al., 2024 Mahajan et al., 2023), that highlights the importance of this parameters in environmental studies. These parameters were analyzed together using the framework of Reed et al. (2009). Step 3 focused on ensuring the availability and accessibility of stakeholder mapping results to all project partners. This included making the outputs of the activity available through dedicated links and integrating them into the planning of co-creation workshops and the overall living labs strategy, supporting continued engagement and strategic decision-making throughout the project.

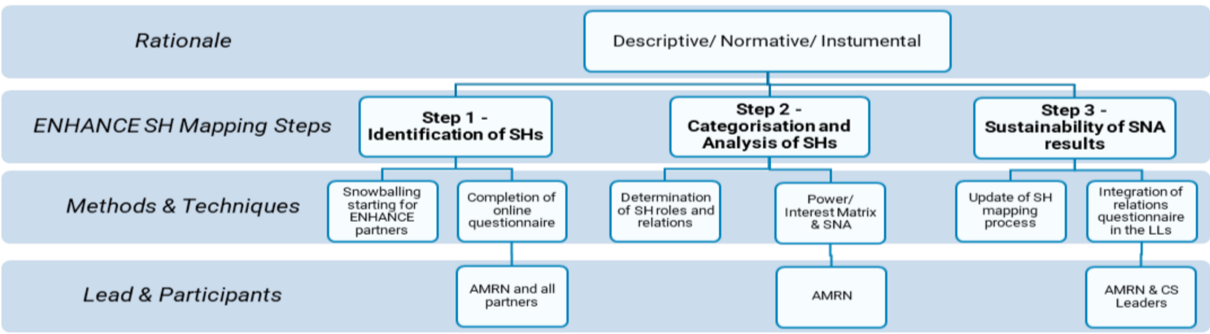

Figure 2. Adaptation of schematic representation of rationale, typology and methods for stakeholder analysis (Reed et al., 2009: 1936) in the ENHANCE project. Categorization and analysis of stakeholders considered their

organizational information (descriptive dimension), power/ interest and relations levels (normative dimension) and relevance of stakeholder mapping for the project (instrumental dimension)

3.1.1. Stakeholders descriptive analysis

The ENHANCE stakeholder mapping activity resulted in the identification and profiling of 82 stakeholders across seven countries/regions (Greece, Spain, Basque Country (Spain), Belgium, Germany, France, pan-European and international) covering local, regional, national, and international levels. These stakeholders were categorized using the Quintuple Helix framework:

- 45 stakeholders (55%) were from the higher education system, including universities, research institutes, and specialized laboratories in fields such as veterinary science, marine biology, public health, and environmental engineering.
- 20 stakeholders (25%) represented the political system, mainly local and regional authorities, municipal agencies, and port administrations involved in environmental management and policy implementation.
- 12 stakeholders (15%) fell under the economic system, covering private sector actors in tourism, food services, and marine consultancy.
- 6 stakeholders (approx. 7%) were categorized under media-based and culture-based public, including NGOs, cultural associations, and citizens' groups.
- A smaller number—around 5—were linked to environmental and sustainability networks, including international agencies and EU-level institutions.

Geographically, 40% were local, 35% regional, 15% national, and 10% international or EU-level. At the same time, 10 stakeholders were reported as linked to CS 1, while 48 were reported as linked to CS 2. In addition, 12 stakeholders were reported as possibly linked in both areas, offering valuable cross-case support while 12 were identified as possibly linked to technical activities of the project without being relevant to the CSs work.

At the same time, the stakeholder mapping carried out in ENHANCE revealed a wide representation across **sectors**. The largest group (25.3%) operates in public administration and defense, reflecting the importance of governance bodies in managing coastal and environmental policies. Professional, scientific, and technical activities represent the second-largest category, with 16.1% representing marine institutes, technical agencies, and scientific bodies. Stakeholders in human health and social work activities make up 9.2%, a key area supporting the project's One Health approach. Fishing and aquaculture are represented by 8%, while crop and animal production accounts for 6.9%, both important for the link between ecosystem and food system resilience. Education institutions contribute 5.7%, with an emphasis on environmental and marine sciences. The accommodation and tourism sector also accounts for 5.7%, relevant for understanding coastal pressures and community dynamics. Other groups include food service activities at 4.6%, administrative and support services at 3.4%, and information technology at 2.3%. Forestry and logging are represented by 1.1%. Finally, 6.9% are classified as non-applicable or mixed, often including NGOs or cultural associations with broad environmental or societal missions.

According to their relevance to **key project sectors**, the results show that:

- Public authorities at local and regional levels account for 33.7%, reflecting their central role in environmental governance and policy implementation. This segment is key to the application of ENHANCE tools and results.
- Research and education institutions (including universities, marine research institutes, and environmental schools) comprise 42.2%. This segment is essential for scientific input, cross-sectoral knowledge exchange, and long-term integration of project findings.
- Associations & NGOs make up 13.3%. Civil society involvement is important for enhancing coastal resilience and One Health advocacy.
- The tourism sector, with businesses like hotels, diving centers, and local eateries, represents 9.6%. Along with civil society's involvement, this indicates how important it is for ENHANCE to engage with actors that directly impact and benefit from sustainable coastal development.
- Environmental technology and planning services (e.g. GIS and spatial planning units) form a small but strategic segment at 2.4%.

Last but not least, with regards to the One Health dimensions, the majority (29 stakeholders) identified as contributing to all three dimensions: human, animal, and environmental health. Fish-related stakeholders (17 in total), often linked to aquaculture and marine research, form the second-largest group, followed by those focused on human health (14 stakeholders), and animal health (10 stakeholders), predominantly from veterinary and public health institutions. A smaller but important group of 8 stakeholders are specifically focused on environmental aspects, including conservation and sustainability.

3.1.2 Stakeholder normative analysis

3.1.2.1 Power Interest Matrix

As part of the ENHANCE stakeholder mapping process, a Power–Interest Matrix was implemented to assess each stakeholder's potential role and influence in the project. The matrix aimed at providing insights on aligning stakeholders' engagement to ENHANCE activities and was structured around key indicators of power, including authority (the formal right to act), capability (ability to deliver impact), credibility (perceived trustworthiness), capacity (resources and skills to act), and mass mobilization (ability to build networks). Each criterion was scored on a 5-point scale, reflecting the perceived strength of each stakeholder in that area.

To complement this, the interest dimension captured stakeholders' hope (their positive expectation toward project outcomes), aspiration (commitment toward achieving shared goals), potential benefit (likelihood of gaining value from project participation), and knowledge-building (interest in developing expertise on One Health and marine ecosystems). In this regard, the results of the Power–Interest matrix were analyzed in connection with the relevance of each stakeholder to the two CSs—Barcelona's urban beaches and the Pagasitikos Gulf. This approach was essential because co-creation activities within ENHANCE are tailored to the specific characteristics and governance ecosystems of each case study (Annex II). Below, the Power–Interest matrix results for each CS are reported and analyzed to support stakeholder engagement planning within ENHANCE.

Case Study 1: Barcelona beaches & Ebro Delta

In CS 1, all stakeholders were identified as having both high power and high interest in relation to project activities, with only minor variations - specifically, 3 (2 from tourism and 1 from the third sector) stakeholders exhibited comparatively lower levels of authority. Academia actors were not included in the list at this stage (Figure 3.2).

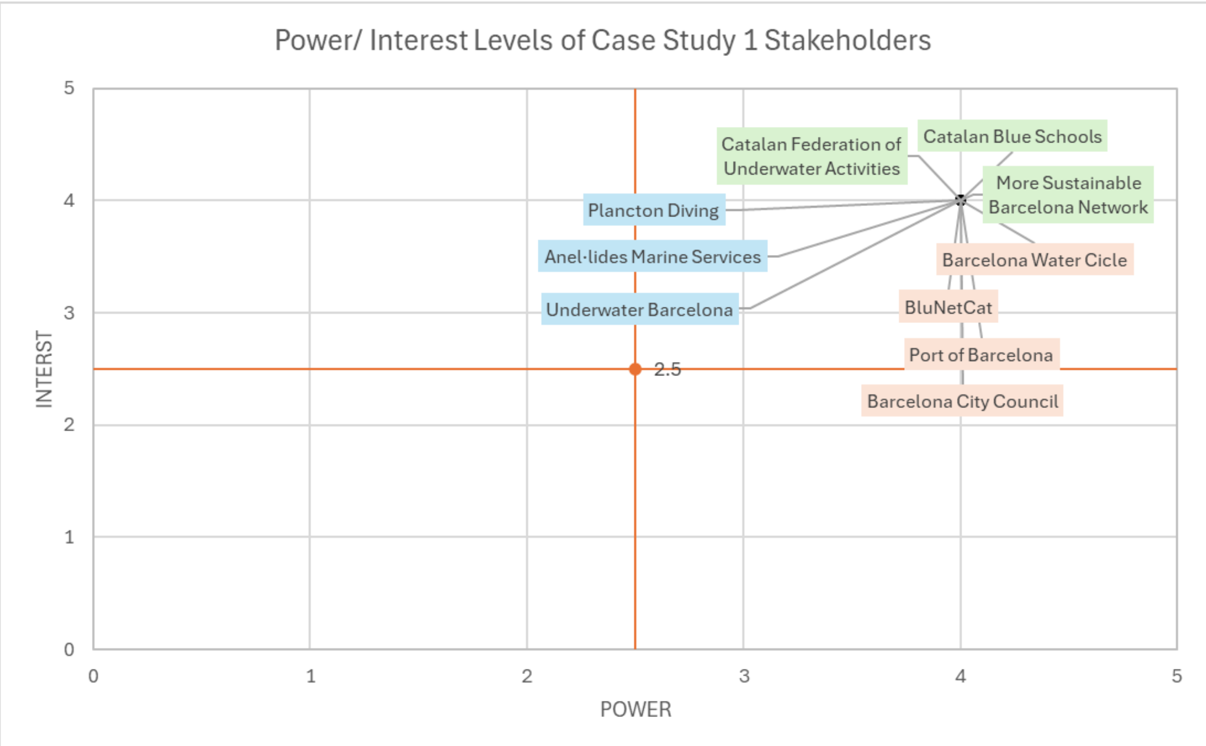

Figure 3 .Power/ Interest Matrix in Case Study 1 presenting Stakeholder Names and ENHANCE Customer Segments

	Public Authority at Local and Regional Levels responsible for policy implementation and environmental management

	Tourism
	Associations & NGOs

Case Study 2: Pagasitikos Gulf

In CS2, a more extensive stakeholder mapping exercise was conducted, revealing a broader range of power and interest levels among stakeholders presented in Graph 3.3. The stakeholder analysis reveals a concentration of high power and high interest levels among stakeholders from academia, with the majority scoring between 4 and 5 on both dimensions. These are mostly involved in fisheries, human health, crop production, and aquaculture. Policy sector stakeholders also consistently show high power (mostly 4 or 5), though their interest levels vary slightly, typically ranging between 3.5 and 4. Their institutional authority is significantly high, especially in areas like waste management, defense, and policy implementation. In contrast, stakeholders from the economic system (especially in coastal tourism and food economies) generally show lower power and interest scores, often between 1 and 2.5. Similarly, media and culture-based stakeholders, including media-based as well as environment-focused NGOs and local groups, display low power (mostly 1–3) and low-to-medium interest.

The stakeholder mapping revealed generally high median scores for both power and interest across academic and public authority stakeholders (typically scoring 4 to 5). However, significant dimensional disparities emerged when comparing individual indicators (like mass mobilization or authority) against overall median values. Academia stakeholders had strong scores in authority, credibility, and skills, but were weaker in building broad networks. Local public authorities had high power but showed lower interest in terms of motivation and long-term engagement. Private sector and tourism stakeholders, including hotels and restaurants, had low scores for power and capacity but showed more interest, especially in learning and benefiting from the project. NGOs and community groups had limited formal power but were often trusted and aligned with the project, showing stronger credibility than authority (Figure 3.3).

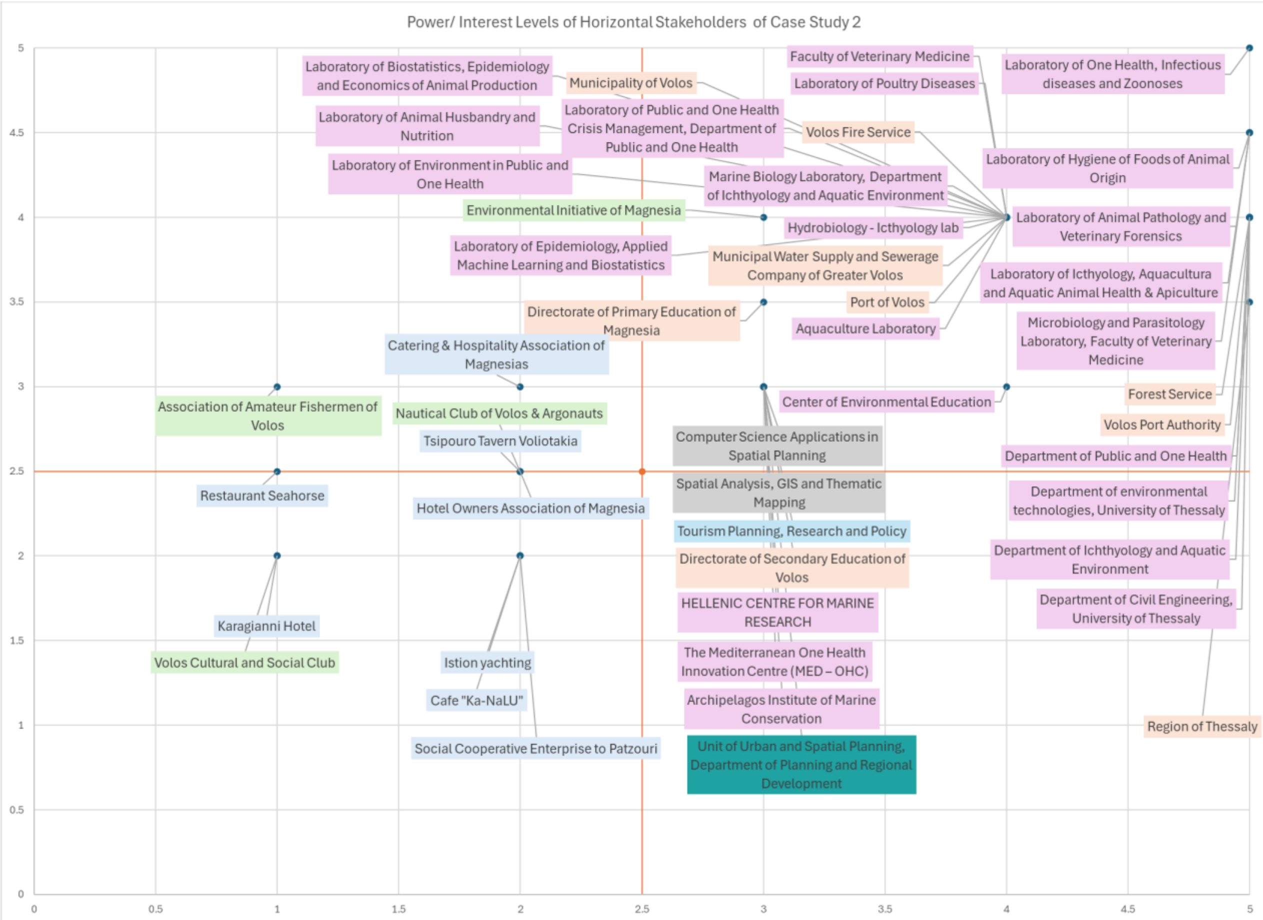

Figure 4. Power/ Interest Matrix in Case Study 2 presenting Stakeholder Names and ENHANCE Customer Segments

	Public authority at Local and regional levels responsible for policy implementation and environmental management
	Tourism
	Associations & NGOs
	Research and education sector – universities
	Developers of applications and software tools focused on environmental management
	Urban beach development

3.1.2.2. Horizontal stakeholders

This group of 12 international and EU-level stakeholders includes public institutions, marine and environmental research bodies, and NGOs. Most belong to the higher education, political, or environmental/media sectors of the Quintuple Helix model. They operate mainly at the global and EU levels, focusing on science, policy, and marine ecosystem management. In terms of the One Health approach, most are connected to the fish category, with others linked to human and animal health.

These stakeholders show strong levels of power, with a median score of 4 across most indicators, making them key players in shaping and supporting the project. While their interest levels vary, they generally show good potential for engagement, especially in areas like knowledge-sharing, research validation, and helping spread project outcomes (Figure 3.4).

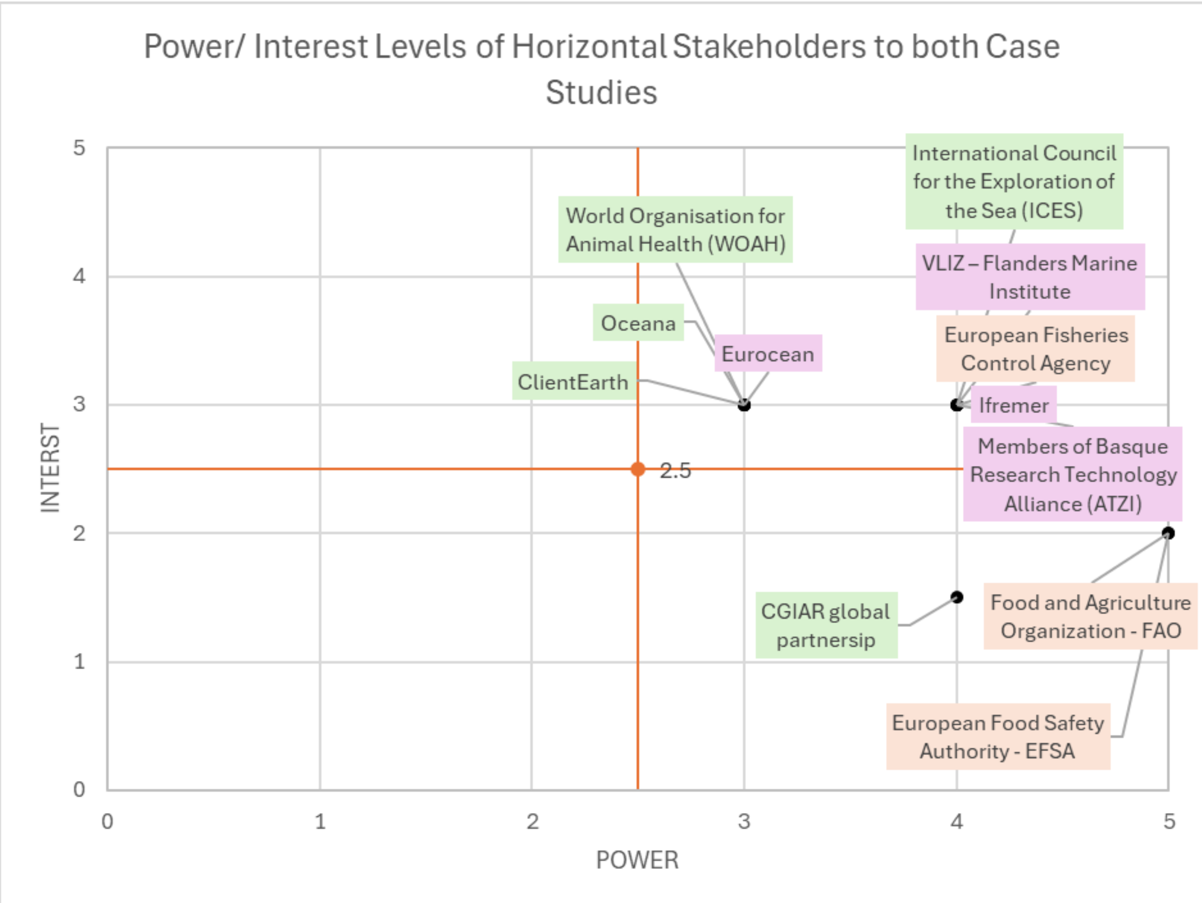

Figure 5. Power/ Interest Matrix in Stakeholder Names relevant for joint actions in between the Case Studies and ENHANCE Customer Segments

	Public Authority at Local and Regional Levels responsible for policy implementation and environmental management
	Associations & NGOs
	Research and Education Sector – Universities

3.1.2.3 Social networks analysis

As part of the stakeholder mapping process, the ENHANCE project assessed the quality of relationships between partner organizations and identified stakeholders using four key indicators: communication frequency, collaboration level, dependence/influence, and trust/alignment. Each was rated on a scale from 1 (lowest level) to 5 (higher level), offering insights into both the intensity and strategic importance of these relationships. The evaluation assessed the extent to which stakeholders who suggested other important actors also interact with them and share a mutual understanding of ENHANCE's fields of activity. [See also Annex I].

Case Study 1: Barcelona Beaches (Area A) & Ebro Delta (Area B)

In CS1, there is a high level of trust with all stakeholders, while at the same time communication and collaboration are mostly moderate, and influence is concentrated in a few actors. The Catalan Federation of Underwater Activities emerges as the most engaged partner overall. The Port of Barcelona, despite lower collaboration and communication, is strategically influential. This suggests a solid foundation for co-creation, but with room to enhance interaction with several stakeholders and expand the network based on the initially identified actors, allowing for the creation of separate stakeholder networks for the two areas of the CS, as shown in Figure 3.5.

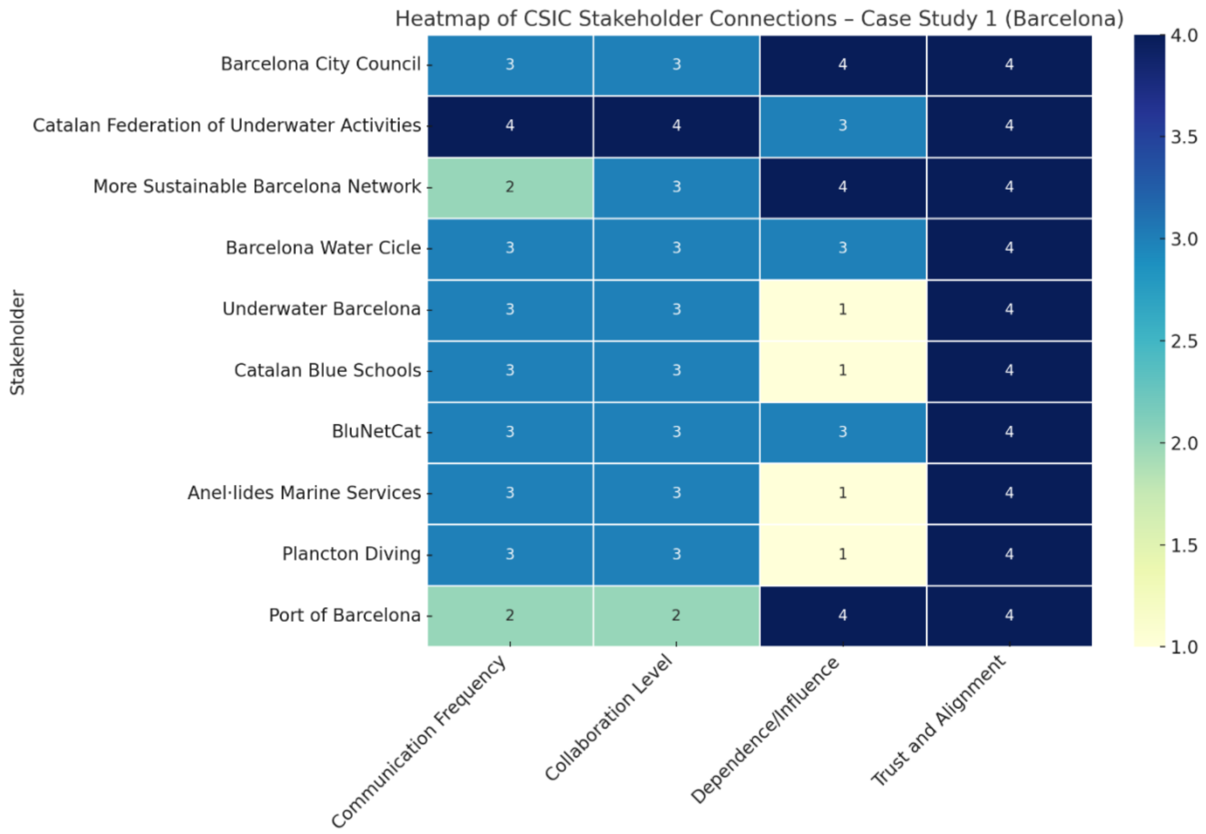

Figure 6. Strength of stakeholders' relations to CSIC relevant for activities in Case Study 1

Case Study 2: Pagasitikos Gulf

In CS 2, most stakeholders show low to moderate engagement levels, typically scoring 2 for communication and collaboration, and 3 for dependence/influence and trust. This indicates that while trust is somewhat established, regular interaction and deep collaboration are still limited. Strengthening partnerships would require more consistent communication and joint activities (Figure 3.6).

Figure 7. Strength of stakeholders' relations to UTH relevant for relevant for activities in Case Study 2

3.1.2.4 Horizontal stakeholders

The heatmap of horizontal stakeholder connections to AMRN reveals a consistent level of trust and alignment (rated 3) across all actors, indicating a baseline of mutual respect and shared strategic interests. However, communication frequency, collaboration level, and dependence/influence remain uniformly low (rated 1), suggesting limited or no current operational engagement. Despite this, these stakeholders have been purposefully mapped due to their high credibility, technical expertise, and strong relevance to marine governance and scientific advancement at the EU and international levels (Figure 3.7).

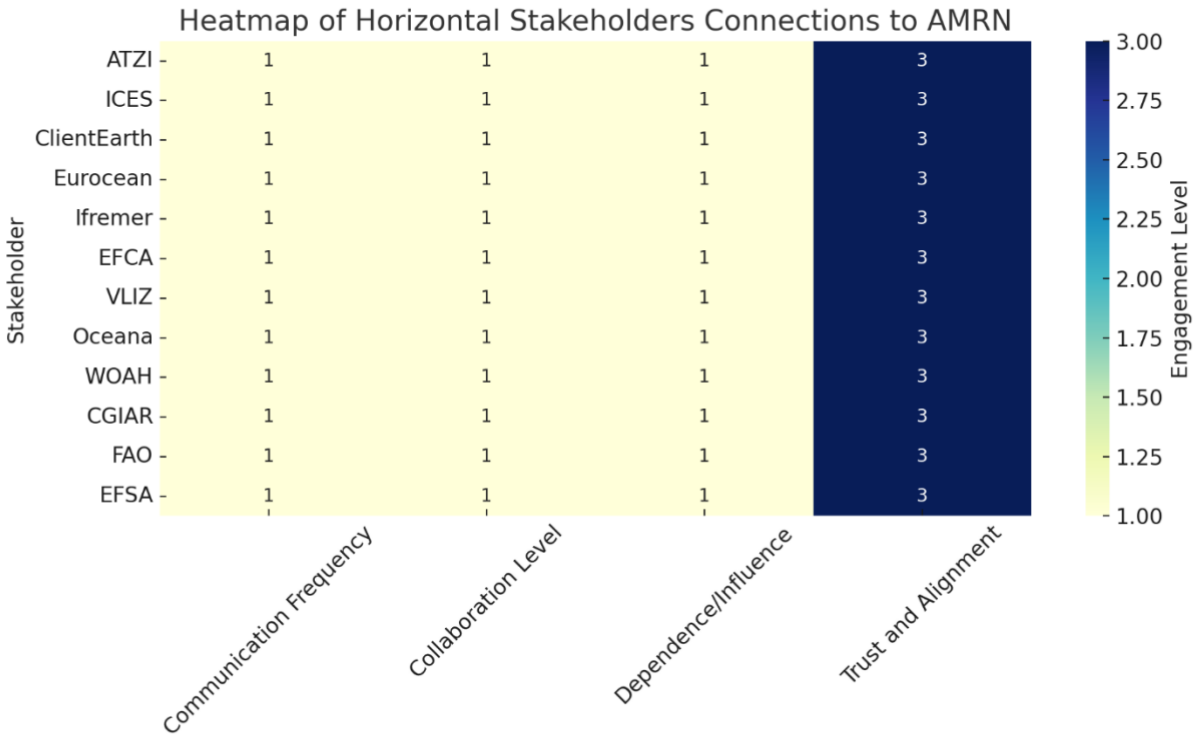

Figure 8. Strength of stakeholders' relations to AMRN relevant for joint actions in between the Case Studies

3.1.3 Instrumental analysis

Stakeholder maps developed within the ENHANCE project will be actively integrated as key decision-support tools. The stakeholder mapping activity has already aided the development of user scenarios under Task 2.3, through the two dedicated workshops implemented (see section 3.3) and will play a central role in shaping the next project phase - specifically the initiation of the living labs across the CS.

In collaboration with CS leaders, maturity assessments[1] have been conducted to better understand the readiness, needs, and context-specific dynamics of each CS.

CS 1 demonstrates a high degree of maturity in both living lab development and stakeholder engagement. Area A (Barcelona Beaches) has a well-established stakeholders' network built through several years of sustained citizen science activities, public outreach initiatives, and institutional collaboration. This has resulted in a robust ecosystem of stakeholders, comprising participatory (citizens), academic (research institutions), mobilizing (intermediary organisations), and facilitating (public authorities) communities. In this context, the Barcelona City Council's integration of marine biodiversity into its agenda exemplifies the impact of coordinated stakeholder engagement and data-driven decision-making. The main challenges ahead involve scaling stakeholder engagement in Area B (Ebro Delta) and addressing barriers related to data integration and platform interoperability. This is because the Ebro Delta reflects an earlier stage of living lab readiness. Stakeholder engagement in this area is comparatively limited, though there is considerable potential to replicate successful strategies piloted in Area A, such as the Biomarathon initiative and the targeted involvement of local actors through small-scale pilots.

Based on that and taking into consideration the stakeholder mapping results in CS 1, priority should be given to living labs and targeted workshops as the main platforms for collaboration. One-on-one meetings and interviews are ideal for high-power actors like the Barcelona City Council and Port of Barcelona, who influence decision-making. Workshops and co-creation sessions will help actively involve NGOs and educational stakeholders such as Catalan Federation of Underwater Activities and Catalan Blue Schools, fostering public awareness and participation. Tourism and private sector stakeholders, while currently less involved, can be engaged through scenario-based activities and by demonstrating clear mutual benefits. A mix of formal sessions and informal outreach is needed to improve communication, build trust, and align stakeholders with ENHANCE project goals.

The living lab maturity in case study 2 is emerging, but there is limited stakeholder involvement thus far. Planned actions, such as methodology training workshops and targeted stakeholder events, will be key to the development of partnerships and support the co-creation of solutions. The success of this case will depend on activating local networks and ensuring alignment between scientific outputs and community needs.

According to stakeholder mapping results, stakeholder engagement in CS 2 should follow a tiered strategy based on stakeholder type and readiness. Academic and institutional actors, who show high trust, alignment, and scientific capacity, are ideal for early involvement through living labs, interviews, and co-design workshops. Local and regional authorities should be engaged in decision-making activities, helping define the One Health framework. Private and tourism stakeholders, although less connected, can be activated in later stages through targeted pilot actions and awareness efforts. NGOs and citizen

[1] This was implemented through focused interviews with Case Study leaders, and specifically on 24/03/2025 with Case Study 1 and 26/03/2025 with Case Study 2.

groups can support communication, community mobilization, and environmental monitoring, especially during the second phase of living lab implementation.

These assessments, combined with stakeholder mapping insights, will support the structured launch of the living labs, beginning with Phase 1: Co-creation and framework design.

This first phase (Figure 3.8) will focus on:

- Validating and updating the identified stakeholder lists.
- Co-defining the vision, objectives, and expected outcomes of each CS living lab.
- Launching targeted co-creation activities tailored to each CS's ecosystem.

Table 2. Living Labs initial plan

Project Phase	**1 – ENHANCE Co-creation Activities, Framework Design & Tools Development**	**2 – ENHANCE Tools Development & Pilot Preparation**	**3 – 1st Pilot Cycle ENHANCE Tools Validation**	**4 – 2nd Pilot Cycle**
Project Phase Time Frame	M1-M16	M17-M24	M25-M30	M31-M36
LL Workshop Aim	Develop a shared Vision – problem statement	Tailor the One-Health Approach to the aims of the CSs	Validate ENHANCE tools with local communities	ENHANCE solutions replication for upscaling (International –joint)
LL Workshop Date	Around M15 – before the initiation of measurement in the CSs	Around M20 – parallel to the CSs 1st demonstration and after training activities on the usage of ENHANCE tools	Around M27 – parallel to CSs 2nd demonstration	Around M32
Contents	Needs Identification Co-creation of Solutions in support of ENHANCE toolkit actions (Section 3.3)	First feedback on the ENHANCE toolkit Co-creation activities during pilot demonstrations Adaptation of solutions for the second full release of the ENHANCE tools	Co-creation and development of solutions Evaluation of social acceptance ENHANCE toolkit validation Co-creation on the exploitation plan Co-design of post-project activities to boost outcomes and visibility	Lessons learned from the 2 CSs Evaluation of the ENHANCE Toolkit Replication Roadmap and recommendations Future scenarios for sustainable coastal management

A core component of this phase will be the organization of one main living lab workshop in each CS, engaging high-power, high-interest stakeholders who are directly relevant to the local context. These actors will contribute to refining the direction and ambition of the living labs and ensure strong ownership of the solutions developed.

In parallel, horizontal stakeholders (e.g., EU-level institutions, NGOs, and technical bodies with cross-case relevance) will be integrated through task-specific activities across the project. To ensure alignment, an internal stakeholder engagement needs assessment will be initiated. This will allow each partner to define their engagement priorities and requirements, enabling a coordinated outreach strategy.

Building on the stakeholder mapping analysis, which examines the roles, influences, and interactions of key actors in coastal governance, the following section focuses on the co-creation of ENHANCE solutions and user scenarios. By incorporating stakeholder insights, this phase employs collaborative and interdisciplinary approaches to develop innovative strategies that enhance coastal resilience and promote sustainable management practices.

3.2 Co-creation of the ENHANCE solutions and user scenarios

As part of the development of the ENHANCE toolkit, it is important to understand the needs and expectations of end-users to design tools that are meaningful, effective, and user-centered. A key element in this process is the development of user personas and user scenarios. User personas are fictional, yet research-based representations of key user groups. They provide insights into the users' goals, behaviours, challenges, and motivations, helping designers empathize with diverse stakeholders and anticipate their needs (Cooper et al., 2014; Pruitt & Adlin, 2006).

Building on personas, user scenarios are narrative descriptions that illustrate how users might interact with a service in real-life contexts to achieve specific objectives. These scenarios help in visualising the user experience, identifying touchpoints, and foreseeing potential barriers. They support the generation of ideas, the exploration of technological possibilities, and the refinement of technical requirements by embedding user needs into design decisions (Carroll, 2000; Sasse, 2006).

To ensure the ENHANCE toolkit effectively addresses real-world challenges, it is crucial to engage key stakeholders across the case studies' sites in the creation of these personas and scenarios. This participatory design approach ensures that the resulting solutions are not only technically robust but also socially relevant and user-appropriate (Sanders & Stappers, 2008). This chapter outlines how ENHANCE approaches the involvement and engagement of end users in the development of the ENHANCE tools within the broader context of co-creation. It describes how technical development is embedded within established social labs and how this development will proceed through three main phases (see Figure 3.9).

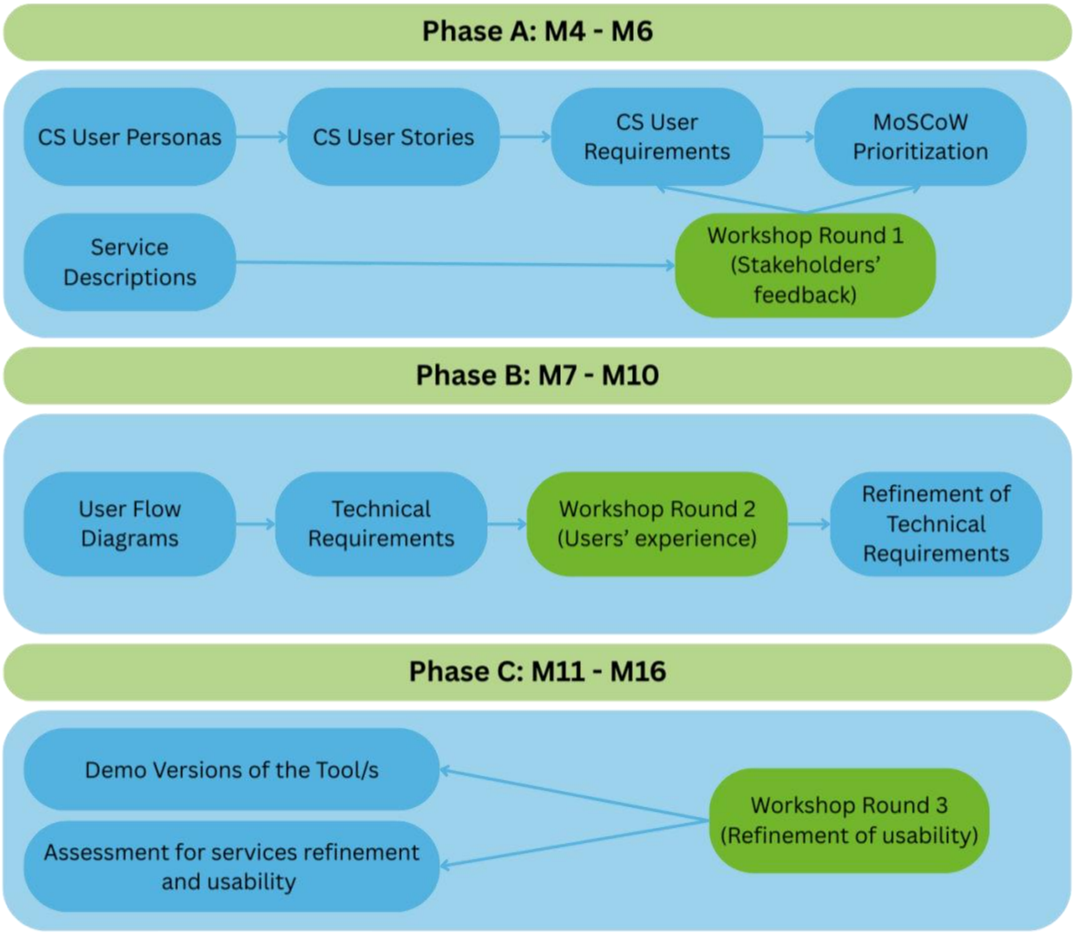

Figure 9. The three phases of the co-creation of the ENHANCE tools

Phase A (M2–M6) focused on gathering information and feedback from ENHANCE stakeholders to better understand the specific needs of the two case studies. The goal was to ensure that the tools developed will be aligned with real-world requirements and effectively support the unique contexts of each case.

Both case studies were asked to provide high-level context, including a brief description of their focus, key needs, relevant stakeholders, and available data. CS1 targeted anthropogenic coastal pressures, while CS2 focused on climate-resilient beaches. Based on this input, each case study identified relevant user personas (see Annex III), which served as the basis for drafting initial user stories.

The user personas identified in the two case studies capture a diverse set of actors involved in coastal and environmental challenges.

For CS1, the identified personas include public sector administrators and managers, educators, aquaculture producers, veterinary and biosecurity professionals, as well as stakeholders from the tourism and hospitality industry.

For CS2, the user personas encompass a general practitioner at a local health center, a fish farming unit owner, an olive oil and vegetable producer, a veterinarian, a tourist accommodation owner, and a secondary school teacher.

Together, these profiles reflect a wide range of perspectives, responsibilities, and needs, highlighting the importance of cross-sectoral approaches in designing effective environmental monitoring.

To enrich and validate this information, each case study conducted a dedicated workshop (Figure 3.11, CS1 online workshop), held in the local language, to facilitate more meaningful engagement and gather deeper, context-specific input from stakeholders. These workshops aimed not only to gather insights into the stakeholders' challenges and needs but also to inform the definition of initial user requirements for the ENHANCE tools. The user requirements will also support the second phase of the co-creation methodology.

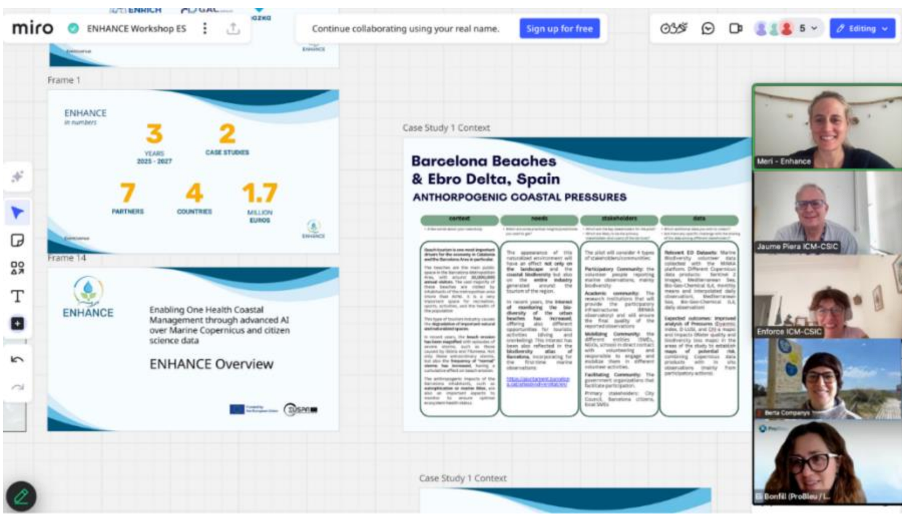

Figure 10. CS1 online workshop

Phase B (M7-M10) focuses on the co-design of user-friendly environments and the development of user flow diagrams. Based on the needs identified by the two case studies, one or two user flow diagrams are created to represent key interactions between end users and the ENHANCE tools. These diagrams help visualise how different user personas engage with the services, highlighting potential user journeys and touchpoints.

A joint workshop will be held in English with stakeholders from both case studies to discuss the proposed diagrams and collect further feedback on the interaction design. This collaborative session ensures that the tools being developed remain aligned with user expectations and operational needs.

Further details on the results of this phase will be included in D2.2: First version of the ENHANCE scenarios and platform specifications.

During **Phase 3** (M11-M16), a more concrete version of the ENHANCE tools and platform specifications will become available for stakeholders to test and provide feedback. This phase emphasizes usability testing and iterative refinement of the tools based on stakeholder input.

A short assessment will also be developed to evaluate the functionality and usability of the tools from the end-user perspective. The insights gathered during this phase help enhance the user experience and contribute to the multidimensional evaluation of the services throughout the case study activities.

Following the development of ENHANCE solutions and user scenarios, the next section explores expert consultations and collaborative workshops aimed at refining these strategies. Drawing on interdisciplinary expertise and case-specific evaluations, this phase enhances the practical implementation of proposed measures, ensuring their effectiveness in addressing coastal resilience and sustainable governance challenges.

3.3 Expert consultation and co-creation workshops

As outlined in the previous chapter, a workshop was conducted during the initial phase of the methodology. This workshop was held in the native languages of the case study regions, Spanish and Greek, to facilitate more meaningful and contextually informed feedback from participants familiar with the local settings. Further details and key outcomes from the workshops are provided in the sections below, offering deeper insights into the discussions, activities, and findings that emerged.

3.3.1 CS1 Barcelona beaches & Ebro Delta results

The workshop for CS1 was held online on April 29th and conducted in Spanish. The session began with an overview of the project to provide context, followed by an icebreaker activity designed to help participants feel more comfortable and engaged with one another. The workshop included two main interactive activities. The first activity (Figure 3.12) invited participants to share their insights on the objectives, key functions, data needs, and user journey of the tool or tools to be developed within the project. The second activity focused on prioritizing the key functions identified in the first round, using the MoSCoW method—categorizing features as Must have, Should have, Could have, or Won't have, for now. To support collaborative input and visual organization, a Miro board was used as the main platform throughout the workshop. Based on the contributions from the attendees, the results are presented as follows.

Based on the context shared by the CS leaders during the workshop and the feedback received from participants, the tool is expected to address several critical challenges related to coastal and marine environmental management. Its primary objectives include enabling real-time monitoring of water quality, particularly in beach areas, enhancing understanding of urban coastal biodiversity, and assessing the effects of pollution on shellfish, agriculture, and broader ecosystems. Key problems it aims to solve include the lack of real-time monitoring capabilities, insufficient understanding of biodiversity in coastal zones, and the impacts of chemical pollution on marine life and food systems. Additionally, the tool seeks to address the fragmentation of monitoring systems at local, national, and EU levels, the limited resources available for educational fieldwork (especially in schools), and the low public awareness around water quality and marine conservation. To tackle these issues, the tool is designed with several overarching goals: promoting environmental stewardship and citizen engagement, integrating various monitoring initiatives and datasets, supporting educational outreach through schools and community science, and enabling informed, data-driven decision-making for coastal and urban water management.

Participants in the workshop identified several essential functions that the tool should include to effectively support coastal and marine environmental management. At its core, the tool should enable comprehensive environmental monitoring, including tracking chemical pollution in the Delta, assessing materials found on coastal and underwater beaches, and studying the shellfish community to monitor ecosystem health. In terms of data collection and analysis, the tool should support the analysis of water parameters and include features for intercalibrating sensors to ensure the accuracy and consistency of collected data. To foster user engagement and collaboration, the tool should help local authorities and users quickly identify environmental issues, support working groups that can coordinate responses to coastal impacts and allow citizens to easily record species observations and contribute data. It should also include mechanisms for gathering user feedback and facilitating open discussions. Concerning accessibility and privacy, the tool must be freely available and designed to protect user data, particularly for students participating through schools. Finally, the platform should serve as a bridge between citizen contributors and marine experts, encouraging broader community involvement and knowledge sharing.

To support its intended functions, the tool must be built on a strong foundation of validated and well-integrated data. It should prioritize the use of validated environmental datasets, such as those from governmental or institutional sources, and ensure that all data complies with FAIR principles—being Findable, Accessible, Interoperable, and Reusable. In addition, the system should incorporate provenance tracking and quality control mechanisms to maintain data integrity and transparency. A diverse range of data types is essential, including high-quality biodiversity data, maps that highlight anthropogenic pressures, marine litter, and various forms of debris, as well as visual indicators of biological impacts—particularly those affecting shellfish. To support responsive action, the tool should also include early warning systems for pollution or environmental degradation events. The platform should be capable of handling multimedia input and output, allowing users to upload or access content in formats such as photographs, audio recordings, and observational logs. Finally, external integration is a key feature, particularly with platforms like EMODnet (European Marine Observation and Data Network), to enrich the tool's marine litter data and connect it to broader European datasets.

The expected interaction flow for the tool follows a structured, participatory approach that encourages broad involvement across user groups. In the acquisition phase, data is gathered by a diverse range of contributors, including citizen science volunteers, subject-matter experts, and school groups participating through educational programs. This inclusive approach ensures a rich and varied dataset. The validation phase involves expert reviewers and advanced users with domain-specific knowledge who assess the submitted data for accuracy and scientific reliability, helping maintain the integrity and credibility of the information. Once validated, the data moves into the visualization phase, where it is transformed into accessible, easy-to-understand formats to support interpretation and communication. These visualizations are designed to engage all actors within the quadruple helix model, academia, the public sector, industry, and civil society, making the data actionable across a range of stakeholders. In the final decision-making phase, these insights empower individuals and institutions to take informed, data-driven action, influencing environmental strategies, shaping policy, and supporting community-led initiatives for coastal and marine management.

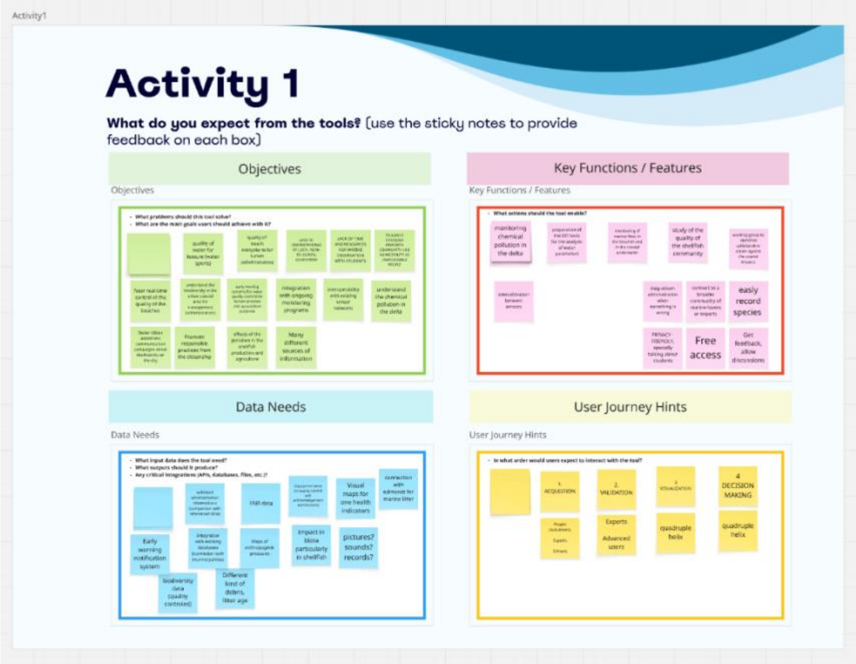

Figure 11. CS1 workshop - Activity 1 results

As part of the second activity, participants were asked to prioritize the key functions and features they wished to see in the tool using the MoSCoW method—categorizing them as Must, Should, Could, or Won't have. This exercise helped clarify what elements are considered essential for the tool's effectiveness and which ones, while desirable, are not strictly necessary.

Among the must-have features, participants emphasized core functionalities such as the ability to report environmental observations, tools for data validation, and a dashboard for tracking and visualizing data. They also highlighted the importance of ensuring privacy compliance, maintaining connections with global repositories, and enabling tools to download validated data. In terms of environmental monitoring, features to measure key environmental parameters and support agile validation processes were considered indispensable.

The should-have features include enhancements that improve usability and collaboration. Participants recommended incorporating AI support tools to streamline operations, developing a user-friendly system, and enabling access through both desktop and mobile applications. Additionally, tools to facilitate interaction among community members, create dedicated spaces for direct end-user contact, and provide maps and filters for more nuanced data exploration were considered valuable.

Features that fell into the could-have category were seen as beneficial but not critical. These included options to gamify data input and user engagement, launch push notifications or calls, and provide interactive visualization systems. Other suggestions involved enhancing multilingual support, improving data ingestion for a better user experience, and incorporating functions to empower policymakers and stakeholders through improved data communication.

Lastly, the won't-have category identified features to be avoided. Participants opposed the inclusion of a static system, emphasizing the need for adaptability and responsiveness. They also raised concerns about making personal data public, underscoring the importance of GDPR compliance. Furthermore, the group cautioned against features that could lead to false alarms, particularly in the context of early warning systems.

Overall, this prioritization exercise helped define a clear vision for the tool's development, focusing on data integrity, privacy, accessibility, interactivity, and meaningful user participation, while deliberately avoiding rigid, insecure, or misleading system components.

3.3.2 CS2 Pagasitikos Gulf results

The workshop for CS2 was held on April 29th in Volos, Greece, and followed a similar structure to the CS1 session. The event began with an introduction to the project, providing stakeholders with context and background. Rather than relying on structured activities, the format was more discussion-based, allowing participants to openly share and explore the key challenges, objectives, and needs relevant to their local context. This approach facilitated a deeper understanding of the specific environmental and sectoral issues affecting the region.

The workshop revealed several critical challenges in environmental management, waste handling, and biosecurity within the coastal and port areas. In maritime waste management, stakeholders highlighted inefficiencies in current systems, noting that although ships are required to pay port fees and dispose of waste, some waste, particularly from yachts, is often dumped at sea, and illegal discharges occur during maintenance activities. Bilge water is transported to Athens for treatment, while solid waste is directed to landfills, and waste oils from port machinery are stored appropriately. Environmental monitoring remains limited, conducted only a few times annually, and focuses mainly on airborne pollutants. Stakeholders expressed the need for a more comprehensive and transparent set of environmental indicators. Anticipated regulatory changes, such as mandatory cold ironing by 2030, were discussed alongside concerns about sea and sediment quality due to inputs from Lake Karla and dredging activities.

On veterinary and agricultural waste, significant gaps were identified, including the absence of facilities for safe manure processing and the improper disposal of animal carcasses, posing serious public health risks. Stakeholders emphasized the urgency of replicating successful waste management models and implementing basic biosecurity practices in farms and slaughterhouses. The misuse of pastureland and growing antibiotic resistance due to insufficient oversight were also major concerns, particularly with upcoming changes such as mandatory electronic prescriptions for antibiotics in livestock by 2026.

In terms of data management, the need to clearly distinguish between data providers and users was stressed, especially for sensitive information like manure distribution. Jurisdiction overlaps between authorities were seen as obstacles to coherent environmental governance in coastal regions. Finally, gaps in marine life monitoring and fish traceability systems were discussed. The lack of coordinated responses to stranded marine mammals and limited public awareness of seafood origins underscored the need for improved communication and the active involvement of fishermen and aquaculture operators in environmental initiatives.

3.3.2 Conclusions

The workshops for CS1 and CS2 provided valuable insights into the environmental, social, and technical challenges facing coastal and marine ecosystems, while fostering a collaborative space for stakeholders to shape the vision of a digital monitoring and engagement tool. Through interactive exercises, participants identified the critical functions, data needs, and user flows required to support real-time environmental monitoring, public awareness, and citizen science efforts. The CS1 session emphasized the importance of integrating diverse data sources, ensuring privacy and accessibility, and enabling informed decision-making through intuitive visualization and engagement features. The prioritization of features using the MoSCoW method brought clarity to the tool's development roadmap, ensuring that core capabilities—such as observation reporting, data validation, and secure data sharing—take precedence, while future enhancements can build on this foundation.

In CS2, the discussions highlighted systemic gaps in waste management, veterinary practices, and biosecurity in coastal zones, emphasizing the urgent need for coherent regulatory frameworks, reliable data infrastructure, and greater transparency. Across both case studies, the recurring themes of stakeholder collaboration, data integrity, and public engagement emerged as central pillars for success. Moving forward, these findings will inform the co-design and implementation of the digital tool, ensuring it is both responsive to local contexts and scalable across diverse European coastal regions. The process reaffirmed the value of participatory design in creating solutions that are not only technologically robust but also socially grounded and environmentally impactful.

Expanding on the insights gained from expert consultations and co-creation workshops, the next section introduces the technical specifications of the ENHANCE platform. By aligning Copernicus and EGNSS technologies, this phase focuses on optimizing data integration and synchronization, enhancing coastal monitoring and management capabilities. Additionally, the incorporation of EGNSS with the Internet of Things (IoT) establishes a framework for more efficient, real-time environmental assessments, ensuring informed decision-making in marine governance.

3.4 Specifications of ENHANCE Platform – Copernicus/EGNSS alignment and synchronization

The design of the ENHANCE platform responds to the growing demand for a robust system that facilitate secure and trustworthy data exchange among stakeholders in the coastal management domain. The evolving landscape of marine and coastal data management in Europe has seen remarkable progress, driven by initiatives like the Copernicus Marine Services. The ENHANCE platform will be the basis for the implementation of the innovative ENHANCE decision support services for the coastal management. It will also enable the use of (big) data and remote sensing to the prevention, conservation and management of marine ecosystems. ENHANCE will leverage ongoing deployment, along the BUILDSPACE project (Arsenopoulos et al. 2024), for the integration of Copernicus data and services.

The ENHANCE platform will extend the data services to enable the integration of citizen repositories and other in-situ data sources. In addition, we will implement appropriate Data Space connectors and facilitate data exchange among marine stakeholders.

The main expected services for the platform are listed below:

- Integration remote sensing data (Copernicus) with in situ observations (mainly from participatory actions)
- Identification of pressures (through D-LUSI index and Chl-a maps)
- Evaluation of impacts (Water quality and biodiversity loss maps)
- Analysis of extreme events
- Maps of potential risk

Table 3.1 provides the reference of the expected products in relation with the Copernicus sources (and complementary sources).

Table 3. ENHANCE primitive indicators in relation to the One Health components and data sources

Dataset name	Domain	Data type	Main variables	Product type	Horizontal coverage	Horizontal resolution	Vertical resolution	Temporal resolution	File format	ENHANCE Service	ENHANCE Case study
DLUSI-SENTINEL 2	RS-Copernicus	Gridded	Multispectral bands	Observation derived	Global	10-60 m	Surface	5-10 days	SENTINEL-SAFE	D-LUSI	CS1, CS2
DLUSI-L3-CMEMS	CMEMS	Gridded		Model and observation derived	Global	0.1°x0.1°	Surface	Daily	Netcdf	D-LUSI	CS1, CS2
DLUSI L4-CMEMS	CMEMS	Gridded		Model and observation derived	Global	0.05°x0.05°	Surface	Daily	Netcdf	D-LUSI	CS1, CS2
CAT-MONITORING	Local monitoring program	Point based	Temperature Salinity Freshwater content Chlorophyll-a Nitrate Nitrite Ammonium Phosphate Silicate	Observation derived	Regional (Catalonia)	Fixed stations	Surface	1-3 months	CSV	D-LUSI	CS1
MINKA-Biodiv	Citizen Obs.	Point based	Biodiversity	Observation derived	Europe	10x10km 1x1 km	Surface	Unstructured, monthly integrated	JSON, CSV	Biodiversity, Ecosystem health status	CS1, CS2
HAB Monitoring	Local monitoring program	Point based	HAB Phytoplankton species	Observation derived	Local Alfacs Bay	5 fixed stations	Fixed depths	weekly	CSV	HAB Detetction	CS1
Chl-a-SENTINEL 2	RS-Copernicus	Gridded	Chl-a derived product	Observation derived	Global	10-60 m	Surface	5-10 days	SENTINEL-SAFE	Chl-a	CS1, CS2

3.4.1 EGNSS and Internet of Things (IoT)

The Internet of Things (IoT) is a term used to describe the extension of the internet to the world of objects. The purpose of IoT is to provide greater connectivity for systems, services, and devices beyond the simple idea of machine-to-machine communication, encompassing a wide range of applications and domains. LoRa is a wireless communication technology, specifically designed for long-range, low-power, and low-data-rate communications, making it ideal for Internet of Things (IoT) applications. The improvement of IoT, has been already identified as one of the key application areas for the European Global Navigation Satellite System (EGNSS, Fig. 3.11). EGNSS offers specialized signal components tailored for IoT applications and low-end receivers. These components aim to improve signal acquisition time, reduce computational complexity, and enable faster first fix for battery-powered devices. EGNSS also offers services like the High Accuracy Service (HAS) that provides corrections for improved positioning accuracy, which can be utilized by IoT devices

Figure 12. EGNSS application areas.

ENHANCE has started exploring the possibilities to connect IoT low-cost devices, using LoRA, and getting the position using EGNSS services

The first exploration activity was implemented with the installation of a LoRa antenna in the roof of the Marine Science Institute (ICM-CSIC, Fig. 3.13). The first communication tests validate the possibility to develop a network of IoT devices, oriented to provide complementary information related to water quality, that could be used potentially for improving the observational systems proposed in ENHANCE.

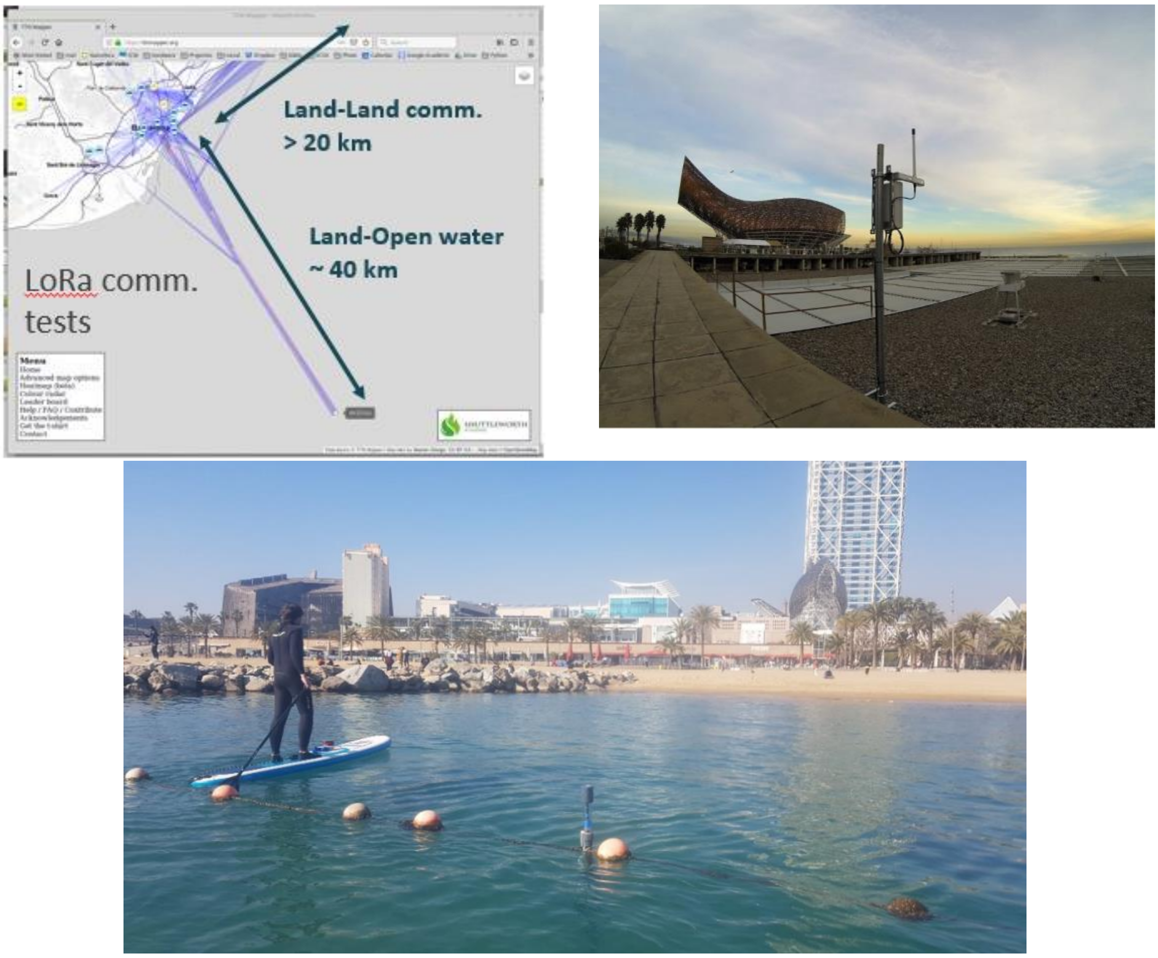

Figure 13. IoT Instruments: Instrument to measure water transparency (KduStick, Rodero et al. 2022). Prototype with Sigfox-LoRa communication capabilities.

Based on these initial results, ENHANCE is planning to explore the development of DIY devices (such as the ones developed in Rodero et al. 2022), with the possibility to include EGNSS compatible receivers to offer the improved IoT services for water quality monitoring.

Building upon the foundational analysis of OH through stakeholder mapping, and collaborative solution development, the subsequent section transitions toward the methodological construction of a composite indicator for OH assessment. This phase establishes a robust theoretical framework, systematically integrating environmental, socio-economic, and governance dimensions to enhance evaluation accuracy. Furthermore, the selection of appropriate indicators and the implementation of a structured data processing workflow ensure the reliability and applicability of OH assessments, supporting evidence-based policy formulation and coastal management strategies.

4. Towards a Holistic One Health Assessment Framework Aligned with Coastal Area Needs

The integration of the OH approach into coastal and marine governance frameworks offers a transformative pathway for addressing interconnected challenges at the interface of human, animal, and environmental health. Coastal zones represent complex and dynamic ecosystems where socio-economic development pressures and ecological vulnerabilities intersect. As such, advancing the OH approach in these areas necessitates holistic, cross-sectoral governance models that foster collaboration among diverse stakeholders, promote evidence-informed decision-making, and ensure policy coherence across spatial and administrative scales. This ENHANCE OH approach not only identifies key best practices, challenges, and policy developments but also provides critical insights that inform and strengthen the conceptual framework underpinning the ENHANCE OH approach. Figure 4.1 summarizes the steps to be followed for the ENHANCE OH framework for coastal areas.

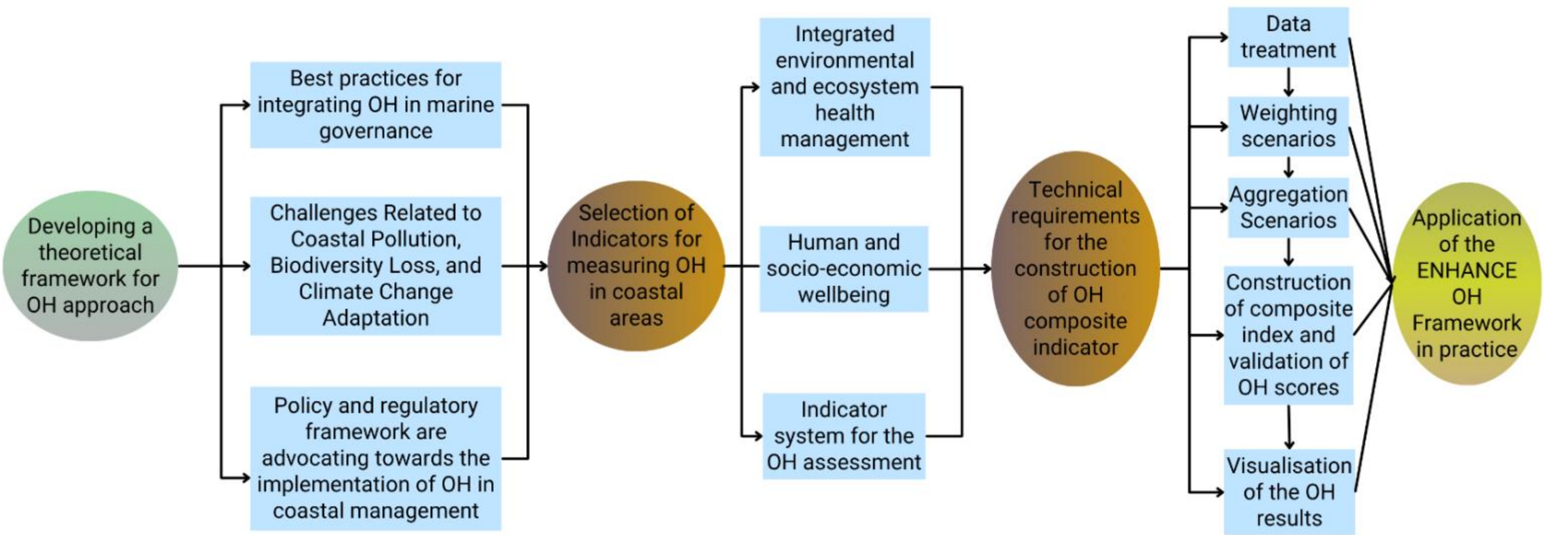

Figure 14. Flowchart of the ENHANCE OH framework

4.1 Developing a Theoretical Framework for OH approach

The development of a composite OH indicator requires a carefully designed framework for selecting and combining variables that truly capture the multifaceted interactions between human, animal, and environmental health. Guided by the "fitness-for-purpose" principle, this process ensures that each variable included serves a specific function in representing the broader OH context. To achieve this, the involvement of interdisciplinary experts and relevant stakeholders is essential from the outset. Their insights help identify critical health determinants, validate data sources, and ensure contextual relevance, while also promoting transparency and legitimacy. Through this participatory approach, the resulting indicator becomes a robust, purpose-driven tool capable of informing policy, enhancing intersectoral collaboration, and guiding targeted interventions within the OH domain. Specifically, CS1 and CS2 workshops played a crucial role in building the indicator list for the development of the composite indicator. Some indicative ndicators that were retrieved from the workshops were micro plastics, antibiotic usage in livestock, and hospital waste management.

ENHANCE OH approach explores current applications of OH in coastal governance, focusing on best practices, challenges, and policy instruments that support their implementation (Destoumieux-Garzón et al., 2018; Essack, 2018).

4.1.1 Best Practices for Integrating One Health in Marine Governance

Integrating OH into marine governance requires a cross-sectoral perspective that bridges disciplines such as marine biology, veterinary science, environmental science, and public health. Effective implementation depends on the collaboration between these sectors. The key best practices identified in the literature include Multistakeholder Platforms (MSPs), Knowledge Integration, and Adaptive Management.

Establishing MSPs is crucial for fostering collaborative governance in coastal management. These platforms bring together diverse stakeholders from local communities, civil society, industry, and governance to jointly address coastal challenges. As reported in recent literature, these collaborative mechanisms enhance decision-making through inclusive processes and the integration of different knowledge systems (Adisasmito et al., 2022; Boudreau LeBlanc et al., 2025; Fountain-Jones et al., 2024; Norman et al., 2023; Selbach et al., 2022; Hitziger et al., 2018).

Knowledge Integration can significantly contribute to improving maritime governance. It is important that scientific knowledge shapes both policy and practice. Integrated approaches - such as multi-criteria analysis, modelling tools and intelligent systems - help turn data into actionable knowledge. These tools facilitate scenario planning and evidence-based decision-making. Moreover, interdisciplinary research that combines expertise from different fields can encourage new collaborations and foster collective action (Destoumieux-Garzón et al., 2018; Essack, 2018; Poto et al., 2021; Selbach et al., 2022; Norman et al., 2023).

Adaptive Management has gained ground as a flexible and iterative approach to address uncertainty in coastal governance. It involves the continuous monitoring, evaluation, and revision of strategies in response to emerging data and changing conditions. This approach is particularly useful in dynamic coastal environments where both environmental and human factors are rapidly evolving. Studies have shown that adaptive systems are best suited for predicting and responding to environmental risks (Fountain-Jones et al., 2024; Essack, 2018; Zhang et al., 2022; Zhou et al., 2022; Boissier et al., 2016; Reed et al., 2022).

4.1.2 Challenges Related to Coastal Pollution, Biodiversity Loss, and Climate Change Adaptation

Coastal regions face specific challenges related to coastal pollution (environmental component), biodiversity loss (animal and environmental component), and climate change adaptation (environmental component). These challenges stem from a complex interaction among intense human activities and vulnerable ecosystems. They are deteriorated by population density (human component), diverse ecosystems, and essential infrastructure found in coastal zones. Key challenges identified in the literature include Coastal Pollution, Biodiversity Loss, and Climate Change Adaptation.

Coastal Pollution, caused by agricultural run-off, industrial dumping and urban waste, is one of the most persistent threats to marine ecosystems. Nutrient loading from agriculture, for example, can cause harmful algal blooms that reduce oxygen and harm aquatic life. Plastic waste, including corrosive coastal landfills, adds another level of pressure. These impacts require robust monitoring systems and mitigation strategies, as highlighted in the literature (Zhou et al., 2022; Norman et al., 2023; Boissier et al., 2016; Destoumieux-Garzón et al., 2018; Essack, 2018; Mehta et al., 2025; Reed et al., 2022).

Biodiversity Loss in coastal ecosystems is a complex phenomenon as a result of the degradation of coastal habitats, such as mangroves, salt marshes, and coral reefs. These are unique ecosystems that are home to rich and diverse biodiversity. The degradation of these habitats, caused by anthropogenic factors such as urbanization, intensive agriculture and overfishing, is leading to a significant loss of biodiversity. These habitats act as natural climatic buffers, reducing wave energy and trapping residues. Therefore, they assist in the protection of coastlines against erosion, as supported by several recent studies (Jato-Espino et al., 2023; Norman et al., 2023; Selbach et al., 2022; Destoumieux-Garzón et al., 2018; Essack, 2018; Reed et al., 2022). Human activities, such as overfishing, coastal development and pollution, add significant pressure on marine ecosystems, impairing their ability to support rich marine biodiversity and ensure their protection. Therefore, conservation and restoration initiatives prove to be essential to preserve biodiversity and maintain ecosystem functions (Destoumieux-Garzón et al., 2018; Essack, 2018; Zhang et al., 2022).

Climate Change Adaptation is essential for protecting coastal areas, which are particularly vulnerable to the impacts of climate change, including sea-level rise, increased storm intensity, and changing weather patterns. Rising sea levels threaten to submerge low-lying areas, while more frequent storms accelerate the erosion of beaches and cliffs (Zhang et al., 2022; Norman et al., 2023; Selbach et al., 2022; Destoumieux-Garzón et al., 2018; Essack, 2018; Mehta et al., 2025). Ecological approaches, such as the restoration of mangroves and coral reefs, can offer natural solutions to combat these threats while promoting biodiversity. In this context, the implementation of adaptive and resilient coastal management strategies is proving essential to mitigate the risks associated with climate change (Essack, 2018; Destoumieux-Garzón et al., 2018; Zhang et al., 2022).

4.1.3 Policy and Regulatory Framework advocating towards the implementation of OH in coastal management.

Effective implementation of OH principles in coastal management expects robust policy and regulatory frameworks that support multi-sector alliance and integrated governance. Key frameworks identified in literature include International and Regional Legal Instruments, European Union Policies, National Coastal Zone Management Programs, Data-Sharing Mechanisms.

Within International and Regional Legal Instruments, the integration of OH, is essential to meeting and addressing global health challenges. Legal approaches that implement OH are based on principles of international environmental law, sustainable development frameworks and governance mechanisms governing global sustainability (Adisasmito et al., 2022; Muhammad-Bashir & Halimah, 2022; Norman et al., 2023; Destoumieux-Garzón et al., 2018; Essack, 2018; Bullón Caro et al., 2024). Regarding the ability to combat pandemics (human and animal component), transform food systems, adapt to climate change, mitigate biodiversity loss and combat pollution, aligning legal instruments with OH principles could be an appropriate strategy (Destoumieux-Garzón et al., 2018; Essack, 2018; Zhang et al., 2022).

Several European Union Policies incorporate the principles of a global approach to health. These are particularly the case for the General Union's Environmental Action Programme 2030, the Zero Pollution Action Plan and the Animal Health Act (Boudreau LeBlanc et al., 2025; Selbach et al., 2022; Norman et al., 2023; Destoumieux-Garzón et al., 2018; Essack, 2018). The aim of these public policies is to constitute a comprehensive framework to protect human health, animal health, and the environment. To this end, they promote sustainable practices across all endeavor sectors. The European Green Deal, the farm-to-table strategy and the biodiversity strategy are examples of policies that benefit from an OH approach (Destoumieux-Garzón et al., 2018; Essack, 2018; Zhang et al., 2022).

National Coastal Zone Management Programs, like those implemented by NOAA, provide a framework for comprehensive coastal management. The purpose of these programs is to support states in addressing important coastal issues, including population growth, flood risk (environmental component), and the need for responsible coastal development. Funding for program development, administration, implementation and improvement is vital to reinforce the evolution of coastal management (National Park Service, 2015; NOAA, 2015).

Enhancing Data-Sharing Mechanisms among research institutions, policymakers, and coastal communities is critical for improving decision-making processes. This is a prerequisite for improving decision-making processes. Standardized data-sharing frameworks, such as the FAIR principles, encourage the free and open dissemination of data within the ocean observation community. Collaboration between data providers and users, formal channels for data requests and policies supporting transparency and accountability are essential elements for effective data sharing (Boissier et al., 2016; Destoumieux-Garzón et al., 2018; Essack, 2018; Deng & Yan, 2020).

4.1.4 Cross-sectoral governance and Policy Integration

Effective coastal management requires a holistic approach that integrates various divisions and policies. The ENHANCE OH framework gives emphasis to cross-sectoral governance and policy integration as an essential overarching pillar for achieving sustainable coastal development (European Commission, 2024). This analysis explores the implementation of MSPs for coordinated coastal governance, the alignment of OH principles with European and international marine conservation policies, and the optimization of data-sharing mechanisms between research institutions, policymakers and coastal communities.

MSPs are designed to combine and collaborate with diverse stakeholders, including local communities, environmental organizations, government agencies and private sector entities, to address complex coastal challenges (Ratner et al., 2022). Integrating diverse perspectives and expertise within MSPs results to improved decision-making processes and ensures inclusive and comprehensive management strategies. This demands clear rules of procedure, capacity-building initiatives and adaptive learning mechanisms. The decision-making process provided by MSPs are based on the latest research and data (Kusters et al., 2022) and they promote increased ecosystem resilience, contribute significantly to the preservation of biodiversity, and encourage the achievement of sustainable development goals (Barletti et al., 2022). In the context of maintaining marine environment, it is critical to understand the alignment of OH principles with European and international marine conservation policies.

The OH approach, is gradually more integrated into European and international marine conservation policies. This approach is proving fundamental in addressing current global health challenges, including zoonoses (animal component), antimicrobial resistance (human component) and climate change (European Commission, 2024).

The interdisciplinary holistic OH approach, must be further integrated and aligned into marine conservation policies, indicating the need of integrating health considerations into environmental regulations and management strategies. This implies a transformation of current models, aiming to adopt more ecological, social and economic sustainable systems. The European Green Deal, the farm-to-fork strategy and the biodiversity strategy are illustrations of policies that benefit from a OH perspective (European Commission, 2024).

Moreover, the effective implementation of OH principles in marine conservation policies requires strong governmental leadership and cross-sectoral alliance. EU must promote the sharing of best practices, strengthen surveillance and monitoring systems, and support interdisciplinary research to direct new threats to health and the natural environment (European Commission, 2024).

The integration of diverse data—biological, physical, chemical, and socio-economic—plays a vital role in assessing environmental conditions and the impact of human activities. Geographic information systems (GIS) and geospatial tools are essential in this process, enabling stakeholders to monitor ecosystem changes, evaluate habitat health, and track coastal degradation. These technologies enhance data collection, analysis, and application, ensuring well-informed policies and conservation strategies (Caribbean Natural Resources Institute, 2025).

It is imperative to adopt and promote collaboration between data providers and users to optimize data sharing mechanisms. This involves establishing formal procedures for data requests, providing metadata and implementing policies that promote transparency and accountability. By improving data ease of access and interoperability, stakeholders are able to make more informed decisions, which contribute to sustainable coastal management (Trice et al., 2021).

4.2 Selection of Indicators for measuring OH in Coastal areas

The selection of indicators for constructing a OH composite index should be grounded in analytical soundness, ensuring that each variable is conceptually robust, empirically measurable, and directly relevant to the interconnected dimensions of human, animal, and environmental health. Indicators must not only reflect the complexity of the OH paradigm but also demonstrate adequate data availability, geographical coverage, and comparability across contexts. Where direct data are limited, the careful use of scientifically justified proxy variables becomes essential. Crucially, this process should be participatory, incorporating the expertise of interdisciplinary scientists, public health professionals, veterinarians, ecologists, and policy stakeholders to validate indicator choices, ensure alignment with real-world OH challenges, and enhance the practical utility of the resulting index.

Additionally, stakeholders and practitioners can identify key pressures or risks in a region, match them to the appropriate indicators (SEQI, AAHRI, EEQI), and use the results to inform planning and intervention strategies. The framework is designed to work alongside the digital services developed in WP3 (OP), allowing real-time data integration and adaptive management. Its flexible structure enables adaptation to diverse coastal contexts and supports iterative updates based on stakeholder engagement and local feedback.

Indicators were selected and classified under the three OH pillars, structured across thematic axes and operationalised through specific sub-indices (Table 4.1). The Human Health pillar includes indicators such as adolescent fertility, infectious and non-communicable disease incidence, household air pollution, and domestic health expenditures. The Animal Health pillar incorporates indicators like zoonotic disease occurrence (e.g., brucellosis, rabies), antibiotic use in livestock, livestock density, and presence of endemic or threatened animal species in coastal ecosystems. The Environmental Health pillar captures local-level metrics such as air pollution (PM, NO_2, O_3), fertilizer consumption, wastewater treatment coverage, urban land use, and biodiversity habitat representativeness.

As the ENHANCE progresses and matures, the indicators used within the OH assessment framework will be upgraded and dynamically adjusted to reflect the evolving needs and priorities of the involved stakeholders. The dialogue with stakeholders will take place through specially designed workshops, which will serve as interactive platforms for the exchange of knowledge, experiences, and expectations. Through these participatory processes, it will be ensured that the final assessment framework is harmonised with local needs, policy priorities, and emerging challenges in the field of OH in coastal areas.

To assess OH, a comprehensive assessment framework is proposed that incorporates the three main pillars: Human Health (Pillar 1), Animal Health (Pillar 2), and Environmental Health (Pillar 3). These pillars are divided into specific thematic fields, which reflect the key dimensions of each domain. These thematic fields are supported by sub-indexes that quantify different aspects of the three dimensions that capture and quantify human, animal and environmental implication. These components contribute to the overall assessment of OH status. Table 4.1 represents the proposed OH assessment framework to be applied by WP3 for the construction of the composite OH indicator an integrated tool for the evaluation of OH status and policy-making.

The following sections explores the critical interconnections between human health, socio-economic development, and systemic inequalities, highlighting how One Health can serve as a catalyst for inclusive, sustainable development and long-term societal well-being in Coastal ecosystems.

4.2.1 Integrated environmental and ecosystem health management

According to Destoumieux-Garzon et al. (2018) combining different techniques and interventions should be developed by connecting the study of the factors underlying stress responses to their effects on ecosystem functioning and evolution for the OH approach to succeed. This can be achieved by simplifying and analysing the barriers of the different sciences that separate human and veterinary medicine from ecological, evolutionary and environmental fields to form the OH approach. This information is necessary to create new management methods that are motivated by the environmental processes and result in the equilibrium and dynamics that are wanted in healthy ecosystems. It is also important to provide a clear framework for coordinated operational activities in the near future. The authors also stress the importance of the addition of ecological health to the "One Health" holistic approach. This is because so far documents and publications concentrate on addressing developing zoonozes from domestic (Day, 2011) or wildlife sources (Mencke, 2013), including their interactions (Papadopoulos & Wilmer, 2011), while largely not considering the significance of inclusive ecosystems (Morand & Figuié, 2016).

They also report ecosystem dynamics and imbalances. Specifically, the biology and ecology of infectious agents, their hosts, and their vectors are related to the development and re-emergence of infectious diseases (Vittecoq et al., 2015). As Destoumieux-Garzon et al. (2018, report, determining the risk of infection requires a thorough understanding of ecosystem dynamics that provides information on the processes that contribute to the appearance or recurrence of infectious agents as well as their dispersion and extinction in natural habitats. In addition to the necessity for a comprehensive understanding of pathogen life cycles, transmission channels, and species barrier transgressions, further research is essential to investigate pathogen dynamics in natural settings and to construct infection models that closely resemble real systems. Moreover, ecology researchers are increasingly expected by administrators to deliver detailed, relevant information on the health and desired equilibrium or dynamics of multifunction ecosystems, to support decisions related to sustainable development, conservation of species, and the health of humans, animals, and plants (Giraudoux et al., 2014). To do this, shared indicators of ecosystem health must be defined, such as biodiversity, ecosystem services, desired "equilibrium," and "evolutions" on relevant space-time scales.

Pathogen dynamics in microbiota, interacting with a host species or a community of hosts, may be better understood thanks to advancements made for specific models (Le Roux et al., 2016; Paillard et al., 2014; Lagadec et al., 2016; Picardeau, 2017). Understanding ecosystem dynamics enables us to evaluate the extent to which changes brought about by human activity contribute to the emergence of widespread infectious outbreaks. Nearly three-quarters of emerging infectious diseases that are deemed to be important for public health also have zoonotic origins (Taylor et al., 2001), with their origin coming from wild animals (Woolhouse et al., 2005). Therefore, studying the ecological parameters that influence infectious agent transmission in wildlife is crucial to comprehending the mechanisms underlying species barrier transgression (also known as host-switching, host-jumping, or host-shifting) and emergence in human populations. Evaluating the risk of zoonotic disease emergence in human populations necessitates the examination of interaction networks among infectious agents, their hosts, and the environments in which they develop (Huffman et al., 2013).

Some of the factors that have been considered important for the appearance of vector-borne and direct transmission agents are the density and diversity of hosts, migration, environmental persistence, and interaction within communities of infectious agents (Destoumieux-Garzon et al., 2018). Changes in species abundance and food web topology—such as the extinction of regulatory predators, the role of super-predators, consumptive competition, impacts on keystone species, biological invasions, the proliferation of resistant disease reservoir species, and density effects related to the emergence of epizootics or zoonotic diseases, etc.—coupled with pollution, substantially heighten the risk of disease (Destoumieux-Garzon et al., 2018). Moreover, some important factors that have been confirmed as catalysts on the occurrence and geographic distribution of infectious agents are destruction and fragmentation of habitat, environmental pollution, and climate change. According to Travers et al. (2008), Bebber (2015) and Vezzulli et al. (2016), diseases that never appeared before, especially at northern latitudes, are caused by global warming by modifying the distribution of pathogens, their vectors, and their reservoirs.

There is a distinct relationship between contagious diseases and spatial arrangement as Moore et al. (2018) present the role of mismatched spatial heterogeneity. Jato-Espino et al. (2021) focus on the development of a spatial indicator system that models the promotion of zoonotic diseases escalation, understanding a region's endowment to OH. Moreover, increased movement of humans, plants and animals that are possible hosts of infectious agents, is caused by trends like trade and exchange globalization, combined with the industrialization of agricultural fields (aquaculture, agribusiness etc) as Stoate et al. (2001; 2009) report. Specifically, breeding and farming practices that are extensively implemented might include the abusive use of pesticides, fertilizers, and antibiotics, which cause resistance of mosquitos to insecticides (Chouaïbou et al., 2016; Tantely et al., 2010). Mosquitos are known as carriers and transmitters of pathogens. Furthermore, bacteria tend to acquire resistance to antibiotics, due to their extensive use (Holmes et al., 2016). Similarly, this is how antibiotic-resistant strains have occurred in human health care. AMR constitutes a multifaceted worldwide health crisis. Proven concepts in eco-evolutionary dynamics are urgently required to discover innovative approaches for bacterial infections that exhibit slower resistance evolution (Read & Woods, 2014). According to Ezenwa et al. (2015) and Mwangi et al. (2016) apart from the spread of viruses or understanding of contamination principles, epidemics are also significantly influenced by history, political contexts, economic inequalities and cultural phenomena.

Three more important terms in the OH studies are toxic risk, multifactorial and non-communicable chronic diseases. First, the toxic risk is especially elevated in densely populated locations, such as coastal regions, where species are exposed to many toxins and pollutants, including natural toxins (for example, poisoning toxins produced by specific harmful microalgae), emerging contaminants (for example, micro-and nanoplastics), and diffuse pollution associated with numerous anthropogenic discharges (Harvell et al., 1999; Burge et al., 2014). Second, multifactorial diseases (de Montaudouin et al, 2010; Mondet et al, 2014; Petton et al., 2015; Barneah et al., 2007; Bossart, 2011; Grogan et al., 2014; Kannan et al., 2010; Rohr et al., 2008) often appear in organisms whose defence capabilities have been diminished by alterations in nutrition, temperature, salinity, pH, exposure to pollutants, toxins, radiation etc. Third, exposure to toxic substances, has proven to contribute significantly to the development of serious chronic non-communicable diseases in humans, including respiratory cardiovascular, neurological, and metabolic disorders, as well as obesity, diabetes and cancer (Destoumieux-Garzon et al., 2018).

Generally, toxicants elevate the risk of infectious diseases by directly or indirectly compromising the immune system (Acevedo-Whitehouse & Duffus, 2009; Marcogliese & Pietrock, 2011; Abi-Khalil et al., 2017; Beasley, 2009; Hégaret et al., 2007; Lafferty & Kuris, 1999). A comprehensive framework that integrates the roles of toxicants in immunity and the endocrine system would enhance the synergy between the theoretical and practical aspects of eco-epidemiology, ecophysiology, and ecotoxicology (Martin, 2009). Pathogenic organisms and chemical contaminants possess distinct characteristics. Interactions between pathogenic organisms and chemical toxicants are of significant interest. Assessing the effects of extensive biocide (products used to control unwanted organisms that are harmful to human or animal health or to the environment, or that cause damage to human activities, according to European Commission) and xenobiotic (a substance which would not normally be found in a given environment, and usually means a toxic chemical which is entirely artificial, according to European Environment Agency) usage has emerged as a priority to foresee the consequences on the entire ecosystem. Incorporating ecotoxicological concerns regarding biocidal agents into the "One Health" framework should enhance the chemical management of pathogen vectors (e.g., mosquitoes) and parasites. The initial step involves the development of "adaptive monitoring" methodologies addressing co-exposure to contaminants and viruses, which is essential. The objective is to evaluate exposure and organism response at both the individual and population levels using suitable methodologies for animals and humans (Rabinowitz et al., 2005). Studies in both in situ and controlled environments and integrated solutions that encompass the various scales of arrangement of living beings are needed to assess the ecotoxicological impact of diffuse pollution, phytotoxins and contaminants of emerging concern, including their adjustments by environmental factors, according to Destoumieux-Garzon et al. (2018).

Regarding human health and the effect of urban lifestyle, air and ground pollution, reduction of exercise, stressful routine and unhealthy diets, are a few important factors that affect human health. People's social life also affects the transmission process of pathogens. In their research, Finger et al. (2016) incorporated environmental variables, such as rainfall, into their epidemiological models to assess their impact on cholera transmission. This integration reflects the essence of ecosystem health management by acknowledging how environmental conditions can influence disease dynamics. Furthermore, the study's use of mobile phone data to track human movement patterns provides insights into how human behaviour interacts with environmental factors to affect disease spread. Moreover, Christakis and Fowler

(2007) report the interconnectedness of human health, social structures, and environmental factors. In this context, the study's findings suggest that social environments—comprising friends, family, and community networks—play a significant role in influencing individual health outcomes, such as obesity. This perspective complements the integrated approach by highlighting how social determinants are integral to health and can inform public health strategies that consider both social and environmental contexts.

Zhang et al. (2022) introduce the Global One Health Index (GOHI) as a comprehensive framework to evaluate OH performance across countries. The authors describe the five steps they implemented to formulate the GOHI index. Specifically, the framework formulation, the indicator selection, the database building, the weight determination, and the score calculation. Our proposed framework is based on these five steps. The GOHI framework incorporates environmental and ecosystem health through its Intrinsic Drivers Index (IDI). This component focuses on the interface between human health, animal health, and ecosystem diversity, emphasizing the interconnectedness of these domains. By assessing factors such as biodiversity, land use, and environmental pollution, the IDI aligns with the principles of integrated environmental and ecosystem health management. The GOHI framework comprises a hierarchical structure of indicators, based on weights. The first-level indicators, which are broad categories that encompass various aspects of One Health. The second-level indicators provide more specific domains within the first-level categories. Last, the third-level indicators, that are detailed metrics used for assessment. In total, the GOHI includes 3 first-level indicators, 13 second-level indicators, and 57 third-level indicators. Moreover, the authors highlight key areas assessed under the IDI. The first category refers to biodiversity. Specifically, it evaluates species diversity and ecosystem variability. Secondly, land use which refers to assessing the impact of urbanization and agriculture on ecosystems. Lastly, environmental pollution refers to measuring air and water quality, and exposure to pollutants.

Halpern et al. (2012) developed and implemented a systematic approach for measuring overall condition of marine ecosystems that treats nature and people as integrated parts of a healthy system. Specifically, the authors proposed a conceptual framework for calculating an index to assess the health and benefits of the global ocean. The index was calculated for every coastal country and consisted of ten public goals, including sub-goals. The main public goals contained food provision with two sub-goals (fisheries, mariculture), artisanal fishing opportunity, natural products, carbon storage, coastal protection, tourism and recreation, coastal livelihoods and economies with two sub-goals (livelihoods, economies), sense of place with two sub-goals (iconic species, lasting special places), clean waters and biodiversity with two sub-goals (habitats, species).

For measuring a region's contribution Jato-Espino et al. (2021) incorporates interactions and effects of human, animal and environmental indicators. The indicators are selected based on the five steps proposed by Jato-Espino et al. (2021). First literature review was incorporated on the use of indicators for OH purposes. Then indicators were selected, based on the outcomes of the literature review. For the third step, Geographical Information Systems (GIS) are used, to characterize of the indicators. Fourth, Multi-Criteria Decision Analysis (MCDA) is implemented for indicator weighting and aggregation. Lastly, we perform the calculation of the impact of green infrastructure on the OH approach. The study incorporates a multidimensional set of indicators across the three fundamental domains of OH. For human health indicators, factors like density, urbanization levels, and access to healthcare services, can influence the susceptibility and response capacity to zoonotic disease outbreaks. For environmental health indicators the study evaluates land use patterns biodiversity levels, and ecosystem fragmentation, recognizing that environmental degradation can alter habitats and increase human-animal interactions, thereby facilitating disease spillover. Finally, for animal health indicators, factors like livestock density, wildlife presence and animal movement patterns are considered, as they play a crucial role in the transmission dynamics of zoonotic pathogens.

All the knowledge delivered from the work described regarding indicators and important factors for the formulation of the OH assessment framework for coastal managemet is gathered and assessed on Table 4.1

4.2.2 Human and socio-economic wellbeing

The effective implementation of the integrated One Health (OH) framework plays a pivotal role in promoting human well-being and fostering socio-economic development, particularly in vulnerable regions. Linking health outcomes with socio-economic advancement through a multidisciplinary lens is essential to address the complex challenges of modern societies (Zinsstag et al., 2011).

Health outcomes are shaped not only by economic and cultural factors but also by the broader socio-ecological systems in which communities operate (Ostrom, 2007; Rock et al., 2009). As such, advancements in public health are largely tied to the reduction of social disparities and the success of international cooperation (Young et al., 2008). In light of global challenges such as pandemics, food insecurity, and environmental degradation—the conventional linear models of economic growth have proven inadequate. These models often fail to incorporate critical social and environmental dimensions, thereby necessitating a more integrated OH approach that emphasizes resilience and the social determinants of well-being.

A successful OH strategy must extend beyond protecting public health to encompass broader goals such as social justice and equity. As Baquero (2021) argues, this entails prioritizing the inclusion and active participation of marginalized groups, particularly in areas where infrastructure deficits, poverty, and exclusion persist (Ezeh et al., 2017). The agricultural sector, while contributing to GDP and employment, also presents challenges to sustainability when intensified, especially through environmental degradation and unequal resource distribution (Garbois et al., 2017). Tackling such systemic issues requires institutional reform that addresses the deeper roots of global inequality, including those reinforced by patriarchal and capitalist structures (Wezel et al., 2009).

The importance of OH becomes particularly evident in times of health crises. Mackenzie et al. (2013) demonstrate that a pandemic like H5N1 could lead to global economic losses in the billions, underscoring the need for a framework that integrates human, animal, and environmental health. Multidisciplinary collaboration—among physicians, veterinarians, and environmental scientists—is crucial to managing these interconnected risks and realizing both health and economic benefits for local communities.

In developing economies, OH has the potential to combat income inequality, enhance food security, and protect public health. Nguyen-Viet et al. (2025) emphasize the role of initiatives like the International Livestock Research Institute (ILRI), which aim to support vulnerable populations, particularly rural and nomadic groups. Effective antimicrobial resistance management and widespread livestock vaccination are essential elements of these efforts (Cleaveland et al., 2017).

4.2.3 Indicator system for the OH assessment

The development of a comprehensive OH assessment framework requires a structured approach that captures the complex interdependencies across human, animal, and environmental health. The proposed indicator system is organized into three main pillars—Human Health, Animal Health, and Environmental Health—each broken down into thematic axes and sub-indexes. These axes reflect key priority areas and critical challenges identified in the literature and stakeholder consultations. The following table outlines the structure of the indicator framework, showcasing the thematic coverage and the specific sub-indicators proposed for each domain.

Table 4. List of indicators proposed for the assessment framework.

Pillar	Thematic axes	Sub-indexes	Composite Index
Human Health	*Reproductive, Maternal, New-born, and Child Health*	Maternal Health; Neonatal Health; Child Health; Adolescent Fertility	-

	Infectious Diseases	Tuberculosis; HIV; Malaria; Neglected Tropical Diseases; COVID-19; AMR-related mortality or resistance prevalence; Zoonotic Disease Incidence (e.g., Brucellosis, Rabies)	-
	Non-communicable Diseases and Mental Health	Cardiovascular Disease; Neoplasms; Diabetes Mellitus; Chronic Respiratory Disease; Suicide; mental health; obesity; smoking	-
	Injuries and Violence	Road Traffic; Unintentional Poisoning; Homicide	-
	Universal Health Coverage and Health Systems	Health Coverage; R&D Expenditures on Health Issues; Domestic Health Expenditures; Infant Vaccination	-
	Health Risk	Unsafe/Unimproved Water, Sanitation and Hygiene; Household Air Pollution; Occupational Risks; life expectancy; microplastics	SEQI (partially)
Animal Health	*Animal Epidemic Disease*	Diseases of Domestic Animals; Diseases of Wild Animals	-
	Animal Welfare, Relevant Regulations, and Policy Support	Overexploited/Collapsed Fish Stocks; Trawling or Dredging Fish	-
	Infectious Diseases	Zoonotic Disease Incidence (e.g., Brucellosis, Rabies); Antibiotic usage in livestock or AMR in zoonotic pathogens	-

	Animal Nutritional Status	Chicken, Pig, Cattle Meat & Milk Production Efficiency	-
	Animal Biodiversity	Endemic Mammal, Bird, Amphibian, Alien species,	AAHRI
Environmental Health	*Air Quality and Climate Change*	Ambient PM Pollution; Household Solid Fuels; Ozone Pollution; Climate Risk; GHG	EEQI
	Land Resources	Area at Risk Elevation; Tree Cover, Grassland, Wetland Loss; Mineral Depletion	EEQI
	Hazardous Chemicals	AMR gene presence in wastewater/environment	EEQI
	Sanitation and Water Resources	Freshwater; Clean Drinking Water; Renewable Freshwater Resources; SEQI	SEQI
	Hazardous Chemicals	Fertilizer Consumption; Fertilizer Consumption; SO2 Growth; NOX Growth; Wastewater Treatment; Electronic Waste; Non-recycled Municipal Solid Waste	EEQI
	Environmental Biodiversity	Protected Areas Representativeness; Species Habitat; Biodiversity Habitat	EEQI

4.3 Technical requirements for the construction of OH composite indicator

The Composite Vulnerability Index developed for the case studies of Pagasitikos Gulf (Greece) and the Catalonian beaches (Spain) is grounded in the OH framework, which integrates the interdependent domains of human health, animal health, and environmental health. The methodology is designed to provide a robust, spatially explicit assessment of unified health in coastal socio-ecological systems, using the Local Administrative Unit (LAU) as the primary unit of analysis. This ensures high-resolution results that reflect the real, localized dynamics of exposure, sensitivity, and adaptive capacity. Figure 4.3 summarises the technical requirements.

4.3.1 Data Treatment

To ensure analytical consistency and reliability, a rigorous data treatment protocol is applied. All indicators are first harmonised in terms of spatial and temporal reference. When data gaps exist at the LAU level, missing values are imputed using values from adjacent LAUs or higher administrative units, with all assumptions documented. Statistical diagnostics, including assessments of skewness and kurtosis, are used to evaluate distributional properties. Where appropriate, transformations such as Winsorisation or logarithmic scaling are applied to mitigate the effect of outliers and ensure comparability. All indicators are then normalised to a common scale using the Min-Max rescaling method. During this process, the directionality of each indicator is adjusted so that higher values consistently indicate greater influence or lower adaptive capacity, maintaining conceptual coherence across the index. Figure 4.2 summarises the data treatment implementation.

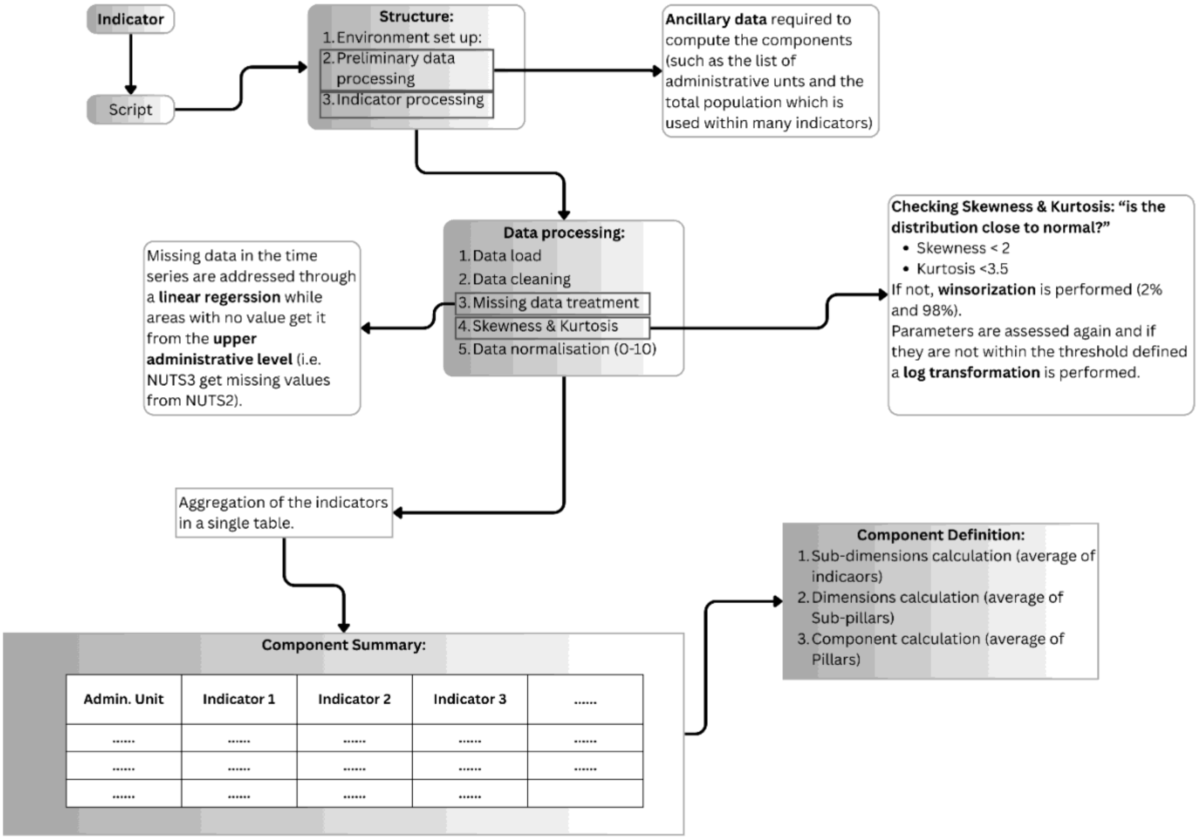

Figure 15. Overview of the Technical Architecture of the ENHANCE One Health Framework

4.3.2 Weighting Scenarios

To accommodate both methodological consistency and contextual relevance, two alternative weighting scenarios are incorporated:

1. **Equal Weighting Scenario:**
   All indicators and dimensions are assigned equal weights across and within the three OH pillars. This neutral baseline ensures methodological transparency and enables sensitivity analysis across LAUs. In general, there are various justifications for most applications choosing equal weights a priori. These include: (1) simplicity of construction, (2) a lack of theoretical structure to justify a differential weighting scheme, (3) no agreement between decision makers, (4) inadequate statistical and/or empirical knowledge, and, finally, (5) alleged objectivity (Decancq and Lugo 2013).
2. **AHP-Based Stakeholder Weighting Scenario:**
   The second scenario involves stakeholder-derived weights through the Analytic Hierarchy Process (AHP). This method is applied via participatory workshops held in

both case study areas, engaging stakeholders including public health authorities, environmental scientists, veterinarians, local administrators, and civil protection agencies. Through structured pairwise comparisons, experts assign weights to each thematic axis and pillar, reflecting locally perceived risk hierarchies and policy priorities. The resulting AHP weights guide the aggregation of indicators into dimension-specific sub-indices. Despite its popularity as a technique to elicit weights (Hermans et al., 2008), it still suffers from the same problem as the Budget Allocation Process (Saisana and Tarantola 2002). That is, on the occasion that the number of indicators is very large, it exerts cognitive stress on decision makers, which in the AHP is amplified due to the pairwise comparisons required (Ishizaka 2012).

4.3.3 Aggregation Scenarios

Two categories of aggregation techniques are applied: compensatory (linear) and non-compensatory (non-linear and MCDA-based) methods. These techniques reflect different conceptual assumptions about the substitutability of weaknesses across dimensions and allow for more nuanced and policy-relevant interpretations of the OH.

The first aggregation scenario follows a linear compensatory approach, using the arithmetic mean to combine sub-indices. This method assumes full compensability across dimensions meaning that poor performance in one indicator or domain can be entirely offset by strong performance in another. This technique is widely used due to its transparency and simplicity and serves as a baseline for comparative analysis. Among the compensatory aggregation approaches, the linear one is the most commonly used in composite indicators (Bandura, 2011).

The second aggregation scenario incorporates non-linear and non-compensatory techniques aligned with Multi-Criteria Decision Analysis (MCDA) frameworks. These approaches reduce or eliminate compensability and are particularly appropriate in OH contexts where deficits in one domain (e.g., animal health or ecosystem function) may not be acceptable even if other dimensions perform well. Specifically, the following methods are tested:

- Outranking methods such as ELECTRE and PROMETHEE, which establish preference relations among LAUs (Local Administrative Units) without requiring full aggregation into a single score. These methods identify dominance relationships and support decision-making in the presence of trade-offs and uncertainty. Non-compensatory aggregation techniques (Roy, 1996) are mainly based on ELECTRE methods (Figueira et al., 2016) and PROMETHEE methods (Brans and De Smet 2016).

4.3.4 Construction of composite index and validation OH scores

Following the application of weights, sub-indices are computed at the LAU level for each OH pillar. These are aggregated into pillar-level scores and then synthesized into a single Composite OH Index per LAU, allowing direct comparison across coastal municipalities.

To validate the framework, correlation analysis (Pearson coefficients) is conducted to identify multicollinearity, ensure internal coherence, and assess the contribution of each indicator to its respective sub-index. Where necessary, indicators are refined, transformed, or reassigned to preserve conceptual clarity and statistical integrity. Correlation analysis is mostly used in the first steps of the construction process to examine the structure and the dynamics of the indicators in the data set (Booysen, 2002)

To ensure the methodological robustness and reliability of the Composite Vulnerability Index, a sensitivity analysis is conducted to evaluate the impact of key methodological choices on final index scores and LAU-level rankings. Specifically, the sensitivity analysis examines the influence of:

(a) the weighting scheme, comparing results under the equal weighting scenario versus the AHP-derived stakeholder weighting, and
(b) the aggregation method, testing both linear (arithmetic mean) and non-linear approaches.

The sensitivity analysis quantifies how changes in these assumptions affect the relative positioning of LAUs in terms of OH. For each scenario combination, rank-order correlation (Spearman's rho) and difference plots are used to assess the degree of divergence across resulting indices. Additionally, confidence intervals are estimated where bootstrapped indicator simulations are applied, particularly to assess the robustness of scores in the presence of data uncertainty or imputation.

4.3.5 Visualisation of OH results

The results of the OH Index are presented through a combination of spatial maps, ranking outputs, and interactive visual tools, enabling effective interpretation and decision-making at the LAU level within the OH framework. Composite scores and sub-indices are visualised through GIS-based choropleth and bivariate maps, accompanied by LAU-level rankings and stability metrics derived from the sensitivity analysis. An interactive dashboard allows users to explore and compare vulnerability patterns across different weighting and aggregation scenarios.

These results will be fully integrated into the ENHANCE platfor**m**, specifically within the suite of OH toolkit, to support local authorities, planners, and health-environment practitioners in risk identification, prioritisation, and strategy formulation.

Figure 4.3 points out the technical requirements for the composite indicator design, development and dissemination.

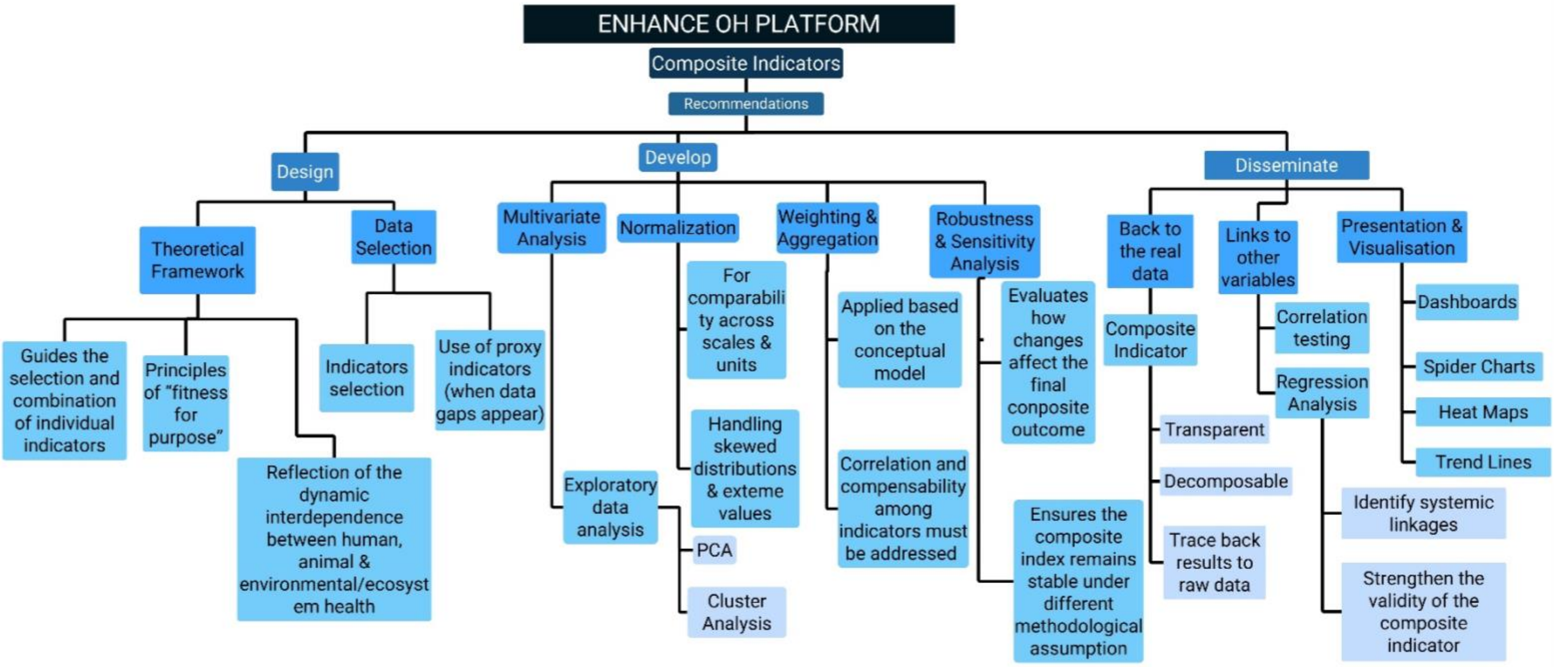

Figure 16. Phases and Technical Requirements for Composite Indicator Development: From Design to Dissemination

4.4 Application of the ENHANCE OH Framework in Practice

In practice, the ENHANCE OH Framework is applied by mapping coastal-specific human, animal, and environmental health challenges to the DPSIR model, and aligning these with the three core domains of OH. The DPSIR framework (Drivers-Pressures-State-Impact-Response) offers a structured approach to coastal management by identifying human-driven causes (Drivers) and resulting environmental stressors (Pressures). It assesses changes in coastal ecosystems (State), their effects on society and nature (Impact), and informs policy or management interventions (Response). This framework supports integrated decision-making by linking socio-economic activities with environmental outcomes. Specifically, for ENHANCE OH framework, Drivers refer to the primary indices used to create the composite index, Pressures are captured through the implementation of D-LUSI maps, State relates to the assessment and monitoring of current environmental conditions, Impacts include indicators such as chlorophyll-a concentration, biodiversity maps, and detection of harmful algal blooms, and Responses are reflected in the formulation and application of the Composite OH Index.

Figure 4.4 presents the architectural logic of the ENHANCE OH Framework, highlighting the key components and their interactions. Inputs include stakeholder needs, environmental and health data (e.g., from Copernicus, IoT sensors, and citizen science), and user personas developed through participatory methods. These feed into co-creation tools and the DPSIR conceptual model, which together support the generation of composite indicators (SEQI, EEQI, AAHRI). All components are integrated within the ENHANCE platform, where validation and dashboard services deliver outputs such as alerts, policy insights, and action pathways for local decision-makers.

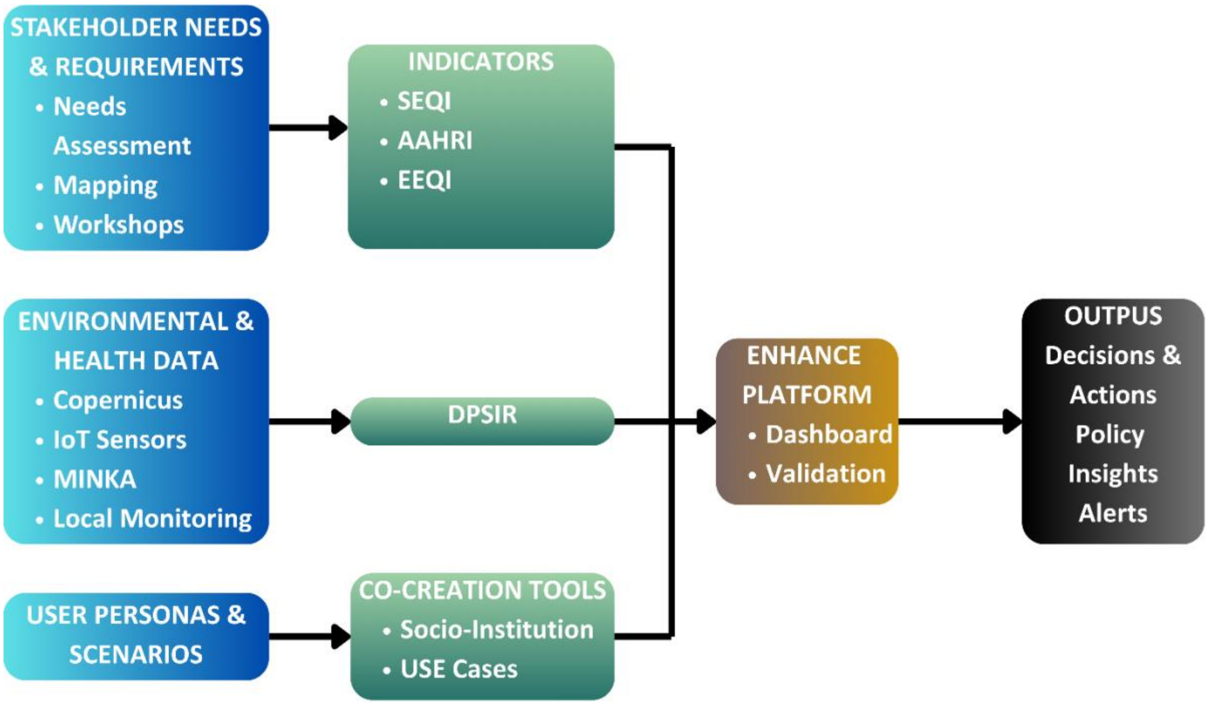

Figure 17. ENHANCE Framework Operational Architecture: From Inputs to Decision-Making

5. Conclusion and discussion

This deliverable presents the first milestone in the development of the ENHANCE OH Framework for Coastal Management. It synthesizes extensive stakeholder engagement, cross-sectoral consultation, and co-creation activities carried out under WP2. Through the integration of literature review, stakeholder mapping, expert workshops, and participatory design, the deliverable outlines a robust, context-sensitive framework that reflects the complexity and interdependence of coastal human, animal, and environmental health systems.

The findings from the two pilot CSs—Barcelona beaches & Ebro Delta (CS1) and Pagasitikos Gulf (CS2)—highlight distinct yet converging challenges faced by coastal communities across Europe. In CS1, the emphasis was placed on biodiversity protection, urban beach management, and public engagement, while CS2 focused more on climate resilience, biosecurity gaps, and waste management. Despite their differences, both cases revealed a shared need for integrated, real-time environmental data, accessible decision-support tools, and collaborative governance mechanisms.

D2.1 demonstrates that the participatory approach employed in ENHANCE is essential for developing an OH platform that is both scientifically credible and socially grounded. The co-creation process contributes to identifying user personas, real-world scenarios, and functional needs that will directly inform the technical development in WP3. Furthermore, the stakeholder mapping and power–interest analysis conducted under T2.2 offer strategic guidance for stakeholder prioritization and living lab engagement in WP4.

By anchoring the OH paradigm within the DPSIR model, ENHANCE provides a flexible yet structured foundation for indicator development and tool design. The initial concepts behind SEQI, EEQI, and AAHRI have been validated through expert input and will evolve into operational services in the next phases. The strong alignment between scientific, technical, and social insights in this deliverable lays the groundwork for a responsive, scalable, and policy-relevant digital ecosystem to support coastal zone resilience in Europe.

Looking ahead, the outcomes of D2.1 will be further operationalized through the specifications (D2.2), platform design activities (WP3), and living lab pilots (WP4), ensuring continuity between early-stage engagement and long-term system implementation. In this way, ENHANCE contributes to the advancement of OH as an actionable framework for addressing interconnected challenges in coastal and marine environments.

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Annex I: ENHANCE Stakeholder Mapping Questionnaire Form

[Entry Date in prefilled by the form] *[person filling this form]*	
Section 1 - General Information	
1	**Please complete the official Name of Stakeholder** [in local language]
2	**Please complete the official Name of Stakeholder** [in English language]
3	**Is there an MoU signed with this Stakeholder?** [Yes/No]
4	**Please complete the Stakeholder website** [open text]
5	**Is there a specific Contact person or details? If yes, please specify** [open text]
6	**In which category and subcategory of the Quintuple Helix system would the stakeholder fall under?** Please select [multiple selection]: • Higher Education System (Universities, Research Institutions, Scientific Services, Other Educational Institutions)/ • Economic System (Industry, Private Sector, Banking Sector) / • Political System (Government, Local/ Regional Authority, Public Administration)/ • Media-based & Culture-based Public (NGOs, citizens' groups, volunteers, activists, media, arts • Environment (sustainability, environmental services, environmental protection]

7	**In which main field of activity (primary sector or industry) does the stakeholder operate or contribute to?** Please select [one option: 1. Crop and animal production 2. Forestry and logging 3. Fishing and Aquaculture 4. Manufacture of food products 5. Manufacture (other) 6. Energy Production and Supply 7. Water Supply 8. Waste Management 9. Construction 10. Wholesale and Retail Trade 11. Transportation and Storage 12. Accommodation and Tourism 13. Food Service Activities 14. Information Technology 15. Communication 16. Financial and Insurance Activities 17. Real Estate Activities 18. Professional, Scientific, and Technical Activities 19. Administrative and Support Service Activities 20. Public Administration and Defense; Compulsory Social Security 21. Education 22. Human Health and Social Work Activities 23. Arts, Entertainment, and Recreation 24. Other Activities 25. Non-Applicable]
8	**Does the stakeholder belong potentially to a defined customer segment of the ENHANCE project?** Please select [one option: • Public Authority at Local and Regional Levels responsible for policy implementation and environmental management/ • Private Sector – Agriculture/ • Private Sector – Aquaculture/ • Private Sector – Fishery/ • Tourism/ • Urban Beach Development/ • Research and Education Sector - Marine research institutes/ • Research and Education Sector – Universities/ • Research and Education Sector - Environmental schools/ • Associations & NGOs/ • Developers of Applications and Software Tools focused on environmental management]
9	**Please indicate the geographic scale on the stakeholder** Please select [one option: • International • Regional (EU) • National • Regional • Local]
10	**In which category of the One Health Approach would the Stakeholder fall under?** Please select [one option: • Animal

	• Human • Fish • Environment • N/A]
Section 2 - Power Interest Assessment	
11	**Please assess the following different indicators of power** of the stakeholder based on your knowledge/perception using a 5-point assessment scale: • 1 = Very Low; • 2 = Low; • 3 = Medium; • 4 = High; and • 5 = Very High Authority (the right to act or right to make rules to govern others) 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ …………………………………………………………………………………… Capability (the ability of the stakeholder entity to achieve a higher mission) 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ Credibility (the ability to generate trust) 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ Capacity (the ability of the stakeholder entity to achieve its objectives) 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ Mass Mobilization (ability to build mutually beneficial relationships – networking with other types of SHs) 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢
12	**Please assess the following different indicators of interest** of the stakeholder based on your knowledge/perception using a 5-point assessment scale: • 1 = Very Low; • 2 = Low; • 3 = Medium; • 4 = High; and • 5 = Very High Hope (feeling of expectation and desire for an outcome - if a SH is opposed to the activities in the DS or disagrees they will have very low Hope) 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ Aspiration (desire for achievement – the stakeholder taking steps towards – if a SH is opposed to the activities in the DS or disagrees they will have very low Aspiration) 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ Potential Benefit (increased chance of becoming beneficiaries) 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ Knowledge-building (desire to extend knowledge in OneHealth for marine ecosystems field) 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢
Section 3 - Strength of Relations Among Stakeholders Assessment Form	

13	**Please assess the Strength of Relations of your Organisation with the Stakeholder identified based on the following indicators:** Communication Frequency: 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ ● 1 = No communication or rarely communicated. ● 2 = Infrequent communication (once every few months). ● 3 = Occasional communication (quarterly or as needed). ● 4 = Regular communication (monthly or bi-weekly). ● 5 = Constant communication (weekly or daily). Collaboration Level 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ ● 1 = No collaboration. ● 2 = Minimal or one-time collaboration. ● 3 = Some collaboration on specific projects or tasks. ● 4 = Regular collaboration with shared objectives. ● 5 = High-level collaboration with joint projects and deep engagement. Dependence/Influence 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ ● 1 = No dependence or influence. ● 2 = Minor influence or occasional need for the stakeholder's input. ● 3 = Moderate influence or dependence in specific areas. ● 4 = Significant dependence or influence on organizational activities. ● 5 = Critical reliance on the stakeholder or vice versa. Trust and Alignment 1 ▢ 2 ▢ 3 ▢ 4 ▢ 5 ▢ ● 1 = Low trust or misalignment of goals. ● 2 = Some trust, but some differences in goals or values. ● 3 = Neutral trust, with occasional alignment. ● 4 = High trust, goals generally align. ● 5 = Complete trust and full alignment of goals and values.
Section 4 - Relevance to project activities	
14	**Please indicate if the stakeholder is related to a CS** [one selection: ● Case Study 1 - Beaches of Barcelona ● Case Study 2 - Pagasitikos Gulf ● N/A]
15	**Please indicate the category-ies of Activities for Stakeholder to be involved** [multiple selection: ● One-Health Framework Definition ● Enhance Solutions/ User scenarios ● AI- services/ One-Health Platform ● Case Study Demonstration (e.g. data collection, observations, test scenarios, evaluation) ● Dissemination and Exploitation ● Other]

16	**Please indicate the preferred means of engagement in the ENHANCE project** [multiple selection: ● Interviews ● Living Labs/ Workshops ● 1-1 meetings ● Material dissemination ● Other]

Annex II: Stakeholder Mapping Output

The Stakeholder mapping output is available here.

Annex III: Case Studies' User Personas

Full Name	Job Title	Age	Needs	Expected Outcomes	Use Stories
Maria Jose Chesa	Responsible for the water quality monitoring in the urban beaches of Barcelona (public company)	50	Access to complementary data on watercontamination (for example. target species as bioindicators)	Access to AI-based alerts on environmental risks (e.g., waterborne pathogens)	I as a water quality monitoring officer responsible for urban beaches in Barcelona, I want access to complementary data on water contamination, such as target species used as bioindicators, so that I can access AI-based alerts on environmental risks like waterborne pathogens.
			Early prevention tools for environmental health risks	Integration of Copernicus data into public health monitoring	I as a responsible officer for water quality monitoring in the urban beaches of Barcelona (public company), want early prevention tools for environmental health risks, so that I can integrate Copernicus data into public health monitoring
			Collaboration with environmentalists and NGOs	Better preparedness for outbreaks linked to water or climate	I as a responsible officer for water quality monitoring in the urban beaches of Barcelona (public company), want collaboration with environmentalists and NGOs, so that we can improve preparedness for outbreaks linked to water or climate

			Informational material for vulnerable groups	Creation of early-warning protocols linking environmental signals to human health	I as a responsible officer for water quality monitoring in the urban beaches of Barcelona (public company), want informational material for vulnerable groups, so that I can create early-warning protocols that link environmental signals to human health
David Tarrasón	Secondary School Teacher	48	One Health educational materials	Access to educational platforms using real marine data & AI visualizations	As a Secondary School Teacher, I want One Health educational materials, so that I can access educational platforms using real marine data and AI visualizations
			Local case studies and experiential activities	Engagement of students in citizen science (e.g., water sampling, biodiversity logs)	As a Secondary School Teacher, I want local case studies and experiential activities, so that I can engage students in citizen science activities like water sampling and biodiversity logs
			Collaboration with NGOs	Increased environmental literacy and understanding of One Health	As a Secondary School Teacher, I want collaboration with NGOs, so that I can increase environmental literacy and deepen students' understanding of the One Health approach.
			School participation in community-based coastal monitoring activities	Support for raising student awareness	As a Secondary School Teacher, I want school participation in community-based coastal monitoring activities, so that I can receive support for raising student awareness

Silvia Ramírez	Aquaculture Farming Unit Owner	47	Systematic water quality monitoring	Timely alerts on harmful algal blooms or pollution events from AI models	As an Aquaculture Farming Unit Owner, I want systematic water quality monitoring, so that I can receive timely alerts on harmful algal blooms or pollution events from AI models
			Dashboard with marine Copernicus data for aquaculture safety	Early warnings for harmful algae and pathogens	As an Aquaculture Farming Unit Owner, I want a dashboard with marine Copernicus data for aquaculture safety, so that I can receive early warnings for harmful algae and pathogens
			Guidance on sustainable aquaculture	Reduced economic losses through predictive water quality forecasting	As an Aquaculture Farming Unit Owner, I want guidance on sustainable aquaculture, so that I can reduce economic losses through predictive water quality forecasting
			Networking with producers and authorities	Guidelines for adaptive aquaculture management based on real-time data	As an Aquaculture Farming Unit Owner, I want networking with producers and authorities, so that I can receive guidelines for adaptive aquaculture management based on real-time data
Joan Soler	Rice producer	55	Access to environmental risk maps (e.g., runoff or salinity zones) via Copernicus	Clean irrigation water	As a Rice producer, I want to access environmental risk maps (e.g runoff or salinity zones) via Copernicus so that there is clean irrigation water
			Support for using organic inputs	Use of AI tools to link environmental conditions to animal/human health risks	As a Rice producer, I want to Use of AI tools to link environmental conditions to animal/human health risks, so that i can support for using organic inputs

			Control of invasive species (based on citizen science based programs)	Monitoring invasive species (potential damage for the rice)	As a Rice producer, I want to Control invasive species (based on citizen science based programs) so that I can monitor invasive species (potential damage for the rice)
			Awareness of farming impacts on water quality	Improved freshwater management practices based on data insights	As a Rice producer, I want to raise Awareness of farming impacts on water quality so that I can Improv freshwater management practices based on data insights
Coloma Rull	Civil Servant. Coordinator of Urban Ecology, Barcelona City Council	45	Updated biodiversity records	Periodic updates about biodiversity status of the urban beaches	As a Civil Servant, Coordinator of Urban Ecology at the Barcelona City Council, I want updated biodiversity records, so that I can receive periodic updates about the biodiversity status of the urban beaches.
			Collaboration with volunteer monitoring activities	Integration of AI-assisted trend analysis for animal disease emergence	As a Civil Servant, Coordinator of Urban Ecology, Barcelona City Council, I want to collaborate with volunteer monitoring activities so that I can integrate AI-assisted trend analysis for animal disease emergence.
			Collaboration with health/environmental bodies	Cross-sectoral data flow between health, animal, and environmental domains	As a Civil Servant, Coordinator of Urban Ecology, Barcelona City Council, I want to collaborate with health/environmental bodies so that there is cross-sectoral data flow between health, animal, and environmental domains.

Eli Bonfill	SME owner (snorkel guided tours)	33	Education on responsible use of beaches installations	Participation in One Health decision-support systems powered by Earth observation	As a Civil Servant, Coordinator of Urban Ecology, Barcelona City Council, I want to educate on the responsible use of beach installations so that there is participation in One Health decision-support systems powered by Earth observation.
			Real-time water quality updates for safe bathing and recreation	Bathing information (near real time)	As an SME owner (snorkel guided tours), I want Real-time water quality updates for safe bathing and recreation so that I have bathing information (near real time)
			Use of AI-powered "eco-labels" or environmental indicators to attract visitors	Promotion of eco-identity of the region	As an SME owner (snorkel guided tours), I want to use AI powered "eco-labels" or environmental indicator to attract visitors so that I can promote the eco-identity of the region
			Participation in ecotourism initiatives	Contribution to local citizen science via beach cleanups or mobile apps. Services to support volunteer based pictures (identification and validation)	As an SME owner (snorkel guided tours), I want to participate in ecotourism initiatives so that I can contribute to local citizen science via beach cleanups or mobile apps. Additionally, I want to offer services to support volunteer-based pictures for identification and validation.
			Health info relevant to tourism	Positioning the region as a smart & sustainable coastal destination	As an SME owner (snorkel guided tours), I want health info relevant to tourism so that the region is positioned as a smart and sustainable coastal destination

Table 5. User Personas - Case Study 1

Full Name	Job Title	Age	Needs	Expected Outcomes	User Stories
Eleni Alexiadou	General Practitioner at the Local Health Center	45	Access to data on water and food contamination	Access to AI-based alerts on environmental risks (e.g., waterborne pathogens)	As a General Practitioner at the Local Health Center, I want access to data on water and food contamination, so that I can receive AI-based alerts on environmental risks (e.g., waterborne pathogens)
			Early prevention tools for environmental health risks	Integration of Copernicus data into public health monitoring	As a General Practitioner at the Local Health Center, I want early prevention tools for environmental health risks, so that I can integrate Copernicus data into public health monitoring
			Collaboration with environmentalists and veterinarians	Better preparedness for outbreaks linked to water or climate	As a General Practitioner at the Local Health Center, I want collaboration with environmentalists and veterinarians, so that I can ensure better preparedness for outbreaks linked to water or climate
			Informational material for vulnerable groups	Creation of early-warning protocols linking environmental signals to human health	As a General Practitioner at the Local Health Center, I want informational material for vulnerable groups, so that I can create early-warning

					protocols that link environmental signals to human health
Antonis Psaropoulos	Fish Farming Unit Owner	51	Systematic water quality monitoring	Timely alerts on harmful algal blooms or pollution events from AI models	As a Fish Farming Unit Owner, I want systematic water quality monitoring, so that I can receive timely alerts on harmful algal blooms or pollution events from AI models
			Early warnings for harmful algae and pathogens	Dashboard with marine Copernicus data for aquaculture safety	As a Fish Farming Unit Owner, I want early warnings for harmful algae and pathogens, so that I can access a dashboard with marine Copernicus data to ensure aquaculture safety
			Guidance on sustainable aquaculture	Reduced economic losses through predictive water quality forecasting	As a Fish Farming Unit Owner, I want guidance on sustainable aquaculture, so that I can reduce economic losses through predictive water quality forecasting
			Networking with producers and authorities	Guidelines for adaptive aquaculture management based on real-time data	As a Fish Farming Unit Owner, I want networking with producers and authorities, so that I can receive guidelines for adaptive aquaculture management based on real-time data

Nikos Laderos	Olive oil and vegetable producer	55	Clean irrigation water	Access to environmental risk maps (e.g., runoff or salinity zones) via Copernicus	As an olive oil and vegetable producer, I want clean irrigation water, so that I can access environmental risk maps (e.g., runoff or salinity zones) via Copernicus
			Support for using organic inputs	Use of AI tools to link environmental conditions to animal/human health risks	As an olive oil and vegetable producer, I want support for using organic inputs, so that I can use AI tools to link environmental conditions to animal/human health risks
			Training on agroecological practices	Improved soil and water management practices based on data insights	As an olive oil and vegetable producer, I want training on agroecological practices, so that I can improve soil and water management practices based on data insights
			Awareness of farming impacts on health	Participation in local citizen science to monitor land-sea pollution pathways	As an olive oil and vegetable producer, I want awareness of farming impacts on health, so that I can participate in local citizen science initiatives to monitor land-sea pollution pathways

Dimitrios Gatos	Veterinarian	40	Data on zoonotic disease outbreaks	Early detection of zoonotic risk hotspots through environmental surveillance	As a veterinarian, I want data on zoonotic disease outbreaks, so that I can achieve early detection of zoonotic risk hotspots through environmental surveillance +G14:G15
			Biosecurity protocols for farms	Integration of AI-assisted trend analysis for animal disease emergence	As a veterinarian, I want biosecurity protocols for farms, so that I can integrate AI-assisted trend analysis for animal disease emergence
			Collaboration with health/environmental bodies	Cross-sectoral data flow between health, animal, and environmental domains	As a veterinarian, I want collaboration with health and environmental bodies, so that I can enable cross-sectoral data flow between health, animal, and environmental domains
			Education on responsible antibiotic use	Participation in One Health decision-support systems powered by Earth observation	As a veterinarian, I want education on responsible antibiotic use, so that I can participate in One Health decision-support systems powered by Earth observation
Anna Papadimitriou	Tourist accommodation owner	33	Clean coasts and marine water	Real-time water quality updates for safe bathing and recreation	As a tourist accommodation owner, I want to access real-time water quality updates, so that I have clean

					coasts and marine water for safe bathing and recreation
			Promotion of eco-identity of the region	Use of AI-powered "eco-labels" or environmental indicators to attract visitors	As a tourist accommodation owner, I want to use AI-powered "eco-labels" or environmental indicators to attract visitors, so that I can promote the eco-identity of the region
			Participation in ecotourism initiatives	Contribution to local citizen science via beach cleanups or mobile apps	As a tourist accommodation owner, I want to participate in ecotourism initiatives, so that I can contribute to local citizen science through beach cleanups or mobile apps
			Health info relevant to tourism	Positioning the region as a smart & sustainable coastal destination	As a tourist accommodation owner, I want access to health information relevant to tourism, so that I can help position the region as a smart and sustainable coastal destination.
Sofia Papakosta	Secondary School Teacher	48	One Health educational materials	Access to educational platforms using real marine data & AI visualizations	As a Secondary School Teacher, I want One Health educational materials, so that I can access educational platforms using real marine data and AI visualizations to enhance student learning and engagement.

			Local case studies and experiential activities	Engagement of students in citizen science (e.g., water sampling, biodiversity logs)	As a Secondary School Teacher, I want local case studies and experiential activities, so that I can engage students in citizen science initiatives like water sampling and biodiversity logging
			Collaboration with NGOs	Increased environmental literacy and understanding of One Health	As a Secondary School Teacher, I want to collaborate with NGOs, so that I can increase students' environmental literacy and their understanding of the One Health approach.
			School participation in community-based coastal monitoring activities	Support for raising student awareness	As a Secondary School Teacher, I want the school to participate in community-based coastal monitoring activities, so that I can raise student awareness

Table 6. User Personas - Case Study 2

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One Planet, One Health for Coastal Resilience

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"This project has received funding from the European Union's Horizon Europe under grant agreement No 101180146 —ENHANCE. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the granting authority. Neither the European Union nor the granting authority can be held responsible for them."