

WP 1 Development of cross-border participative strategies in waste reduction Certification

D.1.9.2 Database of locations where waste is systematic accumulated and types of waste

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Executive Summary

This document, Deliverable 1.9.2, "Identification and mapping of waste accumulations in pilot areas," is a key output of Activity 1.9.2 within Workpackage 1 of the Wastereduce project. The core objective of this deliverable is to provide an accurate and detailed diagnosis of solid waste contamination within the project's designated pilot areas—specific Natura 2000 sites in Italy and Croatia—through the identification, spatial mapping, and typological assessment of waste accumulations.

A preliminary feasibility analysis determined that a reliance on standard remote sensing techniques, such as free satellite imagery, was insufficient for this task. The spatial resolution of these sensors is inadequate for detecting the small, scattered, and often fragmented nature of waste, which includes beached marine litter and diffuse terrestrial littering. To overcome this limitation, a robust, multi-faceted methodological approach was developed, built upon two complementary pillars: the analysis of existing data from authoritative European, national, and citizen-science databases, and the execution of targeted, direct on-field surveys conducted by project partners.

The application of this integrated methodology allowed for a comprehensive assessment of waste contamination in each pilot area. The report details the specific findings for each site, presenting a combined analysis of the data gathered from both the review of online databases and the information collected during on-field inspections. This dual-source approach enabled the identification of recurring waste accumulation hotspots and provided a typological characterization of the waste found in each of the designated Natura 2000 sites. As a final product of this analysis and the creation of a comprehensive database, the data for all identified waste accumulation points are presented in both Excel (.xls) and shapefile (.shp) formats.

1. Introduction and Methodology

1.1 General Context and Objectives

This document constitutes **Deliverable 1.9.2, "Identification and mapping of waste accumulations in pilot areas"** developed within Activity 1.9.2 of Workpackage 1 for the Wastereduce project. The strategic objective of this activity is to provide an accurate diagnosis of solid waste contamination within areas of high natural value: the project's designated pilot areas and Natura 2000 sites in Italy and Croatia. This goal is achieved through the identification, spatial mapping, and typological assessment of the waste itself. A preliminary feasibility analysis considered the use of remote sensing techniques, particularly freely available satellite imagery (e.g., Copernicus Sentinel, see Deliverable 2.13.2). However, this approach was deemed unsuitable. The spatial resolution of these sensors (typically 10 meters or greater) is insufficient to detect the scattered, small-scale, and often fragmented nature of waste accumulations in the study areas, such as beached marine litter or diffuse terrestrial littering. These accumulations are, in effect, invisible to such tools. To overcome this limitation and produce a robust analysis, we have designed a multi-faceted methodological approach. This strategy is built upon two complementary pillars:

1. **Analysis of existing data** from authoritative European, national, and citizen-science online databases.
2. **Execution of targeted, direct on-field surveys** conducted by project partners.

The integration of these two pillars allows for a comprehensive assessment, combining broad-scale data with high-resolution, site-specific information. The following sections detail each component of this integrated strategy.

1.2 Data from Existing Online Databases and Platforms

To build a comprehensive and historically grounded understanding of waste accumulation patterns, the initial phase of our methodology involved a systematic reconnaissance of existing data sources. This multi-source approach is a cornerstone of modern environmental science, as it leverages prior knowledge to optimize new data collection efforts and place new findings within a broader scientific context. While direct field surveys provide a high-resolution, synoptic (snapshot-in-time) view of the state of pollution, the analysis of existing databases offers an essential diachronic perspective, revealing long-term trends, seasonality, and the potential impact of past events or policies. The integration of existing and newly collected data is widely recognized as a best practice for assessing marine litter, in line with the recommendations of major international frameworks like the European Union's Marine Strategy Framework Directive (MSFD). Scientific literature emphasizes that combining datasets from different sources, including official monitoring, academic research, and citizen science, is crucial for

building a complete picture of this complex and transboundary issue (Galgani et al., 2013; Veiga et al., 2016).
A significant portion of publicly available data on waste, particularly coastal litter, is generated through citizen science initiatives. The scientific community increasingly recognizes the immense value of these contributions. Although sometimes characterized by methodological heterogeneity, citizen science data can provide unparalleled spatial coverage and temporal frequency, often identifying local hotspots that official monitoring programs might miss (Hidalgo-Ruz & Thiel, 2015; Hyder et al., 2017). These platforms are therefore not just data repositories, but vital tools for both scientific research and public engagement.

The primary objectives of our data reconnaissance were therefore to:
a) Identify known historical accumulation hotspots within or near the project's pilot areas.
b) Establish a preliminary baseline of litter density and composition to contextualize the findings from our own surveys.
c) Provide an independent dataset against which to compare and validate the results of the Wastereduce field campaigns.

This systematic review led to the identification of several key platforms, categorized by their data type (e.g., marine, riverine) and governance model (e.g., official, citizen-led), which are detailed in the following sections.

1.2.1. European Marine Observation and Data Network (EMODnet)

The European Marine Observation and Data Network (EMODnet) provide access to harmonized marine data from various sources, and its Marine Litter Database, an integral component of the EMODnet Chemistry portal, serves as a crucial resource for our analysis. This platform represents the first comprehensive, pan-European database on marine litter, compiling data from a wide range of contributors, including national monitoring programs, academic institutions, and citizen science initiatives. The database offers standardized, quality-controlled, and validated data, covering several key categories of litter: macro-litter on beaches and the seafloor, as well as micro-litter in the water column and sediments. The data is collected following internationally recognized protocols, such as those recommended by the Marine Strategy Framework Directive (MSFD) and the Barcelona Convention's MEDPOL Programme, ensuring a high degree of comparability across different datasets. To access and query this vast repository of information, users interact with the EMODnet Chemistry portal via an interactive map interface. This allows for detailed spatial queries, enabling us to specifically search for data points located within or near our Croatian pilot areas. Users can apply filters based on various criteria, including the time of data collection, the type of litter (e.g., plastics, glass, metal), and the data source. Once the desired data is identified, it can be downloaded in various formats for further analysis and integration into geographical information systems

(GIS). This systematic query approach allows us to establish a preliminary baseline of litter presence in the Adriatic, providing a critical context for our field survey results. The EMODnet database is not only a data repository but also a key tool for European policy-making and scientific research. Its data have been instrumental in technical reports and assessments, such as those published by the Joint Research Centre (JRC) of the European Commission, which utilizes the data to evaluate progress toward the MSFD's objectives on marine litter (e.g., JRC Technical Report, Veiga et al., 2016). This provides strong scientific validation for using EMODnet as a reliable source of baseline data. For direct access to the database's marine litter section, the main entry point is https://emodnet.ec.europa.eu/en/marine-litter.

1.2.2. ISPRA – Urban Waste Database

For the Italian context, a key data source is the ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale), which serves as the national environmental authority. While its primary focus is on urban waste at national, regional, and municipal levels, its database and annual reports are invaluable for providing a detailed overview of waste generation, management, and disposal in Italy. This is particularly relevant for the "Grave e Zone umide del Brenta" pilot site, as the data can help contextualize general anthropogenic pressure and upstream waste management practices that may influence the accumulation of debris within the riverine environment. The ISPRA database is built upon the national waste registry (Catasto Telematico dei Rifiuti), offering a comprehensive, constantly updated, and easily accessible overview. To query the database, researchers typically consult the "Rapporto Rifiuti Urbani" (Urban Waste Report), which is published annually and provides detailed statistics on waste collection, recycling rates, and disposal methods, broken down by region and province. While the data is not geolocated to the site level, it offers crucial macro-level information that can be used to model potential waste flows and understand the broader context of waste management in the Veneto region. The data has been extensively used in national and regional policy-making and is a foundational resource for environmental assessments in Italy. The annual reports and associated datasets are accessible directly from the official ISPRA website. A direct access point to the waste data collection is available at https://www.isprambiente.gov.it/en/databases/data-base-collection/waste.

1.2.3. Citizen Science and NGO-led Databases

Beyond official governmental portals, citizen science and NGO-led databases are indispensable for our research, offering high-resolution, geolocated data on litter accumulation. While official monitoring often provides a macro-level view, these platforms excel at identifying specific, localized hotspots and clean-up events, as the data is collected directly by volunteers on the ground. The scientific community increasingly acknowledges the value of these contributions, particularly when they adhere to standardized methodologies, which ensures the data is both reliable and usable for scientific analysis (Hyder et al., 2017). For our study, we consulted several key platforms that are highly relevant to our pilot sites.

1) EEA Marine LitterWatch

Managed by the European Environment Agency (EEA), the Marine LitterWatch platform is a robust citizen science initiative that empowers volunteers to collect beach litter data across Europe using a harmonized methodology. This standardized approach makes it one of the most reliable citizen science sources available, as it minimizes the methodological heterogeneity often associated with volunteer-driven efforts. The platform's data is directly used to inform European policy on marine litter, particularly within the framework of the MSFD. To leverage this database, we used its interactive map viewer to explore data submissions and organized clean-up events along the coast of the Istria peninsula, near Croatian pilot sites. This will provide valuable information on the composition and density of beach litter in the region, helping to identify potential accumulation zones that may be overlooked by broader, less-frequent official surveys. The data from this platform will be a key resource for understanding the coastal component of our pilot areas. A direct access point to this database is https://www.eea.europa.eu/en/analysis/maps-and-charts/marine-litterwatch-data-viewer-marine-litterwatch-data-viewer.

2) PADI AWARE – Dive Against Debris®

The PADI AWARE Foundation's Dive Against Debris® is a global citizen science program that provides a unique and crucial perspective on marine pollution. It mobilizes the world's largest community of recreational divers to remove and report underwater debris, creating the largest seafloor litter database of its kind. Given that our pilot sites, such as Uvala Sakarun, are entirely marine and protect sensitive habitats like reefs and Posidonia beds, this database is an exceptionally relevant source for seafloor litter data. The methodology involves divers systematically logging the type, quantity, and location of debris they encounter during their dives, providing precise geolocated data. To use this platform, we navigated its interactive global map, zooming into the Croatian coast to explore dive sites where debris has been logged. The data points include GPS coordinates and detailed item breakdowns, offering high-quality, direct observations of underwater pollution. This information is vital for understanding the true extent of the problem in submerged environments, which are not captured by traditional beaches or riverine surveys. The data has been published in peer-reviewed journals, showcasing its scientific credibility and value (e.g., Martin et al., 2020). The direct link to this database is https://map.padiaware.org/.

3) Litter Intelligence

Litter Intelligence is a high-quality citizen science program that uses the internationally recognized UNEP/IOC survey methodology to provide detailed analytics and maps of litter data. While its core focus has been in New Zealand, the platform serves as an excellent example of how standardized citizen science can produce robust data for long-term monitoring and policy insights. The program provides comprehensive reports and raw data that can be used for benchmarking against international standards and methodologies. Although direct data for our specific pilot areas in Italy and Croatia is less likely to be found on this platform, its data explorer offers valuable insights into survey methodologies and common litter

compositions on a global scale. We consulted this database to inform our own field survey protocols and to contextualize our findings within a broader global context of coastal pollution. The high-quality approach of Litter Intelligence, rooted in a United Nations-endorsed methodology, makes it a reference point for best practices in citizen-led environmental monitoring. The direct link for this database is https://litterintelligence.org/data/.

1.2.4. Data Sources for Riverine Environments

Given that the Italian pilot site, "Grave e Zone umide del Brenta," is a continental riverine system, the marine-focused databases discussed previously are not directly applicable. For this area, our methodology involved consulting specialized data sources focusing on freshwater and riverine litter, which are essential for understanding the terrestrial inputs that contribute to marine pollution.

1) JRC Research on Riverine Litter
The European Commission's Joint Research Centre is a leader in standardizing riverine litter monitoring. Their research and published datasets, often associated with the RIMMEL (Riverine Litter Monitoring Methodology and Application) protocol, represent the most scientifically robust information available on plastic pollution in European rivers. The RIMMEL protocol provides a harmonized methodology for monitoring floating macro-litter in rivers, ensuring that data is comparable across different locations. While the JRC's work is not presented as a simple interactive map for public use, their extensive reports and raw data provide a critical scientific context for understanding expected litter flows and types in major Italian waterways, including the Brenta River. This information is invaluable for establishing a theoretical baseline and contextualizing the findings of our field surveys. The JRC has been instrumental in developing and testing these protocols through various projects, and their findings are often published in technical reports and peer-reviewed journals. For instance, the research of Van der Meulen et al. (2020) provides a detailed application of the RIMMEL protocol to various European rivers, demonstrating how such data can be used to inform policy and environmental management. Reports and data are available at https://data.jrc.ec.europa.eu/.

2) River Cleanup Map
As a complementary resource to the JRC's scientific data, we consulted the River Cleanup Map, a global citizen science platform. This database visualizes the locations of clean-up events conducted by volunteers along rivers worldwide. It serves as a practical tool for identifying specific, publicly reported litter hotspots within our pilot area along the Brenta River. By analyzing the data points on this map, we can pinpoint areas of frequent volunteer activity, which often correspond to chronic litter accumulation sites. The platform provides valuable ground-truth information on where waste is a visible and recurring problem, offering a different perspective from the scientific modeling of riverine litter flows. This database is available at the following link: https://cleanupmap.org/.

2. Description of Pilot Sites

The Natura 2000 network is the cornerstone of the European Union's biodiversity policy, representing a fundamental framework for environmental conservation across its member states. Its sites are designated under two principal legislative instruments: the Birds Directive (1979) and the Habitats Directive (1992), collectively known as the "Nature Directives." The overarching objective is to ensure the long-term conservation of Europe's most valuable and threatened species and habitats, thereby preventing biodiversity loss. This network serves as a key mechanism for fulfilling the EU's commitments under international agreements, such as the Bern Convention on the Conservation of European Wildlife and Natural Habitats, to which the EU is a contracting party. Consequently, Natura 2000 sites represent the EU Member States' formal contribution to the Pan-European Emerald Network developed under this convention. The Birds Directive, in force since 1979, provides a comprehensive protection framework for all wild bird species naturally occurring in the EU. It mandates Member States to classify Special Protection Areas (SPAs) for 194 particularly threatened species listed in Annex I, as well as for all migratory birds, ensuring the preservation of key breeding, feeding, and resting sites. Building on this foundation, the Habitats Directive, adopted in 1992, expanded the scope of conservation to include a wide range of rare, endangered, or endemic natural habitats and non-avian species. It introduced the designation of Sites of Community Importance (SCIs) for the protection of 233 habitat types (Annex I) and over 900 species (Annex II). Once adopted by the European Commission, SCIs must be designated by Member States as Special Areas of Conservation (SACs) within a six-year timeframe. Together, SPAs and SCIs/SACs form the Natura 2000 network. As of 2024, the network comprises over 27,000 sites, covering over 18% of the EU's terrestrial area and over 9% of its marine waters (European Commission, 2024). A defining characteristic of Natura 2000, unlike traditional nature reserves, is that it does not automatically exclude human activities. Instead, it promotes sustainable land and resource use, aiming to reconcile conservation objectives with economic, social, and cultural requirements, in line with the principle of sustainable development. This balanced approach is crucial for the effective management of such an extensive network. However, even within these protected areas, a significant challenge is posed by waste and pollution. Scientific literature and reports from institutions like the European Environment Agency (EEA) increasingly highlight how litter, particularly plastics, negatively impacts the very species and habitats that Natura 2000 aims to protect (EEA, 2019). The presence of waste can lead to species entanglement, ingestion of plastic particles, and habitat degradation, thereby undermining conservation efforts. This issue is particularly critical in coastal and riverine sites, which often act as accumulation zones for waste originating from both land- and sea-based sources. Therefore, a focused study on waste accumulation within these pilot sites is not only relevant but also essential for developing effective management strategies that support the long-term conservation goals of the Natura 2000 network. The subsequent sections of this report will provide detailed descriptions of the pilot areas selected by the project partners, which constitute the specific focus of this study. Table 1 below provides an overview of the official names of these pilot sites, their size, and their official classification according to the Natura 2000 nomenclature.

Site Code	Site Name	Country	Site Type	Official site
HR1000032	Akvatorij zapadne Istre	HR	Bird Directive	https://eunis.eea.europa.eu/sites/HR1000032
HR3000432	Ušće Raše	HR	Habitat Directive	https://eunis.eea.europa.eu/sites/HR3000432
HR3000433	Ušće Mirne	HR	Habitat Directive	https://eunis.eea.europa.eu/sites/HR3000433
HR3000069	Uvala Sakarun	HR	Habitat Directive	https://eunis.eea.europa.eu/sites/HR3000069
IT3260018	Grave e Zone umide della Brenta	IT	Habitat and Bird Directive	https://eunis.eea.europa.eu/sites/IT3260018

Table 1: A list of the selected pilot sites belonging to the Natura 2000 Network in Italy and Croatia, detailing their official names, extent, Natura 2000 classification, and the corresponding web addresses for more detailed information.

2.1. Akvatorij zapadne Istre

The Natura 2000 site "Akvatorij zapadne Istre" (site code HR1000032, Figure 1) is a crucial marine protected area located in the Jadranska Hrvatska region of Croatia. Established as a Special Protection Area (SPA) under the Birds Directive, this site has been officially recognized since July 2013 for its significant role in the conservation of avian biodiversity within the Mediterranean and Marine Mediterranean biogeographical regions. Encompassing an area of 155 square kilometers, with a dominant marine component of approximately 93%, the site's primary conservation objective is the protection of key bird populations. The area provides a vital habitat for six bird species listed in the Birds Directive's Annex I, including the Kingfisher (*Alcedo atthis*), Black-throated Diver (*Gavia arctica*), Red-throated Diver (*Gavia stellata*), the Mediterranean subspecies of Shag (*Phalacrocorax aristotelis desmarestii*), Common Tern (*Sterna hirundo*), and Sandwich Tern (*Sterna sandvicensis*). These species utilize the area for breeding, feeding, and as a resting point during migration, highlighting the

site's importance for the broader regional avian ecology. A key characteristic of "Akvatorij zapadne Istre" is its exclusive focus on avian conservation; notably, unlike many other Natura 2000 sites, it does not have any specific habitat types protected under the Habitats Directive (European Commission, 2023).



Figure 1: Overview of the Akvatorij zapadne Istre pilot site. The map illustrates the site's precise location and boundaries within the Jadranska Hrvatska region of Croatia. The base imagery for the map was sourced from Google Satellite, with processing and scale (1:450,000) managed through QGIS.

2.2. Ušće Raše

The Natura 2000 site "Ušće Raše" (site code HR3000432, Figure 2) is a significant conservation area located in the Jadranska Hrvatska region of Croatia. This site, with a surface area of 44.47 hectares—of which 86% is marine—has been protected under the Habitats Directive since its initial proposal as a Site of Community Importance (SCI) in July 2013 and subsequent confirmation in December 2014. Situated within the Mediterranean and Marine Mediterranean biogeographical regions, "Ušće Raše" is a crucial estuarine ecosystem, representing a vital interface where freshwater from the Raša River meets the Adriatic Sea. The site is designated for the protection of specific, rare species and two key habitat types. It safeguards one species listed in Annex II of the Habitats Directive: Painzza's Goby (*Knipowitschia panizzae*), a small fish species often found in brackish waters, which highlights the ecological importance of this unique transitional environment. The site also protects two distinct habitat types essential for biodiversity: sandbanks that are slightly covered by sea water all the time (habitat code 1110) and estuaries (habitat code 1130). Estuaries, in particular, are among the most productive ecosystems on Earth, serving as critical nursery grounds for fish and providing essential habitats for a wide range of flora and fauna. The

conservation of these habitats is paramount for maintaining the ecological integrity of the Raša estuary and the broader coastal ecosystem of the region (European Commission, 2023).

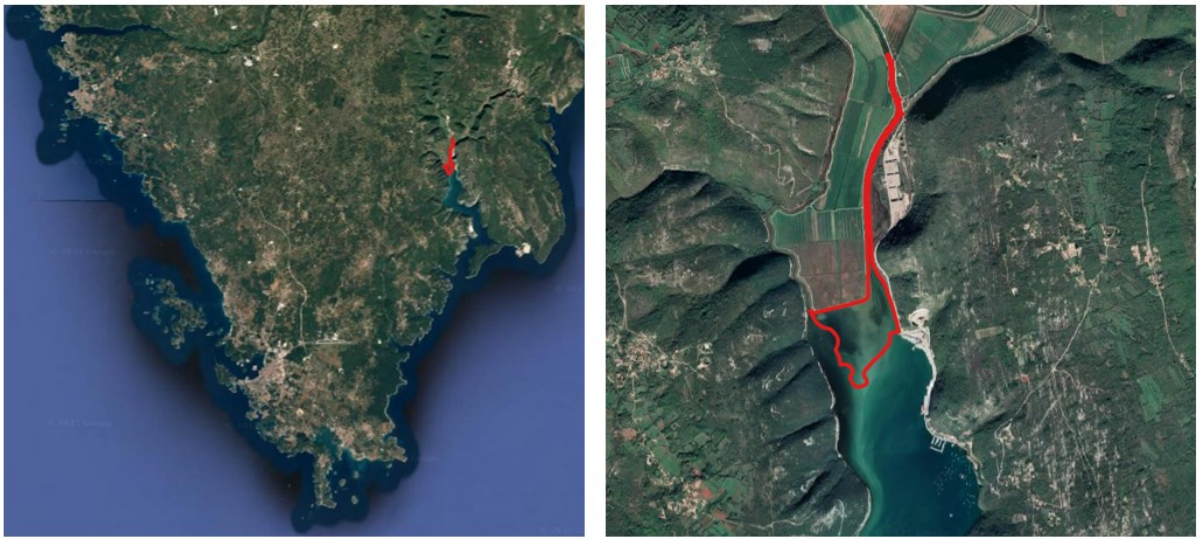


Figure 2: Overview of the Ušće Raše pilot site. The figure presents two maps to illustrate the site's boundaries: a broader regional map on the left (scale 1:300,000) and a more detailed, close-up map on the right (scale 1:37,500). The base imagery for both maps was sourced from Google Satellite, with processing and scale managed through QGIS.

2.3. Ušće Mirne

The Natura 2000 site "Ušće Mirne" (site code HR3000433, Figure 3) is a protected area located in the Jadranska Hrvatska region of Croatia. Covering a surface area of 115.34 hectares, with approximately 50% being marine, this site has been safeguarded under the Habitats Directive since it was first proposed as a Site of Community Importance (SCI) in July 2013 and subsequently confirmed in December 2014. Situated in the Mediterranean and Marine Mediterranean biogeographical regions, the site is notable for its estuarine ecosystem, where the Mirna River meets the sea. While "Ušće Mirne" is not designated for the protection of specific species, its ecological value is centered on the three distinct habitat types it protects. These include sandbanks that are slightly covered by seawater all the time (habitat code 1110) and estuaries (habitat code 1130), which are crucial as nursery areas for fish and crustaceans. Additionally, the site protects Mediterranean and thermo-Atlantic halophilous scrubs (habitat code 1420). This habitat type consists of salt-tolerant vegetation adapted to coastal and brackish environments, playing a vital role in stabilizing soil and supporting unique plant communities. The long-term conservation of these three habitats is essential for maintaining the biodiversity and natural processes of the Mirna River estuary and the surrounding coastal zone (European Commission, 2023).



Figure 3: Overview of the Ušće Mirne pilot site. The figure presents two maps to illustrate the site's boundaries: a broader regional map on the left (scale 1:250,000) and a more detailed, close-up map on the right (scale 1:35,000). The base imagery for both maps was sourced from Google Satellite, with processing and scale managed through QGIS.

2.4. Uvala Sakarun

The Natura 2000 site "Uvala Sakarun" (site code HR3000069, Figure 4) is a significant marine protected area in Croatia, located within the Marine Mediterranean biogeographical region. Encompassing an area of 438.54 hectares, which is entirely marine, the site has been safeguarded under the Habitats Directive since its proposal as a Site of Community Importance (SCI) in July 2013 and subsequent confirmation in December 2014. "Uvala Sakarun" is a key conservation area for two important habitat types that define the ecological character of the site. It is recognized for protecting *Posidonia* beds (*Posidonion oceanicae*) (habitat code 1120) and reefs (habitat code 1170). *Posidonia oceanica* is a species of seagrass endemic to the Mediterranean Sea that forms extensive underwater meadows, which are considered crucial ecosystems for the region. These meadows act as significant carbon sinks, produce oxygen, stabilize the seabed, and serve as vital nursery and breeding grounds for a diverse array of marine fauna (UNEP/MAP, 2011). Similarly, the reefs within the site provide complex habitats that support high biodiversity. Although the site does not protect any specific species under the Nature Directives, the conservation of these habitats is paramount for the overall health and productivity of the marine environment in the Northern Adriatic.



Figure 4: Overview of the Uvala Sakarun pilot site. The figure presents two maps to illustrate the site's boundaries: a broader regional map on the left (scale 1:500,000) and a more detailed, close-up map on the right (scale 1:60,000). The base imagery for both maps was sourced from Google Satellite, with processing and scale managed through QGIS.

2.5. “Grave e zone umide del Brenta”

The Natura 2000 site "Grave e Zone umide del Brenta" (site code IT3260018, Figure 5) is a significant conservation area located in the Veneto region of Italy, within the continental biogeographical region. Encompassing an extensive area of 3,848 hectares, this site has been under legal protection since September 1995 and is designated under both the Birds Directive and the Habitats Directive. This dual classification reflects its exceptional biodiversity, protecting both habitats and a wide array of species. The site was classified as a Special Protection Area (SPA) in August 2003 and later designated as a Special Area of Conservation (SAC) in July 2018. "Grave e Zone umide del Brenta" serves as a vital habitat for 55 species listed in the Nature Directives, highlighting its role as a biodiversity hotspot within the region. The protected species are remarkably diverse, including amphibians like the endemic Italian agile frog (*Rana latastei*), various bird species such as the Kingfisher (*Alcedo atthis*) and Grey Heron (*Ardea cinerea*), as well as significant populations of fishes, invertebrates, mammals, and reptiles. Furthermore, the site protects five important habitat types, which are crucial for maintaining the ecological integrity of the area. These include oligotrophic to mesotrophic standing waters, alpine rivers with ligneous vegetation, and alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*. Alluvial forests in particular, are a rare and important habitat type that supports a unique ecological community. The conservation of these habitats and species is paramount for the long-term ecological health of the Brenta river system and its surrounding wetlands (European Commission, 2023).



Figure 5: Overview of the Grave e Zone umide della Brenta pilot site. The figure presents two maps to illustrate the site's boundaries: a broader regional map on the left (scale 1:500,000) and a more detailed, close-up map on the right (scale 1:250,000). The base imagery for both maps was sourced from Google Satellite, with processing and scale managed through QGIS.

3. Database of Waste accumulation locations in Pilot Areas

The identification and cataloging of waste accumulation sites are a crucial step in understanding pollution dynamics and developing effective management strategies. The methodological approach adopted in this study relies on a hybrid method that combines remote analysis of satellite imagery with data collected through on-field surveys and the interrogation of existing online databases. While remote sensing offers an efficient method for large-scale, long-term monitoring, it has significant limitations in detecting small-to-medium-sized waste accumulations in terrestrial areas. Therefore, the integration of ground-truth data from field surveys and information from online platforms was essential to create a comprehensive, high-resolution map of pollution hotspots. The results of this integrated analysis have allowed us to compile an exhaustive database that catalogs the identified waste accumulation sites. These sites have been documented in an Excel file (.xls) and stored in three distinct shapefiles (.shp) for GIS visualization and analysis, using the coordinate system EPSG 32633 - WGS 84 / UTM zone 33N. The files include the geographic coordinates of each accumulation point and, where available, a detailed description of the type of waste found. The following sections describe the specific findings for each pilot site.

3.1. Akvatorij zapadne Istre

The Akvatorij zapadne Istre pilot area, with its extensive surface area of 155 km², presented a significant challenge for on-field monitoring. The study of waste accumulation sites in this marine protected area required a blended approach, combining a limited ground survey with a targeted analysis of specialized databases.

3.1.1 Field Survey Findings

On-field investigations, conducted by the partner Natura Histrica, focused exclusively on the southeastern portion of the site due to its large size. The survey successfully identified 14 points of waste accumulation (Figure 6). These accumulations were primarily categorized into two types: macro marine litter found along the coastline and illegal dumping sites in the inland part of the area. The marine litter, consisting mainly of plastic debris, fishing nets, and other non-biodegradable materials, was found to be concentrated in specific coastal zones where currents facilitate its accumulation. The illegal dumping sites, on the other hand, were located in more terrestrial areas, often along the sides of unpaved roads and in easily accessible locations. Notably, some of these sites were discovered within a disused quarry, making their access and potential cleanup particularly difficult and complex.



Figure 6: Geographic location of the identified waste accumulation points within the Akvatorij zapadne Istre (HR1000032) Natura 2000 site. The composite map, generated using Google Satellite imagery via QGIS, presents a detailed view (left, scale 1:46,000) and a regional context (right, scale 1:450,000).

3.1.2 Data from Online Databases

To supplement the field data and gain a better understanding of the distribution of coastal and sub-surface litter, a targeted query was performed on previously identified online databases. The results from the EMODnet Chemistry – Beach Litter Database provided critical context for the coastal sections of the pilot area. An analysis of this database for the period 2021–2022 returned data from a total of 11 surveys conducted across three beaches (Figure 7). The findings revealed significant variability in litter abundance. The Lakosase beach showed an extremely high median abundance of 14,983 items, corresponding to a density of approximately 312 items per meter of beach surveyed. In contrast, the Rovinj_Punta Kriz beach reported a median abundance of 2,332 items (approx. 38 items per meter), while the Brijuni beach showed a considerably lower median of 706 items (approx. 5 items per meter). These results suggest that while marine litter is a widespread issue, specific coastal areas act as chronic accumulation hotspots, likely due to a combination of localized sources and hydrodynamic factors.

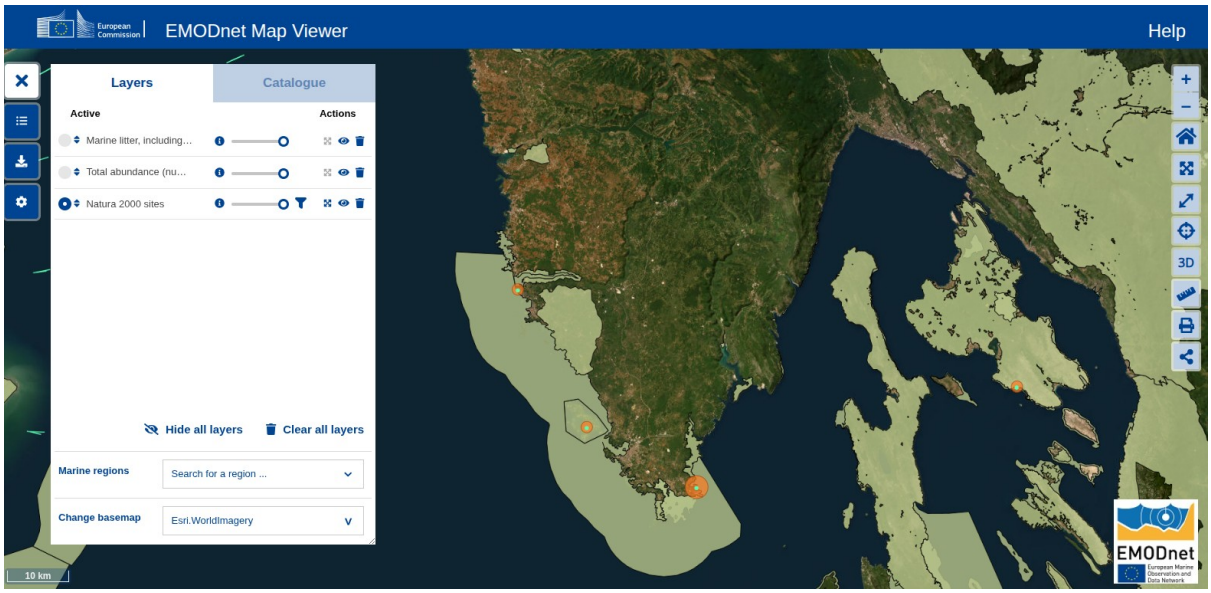


Figure 7: Location of the EMODnet beach litter monitoring sites within the Akvatorij zapadne Istre pilot area. The map illustrates the geographical position of the three surveyed beaches: Rovinj_Punta Kriz, Brijuni, and Lakosase, which were monitored between 2021 and 2022.

Additional accumulation hotspots within the pilot area were identified using the European Environment Agency's Marine LitterWatch (MLW) data viewer. This platform, first published in 2018 and updated through 2023, provides an interactive map that enables the identification of sites characterized by waste accumulation. The map displays all marine litter collection events organized by Marine LitterWatch communities from 2013 to 2025. According to the MLW data, two sites in Akvatorij zapadne Istre were affected by waste accumulation in 2019 (Figure 8). In Uvala Stoja, approximately 4,493 waste items were removed, whereas Valsaline Bay was comparatively less impacted, with a total of 447 waste items recorded.



Figure 8: Location of Marine LitterWatch beach litter collection sites within the Akvatorij zapadne Istre pilot area. The map illustrates the geographical position of the two surveyed beaches: Uvala Stoja and Valsaline Bay, where marine litter was collected in 2019.

Further insight was gained by consulting the citizen science platform PADI AWARE – Dive Against Debris®. A search for debris reports within the Akvatorij zapadne Istre area identified a specific survey conducted by scuba divers in Rovinj (Figure 9). This event, which took place in a 150 m² area at a depth of 5-8 meters, resulted in the collection of 87 debris items, with a total weight of 15 kg. The detailed breakdown of the collected materials revealed that plastic was the dominant component, accounting for 55 pieces (approximately 63% of the total). The remaining items included glass (10 pcs), metal (14 pcs), and a smaller fraction of wood (4 pcs) and cloth (4 pcs). While this data represents a single cleanup event, it strongly corroborates the presence of debris on the seafloor and provides a valuable, high-resolution record of specific underwater accumulation hotspots, which complement the broader data from EMODnet.

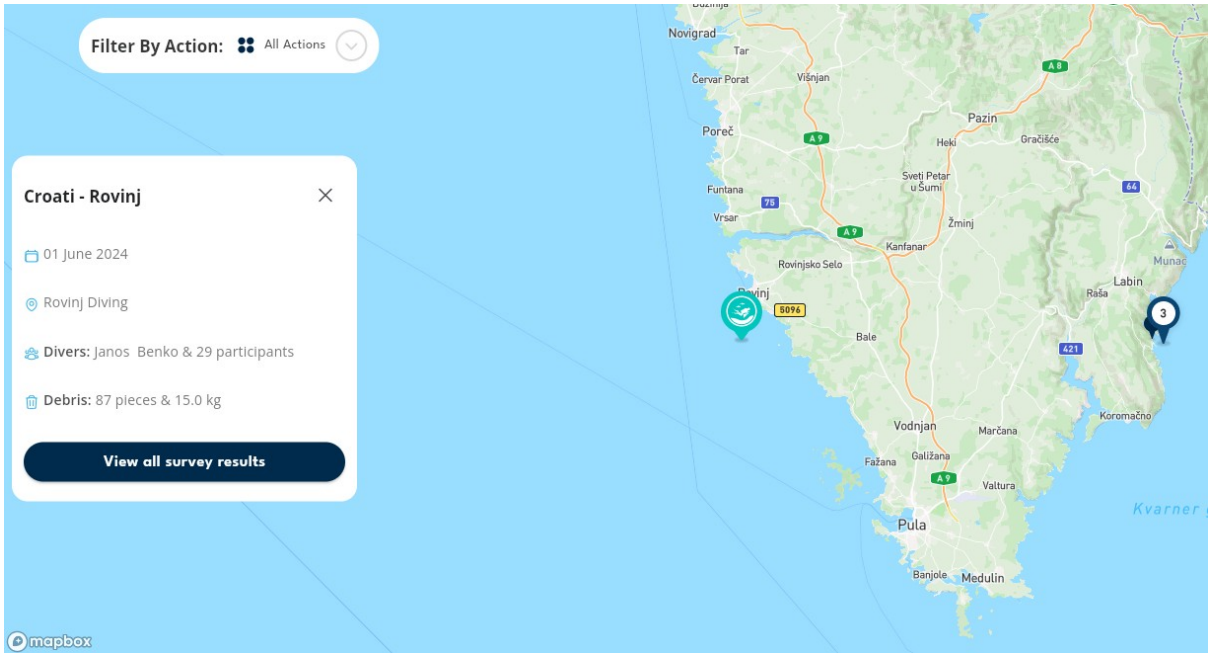


Figure 9: Location of the PADI AWARE – Dive Against Debris® survey in Rovinj. The map shows the specific site where the underwater debris cleanup event took place within the Akvatorij zapadne Istre pilot area, providing a detailed, localized perspective on sub-surface waste accumulation.

3.2. Ušće Raše and Ušće Mirne

For the pilot areas of Ušće Raše and Ušće Mirne, no significant evidence of waste accumulation was found through the methods employed in this study. This conclusion is based on a comprehensive search that spanned both targeted on-field surveys and a systematic review of the online databases and platforms previously identified in Chapter 1.2.

3.3. Uvala Sakarun

The pilot area of Uvala Sakarun is a significant marine site, and its entire beach has been identified as the primary waste accumulation area on Dugi Otok Island. The findings for this

site were primarily derived from a combination of on-field observations and local knowledge, which was then cross-referenced with online data.

3.3.1 On-field Observations

Based on the direct observations from cleaning activities and information provided by local communities, the distinct geographical features of Sakarun Bay make it a natural trap for floating marine litter (Figure 10). According to data from the Copernicus Marine MyOcean Viewer, sea currents in this region typically flow from the southeast towards the northwest. This dynamic causes debris to be transported all the way along the southwestern coast of the island. The unique "hook-shaped" conformation of the bay then acts as a natural barrier, trapping all the debris carried by these currents and causing it to accumulate on the beach. This makes the entire stretch of coastline within the bay a recurring hotspot for marine litter, particularly after periods of strong currents or southerly winds.

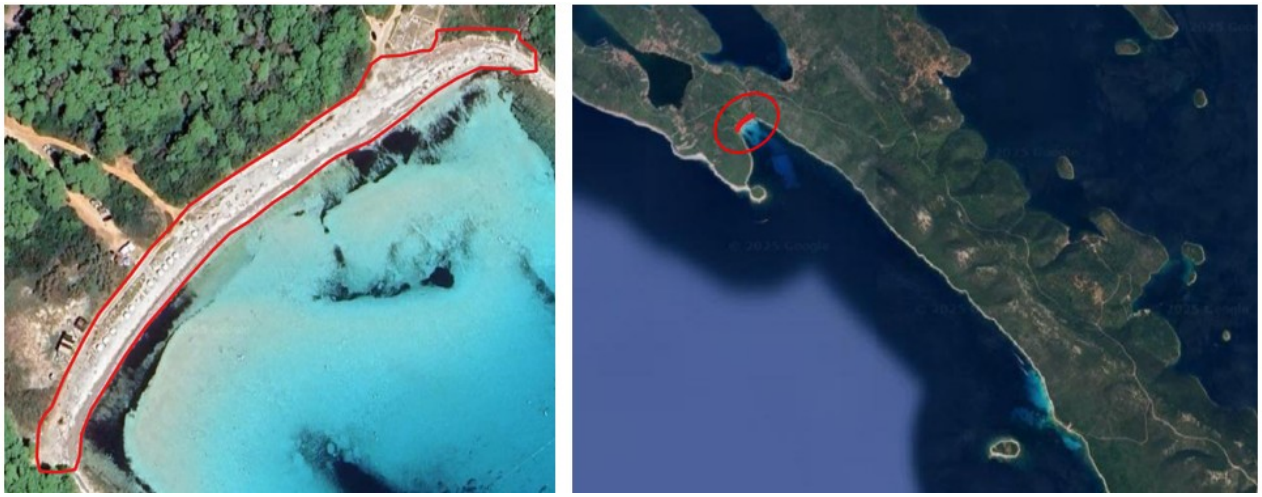


Figure 10: Overview of the waste accumulation area in Uvala Sakarun. The figure presents two maps to illustrate the site's boundaries: a detailed, close-up map on the left (scale 1:1,700) and a broader regional map on the right (scale 1:53,000). The base imagery for both maps was sourced from Google Satellite, with processing and scale managed through QGIS.

3.3.2 Data from Online Databases

To supplement the on-field observations, a focused review of specialized online databases was conducted to provide quantitative data on waste accumulation. The analysis of the EMODnet Chemistry – Beach Litter Database provided a specific data point that corroborates the qualitative findings from local knowledge. A survey conducted on the beach of Sakarun in 2022 revealed an exceptionally high concentration of litter (Figure 11). Over a survey length of just 68 meters, a total of 7,495 litter items were recorded. This corresponds to an exceptionally high density of approximately 110 items per meter of beach surveyed. This single, yet highly significant, data point from the EMODnet database provides quantitative evidence that the beach is a consistent and major hotspot for marine litter accumulation,

reinforcing the observations regarding the bay's geographical conformation and its role as a natural trap for debris.

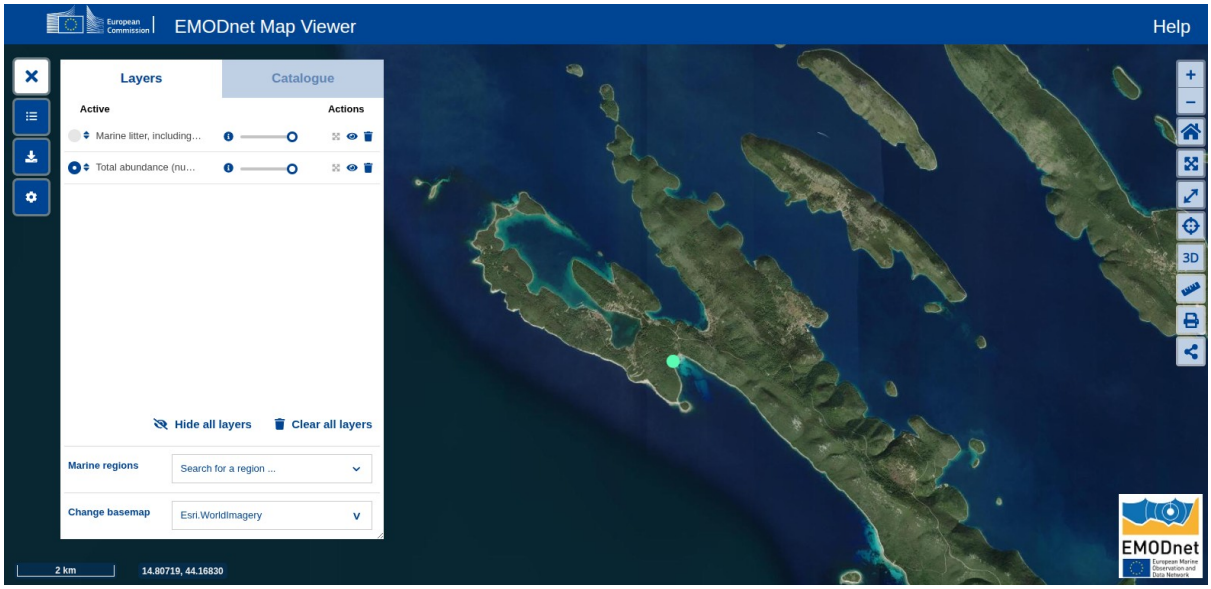


Figure 11: Location of the EMODnet beach litter survey point in Uvala Sakarun. The map illustrates the specific site on Sakarun beach that was monitored in 2022, providing a quantitative data point on waste accumulation.

3.4. Grave e Zone umide del Brenta

The pilot area "Grave e Zone umide del Brenta" represents a continental riverine system, and as such, its waste accumulation dynamics differ significantly from the marine sites. The data for this area was primarily sourced from systematic cleaning actions and on-field observations, which were then contextualized by information from riverine-specific databases.

3.4.1 On-field Observations

The core data for this site was gathered through a series of dedicated cleaning actions conducted by the local partner ETRA along the middle section of the Brenta River over several years. These activities resulted in the identification and cataloging of a total of 27 waste accumulation points (Figure 12). The nature of the waste accumulations in this area is twofold: it includes several illegal dumping sites where various forms of debris, including household and construction waste, have been deposited, as well as litter resulting from recreational activities along the riverbanks. Most of these accumulation points are located directly along the riverbanks, where the flow and human activity intersect. However, some sites were also found further inland, indicating a combination of direct discard into the river system and more distant, land-based sources of pollution.

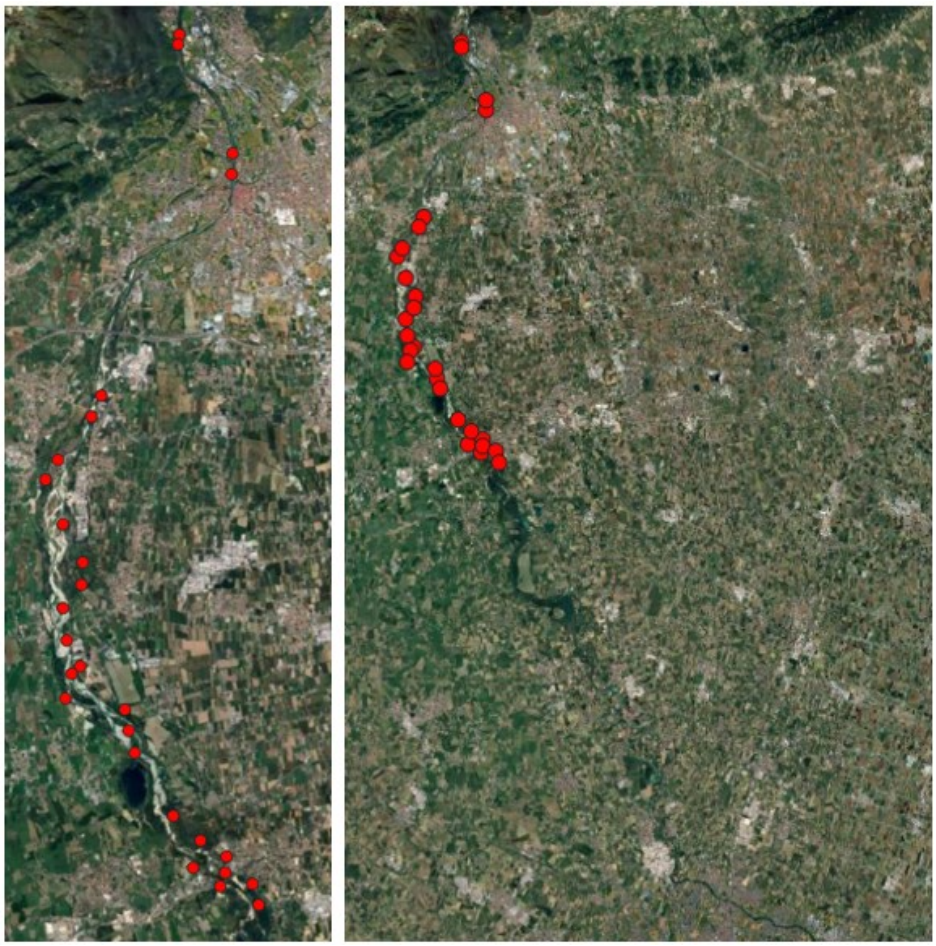


Figure 12: Overview of the waste accumulation points along the Brenta River. The figure presents two maps: a detailed map on the left (scale 1:130,000) showing the accumulation points along a specific portion of the middle Brenta, and a broader regional map on the right (scale 1:360,000) illustrating the entire river. The base imagery for both maps was sourced from Google Satellite, with processing and scale managed through QGIS.

3.4.2 Data from Online Databases

We did not find any specific, geolocated data points for this site in official databases or on citizen science platforms. This absence of data highlights a potential gap in monitoring coverage for the Brenta River on external platforms, which underscores the importance of the on-field surveys conducted by ETRA for this specific and ecologically sensitive area.

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