Interreg

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Italy – Croatia

BRAVE

# Data collection standard 2

## Deliverable Number D.1.1.4

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Interreg Co-funded by the European Union

Italy – Croatia

BRAVE

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# TABLE OF CONTENT

Disclaimer ..... 3
List of abbreviations ..... 3
Project executive summary ..... 4
Introduction ..... 5
Objectives of the Data Collection standard 2 ..... 7
Importance of the Data Collection Standard 2 for the BRAVE Project ..... 8
Existing data ..... 10
Italian and Croatian previous experiences and dataset ..... 10
New Data ..... 13
Pilot Sites: Description ..... 13
Pilot Sites: Context & Justification ..... 15
Pilot Actions: Execution & Tech Stack ..... 19
Data Checklist ..... 22
Data Standardisation ..... 26
Conclusions ..... 29
References ..... 30
ANNEXES ..... 31

## Disclaimer

*This document has been produced with the financial assistance of the European Union. The content of this protocol is the sole responsibility of the BRAVE project and can under no circumstances be regarded as reflecting the position of the European Union and/or Italy-Croatia Programme authorities.*

## List of abbreviations

AAC: Adriatic Advisory Committee
AF - Application Form
AP - Associated Partner
AQ - Aquaculture
AS - Adriatic Sea
AO – Associated Organization
CM - Communication Manager
FM - Financial Manager
IAS - Invasive Alien Species
PSC - Project Steering Committee
LPMT – Lead Partner Project Management Team
MoU – Memorandum of Understanding
PCL - Project Communication Leader
PCM - Project Communication Manager
PFM - Project Financial Manager
PM - Project Manager
PP - Project Partner
RP - Reporting Period
QM - Quality Manager
QP - Quality Plan
SSF - Small Scale Fisheries
WP - Working Package
WPL - Work Package Leaders

## Project executive summary

BRAVE is a European Territory Cooperation project funded under the 2nd call for Operations of Strategic Importance of the Interreg VIA Italy-Croatia 2021 – 2027 Programme, Priority 2 "Green and resilient shared environment", Specific Objective 2.2 "Enhancing protection and preservation of nature, biodiversity and green infrastructure, including in urban areas, and reducing all forms of pollution". The project duration is 36 months (01.07.2025-30.06.2028) and the overall objective is to enhance species knowledge by ensuring ecosystemic functionality and tackling biodiversity loss in the Adriatic Sea (AS), through monitoring activities, creation of a smart digital platform and innovative planning in response to environmental change.

BRAVE intends to address the following common challenges that can have strong environmental (competition for resources and substitution of native species), social (conversion of work activities and change in citizens' habits) and economic (fisheries and aquaculture sectors) impacts:

*Invasive Alien Species (IAS)*: The proliferation of non-native species poses a significant threat to ecosystems, human health, and economic viability

*Biodiversity Loss*: The AS is experiencing a decline in biodiversity due to IAS, climate and environmental change, habitat degradation, pollution, and overexploitation

*Data Fragmentation*: Inconsistencies in existing databases hinder our ability to assess the overall health of the AS

*Data Communication Gap*: Difficulties in dissemination and use of environmental data by non-experts or those involved in monitoring and managing environmental data, increased by the challenging coordination between public bodies, research centres, business and citizens.

To achieve the goals, 13 project partners from the Italian and Adriatic Regions and 2 associated organizations will jointly implement strategic and operational actions.

## Introduction

Work Package 1 (WP1) Knowledge Framework and Data Harmonization defines the knowledge governance architecture of the BRAVE project. It establishes the strategic framework through which environmental information generated across the Adriatic Sea basin is organised, interpreted and mobilised to support coordinated cross-border action.

The Adriatic Sea is characterised by interconnected ecological systems and cumulative pressures that transcend administrative boundaries. However, environmental data are typically collected, managed and reported within national or sector-specific structures. WP1 addresses this structural fragmentation by creating the conditions for a shared transnational understanding of environmental status, trends and risks.

Rather than focusing solely on technical integration, WP1 strengthens the governance dimension of environmental knowledge. It promotes coherence between freshwater and marine assessments, reinforces alignment with EU regulatory frameworks such as the Water Framework Directive and the Marine Strategy Framework Directive, and enhances the science–policy interface across the project area.

A central component of WP1 is the development of the BRAVE Smart Digital Platform, conceived as a shared analytical environment supporting data visualisation, comparison and interpretation. However, WP1 extends beyond the creation of a digital tool. It ensures that environmental knowledge generated through pilot actions and existing monitoring systems contributes to long-term cooperation, adaptive management and evidence-based policy processes at Adriatic scale.

Through this strategic orientation, WP1 provides the enabling framework that connects data generation, analytical tools and mitigation measures, ultimately supporting the resilience and adaptive capacity of the Adriatic Sea ecosystem.

Within the broader framework established by WP1, Activity 1.1 Development of Common Data Collection Protocols focuses on the definition and validation of common data collection protocols supporting the development and effective functioning of the BRAVE Smart Digital Platform.

The activity responds to the need for harmonised, interoperable and operationally feasible data collection approaches capable of integrating traditions. By establishing minimum data requirements, shared structures and standardisation principles, Action 1.1 enables diverse data heterogeneous datasets generated across different sectors, environmental contexts and monitoring streams—ranging from chemical status monitoring to biological, habitat-based and risk-oriented observations—to be structured in a comparable and compatible manner.

The protocol deliverables developed under this activity provide a shared methodological framework for data collection, ensuring consistency across pilot actions while allowing partner-specific adaptations reflecting different environmental settings and technical capacities. Each protocol defines essential variables, metadata standards and validation procedures necessary to ensure reliability, traceability and quality control of the collected information.

Validation is carried out through pilot actions implemented under real-world operational conditions, involving different types of operators, technologies and environmental contexts. This process ensures that the resulting framework functions not only as a project-specific instrument, but as a transferable and adaptable reference applicable to other Adriatic contexts beyond the pilot phase.

In this way, Action 1.1 operationalises the strategic objectives of WP1, translating the project's governance vision into concrete, tested methodologies that support transnational environmental assessment and coordinated mitigation measures.

The general objectives of Activity 1.1 is designed to develop a harmonised framework for data collection by setting shared principles, defining core requirements, and identifying minimum standards to be applied across all activities. It also aims to guarantee that data produced in different environmental domains and pilot areas remain reliable, consistent, and fully traceable.

In addition, the activity ensures that data collection procedures are compatible with the functional specifications of the BRAVE Smart Digital Platform, while promoting the operational testing and validation of agreed protocols through pilot actions and simulation-based exercises.

By achieving these objectives, Activity 1.1 supports the shift from fragmented monitoring practices toward an integrated and interoperable system, enabling collected data to be effectively used for analysis, visualisation, and informed, evidence-based decision-making.

### Objectives of the Data Collection standard 2

Deliverable 1.1.4 defines the Common Data Collection Standard for the evaluation of the effects of major pollution inputs in the project area.

By harmonising environmental monitoring and assessment methods, the protocol enables a clearer understanding of human impacts on marine ecosystems, including pollution dynamics and their effects on biodiversity. These efforts generate consistent data for the Smart Digital Platform, enabling informed decision-making that balances ecosystem protection with the sustainability of sectors like fisheries and aquaculture.

Partner-specific objectives:

**Marche Region (PP4)**: To provide a scalable transferability framework for the collection of environmental and biological data using cuttlefish eggs as sentinel elements to assess pollution pressures in coastal areas, capable of being extended to larger regions throughout the Adriatic Sea.

**Apulia Region (PP5)**: To create a transferable and replicable primary database generated from a field sampling and analyses near pollution sources as a baseline for a future continuous monitoring with an aim to effectively mitigate their endangered influence to marine ecosystem in proximity and wider.

**Primorje – Gorski Kotar County (PP8)**: To establish a continuous pathway of environmental pressures, such as invasive species and pollutants, from inland waters through transitional and coastal waters to the Adriatic Sea.

**Josip Juraj Strossmayer Water Institute (P11)**: To define a replicable data collection approach aimed at generating strategic datasets for the BRAVE Smart Digital Platform, while validating the protocol under real-world conditions through pilot actions.

## Importance of the Data Collection Standard 2 for the BRAVE Project

**PP4**: This protocol addresses the collection of environmental and biological data related to cuttlefish eggs as sentinel elements for the assessment of pollution pressures in coastal areas.

Cuttlefish eggs are particularly suitable for this purpose as they develop in direct contact with the surrounding environment and can integrate information on local contamination levels. The protocol contributes to the BRAVE project by providing a practical and replicable approach to collect pollution-related data under real operational conditions, involving small-scale fisheries operators as active data collectors.

The relevance of this protocol lies in its capacity to bridge scientific monitoring needs with operational feasibility, supporting the development of a shared data framework for the BRAVE Smart Digital Platform.

**PP5:** The protocol establishes a replicable and scalable framework for coastal ecosystem monitoring in the marine area, focusing on brown macroalgae. Field activities will combine in situ observations, environmental DNA (eDNA) analyses, drone surveys, and GIS datasets to link habitat conditions, biodiversity patterns, and anthropogenic pressures. Pilot actions will validate the methodology under real-world conditions and ensure its transferability to broader Adriatic contexts.

The framework integrates benthic ecology, spatial modelling, and remote sensing data, together with bathymetric and geomorphological information. This approach will allow the identification of habitat suitability and biodiversity patterns while distinguishing natural ecological variability from anthropogenic pressures such as tourism, coastal infrastructure, pollution inputs, and invasive species.

The protocol will generate a transferable primary database based on field sampling conducted along the coastal anthropogenic pressure gradient and also near potential pollution sources. eDNA analyses will support biodiversity assessment and early detection of invasive species, contributing data to the BRAVE Smart Digital Platform and supporting future continuous monitoring and ecosystem management in the Adriatic region.

**PP8:** This protocol addresses the collection of environmental and biological data related to the extent of pollution and its possible effect on aquatic ecosystems; the selected pollutants will be analyzed in sediments. The sediments will be sampled at locations with the expected elevated concentrations of both organic and inorganic pollutants, such as ports, marinas, shipyards, oil refinery, suages and thermal power plant. The simultaneous samples

from a nearby uninfluenced location will be taken, but at different distances from the assumed source of contamination, to determine the extent of the area endangered by the pollution.

Apart from chemical analysis simultaneously biocenological transects will be performed by scientific scuba divers to determine the biological condition of the habitat and the long-term influence of the biotic and abiotic factors on it. Use of underwater ROV will be necessary for the localities where SCUBA diving will be too risky. Biocenological investigations will be also done on the control transects to allow comparative analysis. Monitoring of the selected sites will be performed continuously throughout the project duration with scuba divers and the use of underwater ROV to determine the biodiversity state of the identified habitats and possible changes in data trends. Every indigenous species seen or photographed during the field work will be noted.

The relevance of this protocol lies in its ability to integrate sampled and analyzed data for future monitoring into the BRAVE analytical framework, ensuring data comparability, scientific robustness, and long-term continuity.

**PP11:** This protocol covers the collection and analysis of chemical water quality data, with a particular focus on priority substances monitored under the Water Framework Directive, to assess pollution pressures and land–sea interactions affecting the coastal and transitional waters of the Adriatic Sea.

The protocol builds on established national monitoring programmes implemented by the Josip Juraj Strossmayer Water Institute, which provide harmonised and quality-assured data on chemical status across inland, transitional, and coastal water bodies. By screening priority substances along river–coastal gradients, the protocol supports the identification of pollutant transport pathways from land to sea and contributes to understanding cumulative pressures affecting marine ecosystems.

The relevance of this protocol lies in its ability to integrate regulatory monitoring data into the BRAVE analytical framework, ensuring data comparability, scientific robustness, and long-term continuity. In doing so, it supports the development of a shared data framework for the BRAVE Smart Digital Platform and facilitates evidence-based mitigation measures at the transnational Adriatic level.

## Existing data

To support the implementation of the protocols described above, it is first necessary to review the environmental datasets and databases already available within the Adriatic context. The following chapter therefore provides an overview of existing data sources relevant to the BRAVE project.

Existing environmental datasets represent an essential foundation for the development and validation of the BRAVE data collection protocols. Reviewing these sources allows the partnership to identify available information, assess its relevance for the project objectives, and determine how it can be integrated into the BRAVE Smart Digital Platform.

### Italian and Croatian previous experiences and dataset

**PP4:** The development of this protocol capitalises on the experience gained within the **ARGOS project**, where PP4 established a consolidated collaboration network with small-scale fisheries operators in the Marche Region and tested protocols for the collection and laboratory analysis of cuttlefish eggs.

Existing datasets and methodological approaches developed in ARGOS, particularly those related to microplastics (MPs) analysis in cuttlefish eggs, provide a solid baseline for the activities foreseen in BRAVE. The present protocol builds upon this experience by updating, standardising and validating data collection procedures within a transnational framework, ensuring their interoperability and transferability.

**PP5**: The development of this protocol builds on the experience and knowledge gained through the **Biodiversity MARE Tricase project**, implemented in the coastal area between Otranto and Santa Maria di Leuca. The proposed activity aims to extend and systematize this previous work across the wider project area, creating a more comprehensive framework for biodiversity monitoring and habitat assessment.

The protocol will rely on existing datasets derived from scientific literature, previous biodiversity monitoring initiatives, and regional environmental monitoring programmes. In particular, it will draw on monitoring activities carried out by ARPA Puglia through the **CARLIT protocol**, which assesses the ecological status of coastal waters by analysing macroalgal communities and their distribution along rocky shores.

These existing data sources will provide an important baseline for ecological conditions and species presence, allowing the protocol to integrate historical and current information with newly collected field data, remote sensing observations and environmental DNA (eDNA) analyses. This integration will strengthen the reliability of the monitoring framework and support the development of a replicable dataset for the BRAVE Smart Digital Platform and future Adriatic-wide monitoring activities.

**PP8**: The development of this protocol capitalizes on the long-term marine research work of experts in the field of Oceanology and Nature Research and Protection in the area. There is a lot of valuable published data that is elaborating the status of the marine environment and species check lists that we are dealing with through this project. Many marine research institutions such as the Natural History Museum Rijeka have developed databases with useful information regarding species and biocoenosis abundance and spatial distribution. Public health institutions also have databases with information on pollutants and environmental pressure interesting and usable for our project aim.

All these existing datasets adapted and integrated in BRAVE Smart Digital Platform, supplemented and tested with the new data through this project will form a prospective data collection tool for a transnational framework, ensuring their interoperability and transferability.

**PP11***:* The development of this protocol builds on the long-term experience of PP11 in implementing national water quality monitoring programmes and managing publicly accessible environmental datasets relevant to the Adriatic Sea basin.

Existing datasets made available through the Institute's public water quality database, particularly those related to priority substances (such as heavy metals, pesticides and industrial compounds) and chemical status under the Water Framework Directive, provide a solid baseline for the activities foreseen in BRAVE.

These datasets complement the thematic focus of other project partners involved in this report, including biological monitoring using cuttlefish eggs as sentinel species, seabed pollution assessments near ports, and risk-based evaluations of natural and anthropogenic pressures on marine biodiversity.

By integrating chemical status data with biological, habitat-based and risk-oriented information, the present protocol supports a more comprehensive understanding of pollution pathways and cumulative pressures across the Adriatic Sea, ensuring their

interoperability, comparability and transferability for integrated analyses and use within the BRAVE Smart Digital Platform.

Several national data sources are available on the Croatian side of the Adriatic basin. These provide complementary information relevant to water quality monitoring and environmental status assessments.

The **Water Status Report** represents the official annual monitoring-based assessment of ecological and chemical status in the Republic of Croatia. Covering the entire national territory and based on harmonised monitoring programmes implemented under the Water Framework Directive, it provides quality-assured datasets relevant to inland, transitional and coastal waters connected to the Adriatic Sea. Since 2022, the report has been prepared by the Josip Juraj Strossmayer Water Institute (PP11) as part of its mandate within the national water monitoring system. The database includes information on ecological quality elements and priority substances assessed within the chemical status framework.

The status assessment is prepared annually in the second half of the year for the preceding monitoring year. At the time of preparation of this deliverable, the most recent relevant and publicly available assessments cover the reporting period up to and including 2024.

Its public accessibility ensures transparency and facilitates the reuse of standardised national datasets within transnational initiatives such as BRAVE (ANNEX 2 - Table 1).

## New Data

While existing datasets provide an important baseline for understanding environmental conditions in the Adriatic Sea basin, the BRAVE project also generates additional data through pilot actions implemented by project partners. These new datasets complement existing monitoring systems and support the validation of the common data collection protocols developed under Activity 1.1, contributing to the development of the BRAVE Smart Digital Platform.

### Pilot Sites: Description

**PP4:** General activity description "*Implementation of NBS using cuttlefish eggs as sentinel species for Good Environmental Status and implementation of innovative on-land system for a sustainable management and protection of cuttlefish*"

The pilot action implemented by PP4 generates new primary data collected under real operational conditions in collaboration with small-scale fisheries operators.

This activity capitalises on the experience gained within the previous ARGOS project, both in terms of an already established collaboration network with small-scale fishers in the Marche Region and previously tested protocols for the collection and laboratory analysis of cuttlefish eggs, particularly for microplastics (MPs).

New data include:

- field-based environmental, spatial and biological observations related to cuttlefish eggs collected during routine fishing activities;
- laboratory analytical outputs aimed at detecting and quantifying selected contaminants (e.g. microplastics, POPs, PFOAs);
- metadata supporting data traceability and interoperability.

A significant part of the field data is collected directly by fishers using standardised data collection sheets developed within the project. Laboratory analyses provide complementary datasets. All data is structured to support integration into the BRAVE Smart Digital Platform.

**PP5**: General activity description *"Identification and assessment of natural and human-induced threats, along with related risk impacting marine biodiversity and ecosystem services in the Otranto-Leuca area"*

The pilot action will generate new ecological and spatial datasets in the coastal area between Otranto and Santa Maria di Leuca through targeted field surveys and spatial analysis. Georeferenced sampling grids and points will be used to record the presence, coverage and structural characteristics of brown macroalgal communities and associated habitats.

Additional biodiversity information will be collected through environmental DNA (eDNA) sampling as foreseen in *Data Collection Standard 1*, allowing the detection of associated species, ecological indicators and the potential presence of invasive species.

The pilot will also produce spatial datasets derived from satellite imagery and GIS analysis, including environmental variables and mapped anthropogenic pressures such as coastal infrastructures, bathing establishments (lidi), and potential pollution sources. These datasets will contribute to the creation of a structured and transferable database for the BRAVE Smart Digital Platform.

**PP8**: General activity description

- Task 1: *Analysis of the seabed near ports for pollutants and their effect on aquatic ecosystems. Biocenological transects by scientific scuba divers + underwater ROV to set the condition of the habitat*
- Task 2: *Analysis of Waste Disposal Issues and Pollution Sources with Feasible Study on Waste Management Methods: a practical and efficient model, tested through a pilot project to reduce pollution and mitigate its negative impact on fisheries and marine life*

The pilot action focuses on sampling, analyzing, monitoring and interpreting data collected by scientific scuba divers and underwater ROV near the predetermined pollution sources in the project area. Main activities include organic and anorganic analysis of the seabed to identify pollutants and the implementation of biocenological transects. Analyses of seabed will generate chemical and microbial data giving the information of load and level of pollution and consequently risk for the environment. Performing scientific SCUBA transect will show the instantaneous condition of the marine life and habitat and the baseline for monitoring the changes caused by pollution hotspots in the area.

New data include:

- field-based environmental, spatial and biological observations related to biocenosis and species identified, collected or shoot during scientific diving activities;

- laboratory analytical outputs aimed at detecting and quantifying selected and predetermined contaminants (e.g. 16 US EPA PAH, C10-C40, TOC, BPK5. FIB,etc);
- metadata supporting data traceability and interoperability.

All datasets will be noted in an adjusted Excel sheet within the project, designed and structured to enable integration into the BRAVE Smart Digital Platform.

**PP11**: General activity description *"Screening and analysis of mainly priority substances at locations in rivers, coastal and transitional waters to detect trends in transport of pollutants from land to sea, to understand the interconnectedness of Adriatic threats".*

The pilot action implemented by PP11 is based on the use of existing, quality-assured monitoring data generated within national water quality monitoring programmes, with a specific focus on chemical status and priority substances under the Water Framework Directive.

This activity builds on the established monitoring infrastructure and publicly accessible water quality databases, which provide systematic and standardised data across rivers, transitional waters and coastal waters. The pilot action supports BRAVE by structuring and contextualising these datasets for transnational use, enabling the assessment of pollutant transport pathways from inland catchments towards the marine environment.

Data used within the PP11 pilot action include:

- chemical monitoring data related to priority substances *(e.g. heavy metals, pesticides, industrial compounds)* assessed under the Water Framework Directive;
- spatially referenced information on monitoring locations in inland, transitional and coastal waters relevant to the Adriatic Sea;
- time-series data supporting the identification of trends and cumulative pressures;
- metadata ensuring data traceability, quality control and interoperability.

All datasets are prepared and structured to support integration into the BRAVE Smart Digital Platform.

## Pilot Sites: Context & Justification

To ensure the operational feasibility of the protocols and the relevance of newly generated datasets, pilot actions are implemented at selected testing locations across the Adriatic basin. The following section describes the context and justification for the selected pilot sites.

**PP4**

Pilot actions are implemented in at least three coastal sites distributed along the Marche Region coastline. Sites are selected to represent different coastal contexts and operational settings commonly found in the Adriatic Sea.

The testing locations are characterised by:

- their distribution along a north–central–south coastal gradient within the Marche Region;
- the presence of active small-scale fisheries where cuttlefish eggs are naturally found on fishing gear;
- exposure to a range of coastal pressures typical of the Adriatic Sea, such as riverine influence, coastal settlements and maritime activities;
- variability in local environmental conditions, including hydrodynamics and water mass characteristics.

These sites are critical for the project as they allow the validation of data collection protocols under real-world operational conditions, involving non-specialised operators and everyday working practices. Testing the protocol across multiple sites characterised by different environmental and operational settings supports the assessment of its robustness, flexibility and practical applicability, ensuring that the final framework can function as an effective transferability tool adaptable to other Adriatic coastal contexts.

**PP5**

The proposed pilot area “Otranto-Leuca coastline" is situated in a significant region within the Mediterranean Sea, between the Southern Adriatic Sea and the Western Ionian Sea, characterized by rich marine biodiversity and ecological interactions mostly in the coastal environments. The area is currently undergoing the process of establishing a Marine Protected Area (MPA), an initiative that will significantly strengthen the sustainable management of marine resources and the conservation of biodiversity, while generating important environmental, social, and economic benefits for local communities through ecosystem protection, enhanced fisheries sustainability, and opportunities for nature-based tourism and research.

The Otranto Channel’s unique hydrological features and its role as a connector between the Adriatic and Ionian Seas make it an ecological hotspot. This area supports a diverse array of marine life, characterized by intricate predator-prey dynamics and ecological fluctuations over time (*Guglielmo et al., 2019; Giampaoletti et al., 2020*). The presence of highly biodiverse habitats, including coralligenous reefs, which are critical for sustaining marine life and

increasing biodiversity, emphasizes the importance of proactive management strategies in the region. These habitats support a wealth of species and facilitate ecological processes essential for the overall health of marine ecosystems, along with crucial spawning and nursery grounds for many fish species of commercial interest to fisheries.

The study area includes two SACs: Posidonieto Capo San Gregorio – Punta Ristola (IT9150034) and Costa Otranto – Santa Maria di Leuca (IT9150002). This area is characterized by extensive rocky shore rich in caves, cavities, gorges, and inlets, often sheltering small sandy beaches.

These habitats, extremely sensitive to climate change and increasing anthropogenic pressures—as highlighted by the Prioritized Action Framework (with particular reference to reefs 1170 and submarine caves 8330)—require urgent protection and sustainable management measures to safeguard habitats, biodiversity, and ensure the maintenance of ecosystem goods and services.

The Otranto–Santa Maria di Leuca sector represents a biogeographic corridor between the eastern and western Mediterranean and therefore is a priority area for systematic monitoring of invasive alien species (IAS). Its position as a gateway, particularly for taxa arriving from the Levantine Basin, combined with frequent commercial shipping and ballast-water discharge, increases the probability of introduction and establishment of propagules and larval stages that can disrupt native communities and generate measurable socioeconomic impacts on fisheries, aquaculture and coastal tourism.

At the same time, the progressive regression of Cystoseira-dominated macroalgal assemblages—driven by warming, hydrodynamic alterations, coastal pressures, and other anthropogenic stressors—provides a sensitive and highly informative indicator of habitat degradation. Because Cystoseira belts are among the most valuable and vulnerable components of coastal rocky ecosystems, their distribution, structure, and health can be used to assess cumulative human impacts, detect early signs of ecological disturbance, and evaluate the effectiveness of protection and restoration measures. For these reasons, targeted surveys and high-resolution mapping of Cystoseira beds and adjacent benthic habitats are strategically essential to (i) establish a baseline of ecological condition and community composition, (ii) monitor changes linked to anthropogenic pressure and environmental stress, (iii) detect early incursions of non-native taxa, and (iv) inform adaptive management actions aimed at mitigating ecological and economic risk while supporting conservation planning.

**PP8**

Pilot actions are chosen after elaboration of all potential pollution hot spots along the coastal area of Primorje and Gorski Kotar County. Sites are selected to represent all kinds of diverse sources of pollution makers to the sea in the project area.

The testing locations are characterised by:

- with a facility known to have waste streams directed to the sea
- with a concentrated activities that during normal operation produce toxic material and compounds
- with a facility which during accidents or malfunction operations can cause environmental pollution
- relevance for assessing chemical status and priority substances in accordance with EU legislation
- their hydrodynamic position and significant influence on the surrounding area

These sites are critical for the BRAVE project as they represent the majority of potential types of pollution sources along the coast of the Adriatic Sea. Comprehensive and systematical testing throughout this project and pilot actions will give us guidelines for improvements and implementation on a wider scale. Inclusion of the collected dataset to BRAVE analytical framework demonstrating how the pilot model of collecting data by one partner can be effectively integrated with complementary datasets provided by other project partners operating in different parts of the Adriatic basin thus expanding the significance and comprehensiveness of the established database.

**PP11**

The pilot action is implemented through a selection of existing national monitoring stations located in Croatia, covering rivers, transitional waters and coastal waters along the eastern Adriatic coast. These stations form part of the Croatian national water quality monitoring network and are not newly established for the project, but represent strategically selected locations relevant for analysing land–sea pollutant transport and cumulative pressures affecting the Adriatic Sea.

The selected monitoring locations are characterised by:

- their position within Croatian river basins and coastal zones hydrologically connected to the eastern Adriatic Sea;
- exposure to anthropogenic pressures typical of the eastern Adriatic context, including urban wastewater discharges, agricultural runoff and industrial activities;
- relevance for assessing chemical status and priority substances in accordance with EU legislation;
- availability of long-term, quality-assured datasets supporting spatial and temporal analyses.

These sites are critical for the BRAVE project as they allow the use of existing regulatory monitoring data from the Croatian part of the Adriatic basin to support transnational analyses, without implying coverage of the entire Adriatic coastline. Their inclusion strengthens the robustness and transferability of the BRAVE analytical framework by demonstrating how nationally collected monitoring data from the eastern Adriatic coast can be effectively integrated with complementary datasets provided by other project partners operating in different parts of the basin.

## Pilot Actions: Execution & Tech Stack

Following the description of the testing locations, the next section outlines how pilot actions are implemented in practice, including operational procedures, technological tools and data structures used for the collection and processing of information.

**PP4**

*Operations:* the pilot action focuses on field data collection by fishers during normal fishing operations, recording environmental and biological information at the time of egg collection, and laboratory analyses building on ARGOS experience, particularly for microplastics assessment. This activity supports the validation of the data collection standard defined under Deliverable D.1.1.4.

*Technology:* standardised spreadsheet-based data collection tools for fishers;

- Laboratory facilities for contaminant analysis;
- Structured datasets prepared for Smart Digital Platform integration.

*Data profiles:*

- Field metadata and operator-based observations;
- Laboratory analytical outputs;

- Associated metadata ensures traceability.

**PP5**

*Operations:* The pilot action will focus on the modelling and monitoring of brown macroalgal habitats along the coastal stretch between Otranto and Santa Maria di Leuca. Field activities will include georeferenced grids, points, observations, and environmental DNA (eDNA) sampling to record macroalgal presence, canopy structure, and associated biodiversity. These data will be integrated with spatial variables to model habitat suitability and ecological status, while distinguishing natural habitat conditions from anthropogenic pressures affecting coastal ecosystems.

*Technology:* The pilot will combine in situ ecological surveys, eDNA, drone-based coastal mapping, and satellite data processing using imagery from Sentinel-2. Spatial analysis and modelling will be conducted using GIS tools and species distribution modelling approaches, integrating bathymetric datasets, coastal morphology and environmental indicators derived from remote sensing.

*Data Profiles:* The pilot will generate georeferenced ecological and environmental datasets, including macroalgal distribution records, biodiversity data from eDNA analyses, satellite-derived environmental indicators and spatial layers representing anthropogenic pressures (e.g. coastal infrastructures, tourism facilities, potential pollution sources). These datasets will be structured to ensure interoperability and integration into the BRAVE Smart Digital Platform, supporting scalable biodiversity monitoring across the Adriatic region.

**PP8**

*Operations:* The pilot action focuses on field data collection by scientific divers, seabed sampling and underwater biocenological survey. The activities will be supported by ROV due to some of the investigated localities being places with increased risk of accidents, not suitable for SCUBA operations. Analyzes will be performed afterwards in the laboratories. Final output will be structured data aligned with BRAVE requirements. This work supports the validation and application of data integration standards defined under *Data Collection Standard 2.*

*Technology:*

- Laboratory facilities for seabed samples analysis;
- Structured datasets prepared for Smart Digital Platform integration.
- ROW shooting capabilities

*Data profiles:*

- Field metadata and scientific divers-based observations (species diversity and abundance, list of biocenosis, etc)
- Laboratory analytical outputs;
- Associated metadata ensuring traceability.

**PP11**

*Operations:* The PP11 pilot action focuses on the analysis, screening and harmonisation of chemical monitoring data. Activities include the selection of relevant monitoring stations, extraction and validation of datasets related to priority substances, and the preparation of structured data outputs aligned with BRAVE requirements. This work supports the validation and application of data integration standards defined under Deliverable D 1.1.4.

*Technology:*

- existing national water quality databases managed by the PP11;
- spreadsheet-based data structuring tools used for dataset harmonisation and exchange;
- standardised metadata formats ensuring compatibility with the BRAVE Smart Digital Platform.

*Data Profiles:*

- chemical status data and concentrations of priority substances;
- spatial and temporal metadata related to monitoring locations;
- quality-controlled datasets ensuring traceability, consistency and interoperability.

## Data Checklist

In order to ensure consistency across pilot actions and facilitate data integration within the BRAVE Smart Digital Platform, a common set of minimum data requirements has been defined. The following section presents the data checklist applicable to the different protocols.

Data are organised into macro-themes to ensure clarity, interoperability and operational feasibility.

Defined set of minimum data requirements:

*PP4*

The data checklist defines the minimum dataset required to support protocol validation and to populate the BRAVE Smart Digital Platform. Minimum data requirements include:

1. Sampling and spatial context
   - sampling date
   - geographic coordinates
   - fishing area
   - gear type
2. Environmental context (operator-based)
   - seabed type
   - water depth
   - presence of freshwater inputs
   - recent extreme events
3. Biological observations
   - presence and condition of cuttlefish eggs
   - visible biofouling or anomalies
4. Laboratory analytical data
   - microplastics occurrence and typology
   - selected chemical contaminants (where applicable)

Optional data may include photo documentation and free-text notes. The data checklist is designed to be validated in collaboration with Adriatic Advisory Committee (AAC) members through stakeholder feedback, ensuring that the collected datasets are relevant, feasible and aligned with project objectives.

*PP5*

To ensure consistency across pilot actions and facilitate integration into the BRAVE Smart Digital Platform, a minimum set of data requirements has been defined for the macroalgal monitoring protocol. This checklist covers ecological, environmental, and anthropogenic variables, combining existing datasets, literature, and primary data collected during pilot actions using field surveys, eDNA sampling, drones, and satellite imagery.

Data categories include:

1. Sampling and spatial context
   - Georeferenced sampling points and transects
   - Date, depth and distance from shore
   - Drone imagery or photogrammetric surveys
2. Environmental context (operator-based)
   - Substrate type and coastal morphology
   - Presence of nearby infrastructures or potential pollution sources
   - Environmental variables derived from satellite data
   - Biological observations
   - Presence and coverage of brown macroalgal communities
   - Associated species and potential invasive species
3. Laboratory analytical data
   - eDNA sampling metadata
   - Taxa detected through metabarcoding analyses
4. Optional data
   - Additional water quality parameters (e.g. turbidity, temperature)
   - Historical biodiversity or monitoring data available for the area.

*PP8*

The data checklist defines the minimum dataset required to support protocol validation and to populate the BRAVE Smart Digital Platform.

Minimum data requirements include:

1. Sampling and spatial context
   - sampling date
   - geographic coordinates
   - sampling gear type
2. Environmental context
   - seabed type

- sea depth

3. Biological observations
   - species abundance
   - habitat type and condition
   - protected species
   - Natura2000 habitats and species
   - Invasive species
4. Laboratory analytical data detecting and quantifying contaminants; 16 US EPA PAH, C10-C40, TOC, BPK5, FIB, etc).

Optional data may include photo documentation and free-text notes. The data checklist is designed to be validated in collaboration with AAC members, ensuring that the collected datasets are relevant, feasible and aligned with project objectives.

*PP11*

The data checklist defines the minimum dataset required to support the screening and analysis of chemical status and priority substances under the Water Framework Directive and to populate the BRAVE Smart Digital Platform.

Minimum data requirements include:

1. Monitoring station and context
   - monitoring station code
   - water body type (river, transitional water, coastal water)
   - geographic coordinates
   - river basin district / coastal sector
   - monitoring frequency
   - sampling matrix (water, biota, sediment, where applicable)
2. Chemical status parameters
   - concentrations of priority substances *(e.g. heavy metals, pesticides, industrial compounds)*
   - compliance with Environmental Quality Standards (EQS)
   - identification of substances exceeding EQS
3. Supporting environmental information
   - physico-chemical parameters relevant for data interpretation
   - information on pressures influencing the monitoring site (where available)

Optional data may include trend indicators derived from time-series analysis, links to publicly accessible datasets, and additional contextual notes supporting data interpretation.

The data checklist is designed to ensure that existing regulatory monitoring data can be effectively harmonised and reused within a transnational framework, supporting integrated analyses of land–sea interactions and cumulative pressures, and ensuring compatibility with the BRAVE Smart Digital Platform.

## Data Standardisation

Data standardisation constitutes a key component of Activity 1.1, ensuring that datasets generated across different protocols, environmental domains and partner institutions can be integrated into a coherent and interoperable framework. This approach enables the effective functioning of the BRAVE Smart Digital Platform and supports a shared transnational understanding of environmental pressures across the Adriatic Sea basin.

Building on the minimum data requirements defined within individual protocols (PP4, PP5, PP8 and PP11), a common standardisation framework has been developed. While protocols address different thematic areas—ranging from chemical monitoring and seabed analysis to biological observations and spatial data—their data structures converge into a shared set of harmonised categories, identifiers and formats.

Given the pilot nature of the activity and the diversity of data sources across protocols, the level of detail and completeness of standardised datasets may vary among partners. The standardisation framework therefore defines a common reference structure while allowing a degree of flexibility in its implementation.

### *Harmonised Data Categories*

Across all protocols, data are organised into four core categories, reflecting common elements identified in all data checklists.

*Sampling and spatial context* represents a mandatory component across all datasets and includes sampling date and time, geographic coordinates (WGS84), water body type (river, transitional, coastal, marine), sampling location descriptors (e.g. fishing area, river basin district, coastal sector), sampling matrix (water, biota, sediment, where applicable), and sampling method or gear type.

For spatially detailed protocols, this is complemented by georeferenced transects and sampling points, depth and distance from shore, and references to drone or photogrammetric surveys.

*Environmental context* captures site-specific conditions influencing observations and includes seabed or substrate type, water depth and coastal morphology, presence of freshwater inputs, nearby infrastructures or potential pollution sources, records of extreme

events, and environmental variables derived from satellite data. Where relevant, supporting physico-chemical parameters are also included.

*Biological observations* are harmonised using standardised descriptors and scientific nomenclature and include species presence, abundance or coverage, habitat type and condition, protected and Natura 2000 species, invasive species, and protocol-specific indicators such as macroalgal communities, cuttlefish egg condition or biofouling.

*Laboratory analytical data* are structured through predefined reporting formats and include chemical monitoring data (e.g. priority substances such as heavy metals, pesticides and industrial compounds, including EQS compliance), contaminant analyses (e.g. microplastics, hydrocarbons, PAHs, TOC, BPK5, FIB), and biological laboratory outputs (e.g. eDNA metadata and taxa identified through metabarcoding). Harmonised units, detection limits and analytical descriptors are applied across all datasets.

### *Common Identifiers and Data Linking*

To enable integration across protocols, datasets are structured using a shared system of identifiers, including Sampling_ID (sampling event), Station_ID (monitoring or sampling location), Protocol_ID (protocol reference) and Parameter_Code (standardised variable identifier).

These identifiers allow consistent linking of field observations, laboratory results, biological datasets and spatial information into unified data tables, ensuring traceability and enabling cross-protocol analysis.

### *Controlled Vocabularies and Units*

Consistency across datasets is ensured through the use of controlled vocabularies and harmonised units. Water body types are aligned with classifications defined under the Water Framework Directive, while parameters and substances are identified using standardised codes.

Measurement units are harmonised (e.g. µg/L, mg/kg), and qualitative variables (e.g. seabed type, habitat condition, biofouling) are defined through predefined classes to minimise subjectivity. Species names follow scientific nomenclature to ensure consistency across biological datasets.

*Metadata and Data Quality*

To support data traceability and facilitate integration into the BRAVE Smart Digital Platform, a basic set of metadata elements is associated with each dataset. These may include information on data origin (data owner or responsible partner), description of data collection or analytical method (where applicable), and basic quality or validation status.

Given the pilot nature of the activity, the level of metadata detail may vary across datasets and protocols. The framework therefore adopts a flexible approach, allowing partners to provide available metadata while ensuring that essential information required for data interpretation and reuse is retained. Where feasible, additional elements such as links to existing datasets, contextual notes or supporting documentation may be included.

*Data Format and Platform Integration*

Datasets are structured in standardised tabular formats (CSV or Excel), using predefined column structures aligned across protocols. This enables direct integration into the BRAVE Smart Digital Platform and facilitates interoperability between datasets generated by different partners.

## Conclusions

The data standardisation approach developed within Activity 1.1 establishes a coherent and interoperable framework for integrating heterogeneous datasets generated across different protocols, environmental domains and partner institutions.

By aligning protocol-specific data requirements into a shared structure based on harmonised data categories, common identifiers and controlled vocabularies, the BRAVE project enables the consistent integration of chemical, biological, spatial and environmental data across inland, transitional, coastal and marine systems.

This framework ensures comparability of datasets across environmental compartments, interoperability at transnational level, and scalability for future data use beyond the project. In this context, it provides the essential foundation for the development and operationalisation of the BRAVE Smart Digital Platform, enabling the integration, visualisation and analysis of diverse datasets within a shared digital environment.

Beyond its technical function, data standardisation contributes to a broader project objective by strengthening the understanding of environmental pressures across the land–sea continuum, including pollutant transport pathways and ecological impacts in the Adriatic Sea basin.

By supporting the effective use of data within the BRAVE Smart Digital Platform, the standardisation framework further contributes to integrated environmental assessments, evidence-based decision-making, and coordinated cross-border management actions aimed at improving the resilience and environmental status of the Adriatic Sea.

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## ANNEXES

- ANNEX 1 - Data Collection Tables - standard 2
- ANNEX 2 – Overview of the Water Status Report database (Croatia)

| Project type | DB name | Project target | Area | Period | Data type | Link to DB |
|---|---|---|---|---|---|---|
| Annual report on water quality | Water Status Report | Ecological and Chemical Status | Overall territory of Croatia | 2022-2024 | Biological and chemical data | Izvješće o stanju voda |