D4.1 Evaluation Methodology & Test Scenarios.

WP4: Case Study Demonstration and Evaluation

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Abbreviations	Explanation
CS	Case Study
D	Deliverable
DPSIR	Driver–Pressure–State–Impact–Response
EEQI	Ecological Environmental Quality Indicator
EGNSS	European Global Navigation Satellite System
EU	European Union
FAIR	Findable, Accessible, Interoperable, and Reusable
GIS	Geographical Information Systems
GOHI	Global One Health Index
IoT	Internet of Things
KPIs	Key Performance Indicators
LAU	Local Administrative Unit
MCDA	Multi-Criteria Decision Analysis
MoSCoW	Must Have, Should Have, Could Have, Won't Have this time
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 presents the evaluation methodology and test scenarios that will guide the assessment of ENHANCE tools across the two Case Studies: one in the West Mediterranean, including two main human pressures: Urban (Barcelona) and Agricultural (Ebro delta), and other in Easter Mediterranean evaluating the impact of extreme events (Pagasitikos gulf).

It defines the One Health indicators, the data sources supporting them, and the user profiles involved in each Living Lab.

The document also outlines the evaluation components, to determine the performance, usability, relevance, and adoption potential of the ENHANCE products. More specifically, the evaluation will:

1. Validate that **data products** meet the required levels of **accuracy, and operational performance** across case studies.
2. Assess whether **users** from different profiles can effectively access, **understand and apply the One Health indicators** provided through the ENHANCE solutions.
3. Determine the degree of **stakeholder acceptance**, perceived usefulness and readiness for adoption of the ENHANCE outputs within the Living Lab contexts.
4. Generate evidence that supports **iterative improvement of tools**, workflows and interfaces between the first (M20) and second (M27) pilot operations waves.
5. Ensure **comparability of results** across case studies and generate insights that support the future replication and scalability of the ENHANCE methodology.

Performance has been evaluated in three main domains:

- **Technical.** Covering the verification of remote sensing outputs, citizen-science data products and AI-assisted classification tools
- **User-experience,** focussed on assessing whether users can effectively interact with the ENHANCE platform and understand the One Health indicators relevant to their profile
- **Socio-economic evaluation** to assess the extent to which environmental indicators generated within the project translate into tangible societal and economic value.

The methodology will be applied during the first and second pilot iterations, and the resulting findings will be reported in D4.2 and D4.3.

1. Introduction

This deliverable (D4.1) outlines the evaluation methodology considering the tools performance, user experience and also social-economic and environmental aspects.

This document defines **detailed scenarios** for each case study pilot, indicating the selected One health (OH) indicators, the involved users and the **methodology for evaluating** them. Each test scenario (use case) is crafted to reflect the user and system requirements gathered in WP2, while also showcasing the full potential of the ENHANCE toolkit in a real-world context. Key preparatory actions include **assembling all required data** (remote sensing, in situ, and citizen science) and **configuring the pilot sites** with necessary instruments. It is important to note that the execution and results of these scenarios will be documented in subsequent deliverables: D4.2 First wave of pilot operations and evaluation report (at project month 20) and D4.3 Second wave of pilot operations and evaluation report (at month 27), which will detail the findings and evaluation outcomes of the pilot implementations.

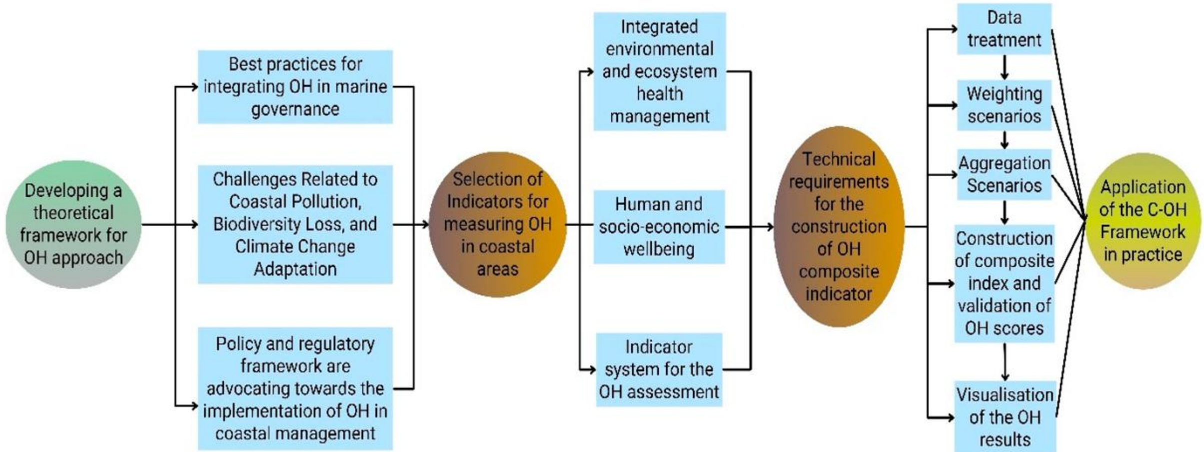

Figure 1 Coastal One Health Framework: Building a Composite Index from Theory to Practice. Source D2.1 and publication: Ioannou et al., 2025 https://www.mdpi.com/2071-1050/17/21/9359

2. One Health frameworks in test scenarios

The evaluation of the ENHANCE tools requires a clear understanding of the selected indicators for One Health and the stakeholders involved in each test scenario (referenced as Case Studies). This section reviews the selected OH indicators and the main user profiles participating in the linked Living Labs for each case, describes how the different groups contribute to the operationalisation of the OH framework

2.1 Case Study1-A Barcelona: Urban beaches

The beaches around Barcelona are most at risk of suffering from the **eutrophication process** in Catalonia due to the anthropogenic pressure. In this case the One Health (OH) approach has been framed on the effects of the anthropogenic activity. The area has the most intensive participation of people in the context of **biodiversity monitoring**, making the case the ideal scenario to evaluate ENHANCE products based on citizen science.

2.1.1 One Health Indicators for Case Study 1-A

Human health in Barcelona's urban beaches is directly affected by episodic pollution events and variations in bathing-water quality linked to intense recreational use and stormwater overflows. From an environmental health perspective, these coastal areas experience strong anthropogenic pressures that can modify ecological dynamics, accelerate eutrophication processes, and impact biodiversity, making them ideal for testing ENHANCE's integrated One Health indicators.

1st Level indicator	2nd Level indicator	3rd Level indicator (in each beach)	Primary source of data: 1) Copernicus 2) Citizen Science 3) Complementary data	ENHANCE Product
Human Health	Health Risk	Unsafe water	Copernicus Sentinel-2 data. Specifically, using single ocean colour images of high spatial resolution and a corresponding threshold.	**Turbidity maps.** Generated maps will provide information on possible wastewater overflows. Categorized maps of possible bacterial contamination of coastal waters, which can be used as an early warning.
Animal Health	Animal Biodiversity	Coastal Fish assemblages Presence of Alien species	Citizen Science data from MINKA observatory	**Fish Species richness** (occurrence data) **maps** **Alien species list**

Environmental Health	Water quality	Eutrophication risk	CORINE Land Cover (information on LULC and coastline morphology). Fluvial inflows data from IDESCAT (Official statistics of Catalonia). Copernicus-Sentinel-2. Specifically, performing mosaics with multiple ocean colour images of high spatial resolution and a corresponding threshold.	**D-LUSI maps.** Generated maps will provide information on the risk of eutrophication of coastal waters from land. **[Chl-*a*] maps.** Generated maps will provide information on the risk of eutrophication of coastal waters one step beyond D-LUSI, as it is assessed directly on coastal waters. Categorized maps of eutrophication risk of coastal waters.

Table 1: OH selected indicators and sources of data to elaborate ENHACE products in CS 1-A

2.1.2 User Profiles & Key roles for Case Study 1-A

The Barcelona Living Lab brings together recreational users, citizen scientists, managers and researchers who interact with the coastal environment at different levels. Their participation helps generating species-occurrence data, validating satellite-derived products and building indicators for local decision-making regarding bathing water quality, coastal management and environmental monitoring.

Profiles	Communities from the proposed Living Labs	Main roles in data acquisition, validation, exploitation for OH indicators
No login users	Members (scuba-divers) of the “Catalan Federation of Underwater Activities” (FECDAS) Diving clubs in Barcelona Beaches Snorkelers	**Data collection** **Sometimes (collaborative) validation** People that it is already involved in MINKA data collection, some of them with their own citizen science projects in the area of interest
Urban planners & Coastal Managers	Barcelona City Council	**Data exploitation (Informed decision-making)** Barcelona Biodiversity Atlas Coastal / Beach Management /WFD and MSFD - and the derived national and regional laws
Animal and Human Health professionals	BCASA	**Data exploitation (monitoring)**

		Public company in charge of water quality monitoring in the area of Barcelona and other related administrations
Researchers and scientists	ICM-CSIC	**Data validation** **Data exploitation (research)** ENHANCE partner

Table 2: User Profiles & Key roles in OH framework for Case Study 1A.

2.2 Case Study 1-B: Ebro Delta

The Ebro Delta is one of the most ecologically significant wetlands in the Western Mediterranean and represents a highly dynamic system where agriculture, aquaculture, tourism and conservation coexist. This complexity makes the territory particularly suitable for the One Health approach, as changes in ecological status have direct implications for human health, animal biodiversity and the resilience of the ecosystem.

2.2.1 One Health Indicators for Case Study 1-B

The Delta is especially vulnerable to eutrophication due to riverine inputs, intensive agricultural activity and the geomorphological characteristics of its bays, which favour nutrient retention. At the same time, the region hosts rich communities of coastal plants and bird species, making it a key site for assessing animal and environmental health using citizen-science data. ENHANCE enables the combination of satellite observations, in-situ datasets and citizen-generated records to produce operational indicators that support early warning, guide protected-area management and contribute to long-term strategies for climate resilience and coastal protection.

1st Level indicator	2nd Level indicator	3rd Level indicator	Primary source of data: 1) Copernicus 2) Citizen Science 3) Complementary data	ENHANCE Product
Human Health	Health Risk	Algal blooms (Optically detectable)	Copernicus Sentinel-2 data. Specifically, using single ocean colour images of high spatial resolution and a corresponding threshold.	**[Chl-*a*] maps.** Generated maps will provide information on concentration of phytoplanktonic biomass. **Categorized maps** of possible presence of algal blooms on coastal waters, which can be used as an early warning.

Animal Health	Animal Biodiversity	Bird occurrences Presence of Alien species	Citizen Science data from MINKA observatory	**Bird Species richness** (occurrence data) **maps** **Alien species list**
Environmental Health	Plant Biodiversity Water quality	Coastal plant occurrences Eutrophication risk	Citizen Science data from MINKA observatory CORINE Land Cover (information on LULC and coastline morphology). Fluvial inflows data from IDESCAT (Official statistics of Catalonia). Copernicus-Sentinel-2. Specifically, performing mosaics with multiple ocean colour images of high spatial resolution and a corresponding threshold.	**Plant Species richness** (occurrence data) **maps** **D-LUSI maps.** Generated maps will provide information on the risk of eutrophication of coastal waters from land. **[Chl-*a*] maps.** Generated maps will provide information on the risk of eutrophication of coastal waters one step beyond D-LUSI, as it is assessed directly on coastal waters. **Categorized maps** of eutrophication risk of coastal waters.

Table 3: OH selected indicators and sources of data to elaborate ENHACE products in CS 1-B

2.2.2 User Profiles & Key roles in Case Study 1-B

The Ebro Delta involves a diverse community of observers, conservation managers, research institutions and actors linked to environmental monitoring. Their contributions help generating species-occurrence data and support AI validation. They will be testing the exploitation of ENHANCE outputs for water-quality assessments, ecosystem conservation, and coastal-zone management.

Profiles	Communities from the proposed Living Labs	Main roles in data acquisition /validation for OH indicators
No login users	Snorkelers Birdwatchers Hikers (coastal plant species monitoring) SMEs involved in scientific tourism Beachgoers	People that it is already involved in MINKA data collection, some of them with their own citizen science projects in the area of interest Plàncton Divulga. An SME involved in non-formal education and scientific tourism activities in this area

Urban planners & Coastal Managers	Delta Natural Parc	Main environmental managers of the territory and administrations in charge of water quality / Coastal zone management /WFD and MSFD - and the derived national and regional laws
Animal and Human Health professionals	IRTA ACA (Water Catalan Agency)	Public institution in charge of phytoplankton monitoring in the area. IRTA has been in charge of producing the dataset PHYTOENVDELTA. Physicochemical monitoring of the Water Catalan Agency.
Researchers and scientists	(1) ICM-CSIC (2) UPC and EURECAT	(1) ENHANCE partner, main coordinator of the case study (2) Partners from COAST-SCAPES project (where Ebro Delta is a use case for Coastal Resilience)

Table 4: User Profiles & Key roles in OH framework for Case Study 1B.

In summary, Case 1 will be focused mainly in two different pressure scenarios: anthropogenic in the case of Barcelona beaches and agricultural in the case of Ebro delta. In both scenarios the main complementary data to the ones derived from Copernicus, will be citizen science based, generated through the MINKA platform. The main AI development will be focussed on hybrid and hierarchical methods of automatic classification of observations.

2.3 Case Study 2: Pagasitikos Gulf

Post-flood conditions in the Pagasitikos Gulf introduced unusually high turbidity and altered optical properties, affecting the accuracy of satellite-derived parameters such as chlorophyll-a (Chl-a) and Total Suspended Matter (TSM). This requires careful validation with in-situ measurements during pilot preparation. Runoff and land-based inputs may exhibit strong temporal variability after extreme events, influencing the distribution of environmental pressures captured through D-LUSI components.

Furthermore, integrating heterogeneous datasets, satellite observations, in-situ measurements, laboratory analyses and complementary environmental records, requires temporal alignment and consistency in spatial resolution to ensure reliable use within the ENHANCE methodology.

2.3.1 One Health Indicators for Case Study 2

The indicators for CS2 (Pagasitikos Gulf) are supported by a combination of satellite-based, in-situ and laboratory datasets. Copernicus Earth Observation (EO) products include Chl-a and TSM, which provide high-resolution information on phytoplankton biomass and water turbidity respectively. TSM represents the concentration of suspended particles (e.g., sediments, organic material), which increased significantly after the 2023 flood and is directly linked to coastal water quality and eutrophication pressure. Moreover, Copernicus EO images will be further processed if needed. Additionally, Sea Surface Temperature (SST) is obtained from the CMEMS service through the MyOcean Pro platform, enabling the monitoring of temperature variability relevant to phytoplankton dynamics and HAB development. These satellite products are complemented by in-situ water quality measurements from UTH and laboratory analyses of fish tissues for pathogens and antimicrobial resistance (AMR).

Urban and land-based pressures (obtained from Copernicus) are characterised through D-LUSI components derived from land-use patterns and runoff points, while wastewater effluent datasets provide essential information on coastal nutrient and organic inputs. Together, these datasets supply the foundational inputs required for the pilot preparation, enabling the configuration of the processing workflows, HAB risk modelling and environmental pressure layers to be used in the subsequent phases of ENHANCE.

1st Level indicator	2nd Level indicator	3rd Level indicator (in each beach)	Primary source of data: 1) Copernicus 2) Citizen Science 3) Complementary data	ENHANCE Product
Human Health	Health Risk	Unsafe water	Satellite-derived water quality parameters (e.g., Chl-a, TSM, SST) from Copernicus services Complementary datasets from national authorities (e.g., bathing water classifications, environmental monitoring)	**Human Health Outcome Index (HHOI)** for coastal bathing sites in Pagasitikos Gulf (annual values)
Animal Health	Fish Health	Occurrence of antimicrobial resistance and pathogens in fish tissue	Laboratory analysis of fish tissue samples collected in Pagasitikos Gulf (antimicrobial resistance profiles, detection of selected pathogens)	**Aquatic Animal Health Risk Index (AAHRI)** based on AMR patterns and pathogen occurrence in fish tissue.

Environmental Health	Water quality & Ecosystem Status	Eutrophication risk / ecological pressure	Copernicus products Complementary datasets for environmental monitoring	**Environmental Ecosystem Quality Index (EEQI)** capturing ecosystem pressure and water-quality status in the gulf

Table 5: OH selected indicators and sources of data to elaborate ENHACE products in CS 2

2.3.2 User Profiles & Key roles in Case Study 2

The Pagasitikos Gulf Living Lab mobilises local residents, public authorities, environmental and health professionals, and academic partners. These stakeholders contribute to the provision and interpretation of socio-environmental information, support the validation of One Health indicators (e.g., water quality, AMR and environmental pressures), and use ENHANCE outputs to inform planning, early-warning protocols and post-flood resilience strategies.

Profiles	Communities from the proposed Living Labs	Main roles in data acquisition, validation, exploitation for OH indicators
No login users	Local residents and beach users, swimmers and snorkelers, tourists and visitors, small tourism businesses (e.g. accommodation owners) around Pagasitikos Gulf.	Awareness and information uptake. Use ENHANCE dashboards and alerts to understand coastal water conditions and identify safe or unsafe bathing areas. Adjust recreational activities based on water quality information and warning notifications, contributing indirectly to risk communication and public awareness.
Urban planners & Coastal Managers	Region of Thessaly services (environment, agriculture, public health, civil protection), Municipality of Volos and neighbouring coastal municipalities, port and coastal zone authorities, planning and geological/technical chambers.	Data exploitation and decision support. Use ENHANCE outputs (water quality status, environmental pressure indicators) to support coastal planning, bathing-water management, emergency response and post-flood recovery actions. Apply validated One Health indicators to inform regulatory decisions, prioritise interventions, and support coordination across environmental, public health and civil protection services.
Animal, Human and Environmental Health professionals	Public health professionals (general practitioners, hospital doctors), regional public-health directorates; veterinarians and animal-health services; aquaculture veterinarians and fish-farm health managers; laboratory staff analysing environmental and tissue samples.	Validation and interpretation of health-related indicators. Review and interpret water-quality, pathogen and AMR indicators in relation to human and animal health risks. Contribute expert judgement to validate One Health outputs, and provide guidance on risk mitigation measures for vulnerable groups and food-safety considerations.
Researchers and scientists	University of Thessaly and other Greek research groups involved in water quality,	Scientific validation and knowledge exploitation. Support the methodological validation of One Health indicators, analyse trends and relationships

	marine ecology, AMR, EO/AI and climate-risk analysis; collaborating institutes and students (MSc/PhD).	between environmental pressures and health outcomes, and translate ENHANCE results into scientific evidence, policy recommendations and training material for stakeholders involved in the Living Lab.

Table 6: User Profiles & Key roles in OH framework for Case Study 2.

In summary, Case 2 will be focused mainly in monitoring post-flood conditions in the Pagasitikos Gulf, supported by a combination of satellite-based, in-situ and laboratory datasets. AI activities are planned as predictive and early warning systems

2.4 Benefits and expectations from the OH Framework

As a summary, the following tables provides the link between the different ENHANCE proposed products and the potential benefits for the different identified end-users

One health indicator	ENHANCE product	No login users	Urban planners & Coastal Managers	Animal and Human Health professionals	Researchers and scientists
Human Health	Detection map of wastewater overflows	Information to avoid the risk places to practice their activities	Improvement of wastewater management and related infrastructures	Adaptive monitoring increasing sampling effort in critical areas	Time series to exploit for predictive models of wastewater overflows
Animal Health	Fish and bird Species occurrences Alien species	Active collaborators for species reporting Consultation of interesting/target species	Information for coastal management strategies to avoid biodiversity loss	Proxy for evaluation the animal biodiversity status (operational monitoring)	Data validators, Fish and bird Species distribution models
Environmental Health	Eutrophication risk Plant Species occurrences Alien species	Information to avoid the risk places to practice their activities Active collaborators for species reporting	Information for coastal management strategies to prevent /mitigate eutrophication strategies to avoid plant biodiversity loss	Proxy for evaluation the ecosystem status including plant biodiversity (operational monitoring)	Time series to exploit for predictive models for eutrophication risk Plant Species distribution models

Table 7: Benefits and Expectations from OH Framework (Case Study 1)

One health indicator	Enhance product	No login users	Urban planners & Coastal Managers	Animal and Human Health professionals	Researchers and scientists
Human Health	Bathing water quality & microbial contamination risk maps Human Health Outcome Index (HHOI)	Information to avoid high-risk bathing areas	Decision support for beach closures/openings and Prioritisation of remediation actions	Adaptive monitoring: increase sampling effort in microbial "hotspots" Support public health risk assessment & targeted investigations	Exploitation of HHOI indicator results for research purposes.
Animal Health	Fish tissue pathogens & AMR (antimicrobial resistance) Aquatic Animal Health Risk Index (AAHRI)	Information/awareness for seafood safety	Support fisheries management measures.	Operational monitoring proxy for animal health status Link animal health signals with water-quality pressures	Datasets for prevalence & AMR trend analysis
Environmental Health	Water quality parameters (Chl-a, turbidity/TSS, Temperature, wastewater loads)	Information on environmental status	Coastal management strategies to mitigate eutrophication & Monitor ecosystem recovery	Proxy for ecosystem status to steer monitoring plans Support integrated One-Health interpretation (environment ↔ animal ↔ human)	Time series to explore predictive models and pressure dynamics.

Table 8: Benefits and Expectations from OH Framework (Case Study 2)

2.5 Timelines for Case Studies

The time lines using Gantt diagrams for Case 1 (Figure 2.1) and Case 2 (Figure 2.2) are structured to follow the project's 36-month duration (M1–M36, starting 1 Dec 2024) and to keep WP4 activities aligned with the planned deliverables and pilot waves (D4.1 at M13, D4.2 at M20, D4.3 at M27, D4.4 at M34).

A. Preparation & evaluation methodology.

The evaluation methodology, monitoring plan, data pipeline design, and KPI definition are scheduled early because they are prerequisites for credible pilot execution and measurable impact assessment. This ensures that (i) data collection and model training follow agreed protocols, (ii) pilot test scenarios are defined before field deployment, and (iii) the consortium can report consistently against WP4 performance indicators.

B. Living Lab implementation (continuous, with phased co-creation).

Living Lab activities run across the project because stakeholder needs evolve as tools mature and the ecosystem recovers post-flood. The phased structure (mapping → co-design → validation → replication/upscaling) creates iterative feedback loops: early stakeholder mapping and needs identification inform tool tailoring; mid-project co-creation supports pilot operations; late-stage workshops focus on uptake, replication and policy relevance. This matches ENHANCE's co-creation-driven methodology, where Living Labs support both development and validation cycles.

C. Data collection, measurement & evaluation (starts early and persists).

Continuous data acquisition is justified in CS1 for the implication of participants in citizen scince data and in CS2 because is explicitly about tracking disaster impact and recovery over time. Starting early allows: (i) baseline and trend establishment from Copernicus/official and citizen science sources, (ii) dedicated efforts in large scale participatory events (BioMARathons) in CS1 that will be adopted as well in CS2 as early adoption methodology, but without the aim to use that data for implementing the main ENHANCE products. At the end of each event there will be dedicated workshops to evaluate the results (WS5 and WS6). In CS2 the main complementary data will be obtained with sustained in-situ and lab campaigns (water quality and fish tissue analyses for pathogens/AMR), and (iii) sufficient data volume for model calibration/validation before and during pilot waves.

D. Reporting & deliverable contributions (synchronised with pilot waves).

Reporting tasks are timed to support WP4 outputs: methodology/test scenarios feed D4.1; pre-pilot and first operational results feed D4.2; refined/scaled operations feed D4.3; and the consolidated socio-economic acceptance + KPI monitoring feed D4.4. This sequencing reduces delivery risk by ensuring each report is backed by completed activities and validated datasets, while keeping stakeholder engagement evidence and KPI calculations up to date.

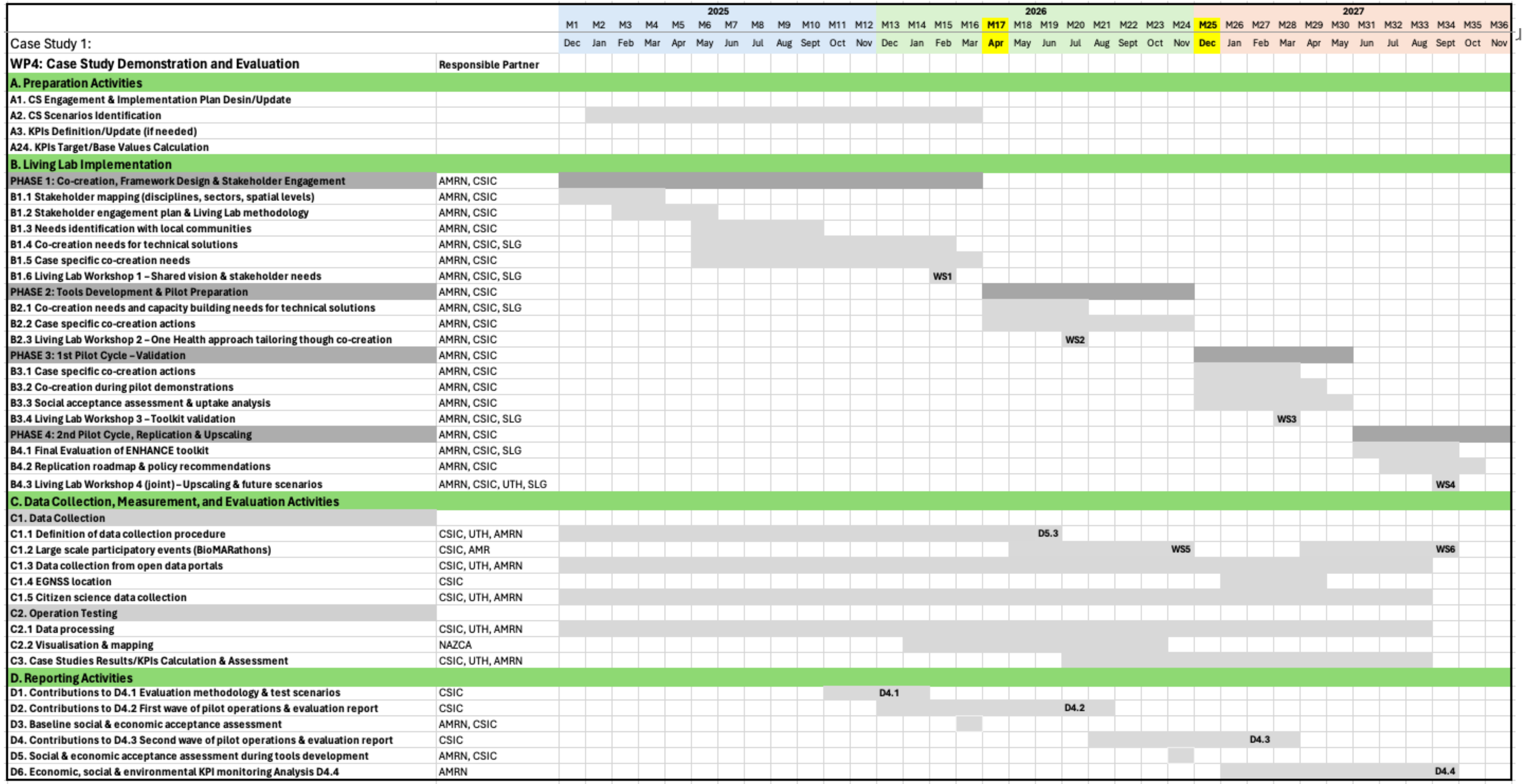

Figure 2 Summarises the planned timeline for Case Study 1. The schedule includes the preparation activities, data collection and processing tasks, visualization and mapping workflows, and the assessment of results, followed by reporting activities contributing to the evaluation deliverables

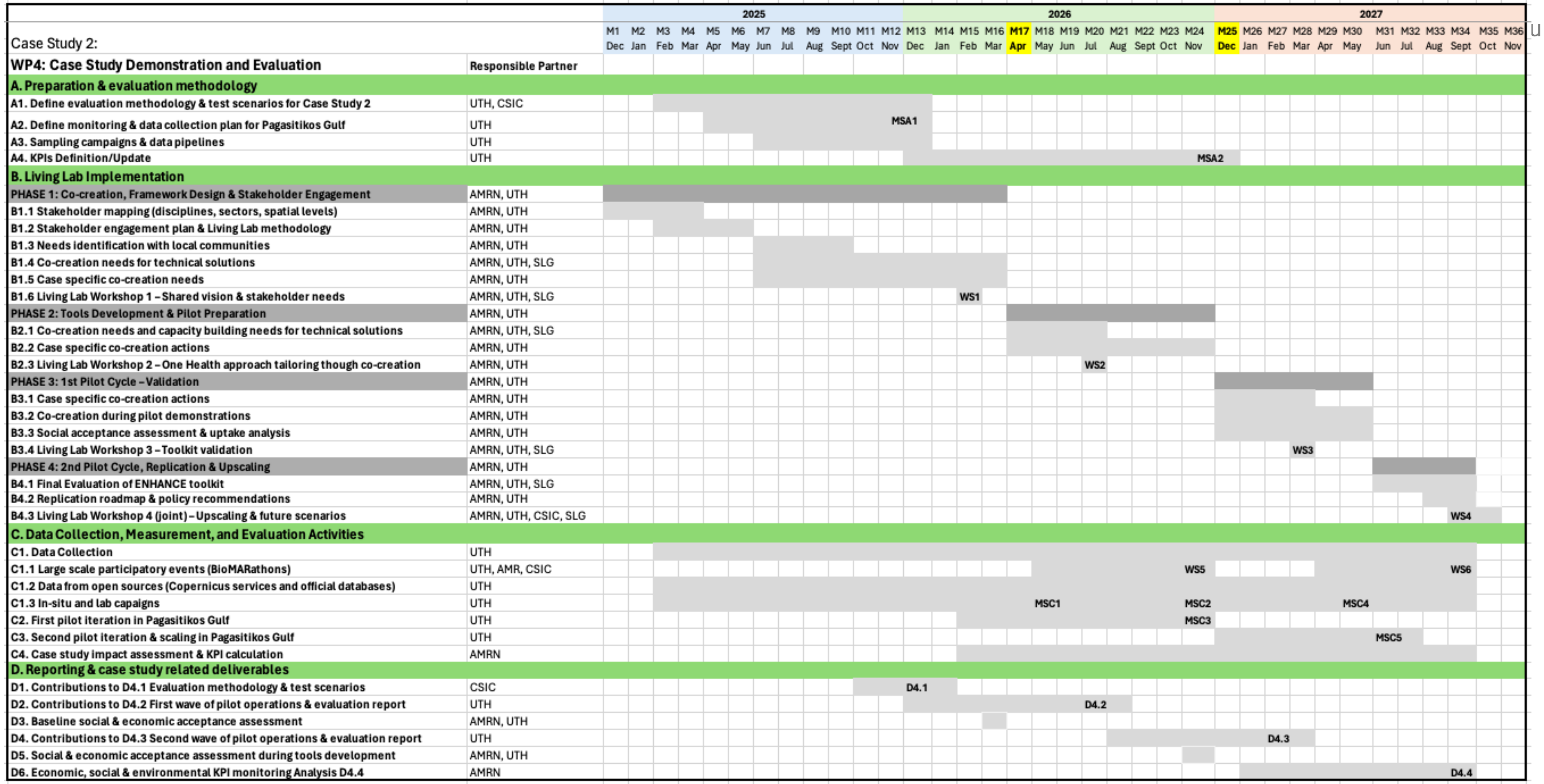

Figure 3: Summarises the corresponding timeline for Case Study 2. The schedule includes the methodological preparation and data collection activities, Living Lab engagement processes, and the two planned pilot iterations, followed by reporting tasks

3. Case Studies data sources

This section covers the identification of relevant data sources, mainly those based on FAIR principles (Findable, Accessible, Interoperable and Reproducible), and state-of-the-art information used to set up the pilot scenarios on the ENHANCE project. These sources include Copernicus Earth observation products, citizen science observations, and AI-based tools that support the generation and validation of One Health (OH) indicators. The section also highlights key challenges related to data quality, heterogenous sampling effort, and the integration of advanced AI tools into the pilot flows.

3.1 Copernicus data sources for OH Indicators

Human and Environmental Health Indicators

In order to provide the products, images of Sentinel-2 of high spatial resolution will be downloaded from Copernicus Data Space Ecosystem (https://dataspace.copernicus.eu/browser) of the European Space Agency. These images will then be processed with the repository ACOLITE (https://github.com/acolite) developed by the Royal Belgian Institute of Natural Sciences (https://www.naturalsciences.be).

Besides, the European Coordination of Information on the Environment (CORINE) Land Cover will be also downloaded from the Copernicus Land Monitoring Service webpage (https://land.copernicus.eu/en/products/corine-land-cover).

These products support **turbidity maps** (related to human health) and **Chlorophyll-a maps** for eutrophication assessment (environmental health). These products provide consistent, spatially extensive information; however, coastal zones pose challenges due to land–water mixing, requiring careful validation and interpretation.

Animal Health Indicators

ENHANCE project will not use information from Copernicus data sources to cover this indicator, as it cannot directly capture data about **number or species distribution**. The collected data could further link with the variables provided by the Copernicus Marine Service, that provides complementary information (Figure 4)

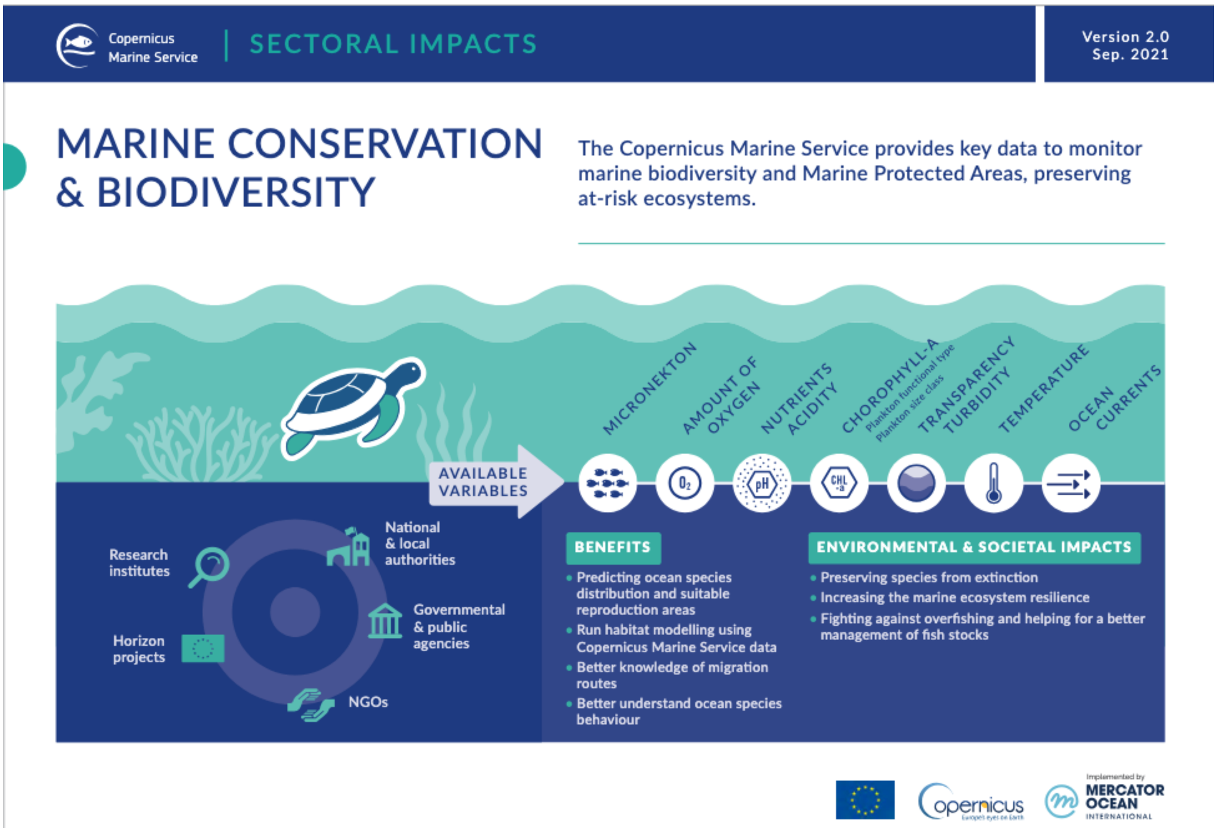

Figure 4: Copernicus data products to be used as a complementary information for the proposed ENHANCE biodiversity indicators (from https://marine.copernicus.eu/services/markets/marine-conservation-biodiversity)

3.2 Citizen Science data sources for OH Indicators

Animal and Environmental Health Indicators

Citizen science is the main data source for the Animal Health indicators and some Ecosystem Health in ENHANCE, based on fish and alien species occurrences. As explained below, species-level biodiversity information cannot be reliably obtained from Copernicus products. Through the MINKA citizen observatory, volunteers contribute observations of coastal biodiversity that directly support the indicators defined for Case Study 1A (Barcelona) for fishes (Animal Health) and Case Study 1B (Ebre) for plants (Environmental/Ecosystem Health). Furthermore, these observations allow the project to document the presence of alien species.

These records provide a proxy for habitat condition and ecosystem health in a dynamic coastal system where local environmental changes are often not detectable through satellite imagery alone.

3.3 Complementary data

ENHANCE complements Copernicus Earth Observation products with targeted in situ monitoring and local administrative datasets to capture post-disaster dynamics, validate EO-derived indicators, and support the modelling of One Health risks. UTH has been conducting regular sampling campaigns to monitor the evolution and recovery pathways of the gulf, analysing water quality parameters (e.g., pH, turbidity, dissolved oxygen, etc.) and fish tissue for pathogens and antimicrobial resistance. These data streams are crucial because they provide ground-truth information at the local scale, including variables and impacts that cannot be directly observed from satellites.

Local OECD/open data portal (environmental & human health context)

Additional environmental and human-health-related indicators from the relevant local OECD/open data portal, with emphasis on environmental parameters and indicators that are already derived from (or consistent with) Copernicus services and pre-adjusted to the areas of interest. These datasets provide operational context and continuity (often time-series, administratively curated), complementing both satellite-derived layers and campaign-based measurements.

Local water utility data (pressures and nutrient/organic load proxies)

To better quantify land-based pressures reaching (especially relevant after flood-driven runoff and potential wastewater system disruptions), ENHANCE will integrate routine measurements from local water utilities, like the ones provided by the Water Catalan Agency in Case 1, and Municipal Water Supply and Sewerage Enterprise of Greater Volos (DEYAMV) in Case 2. The initial proposed parameters are:

- BOD_5 (mg/L) – biodegradable organic load proxy
- COD (mg/L) – total oxidisable load proxy
- TSS (mg/L) – suspended solids load proxy (complements turbidity/TSM)
- TP (mg/L) – total phosphorus (key eutrophication driver)
- NH4-N (mg/L) – ammonium (nutrient load; also toxic at higher pH/temperature)

These parameters strengthen the pressure characterisation side of the extended DPSIR/One Health logic by providing upstream inputs that can explain or predict observed marine responses.

Local Bathing Water Profiles Registry (Human Health relevance)

For the human-health pillar, ENHANCE will incorporate datasets from the local authorities, such as the Greek Bathing Water Profiles Registry in Case 2. These records provide structured, site-based information that typically includes bathing water characterisation, known pressures/pollution sources, and monitoring-based quality classification.

In situ coastal water sampling campaigns (UTH)

As in the Case2 the Citizen Science data will be used only as early adoption of the community building, UTH will provide additional data with systematic field campaigns in Pagasitikos focusing on surface/coastal water conditions. The core parameters include:

- Surface temperature (thermal stress indicator and driver of metabolism, disease susceptibility, and algal bloom dynamics)
- Salinity (freshwater intrusion/mixing proxy and physiological stressor)
- Turbidity / suspended matter (sediment resuspension, runoff signal, reduced gill function / feeding efficiency, light limitation)
- Chlorophyll-a (Chl-a) (phytoplankton biomass proxy; supports eutrophication and bloom risk assessment)

These measurements are aligned with ENHANCE's approach to track extreme-event impacts and recovery time, where water quality variables such as turbidity, water temperature, salinity and pH are explicitly used to characterise conditions affecting marine fauna. In addition, Chl-a observations provide direct support to eutrophication/HAB monitoring and can be paired with EO-based Chl-a and turbidity retrievals (e.g., Sentinel-2 processing chains).

Fish tissue analysis (Animal Health / Food Security relevance)

In a similar way, to connect environmental pressures with animal health outcomes, UTH will analyse fish tissue for pathogens and antimicrobial resistance (AMR). These measurements provide an animal-health "impact" layer (biological response) that can be linked to environmental conditions and pollution pressure indicators. Within the ENHANCE demonstration logic for Pagasitikos, pathogens measured in fish are also used to support One Health assessment alongside bathing water quality and other risks.

5. Evaluation Framework and Methodology

5.1 Evaluation objectives and principles

The evaluation framework of ENHANCE assesses whether the tools, indicators, and methodologies developed in the project effectively support the generation, interpretation, and operational use of One Health information across the two Case Studies. It builds upon the requirements collected in WP2 and adopts a multi-dimensional approach combining technical validation, user-experience assessment, and stakeholder-driven analysis.

The overall goal is to determine the performance, usability, relevance, and adoption potential of the ENHANCE products. More specifically, the evaluation will:

6. Validate that **data products** meet the required levels of **accuracy, and operational performance** across case studies.
7. Assess whether **users** from different profiles can effectively access, **understand and apply the One Health indicators** provided through the ENHANCE solutions.
8. Determine the degree of **stakeholder acceptance**, perceived usefulness and readiness for adoption of the ENHANCE outputs within the Living Lab contexts.
9. Generate evidence that supports **iterative improvement of tools**, workflows and interfaces between the first (M20) and second (M27) pilot operations waves.
10. Ensure **comparability of results** across case studies and generate insights that support the future replication and scalability of the ENHANCE methodology.

The evaluation also verifies compliance with the data, functional and user requirements defined in WP2, ensuring that the tools, indicators and workflows are assessed against the specifications collected during the co-design process.

The evaluation relies on a set of Key Performance Indicators (KPIs) covering technical performance, user experience, and stakeholder adoption across the three case studies. These indicators provide a common measurement framework and allow comparison of results between pilot cycles. The KPIs listed below will be used to assess the ENHANCE tools, data products, and interactions with users and stakeholders.

5.2 Technical performance evaluation

The technical performance evaluation covers the verification of remote sensing outputs, citizen-science data products and AI-assisted classification tools. Detailed procedures for each case have been included in the annex section. Technological KPI thresholds have been proposed as the values required to achieve a minimum performance, but it may be reviewed and updated from further analysis and results.

ID	**TP1**
Category	Human Health
Name	Early warning based on turbidity maps for wastewater overflow
Description	Turbidity maps retrieved from ocean colour images obtained by Sentinel-2 and processed with ACOLITE. Once categorized, they inform about possible bacterial contamination of coastal waters, which can be used as an early warning.
Formula (Calculation Method) – if needed	Verification of the bacterial contamination with "in situ" reference data (regular monitoring)
Data Sources	Copernicus Data Space Ecosystem (https://dataspace.copernicus.eu/browser)
Relation to Service	Human Health indicator for Case Study 1A (Barcelona)
Target	Early warning system for bacterial contamination in water (health risk). High performance (at least 60% of true positive warnings)
Baseline Assessment – if applicable	No data product available before ENHANCE
ID	**TP_2.1**
Category	Animal Health Indicators
Name	Fish species richness (as biodiversity indicator)
Description	List of observed species + quality data indicator
Formula (Calculation Method)	All the fish species list will be complemented with a quality indicator index (See Annex I)
Data Sources	MINKA Citizen Observatory
Relation to Service	Animal Health indicator for Case Study 1A (Barcelona)
Target	Citizen Science Based Monitor in Barcelona Beaches achieving fish species list in all of them with a minimum quality indicator QI > 0,7
Baseline Assessment	14.000 observations from 127 of fish species before starting ENHANCE project beaches reported in 10 beaches.
ID	**TP2.2**
Category	Animal Health Indicators
Name	Precision of AI-assisted fish identification
Description	Measure the precision of AI to identify the correct fish species
Formula (Calculation Method) – if needed	Number of accepted validated observations (*with the help of AI systems)

Data Sources	MINKA Citizen Observatory
Relation to Service	ENHANCE AI tools
Target	>30% of new fish observations from Barcelona urban beaches submitted to MINKA are automatically validated by the AI classifier
Baseline Assessment	14.000 observations from 127 of fish species before starting ENHANCE project beaches reported in 10 beaches Heterogeneous sampling effort in the different beaches (need to homogenize) 0% of fish observations from Barcelona urban beaches submitted to MINKA automatically validated by the AI classifier with all records being manually validated by experts
ID	**TP3**
Category	Animal Health Indicators – AI Tools
Name	Automatic AI-assisted fish identification
Description	Measure the precision of AI to identify the correct fish species
Formula (Calculation Method)	Performance of the automatic classification: percentage of correct fish species classifications
Data Sources	MINKA Citizen Observatory
Relation to Service	ENHANCE AI tools
Target	>30% of new fish observations from Barcelona urban beaches submitted to MINKA are automatically validated by the AI classifier correctly
Baseline Assessment – if applicable	14.000 observations from 127 of fish species before starting ENHANCE project beaches reported in 10 beaches. 0% of fish observations from Barcelona urban beaches submitted to MINKA automatically validated by the AI classifier with all records being manually validated by experts.
ID	**TP4**
Category	Environmental Health
Name	[Chl-a] map
Description	[Chl-a] map retrieved from ocean colour images obtained by Sentinel-2, processed with ACOLITE and mosaicked will provide information on the risk of eutrophication of coastal waters one step beyond D-LUSI, as it is assessed directly on coastal waters.
Data Sources	Copernicus Data Space Ecosystem (https://dataspace.copernicus.eu/browser)
Relation to Service	Environmental Health indicator for Case Study 1A&B
Target	
ID	**TP5**
Category	Ecosystem Health Indicators
Name	Plant occurrences in coastal areas

Description	List of plant occurrences as proxy of biodiversity quality List of alien species
Formula (Calculation Method)	Number of validated observations (*with the help of AI systems) Number of validated alien species Ensure that the curve of Num of species vs Num of observations reaches the maximum value (following Michaelis-Menten approach)
Data Sources	MINKA Citizen Observatory
Relation to Service	Animal Health indicator for Case Study 1B (Ebre)
Target	Ensure to reach saturation values curve of plants (following Michaelis-Menten approach) >30% of new coastal plant observations from the Ebro delta (and if available, Pagasitikos) submitted to MINKA are automatically validated by the integrated Pl@ntNet-based classifier (high-confidence predictions)
Baseline Assessment	169 observations from 82 plant species before starting ENHANCE project. ENHANCE does not use automatic validation of coastal plant observations in the pilot areas.
ID	**TP6**
Category	Environmental Health
Name	HAB Risk
Description	Prediction model for HAB risk (using chl-a)
Formula (Calculation Method) - if needed	Model formula that will include chl-a (ground truth)
Data Sources	In situ sampling and lab data, Satellite data
Relation to Service	Environmental Health indicator for Case Study 2
Target	Improve accuracy by 10-20% compared to satellite.
Baseline Assessment - if applicable	HAB Risk Maps based only on satellite data
ID	**TP7**
Category	Environmental Health
Name	Coastal water quality data
Description	Data on water quality from in situ sampling and lab analysis
Formula (Calculation Method) - if needed	Identify the sampling location using satelite data as a guide
Data Sources	In situ and lab data
Relation to Service	Environmental Health indicator for Case Study 2

Target	Water quality data > 7 collections
Baseline Assessment - if applicable	
ID	**TP8**
Category	Animal Health
Name	Fish tissue analysis
Description	Collection of fish from specific points in case study 2
Data Sources	In situ data
Relation to Service	Environmental Health indicator for Case Study 2
Target	Identify variables that affect the fish health > more than 2 variables identified
ID	**TP9**
Category	One Health status
Name	Coastal One Health Assessment Index
Description	Composite index that assess the One Health status of coastal areas by combining environmental quality, human health outcomes and animalhealth, to identify hotspots and support prevention and adaptation measures.
Formula (Calculation Method) - if needed	For each spatial unit, three normalized composite sub-indices (HHOI-Human health outcome index; AAHRI-Aquatic animal health risk index, and EEQI-Environmental Ecosystem quality index) are produced and combined into an overall index with equal (baseline scenario) and stakeholder-defined weights (alternative scenario)
Data Sources	Environment: OECD environmental indicators, including Copernicus-based products downscaled to each coastal pilot area. Human Health: OECD health databases (mortality, morbidity, hospital admissions, risk factors) for the relevant coastal regions. Animal Health: National and regional monitoring programmes and surveillance records.
Relation to Service	Core indicator for the ENHANCE service to evaluate and communicate One Health conditions in coastal areas, prioritize interventions and track changes over time.
Target	no of indices: 3 composite indices (one per dimension) + 1 overall aggregate index; weghting scenarios: 2 weighting scenarios (equal vs expert-based); Pilot sites: indicators tested in case Study 1 & 2; time coverage: 2010–2023; no of maps: 2 interactive maps (one per case study) showing temporal evolution of OH status.
Baseline Assessment - if applicable	No integrated One Health coastal assessment or composite index exists for the pilot areas.

ID	TP10
Category	Multi-hazard coastal risk assessment
Name	Dynamic multi-hazard coastal risk maps
Description	Spatially explicit maps that show how prone coastal communities are to multiple natural hazards for current and future conditions. The maps are “dynamic” because they integrate time-varying hazard intensities with evolving patterns of exposure and social vulnerability, allowing users to explore how risk changes across space and time
Formula (Calculation Method) - if needed	Risk is calculated for each spatial unit (e.g. grid cell, administrative unit) as a composite of Hazard (H), Exposure (E) and Vulnerability (V)
Data Sources	Multi-hazard layers from copernicus services; High-resolution population grids (e.g. Eurostat GEOSTAT, national census); land-use / land-cover (e.g. CORINE, Copernicus Land Monitoring Service); location of critical infrastructure (transport, energy, health, emergency services, schools) from national agencies and OpenStreetMap; digital elevation models (e.g. EU-DEM) for the production of low-coastal-elevation zones. Socio-economic and demographic indicators (age structure, income, employment, education, disabilities, housing quality, tenure, access to services) from Eurostat, national statistical offices, municipal datasets
Relation to Service	Core decision-support tool that translates complex risk information into intuitive maps for urban and coastal planners and local authorities, guiding land-use planning and emergency preparedness.
Target	no of indices: 3 composite indices (one per dimension) + 1 overall risk index; pilot site: case study 2; spatial unit: coastal municipalities of the Magnesia regional unit; temporal scale: 3 periods (pre-, during, post-event, subject to data availability); no of maps: 1 interactive risk map depicting spatio-temporal evolution.
Baseline Assessment - if applicable	Currently only static, single-hazard or partial maps exist; no integrated H–E–V dynamic multi-hazard risk maps are available for the pilot communities.

Table 9: Technological KPIs

5.3 User Experience evaluation

The user experience (UX) evaluation focuses on assessing whether users can effectively interact with the ENHANCE platform and understand the One Health indicators relevant to their profile.

The evaluation is executed by observations and interviews with end users. Users are given tasks or scenarios they have to solve. The assessment is based on short, predefined tasks derived from the requirements collected in WP2, such as locating an alert or interpreting an indicator map. These tasks are carried out during dedicated sessions in each pilot site or online.

During these sessions, facilitators record task completion and whether participants need assistance. A brief discussion will be conducted to capture the perceived clarity of the outputs, with at least 5 users. These observations provide quantitative and qualitative evidence on usability, interpretability and fitness for purpose of the interface and visual products. Qualitative feedback is especially useful for IT teams.

The UX evaluation follows the KPIs defined for this component in Section 5.2 and will inform iterative improvements across the pilot cycles.

User experience KPIs, evaluating usability, clarity and completion of user tasks aligned with the requirements defined in WP2.

ID	Name	Description	Formula / Method	Data sources	Target
UX-P1	**Likelihood to use Enhance services**	% of users completing visualization and analysis tasks during workshops.	Likely scale 0-5 points.	Form post workshop	median rate > 4
UX-P2	**Likelihood to ask for help while using ENHANCE services**	% of users requiring facilitator support to complete tasks.	{Users needing help / Total users} *100	Facilitator observation sheet.	Downward trend across iterations
UX-P3	**Output clarity and perceived easy-to-use**	Perceived interpretability of OH maps and/or indicators shown through the interface.	Qualitative feedback, online/onsite	5' interview to at least 5 users.	Improvement from Wave 1 to Wave 2

Table 10: User experience KPIs

5.4 Socio-economic evaluation

A socio-economic evaluation framework is adopted to assess the extent to which environmental indicators generated within the project translate into tangible societal and economic value. The framework is grounded in the ENHANCE One Health conceptual approach (Ioannou et al., 2025) and recent literature (Olander et al., 2024), which 31points out that environmental information creates impact only when it is socially understood, institutionally embedded, and economically actionable. Accordingly, the evaluation moves beyond the assessment of environmental status alone and focuses on the conditions under which environmental indicators support prevention, informed decision-making, and long-term resilience in coastal socio-ecological systems.

At the core of this framework lies the integration of **societal readiness** with **economic evaluation**. Societal readiness is understood as the degree to which stakeholders and institutions are prepared to interpret, trust, and use environmental information in practice. Recent studies highlight societal readiness as a critical determinant of the effectiveness of sustainability-oriented innovations, particularly in complex governance contexts such as coastal management, where scientific outputs must inform decisions across multiple sectors and scales (Braun et al., 2025; Olander et al., 2024; WHO, 2023). Within ENHANCE, societal readiness is therefore treated as a necessary precondition for the realization of socio-economic benefits.

Within this conceptual framing, the **stakeholder adoption and engagement evaluation** constitute a key operational component of the socio-economic assessment. This evaluation examines how relevant actors perceive the usefulness of ENHANCE outputs, their intention to adopt them in practice, and their level of participation in Living Lab activities, as these elements directly reflect the readiness of stakeholders to translate environmental indicators into socio-economically meaningful action.

The surveys capture process satisfaction, perceived usefulness of the indicators and intention to use the ENHANCE services. Participation logs provide information on attendance and involvement in the Living Lab. Together, these elements offer insights into the acceptance, relevance and operational value of the tools for local authorities, practitioners and community users.

The evaluation follows the adoption and engagement KPIs defined in Section 5.2 and will support refinement of the services and their alignment with stakeholder needs across the pilot cycles.

Socio-economic adoption KPIs, evaluating ENHANCE outputs perceived socio-economic relevance and impact as well as and the role of Living Lab engagement in enabling meaningful adoption.

ID	Name	Description	Method	Data Sources	Target
SE-P1	**Living Lab process satisfaction**	Perceived quality of engagement, facilitation, transparency and	Mean score (1–5 Likert) across 4–6 items	Post-workshop surveys; debriefs	≥ 4.0/5

		workload balance during co-creation			
SE-P2	**Perceived socio-economic usefulness and value of OH products**	Relevance and actionability of products for local needs	Mean score (1–5 Likert)	Surveys after demonstrations; debriefs	≥ 4.0/5
SE-P3	**Adoption intention rate**	Willingness to use or recommend ENHANCE services after the pilot	{Stakeholders intending to adopt} / {Stakeholders surveyed} * 100	Short surveys; debriefs; LL workshops' sessions	≥ 50%
SE-P4	**Increased support decision-making in coastal management.**	Applications support decision making in coastal management	Number of use cases where the developed tools and risk maps have been applied to support decision making in coastal management	Short surveys; debriefs; LL workshops' sessions	≥ 5
SE-P5	**Vulnerability and resilience potential**	Qualitative evidence in both case studies that ENHANCE outputs support preventive action, improved preparedness, or resilience planning, documented through Living Lab feedback and expert assessment	Workshops' materials review	Short surveys; debriefs; LL workshops' sessions	1 link to preventive action per CS
SE-P6	**Participation rate per Living Lab main workshops**	Attendance in co-creation, test scenario and evaluation events	{Attendees / Invited/registered} * 100	Registration + attendance sheets	≥ 60–70%
SE-P7	**Number of SDG-relevant use cases supported**	Number of documented use cases where ENHANCE tools and risk maps are applied to assess or discuss conditions relevant to SDGs (SDG 3, 6, 11, 13, 14, 15)	Identification and validation of documented use cases explicitly linked to SDG-relevant societal challenges	Living Lab reports, workshop minutes, use-case documentation, SDG mapping exercises	≥ 1 validated SDG-relevant use case per case study
SE-P8	**Stakeholder perception of**	Degree to which stakeholders	Post-session surveys using	Stakeholder surveys, Living	≥ 70% rate usefulness as

	societal usefulness	perceive ENHANCE outputs as useful for understanding societal risks (health, water quality, ecosystem degradation)	Likert-scale questions on perceived usefulness and relevance	Lab evaluation forms	"high" or "very high"
SE-P9	**Number of economic-sector use cases**	Number of documented use cases where ENHANCE outputs are applied in contexts relevant to aquaculture, fisheries, tourism, agriculture, or local businesses	Counting validated cases where tools inform sector-specific discussions or decisions	Living Lab documentation, sectoral stakeholder feedback, pilot reports	≥ 1 economic-sector use case per relevant case study
SE-P10	**Perceived economic benefit from ENHANCE use**	Stakeholders' perception of expected or observed economic benefits (e.g. reduced risk, avoided losses, improved planning efficiency)	Structured surveys and interviews assessing perceived economic gains	Business stakeholder surveys, interview summaries	≥ 70% of business stakeholders report expected or observed benefits
SE-P11	**Early adopter engagement**	Number of businesses or sectoral organisations actively engaged in pilots and evaluation activities	Review of participation logs and formal expressions of interest	Participation records, letters of support, pilot engagement logs	≥ 8 engaged business or sectoral stakeholders
SE-P12	**Policy-relevant use cases**	Number of use cases where ENHANCE outputs support analysis of current conditions or future scenarios for coastal management	Identification of documented references to ENHANCE outputs in policy-oriented discussions or materials	Workshop reports, policy briefs, authority feedback	≥ 1 policy-relevant use case per case study
SE-P13	**Uptake of best practices and recommendations**	Degree to which ENHANCE best practices and recommendations are incorporated into EU or international initiative reports	Review of external reports and initiatives referencing ENHANCE outputs or recommendations	EU initiative reports, dissemination outputs	≤ 3 documented uptake instances (aligned with LE1 target)

SE-P14	**Replication and scaling actions initiated**	Number of actions supporting replication and scaling of ENHANCE beyond the case studies	Counting formal replication outputs and dissemination actions	Replication roadmap, Enrich Global platform records	≥ 1 replication roadmap and ≥ 1 international dissemination action

Table 11: Socio Economic KPIs

These KPIs will be measured during the pilot execution cycles and will guide improvements to the tools and workflows. The results will be reported in **D4.2, D4.3 and D4.4**.

5.5 Evaluation workflow

The evaluation workflow follows an iterative process in which the ENHANCE tools and data products are deployed, tested and refined across the pilot sites. Each evaluation cycle includes the configuration of the software components, the execution of the test scenarios, and the collection of performance and user-related evidence. Where applicable, the workflow also includes the setup and testing of sensors or other hardware components required to obtain the measurements defined in the pilot scenarios. The results are analysed against the KPIs defined in Section 5.2 to assess technical accuracy, usability and stakeholder uptake.

Workshops and meetings with project partners and local stakeholders complement this process by supporting the interpretation of results, validating indicators and identifying needs for adjustment. These activities ensure alignment with the requirements specified in WP2 and facilitate the refinement of the tools and data workflows before the next iteration.

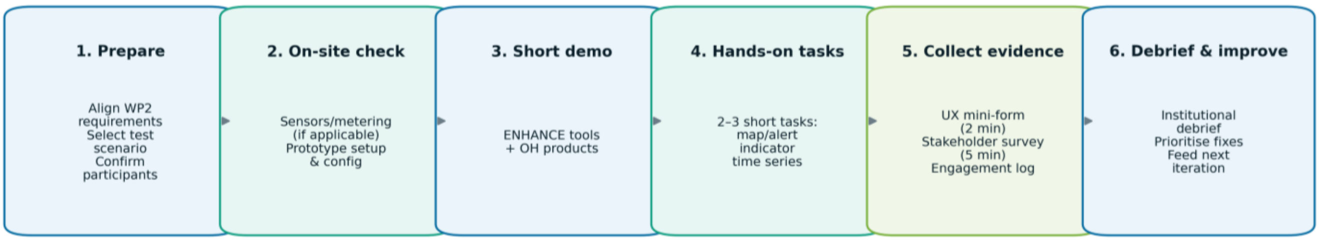

Figure 5: Evaluation Workflow

This iterative approach ensures that the solutions evolve based on operational testing and stakeholder input. The outcomes of each evaluation cycle will be documented in D4.2 and D4.3 and will contribute to the development of replication guidelines for future application in other regions.

6. Conclusion

The deliverable presents a robust and multi-dimensional evaluation methodology designed to assess the effectiveness and impact of the ENHANCE tools across diverse coastal case studies. By integrating technical, user experience, and socio-economic evaluation frameworks, the document ensures that the assessment process is both rigorous and holistic. The methodology is grounded in real-world scenarios, leveraging a combination of satellite data, citizen science, and in-situ measurements to generate and validate One Health indicators relevant to human, animal, and environmental health.

The evaluation approach is iterative, involving continuous stakeholder engagement through Living Labs, workshops, and feedback loops. This participatory process not only supports the technical validation of the tools but also fosters stakeholder acceptance, readiness, and adoption—key factors for the long-term sustainability and scalability of the ENHANCE solutions. The use of clearly defined Key Performance Indicators (KPIs) enables consistent measurement and comparison across pilot cycles, supporting evidence-based improvements and future replication.

Ultimately, this deliverable lays a strong foundation for the subsequent phases of the project, ensuring that the ENHANCE toolkit is tested, refined, and validated in operational contexts. The findings and lessons learned from the pilot implementations will inform future deliverables and contribute to the broader adoption of One Health approaches in coastal management, supporting resilience, informed decision-making, and societal benefit across Europe's coastal regions.

Annexes

Methods for technical verification

Remote sensing derived products verification

The verification of remote sensing products is based on comparing Sentinel-2–derived outputs with long-term in situ reference datasets available for the pilot areas. For the Barcelona and Ebro Delta case studies, turbidity and chlorophyll-a products generated through ACOLITE processing will be validated against the time-series database of the National Catalan Coastal Water Monitoring Program, which has been operating since 1990 (https://aplicacions.aca.gencat.cat/sdim21/).

For the Ebro Delta, additional validation will be performed using the PHYTOENVDELTA dataset, which includes phytoplankton abundance, composition and physicochemical parameters collected between 1990 and 2019 in the Alfacs and Fangar bays (https://ipt.vliz.be/eurobis/resource?r=irta_phyto). Remote sensing estimates of phytoplanktonic biomass and eutrophication indicators will be compared with these measurements to assess consistency across seasons and spatial gradients.

This process ensures that satellite-based products used in the ENHANCE indicators reflect local conditions and can reliably support the assessment of human and environmental health risks in the coastal areas of the case studies.

Citizen Science derived products verification

The verification of citizen science products focuses on assessing whether the number and distribution of observations are sufficient to describe the fish and plant communities in the pilot areas. To determine this, ENHANCE applies the concept of an observational maximum (Emax): the point at which additional observations no longer increase the number of species detected. A quality index (QI) of the reported species richness could be estimated as the ratio between the number of reported species (E_{max-o}) and the estimated maximum number of species (E_{max})

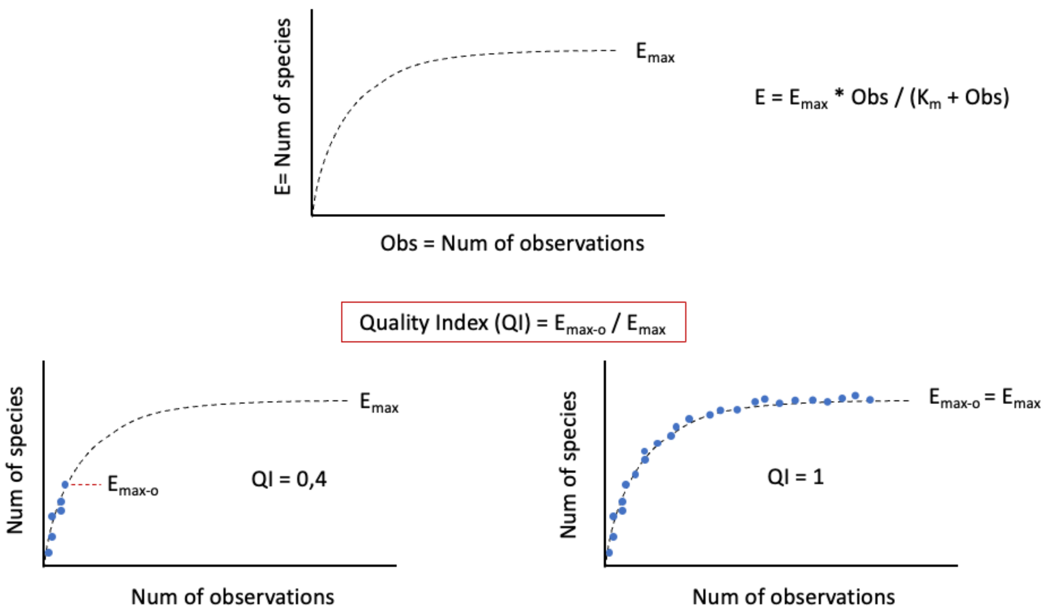

Figure 6 Illustration of the method proposed to quantify the completeness of the sampling effort

Reaching this "saturation state" confirms that sampling effort is sufficient to capture the diversity of the target communities. This behaviour can be described using a Michaelis–Menten type relationship, and the saturation curve can be analysed using classical linearised representations such as Lineweaver–Burk or Eadie–Hofstee plots.

This verification method ensures that species occurrence data reported through the MINKA observatory are adequate for producing operational indicators for Case Study 1.

Artificial Intelligence derived products verification

To facilitate the correct classification of species occurrences, ENHANCE applies a hybrid intelligence strategy that combines expert validation with AI-assisted species identification. This includes the integration of the Pl@ntNet identification service for plant observations and the development of a dedicated classifier capable of recognising fish species in underwater images from citizen scientists. As these tools mature, they will increase the proportion of automatically validated observations and strengthen the operational capacity of biodiversity monitoring within the project.

ENHANCE is developing a hybrid intelligence approach that combines AI with human expertise, integrating the Pl@ntNet species identification service with the MINKA citizen observatory platform to improve biodiversity data classification.

Implementing advanced AI solutions in the ENHANCE pilots comes with several challenges like data quality and heterogeneity, or the classification of large volumes of data in a timely and accurate way. The project addresses this and similar challenges by employing a hybrid intelligence strategy, where automated algorithms are combined with expert oversight to improve accuracy. Additionally, the AI models must generalize across different environments (an algorithm trained on one beach or region should adapt to others), which demands robust model design and diverse training data.

These challenges are being managed through iterative testing, stakeholder feedback, and incremental fine-tuning of the AI components throughout the pilot phases.

Once the system reaches mature performance, these validated datasets will enable the operational generation of biodiversity products such as fish species richness maps, which can complement and enhance existing CMEMS biodiversity services.

AI/Statistical methods workflow for Case Study 2

In Case Study 2 (Pagasitikos Gulf), UTH will explore and potentially develop and validate AI/statistical-enabled products. UTH's approach combines (i) in situ coastal sampling (surface temperature, salinity, turbidity, pH and chlorophyll-a) with (ii) Copernicus Earth observation products to produce robust spatio-temporal estimates of eutrophication-related variables and associated uncertainties. This is supported by the ongoing sampling campaigns in the area, including water quality measurements and fish tissue analyses for pathogens and AMR, which provide an essential ground-truth and biological "impact" reference for model validation and interpretation. The number of in-situ sampling campaigns is estimated at 14 to 20.

AI/statistical model for Chl-a nowcasting/gap-filling and local calibration

UTH will explore the potential implementation of Chl-a prediction model that fuses satellite-derived information with in-situ and lab observations. The AI/statistical component will be trained using collocated in situ–satellite matchups to:

- reduce local bias in satellite Chl-a retrieval under complex coastal optical conditions,
- fill temporal gaps, and

generate consistent Chl-a field at the scales required by the pilot.

Examples for User Experience evaluation

Interview guide or questionnaire (5 minutes)

When: immediately after the hands-on tasks.

Who: all participants who interacted with the tool.

Participant profile

- Case study: □ CS1-A Barcelona □ CS1-B Ebro □ CS2 Pagasitikos
- Profile: □ No-login user □ Urban planner/coastal manager □ Health professional □ Researcher/technical

Tasks (tick one per task)

Task 1 – Locate an OH map/alert relevant to your area

- Completed? □ Yes □ No
- Needed help? □ Yes □ No

- Time to complete (minutes): ___

Task 2 – Interpret an indicator map

- Completed? □ Yes □ No
- Needed help? □ Yes □ No
- Time to complete (minutes): ___

Output clarity (KPI 18)

On a 1–5 scale, what you saw was understandable.

1 □ 2 □ 3 □ 4 □ 5 □

Discussion:
(for qualitative feedback)

How was the experience? Was it easy to complete? Why? What was clear? What was confusing? ...

Short stakeholder feedback survey (5 minutes)

When: after key co-creation milestones or OH product demos.

Who: project partners + external stakeholders participating in the LL.

Scale: 1 (strongly disagree) – 5 (strongly agree)

Process satisfaction

1. The objectives of this workshop were clear.
2. The facilitation enabled balanced participation.
3. I understood my role and expected contribution.
4. I feel my input was considered in decisions.

Output satisfaction
5. The OH products shown address relevant local needs.
6. The outputs appear sufficiently clear for interpretation.

Adoption intention
7. I would consider using these outputs again in my role/organisation.
(Use this as your simplified KPI 22 item.)

Open

8. The main improvement I would prioritise is: ________________

Guidelines for structured debriefs

Purpose: To capture:
practical readiness of OH products,
conditions for adoption, and
integration barriers into existing institutional workflows.

Who to include: Per pilot site, ideally:
1–2 **local/regional authorities**,
1 **monitoring or management agency**,
1 **health/food safety/aquaculture representative** (if relevant),
1 **technical/data representative**.
Timing
30–45 minutes after a demo milestone.
At least once per pilot wave.
Evidence to record: Short notes + a 1-page debrief summary with:
key quotes,
adoption conditions,
feasibility level (low/medium/high),
any commitment signals.

Example of structured debrief template

ENHANCE Living Lab – Institutional Debrief (Pilot Site: ___)
Stakeholder organisation: ___
Role: ___
Date: ___
Wave: □ 1 □ 2

A) Relevance and usefulness

1. Which OH products are most relevant for your mandate?
2. What local decisions could they support?

B) Readiness for real use

3. What minimum reliability, resolution or update frequency do you need?
4. Are the indicators/thresholds aligned with your operational needs?

C) Workflow integration

5. Where could this fit in your current processes (planning/monitoring/early warning/communication)?
6. What formats, interoperability or access requirements are essential?

D) Barriers and enablers

7. What is the main barrier to adoption?
8. What would make adoption easier within 6–12 months?

E) Adoption signals

9. Is there a realistic path to continued use after the pilot?
   □ Yes □ Possibly □ No
10. Would you nominate an internal focal point?
   □ Yes □ No

Notes on concrete commitments (if any):

- Planned internal briefing: □
- Staff time allocation: □
- Integration pilot/roadmap: □
- Reference in plan/strategy: □

Facilitator summary (3 bullets):

- Strength: ___
- Gap: ___
- Next iteration priority: ___

Engagement pulse (1 minute)

When: embedded at the end of any workshop.
Scale 1–5
The engagement process felt fair and transparent.
Communication and expectations were clear.

References

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