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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
MPA – Marine Protected Area
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) defines the knowledge governance architecture of the BRAVE project. It establishes the strategic framework through which environmental information generated across the AS basin is organised, interpreted and mobilised to support coordinated cross-border action.

The AS 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 AS ecosystem.

Within the broader framework established by WP1, Activity 1.1 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.

This deliverable presents the common data collection standard for the evaluation of the effects of Maritime Spatial Planning (MSP) within climate change processes in the AS, developed within the BRAVE project. The document contributes to WP1 by defining harmonised methodologies aimed at improving environmental knowledge, data interoperability and cross-border governance.

The AS is currently facing significant challenges, including biodiversity loss, the spread of invasive alien species, increasing environmental pressures and the impacts of climate change. These challenges are further exacerbated by data fragmentation and limited accessibility of environmental information across institutions and countries. In this context, the development of common data collection standards represents a key step towards



ensuring consistency, comparability and usability of environmental data. The deliverable builds on an extensive analysis of existing datasets, projects and databases at both national (Italy and Croatia) and cross-border levels. While a substantial knowledge base is available, the assessment highlights significant heterogeneity in data formats, accessibility and methodologies, confirming the need for harmonised and interoperable approaches. To address these gaps, the document defines a structured framework based on five common data collection standards, covering key thematic areas such as ecosystem functioning, pollution pressures, biodiversity, climate change interactions and aquaculture impacts. These standards are designed to support the development of the BRAVE Smart Digital Platform, enabling integration of multidisciplinary datasets and improving decision-support capacity. The framework is validated through pilot actions implemented across diverse Adriatic contexts, including Natura 2000 areas, marine protected areas, aquaculture zones and high-pressure coastal systems. These pilot activities combine field monitoring, GIS-based spatial analysis, modelling and stakeholder engagement, ensuring that the proposed methodologies are robust, adaptable and applicable in real operational conditions. A key output of the deliverable is the definition of a minimum common dataset, structured according to macro-themes and supported by data standardisation procedures. These include harmonisation of units, spatial referencing, metadata and data formats, as well as alignment with cross-border datasets. The process is supported by the Adriatic Advisory Committee (AAC) and stakeholder consultations, ensuring relevance and usability of the data for both scientific and policy purposes.

Overall, the deliverable provides a solid methodological and operational basis for improving environmental monitoring and MSP processes in the AS. By promoting data harmonisation, interoperability and integration into a shared digital platform, it contributes to strengthening evidence-based decision-making and cross-border cooperation. The proposed approach ensures scalability and transferability, supporting long-term impacts in the field of sustainable marine management and climate resilience.

The definition of the five common data collection standards represents a core pillar of the BRAVE Project, ensuring a harmonised and integrated approach to environmental monitoring across the AS. Each standard addresses a key dimension of ecosystem assessment—ranging from trophic chain integrity and primary production, to pollution pressures, climate change interactions within MSP processes, invasive species impacts, and aquaculture-related effects—thereby enabling a comprehensive understanding of marine

and coastal dynamics (Table 1). Their importance lies in overcoming data fragmentation and methodological inconsistencies by providing shared protocols that guarantee comparability, reliability and interoperability of data across countries and sectors. This unified framework supports the development of the smart digital platform, enhances evidence-based decision-making, and strengthens cross-border governance, ultimately contributing to more effective and coordinated responses to biodiversity loss, environmental pressures and climate change in the Adriatic region.

The common data collection protocols aim to:

- Establish a harmonised and interoperable framework for environmental data collection across the AS;
- Improve the quality, consistency and comparability of data related to ecosystem status, anthropogenic pressures and climate change impacts;
- Support evidence-based decision-making within MSP and environmental governance processes;
- Enable integration of multidisciplinary data sources into a shared digital platform;
- Facilitate cross-border cooperation and knowledge exchange among stakeholders;
- Ensure scalability and adaptability of methodologies to different territorial and environmental contexts.

Objectives of the Data Collection standard 3

In line with the common data collection standards defined within WP1, each Project Partner contributes to the achievement of the shared objectives through site-specific pilot actions, data generation and validation activities. These contributions ensure the collection of strategic data, the provision of functional inputs for the smart digital platform, and the validation of protocols in real operational contexts, ultimately supporting the development of a scalable and transferable framework across the AS.

Partner-specific objectives

Friuli-Venezia Giulia Autonomous Region (PP2): to characterise the ecological role of the fishing valli system in the Marano and Grado lagoon (Natura 2000 site), in terms of species (EU Directive 2009/247/CE) and habitats (EU Directive 92/43/CEE) protection and restoration.

Istria County (PP7): to implement pilot actions focused on habitat condition assessment, invasive species management and climate adaptation in coastal ecosystems of the Istria Region. For Objective 1, PP7 collects and integrates ecological, environmental and spatial data related to shellfish habitats, invasive species distribution and key environmental drivers (e.g. salinity, temperature, habitat characteristics). For Objective 2, PP7 provides functional inputs to the platform through structured datasets, including habitat condition classification, species occurrence and risk-based prioritisation of intervention areas, ensuring interoperability and comparability with other partners. For Objective 3, PP7 validates the protocols through pilot actions implemented in representative coastal systems and controlled environments, combining spatial analysis, targeted field observations and stakeholder engagement. Contribution to Final Result: PP7 supports the development of a transferable and scalable framework for habitat-based assessment, invasive species management and climate-resilient aquaculture solutions in the Adriatic Sea.

Primorje-Gorski Kotar County (PP8): to implement a comprehensive strategic, technological, and spatial planning framework for the sustainable and climate-resilient development of mariculture in the Primorje-Gorski Kotar County. In the context of building upon the results of the ARGOS project and implementing the BRAVE project, a detailed analysis of the current situation, regulatory framework, and spatial conflicts enabled the identification of optimal farming zones and the assessment of their carrying capacity, fully aligned with biodiversity conservation objectives. This represents a final professional basis for amendments to spatial plans, specifically for defining new locations within the development of the mariculture spatial plan in the Primorje-Gorski Kotar County. The final result is an operational and applicable document that serves as a professional foundation for spatial planning amendments, investment planning, and concession allocation, while ensuring the long-term sustainable development of mariculture in line with national and European strategic objectives.

Zadar County (PP9): to preserve economically important bivalve species in accordance with the Habitats Directive, and for areas where habitat protection under the same directive can safeguard biological capital for the future active restoration. Outputs will be provided in both descriptive and GIS formats to support evidence-based management and conservation planning.

RERA S.D. (PP10): to monitoring the status of strictly protected species as well as habitat mapping up to Level 5 complexity in accordance with Regulation (EU) 2024/1991 in the MPA Stupišće – Island of Vis

Development Agency of Šibenik-Knin County (PP12): to establish a standardized data collection protocols and monitoring system to balance aquaculture growth with environmental protection in the Krka River estuary. This framework will serve as a foundation for establishing a monitoring centre and formulating a long-term socio-economic strategy for aquaculture development in Šibenik-Knin County.

Importance of the Data collection standard 3 for the BRAVE Project

PP2 will contribute to the objectives by generating strategic ecological data on the role of traditional fish farming systems within the Marano and Grado lagoon (Natura 2000 site). Through advanced mapping tools (drones, GPS) and stakeholder engagement, the activity supports Objective 1 by characterising habitats, species and ecological gradients across managed and abandoned areas. The collected data provide functional inputs (Objective 2) for the platform, particularly in relation to ecosystem services and biodiversity conservation linked to aquaculture practices. The involvement of local operators and the application of standardised monitoring approaches contribute to protocol validation (Objective 3), demonstrating the replicability of sustainable fish farming models in transitional ecosystems.

PP7 will focus on the assessment of habitat conditions and recovery potential of shellfish communities, the analysis of environmental drivers influencing the spread of invasive species (with emphasis on blue crab), and the evaluation of climate-resilient aquaculture solutions through controlled experimental systems.

The protocol integrates three complementary components:

i. habitat-based assessment of shellfish communities in representative coastal ecosystems, including Natura 2000 sites, transitional waters and shallow marine areas;
ii. analysis of environmental drivers and spatial distribution of invasive alien species, with a focus on identifying priority areas at risk and testing feasible mitigation approaches;

iii. feasibility testing of recirculation aquaculture systems (RAS) for controlled reproduction and early life-stage development of selected shellfish and crustacean species.

The approach combines spatial data analysis (including national and European databases), targeted field observations, stakeholder-derived knowledge and experimental trials in controlled environments. Particular emphasis is placed on identifying key environmental variables (e.g. salinity, temperature, habitat characteristics) influencing species distribution, population viability and ecosystem resilience.

The pilot supports Objective 1 through the collection and integration of ecological, environmental and spatial data related to habitat condition, invasive species dynamics and aquaculture systems.

For Objective 2, the protocol provides structured and harmonised datasets, including habitat classification, species occurrence, environmental parameters and feasibility assessments, ensuring their integration into the BRAVE Smart Digital Platform.

Regarding Objective 3, the protocol is validated through pilot actions implemented in diverse environmental and operational contexts, including natural coastal systems and controlled aquaculture environments, ensuring its applicability and transferability across the Adriatic region.

Contribution to Final Result: PP7 delivers a transferable, habitat-based and risk-oriented framework for ecosystem assessment, invasive species management and climate-resilient aquaculture, supporting integrated and adaptive management of coastal and marine environments in the AS.

PP8 will contribute to the objectives by supporting the evaluation of MSP effectiveness under climate change conditions through integrated spatial, environmental and policy data analysis. The pilot activities address Objective 1 by collecting and harmonising multi-source datasets, including spatial planning layers, environmental indicators, climate projections and aquaculture-related data, as well as site-specific environmental screening near coastal and port areas. For Objective 2, PP8 provides functional inputs to the platform through GIS-based multi-criteria analysis (MCA), spatial plan comparison and scenario-based assessments, enabling the integration of policy, environmental and climate datasets into decision-support tools. Regarding Objective 3, PP8 validates the protocols through real-case applications, including the assessment of inconsistencies between regional and local spatial plans, testing of innovative aquaculture solutions (e.g. bioindicator species), and evaluation of climate-driven pressures on marine ecosystems. Contribution to Final Result: PP8 supports the

development of a transferable and interoperable MSP framework that integrates environmental, spatial and climate data, enhancing the scalability of BRAVE protocols across the AS.

PP9 will contribute by developing spatially explicit assessments of shellfish habitats and conservation priorities, supporting Objective 1 through the systematic collection and integration of ecological and socio-economic data. The production of GIS-based recommendations provides Objective 2 outputs, enabling the integration of spatial layers into the digital platform and supporting MSP processes. The methodological approach, designed for applicability across the Adriatic basin, ensures Objective 3 through validation in real planning contexts, contributing to the establishment of a transboundary framework for habitat protection and sustainable resource management.

PP10 will contribute by strengthening long-term ecological monitoring in the Stupišće Marine Protected Area. The collection of high-resolution biodiversity and habitat data (including mapping up to Level 5 of the National Habitat Classification) directly addresses Objective 1. These datasets provide Objective 2 inputs to the platform, enhancing knowledge on protected areas and ecosystem status. The development of a structured monitoring programme and its alignment with EU regulatory frameworks ensures Objective 3, validating the protocols within a protected area context and supporting their scalability to other marine conservation sites.

PP12 will contribute by addressing data fragmentation through the integration of environmental monitoring, MSP and aquaculture datasets in the Krka estuary pilot area. This supports Objective 1 by structuring and harmonising multi-source data relevant to ecosystem-based management. The pilot generates Objective 2 inputs by defining data requirements and interoperability needs for the digital platform. By testing a transferable methodological framework in a complex coastal system, PP12 ensures Objective 3, demonstrating how integrated data approaches can be applied across similar Adriatic contexts.

Overall Contribution to Final Result

Collectively, these contributions ensure that the developed protocols are tested across diverse environmental, governance and socio-economic contexts. This integrated approach enables the consolidation of a scalable and transferable framework, capable of being

extended to larger regions throughout the AS, supporting coordinated and evidence-based environmental management.

Existing data

To facilitate the implementation of harmonized protocols for the evaluation of Maritime Spatial Planning (MSP) and its efficacy within climate change adaptation processes, it is necessary to conduct a systematic review of available environmental datasets. Existing datasets represent the essential technical foundation for the development of the BRAVE data collection standard. Reviewing these sources allows the partnership to identify established baselines, assess their relevance for evaluating MSP effects—such as coastal vulnerability and habitat shifts—and determine the interoperability requirements for integration into the BRAVE Smart Digital Platform.

Italian projects and databases

The Italian datasets contribute specialized longitudinal data regarding the interaction between managed coastal zones and environmental stressors:

Natura 2000 Monitoring (FVG Region)

Longitudinal monitoring in the Marano and Grado lagoon provides a baseline for evaluating how managed aquaculture areas mitigate climate change effects, including coastal erosion, floods, and marinisation. These datasets characterize the ecological role of managed areas as breeding hotspots for protected species, offering a metric for MSP effectiveness in high-pressure coastal environments.

CRADLES Project

This initiative provides critical data on the role of saltmarshes in carbon sequestration and their function as nursery areas in the North Adriatic. By comparing natural and artificial saltmarshes, CRADLES offers evidence for nature-based solutions within MSP to enhance carbon sinks as a climate mitigation strategy.

Croatian projects and database

Croatian data sources provide high-resolution spatial and biological parameters necessary for cross-referencing spatial planning with ecosystem health:

Nature Protection Information System (Bioportal)

This is a primary source for spatial layers regarding habitat types, species distribution, and Natura 2000 areas. These datasets are essential for comparing "attractiveness" for development against ecological "vulnerability" in spatial planning.

Regional Spatial Plans

Datasets from the Spatial Plans of Zadar, Primorje-Gorski Kotar, and Istria provide the regulatory baseline for mariculture concessions and coastal land-use. Furthermore, expert baseline studies for Marine Protected Areas (MPAs), such as Cape Stupišće, provide high-value data on species and habitat status prior to the implementation of restrictive MSP measures.

Environmental Monitoring (DHMZ & IZOR)

National records provide historical data and future projections for sea temperature, salinity, currents, and wave dynamics, which are critical for simulating the impact of climate change on specific maritime zones.

Common projects and databases (IT+HR)

Transnational initiatives represent the most advanced attempts to synchronize MSP with climate dynamics in the Adriatic:

ARGOS (Interreg IT-HR)

This project established a comprehensive baseline for evaluating MSP effects within climate change processes. ARGOS utilized GIS-based Multi-Criteria Analysis (MCA) to model mariculture development while assessing climate impacts across RCP4.5 and RCP8.5 scenarios (up to 2070). A critical finding was the lack of harmonization between regional and local municipal plans, highlighting the need for standardized MSP implementation to protect vulnerable species like sea bass and shellfish from projected temperature increases.

SHAREMED (Interreg MED)

This project provided a system for exchanging data on marine threats, demonstrating that MSP must adopt more restrictive nautical routes in certain biodiversity hotspots to mitigate anthropogenic pressures and maintain "Good Environmental Status" (GES).

European Environmental Platforms

Integration with EMODnet and Copernicus Marine Service offers the necessary large-scale environmental datasets (e.g., seabed characteristics, salinity) to support broader spatial and environmental analysis within the BRAVE framework.

Despite these resources, current datasets remain fragmented and heterogeneous regarding spatial resolution and temporal coverage, which limits their practical use for evaluating the

multi-dimensional effects of climate change on MSP. The BRAVE project addresses these gaps by developing harmonized protocols that integrate these diverse sources into a single, standardized framework for the Adriatic Sea.

New Data

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.

Overall Justification

The selected pilot areas collectively cover a wide range of environmental conditions, including protected areas, productive ecosystems, aquaculture zones and high-pressure coastal systems. This diversity ensures that the protocols are tested across multiple gradients of ecological complexity and governance frameworks, strengthening their robustness and enabling the development of a transferable tool applicable at the Adriatic scale.

Pilot Sites: Description, Context & Justification

The pilot studies represent key testing environments for the validation of common data collection standards within the BRAVE project. Each pilot area has been selected to reflect specific environmental, ecological and governance conditions across the Adriatic Sea.

The "*Where*" defines the geographical and ecological characteristics of each testing site, while the "*Why*" explains its relevance for testing protocols under real-world conditions. Together, these pilot cases ensure that the developed methodologies are robust, adaptable and transferable across different contexts.

PP2

"*Where*": Low-intensity aquaculture areas within the Marano and Grado lagoon, a Natura 2000 site characterized by transitional ecosystems of high ecological value.

"*Why*": These areas are critical for testing protocols as low-intensity fish farming systems actively contribute to the conservation of protected habitats and bird species under the Habitats and Birds Directives. The coexistence of aquaculture and biodiversity makes this site ideal for validating ecosystem-based approaches and assessing the role of traditional practices in maintaining ecological integrity.

PP7

"*Where*": Representative coastal and marine areas of the Istria Region, including Natura 2000 sites, estuaries, lagoons and shallow coastal systems, as well as controlled experimental environments (Aquarium Pula).

"*Why*": These sites represent a range of ecological conditions, from natural habitats affected by biodiversity loss and invasive species to controlled systems used for testing climate adaptation measures. This diversity allows validation of data collection protocols under different environmental and operational contexts, ensuring their applicability to habitat assessment, invasive species management and sustainable aquaculture development.

PP8

"*Where*": Selected coastal and marine areas representing two main typologies: strategic mariculture expansion zones (offshore/deep sea) and anthropogenic pressure hubs (port areas).

"*Why*": These sites allow testing of protocols under contrasting conditions, from relatively undisturbed offshore environments to highly impacted coastal zones. This diversity is crucial for validating data collection standards addressing climate change, spatial planning inconsistencies and human pressures, ensuring their adaptability across different MSP scenarios.

PP9

"*Where*": Marine waters of Zadar County, including sensitive habitats listed under Regulation (EU) 2024/1991, identified for conservation and restoration.

"*Why*": The site is essential for evaluating protocols related to habitat protection and restoration, particularly for shellfish species. It enables testing of approaches that combine conservation and sustainable resource use, including the use of natural stocks for restocking and the preservation of genetic biodiversity. This context supports validation of protocols addressing biodiversity resilience and ecosystem recovery.

PP10

"*Where*": The protected marine area of Cape Stupišće (Island of Vis), part of the Natura 2000 network and UNESCO Global Geopark, with a nearby unprotected reference site for comparison.

"*Why*": This pilot provides a controlled environment to assess the effectiveness of protection measures through comparative analysis between protected and non-protected areas. The use of visual census methods and detailed habitat mapping allows validation of biodiversity monitoring protocols and assessment of ecological changes, ensuring their applicability in marine protected areas.

PP12

"*Where*": The Krka River estuary, a highly productive and stratified transitional ecosystem extending from Skradin to the Sibenik coastal area, characterized by aquaculture activities and multiple human uses.

"*Why*": This site represents a complex environment where natural productivity, aquaculture, and anthropogenic pressures coexist. It is particularly suitable for testing protocols related to MSP, environmental pressures and ecosystem health, including pollution (heavy metals, microplastics), tourism impacts and invasive species risks. The presence of multiple stakeholders and uses makes it ideal for validating integrated and operational data collection approaches in real governance contexts.

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.

The pilot actions implemented by the project partners represent the operational phase for testing, validating and refining the common data collection standards within real environmental and governance contexts. Each partner contributes through site-specific activities, combining field monitoring, spatial analysis, modelling and stakeholder engagement to ensure the robustness, interoperability and transferability of the developed protocols.

PP2

Operations: PP2 conducts monitoring of the morphologies characterising existing fish farming systems in the Marano and Grado lagoon, defining a productivity gradient across aquaculture sites. This approach enables the identification of areas with the highest

ecological value for Natura 2000 habitats and species, while assessing the role of aquaculture practices in habitat protection and restoration.

Technology: Deployment of drones and GPS devices supports high-resolution spatial mapping of lagoon morphologies and aquaculture infrastructures.

Data Profiles: Collected data include aquaculture production data (reared fish species), habitat mapping datasets and bird breeding census data. These are integrated to characterise ecological functions and productivity gradients, providing structured inputs for the Smart Digital Platform.

PP7

Operations: PP7 implements pilot actions focused on (i) assessment of habitat condition and recovery potential of shellfish communities, (ii) analysis of environmental drivers and mitigation of invasive blue crab, and (iii) feasibility testing of recirculation systems for controlled reproduction of shellfish and crustaceans. Activities combine spatial data analysis, targeted field observations, stakeholder engagement and experimental trials in controlled environments.

Technology: The pilot relies on the use of spatial datasets (Bioportal, EMODnet), satellite-derived environmental data (Copernicus Marine Service), GIS-based analysis and low-cost experimental setups in recirculation systems. The approach prioritises simplicity, scalability and compatibility with existing data sources.

Data Profiles: Data include species occurrence and population structure indicators, habitat characteristics, environmental parameters (e.g. salinity, temperature), invasive species distribution, and experimental data on larval development and survival. Outputs are structured into harmonised datasets and classification frameworks (e.g. habitat condition, suitability and feasibility) for integration into the BRAVE Smart Digital Platform.

PP8

Operations: PP8 implements pilot actions focused on the evaluation of MSP effectiveness under climate change conditions, building on previous ARGOS results. The activities include spatial plan comparison (regional vs local), identification of inconsistencies in mariculture zoning, and assessment of environmental and climate-related pressures affecting coastal

and marine areas. Real-case validation is carried out through the analysis of existing and potential aquaculture sites, including offshore and land-based solutions.

Technology: The pilot relies on GIS-based multi-criteria analysis (MCA), integration of climate models (e.g. Representative Concentration Pathways, RCPs), and use of spatial planning tools to assess vulnerability and suitability of marine areas. Data processing combines environmental datasets, planning layers and modelling outputs.

Data Profiles: Data include integrated spatial datasets (MSP plans, Natura 2000 layers, aquaculture zones), climate projections (temperature, salinity, currents, waves), fisheries and environmental monitoring data, and scenario-based outputs. These datasets are structured to support decision-making and to feed the Smart Digital Platform with harmonised, multi-layer information.

PP9

Operations: PP9 performs a GIS-based assessment of marine habitats with potential for shellfish preservation, evaluating their compatibility with protected habitats under Regulation (EU) 2024/1991. Spatial analysis integrates existing and planned marine uses, identifying areas requiring protection or restoration through overlay techniques.

Technology: Advanced GIS tools are applied, including spatial operations such as buffer, intersect, clip, erase and union, to support multi-layer analysis and decision-making.

Data Profiles: Outputs consist of harmonised GIS datasets, including habitat suitability maps, compatibility analyses and spatial layers of pressures and uses, directly structured for integration into the Smart Digital Platform.

PP10

Operations: PP10 establishes a monitoring system for the Stupišće Marine Protected Area, combining visual census surveys with comparative analysis against unprotected reference sites. The pilot also includes the development of a long-term monitoring proposal and detailed habitat mapping up to Level 5 of the National Habitat Classification.

Technology: Field-based ecological monitoring techniques (visual census) are integrated with GIS-based habitat mapping tools.

Data Profiles: Data include biodiversity observations, habitat classification maps and monitoring protocols, forming validated datasets for protected area management and platform integration.

PP12

Operations: PP12 implements a multi-layer pilot action in the Krka estuary, combining spatial analysis, environmental screening and stakeholder validation. Activities include MSP document review, mapping of aquaculture intensity, identification of spatial conflicts, in situ measurements and consultation with stakeholders to validate data usability and monitoring indicators.

Technology: A modular and scalable technological setup is deployed, including portable multiparameter probes, GIS-based tools and structured data templates aligned with the BRAVE data model.

Data Profiles: Data include environmental measurements (raw sensor data), pressure indicators, spatial datasets and stakeholder-validated indicators, organised into harmonised datasets and metadata structures for platform integration.

Overall Contribution

Across all pilot actions, the combination of field monitoring, GIS analysis, modelling and stakeholder engagement ensures the generation of high-quality and interoperable datasets. These activities enable the validation of common protocols, support the development of the BRAVE Smart Digital Platform, and contribute to a scalable and transferable framework for environmental data collection and MSP-based decision-making across the AS.

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.

The definition of a minimum dataset represents a key step for ensuring consistency, interoperability and usability of data within the BRAVE Smart Digital Platform. This dataset is structured according to macro-themes and integrates both existing data sources and primary data collected through pilot actions. The AAC, in collaboration with all project partners, is responsible for defining the minimum data requirements and ensuring their harmonisation across the Adriatic region.

To support validation and usability, questionnaires and stakeholder engagement activities are implemented to verify the relevance and applicability of the selected data categories, ensuring alignment with operational needs and decision-making processes.

PP2

PP2 contributes to the definition of the minimum dataset through biodiversity, ecological and aquaculture-related data, including bird species breeding pairs, Natura 2000 species and habitats, embankment morphologies and reared fish species. These datasets provide a comprehensive representation of ecosystem functioning and aquaculture-environment interactions.

PP7

PP7 contributes to the minimum dataset through the collection and integration of ecological, environmental and experimental data.
The dataset includes species presence and relative abundance, population structure indicators (e.g. size classes, recruitment signals), habitat characteristics (substrate, depth, exposure), and environmental parameters such as salinity and temperature.
Additional data relate to invasive species occurrence and distribution, as well as experimental data on larval development, survival and reproduction in controlled systems.
The dataset also includes derived outputs such as habitat condition classification, recovery potential and site prioritisation.

All data are structured according to common standards, ensuring interoperability and integration within the BRAVE Smart Digital Platform.

PP8

PP8 contributes through integrated spatial and environmental datasets, including georeferenced planning layers, aquaculture concessions, protected areas ("no-take zones") and policy metadata. Additional data are derived from environmental screening and biological validation activities.

PP9

PP9 contributes to the definition and validation of the minimum dataset through the harmonisation of spatial and environmental data related to habitat protection and aquaculture activities. The AAC plays a central role in validating data categories and ensuring consistency.

PP10

PP10 provides detailed ecological datasets derived from field research using autonomous scientific diving and visual census methods. Data include species occurrence, abundance and benthic community structure, supporting the development of high-resolution habitat maps (Level 5 classification).

PP12

PP12 contributes a multi-layer dataset including environmental measurements, spatial planning layers, pressure mapping outputs, stakeholder-derived qualitative inputs and metadata compliant with BRAVE standards. These datasets are designed to support early detection of environmental anomalies, improve MSP feedback mechanisms and enhance operational awareness for stakeholders

Data Standardisation

Data standardisation aims to ensure that information collected by different partners is homogeneous, comparable, and suitable for integration within the Smart Digital Platform. A common structure for data recording has been defined, including harmonised field names, units of measurement, coordinate reference system, and metadata requirements.

The combined efforts of all partners ensure the definition of a robust, harmonised and interoperable minimum dataset, validated through both technical and stakeholder-driven processes. This approach enables efficient data integration within the BRAVE Smart Digital Platform and supports scalable, cross-border environmental monitoring and MSP-based decision-making across the AS.

Data standardisation is achieved by PP2 through the *harmonisation of ecological and production dataset*s, ensuring comparability across sites. PP2 collaborates with AAC and ICT partners to structure data in homogeneous formats suitable for integration into the Smart Digital Platform.

PP7 ensures data standardisation through the application of *harmonised data structures, common indicators and consistent spatial referencing* across all pilot actions. Data collected from different sources, including field observations, spatial datasets and experimental results, are aligned in terms of units, temporal resolution and classification systems. Particular attention is given to the use of standardised indicators such as species presence, relative abundance, size structure and habitat condition classes, ensuring comparability across sites and partners. PP7 collaborates with AAC and ICT partners to ensure that datasets are fully compatible with the BRAVE Smart Digital Platform, supporting interoperability, traceability and future scalability.

Standardisation is ensured by PP8 through the integration of multi-source datasets into a coherent GIS-based framework, aligned with BRAVE interoperability standards. The approach includes harmonisation of spatial planning data, environmental indicators and climate-related datasets, enabling consistent evaluation of MSP under climate change scenarios.

PP9 supports the development of *homogeneous data tables* and contributes to defining *data integration procedures* within the platform, ensuring interoperability and alignment with BRAVE standards.

Standardised methodologies for fish population research and benthic habitat description are applied by PP10, ensuring data comparability. Visual census protocols follow consistent transect-based approaches conducted by trained divers, guaranteeing methodological robustness and reproducibility.

For PP12, standardisation focuses on harmonising heterogeneous datasets through alignment of units, temporal resolution, georeferencing and metadata completeness. Particular attention is given to interoperability with cross-border datasets and future automation potential within the BRAVE digital ecosystem. Stakeholder questionnaires are used to validate the relevance of the minimum dataset.

Harmonised Data Categories

Within the framework of Data Collection Standard 3, data standardisation represents a fundamental step to ensure that information collected across different pilot areas, institutional contexts and monitoring systems is consistent, comparable and fully interoperable. In line with the overall objectives of WP1, the process is aimed at defining a robust and harmonised minimum common dataset capable of supporting integrated environmental assessment, MSP processes and cross-border decision-making across the AS.

Building on the assessment of existing datasets, which highlighted significant heterogeneity in data formats, accessibility and methodologies, the minimum dataset is conceived as a structured and shared information framework integrating multi-source data generated by PPs. The dataset combines spatial, environmental, ecological, climate-related and governance components, ensuring a comprehensive representation of marine and coastal systems and their interactions with anthropogenic pressures.

The minimum common dataset includes the following core data categories:

Spatial and planning data, consisting of georeferenced layers related to MSP, including aquaculture concessions, mariculture zones, protected areas (e.g. Natura 2000 sites), no-take zones, existing and planned marine uses, and spatial conflict areas;

Environmental parameters, such as water temperature, salinity, currents, wave exposure, habitat characteristics and water quality indicators, ensuring the assessment of ecosystem conditions and pressures;

Climate-related data, including historical trends and scenario-based projections relevant to ecosystem vulnerability, aquaculture suitability and long-term environmental change;

Ecological and biodiversity data, covering habitat distribution, sensitive ecosystems, indicator species and biological validation elements supporting ecosystem-based assessments;

Governance and metadata information, including data source, spatial and temporal resolution, methodological approach, level of validation, and institutional ownership, ensuring traceability and transparency.

To guarantee interoperability, all data are structured according to harmonised standards, including common field names, standard units of measurement, shared coordinate reference systems, and consistent metadata requirements. Data formats are designed to be compatible with GIS-based environments and the BRAVE Smart Digital Platform, enabling seamless integration, visualisation and analysis.

The definition of the minimum dataset is supported by the Data Checklist developed by the partnership and coordinated through the AAC, ensuring alignment across partners and thematic areas. In addition, stakeholder engagement processes, including targeted questionnaires and consultation activities, are implemented to validate the relevance, usability and operational applicability of the selected data categories, in line with real decision-making needs.

The robustness of the dataset is further ensured through validation in real operational contexts. Pilot actions implemented across diverse environmental settings—ranging from offshore mariculture zones to coastal areas affected by anthropogenic pressures—allow testing of data collection, structuring and integration procedures. These activities confirm the feasibility and adaptability of the dataset across different MSP scenarios and governance frameworks.

Overall, the standardised minimum dataset provides the technical and methodological foundation for efficient data integration within the BRAVE Smart Digital Platform. By ensuring harmonisation, interoperability and scalability, it supports the development of a transnational evidence base, enhances cross-border environmental monitoring, and strengthens MSP-based decision-making processes under climate change conditions across the Adriatic region.

Conclusions

The development of the common data collection standard for the evaluation of the effects of MSP within climate change processes represents a fundamental step towards strengthening integrated and evidence-based environmental governance in the AS.

The analysis carried out within this deliverable highlights the availability of a wide range of existing datasets and project-based knowledge across the partnership, as well as the persistence of significant fragmentation, heterogeneity and limited interoperability among data sources. These limitations confirm the necessity of adopting harmonised protocols capable of ensuring consistency, comparability and effective integration of data across different territorial and institutional contexts.

The pilot actions implemented by the project partners have demonstrated the feasibility of collecting, structuring and validating multi-source datasets, combining environmental monitoring, spatial analysis, modelling and stakeholder engagement. These activities have enabled the identification of a minimum common dataset and the testing of standardisation procedures under real operational conditions, ensuring their applicability within diverse ecological and governance frameworks.

Particular relevance is given to the integration of MSP-related data with climate change indicators, allowing for a more comprehensive assessment of environmental pressures, ecosystem responses and spatial planning effectiveness. The adoption of interoperable data structures and harmonised methodologies provides a solid foundation for the BRAVE Smart Digital Platform, enhancing its role as a decision-support tool for policymakers, researchers and stakeholders.

In this context, data standardisation and the definition of a minimum common dataset emerge as key enabling elements for achieving true interoperability and operational usability of environmental information. By establishing shared data structures, harmonised variables, standard units, common spatial references and consistent metadata requirements, the project ensures that heterogeneous datasets can be effectively integrated, compared and reused across different pilot areas and institutional contexts. The minimum dataset, structured around spatial, environmental, ecological, climate and governance dimensions, provides a coherent and scalable data backbone that supports both analytical processes and decision-making needs. Its validation through technical procedures and stakeholder-driven

processes further guarantees its relevance, reliability and applicability beyond the project scope.

Overall, the results of this deliverable contribute to overcoming existing data gaps and inconsistencies, supporting cross-border cooperation and promoting a shared understanding of marine and coastal dynamics in the Adriatic region. The proposed approach ensures scalability and transferability, enabling its application to broader geographical contexts and reinforcing the long-term impact of the BRAVE project in advancing sustainable marine management and climate-resilient MSP processes.

References

Alfier D., Čulav B., Marinčić A., (2020)., *Idejni projekt za izdavanje lokacijske dozvole za postavljanje uzgojnih polja školjkaša i riba u zoni rijeke Krke*, Šibenik, Klamfa d.o.o.

Cvitković i sur., (2019)., *Monitoring ušća Krke; Izvještaj o početnoj procjeni bioloških i oceanoloških pokazatelja*, Split, IZOR

Haramina i sur., (2017)., *Mapiranje resursa i održivo upravljanje sektorom marikulture u Šibensko-kninskoj županiji,* Zagreb, Zelena infrastruktura

Maribu d.o.o. (2021). *Analysis of implementation measures for conservation and sustainability of the fisheries sector with emphasis on promoting innovative aquaculture in Primorsko-goranska and Istra counties* (Original title: Analiza implementacijskih mjera za očuvanje i održivost sektora ribarstva s naglaskom na promicanje inovativne akvakulture u Primorsko-goranskoj i Istarskoj županiji). The study was conducted as part of the Interreg Italy – Croatia project ARGOS

Regione Emilia-Romagna. (2026). *Documento di supporto ai lavori di redazione del Piano regionale delle Zone Allocate per l'Acquacoltura (AZA).* Bozza del 15/12/2025.

Viličić, (2024)., *Pregled istraživanja i znanstvenih spoznaja iz estuarija rijeke* Krke

Zelena infrastruktura d.o.o. & Gekom d.o.o. (2023). *Mariculture modelling study in the restriction area of protected coastal area in Primorje – Gorski Kotar County with a climate impact assessment* (Original title: Studija modeliranja marikulture na području ograničenja zaštićenog obalnog područja mora Primorsko goranske županije uz procjenu klimatskog utjecaja). This study was developed as Final Version V.1, Deliverable D.5.3.1, for the Interreg Italy – Croatia project ARGOS

https://programming14-20.italy-croatia.eu/web/argos

https://programming14-20.italy-croatia.eu/web/cascade

https://ribarstvo.mps.hr/

https://www.interregnextmed.eu/project-page/share4med/media/

ANNEXES

- ANNEX 1 – Data collection Tables - standard 3