PER24 – Pollutants' Environmental Research 2024

11th - 28th October 2024

R/V "Gaia Blu"

Cruise Final Report

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Abstract

Anthropic impact on coastal areas led to the input of contaminants from land to the deep sea, both legacy (*e.g.*, heavy metals, PAHs, NPs), and emerging (*e.g.*, PFASs, PPCPs, BPA). These pollutants impact both marine and benthic ecosystems, entering the biogeochemical cycles. From the 11^{th} to the 28^{th} of October 2024 (departure/arrival port: Bari, Italy, Southern Adriatic Sea), the Italian National Research Council completed the PER24 expedition, on board the R/V "Gaia Blu", expanding the area surveyed in 2016 with the PERTRE campaign. The operations included the collection of 1784 sediment samples (ranging in depth from 0 to 44 cm) by means of a cylindrical box corer. After sampling, sediments were treated on board and stored. The PER24 campaign also conducted acoustic surveys (*i.e.* MBES - 394 transects, CHIRP-SBP - 37 transects, L-ACDP - 51 acquisitions) and the physico-chemical water characterization (*i.e.* CTD - 60 stations with 7 repetitions) to investigate geomorphology of the seafloor, transport mechanisms (*e.g.*, currents), and water column profile variation. Planned analyses comprise biogeochemical analysis, C and N stable isotopes measurements, organic and inorganic pollutant determination, microbiological composition, foraminiferal association, stratigraphic and geochronological analysis.

1. Introduction

The Anthropocene represents an informal geological epoch, indicating the current period in our Earth's history, marked by the dominance of the human footprint, resulting in modifications on Planet's climate and ecosystems (Owens, 2020). Contaminants produced by anthropic activities are one of the human contributions to the environment that define the Anthropocene.

Organic and inorganic contaminants (*e.g.*, heavy metals, Polycyclic aromatic hydrocarbons - PAHs, Nonylphenols - NPs, Per- and Polyfluorinated alkyl substances - PFASs, Pharmaceuticals and Personal care products - PPCPs, Bisphenol A - BPA) can be transported by rivers, runoff processes or discharged directly into the sea by industrial waste or sewers. These substances may accumulate in coastal or shelf sediments through processes of sedimentation, reworking, and early diagenesis. Under certain conditions, they can be transferred to deep marine environments, where they are either permanently deposited or undergo biogeochemical processes that allow them to recirculate into the water column and food chain (leading to bioaccumulation), with serious consequences for aquatic ecosystems and human health. For these reasons, monitoring and assessing the ecological health of marine environments requires an integrated approach combining sedimentological, chemical, biological, and geophysical analyses.

The PER24 campaign left the port of Bari (Southern Italy) on October 12^{th}, 2024, and lasted till October 28^{th}, on board the R/V "Gaia Blu", coordinated by the Italian National Research Council (CNR). The expedition has been conducted in the Italian Exclusive Economic Zone (EEZ), specifically that Southern Adriatic Sea/Northern Ionian Sea, and based on a multidisciplinary approach: sediment and water column investigations, geophysical surveys, geochemical analyses were performed. One of the aims of the campaign was to cover the entire area of the Italian EEZ not sampled during the PERTRE campaign (2016), particularly the deeper areas of the basin. During the PERTRE expedition, Hg concentrations in surface sediments were examined to assess the influence of both natural factors and human activities (Droghini *et al.*, 2019). Additionally, the spatial distribution patterns of PAHs were analyzed in function of sediment grain size and its biogeochemical properties (Frapiccini *et al.*, 2024). Furthermore, investigations into foraminiferal distribution and diversity were conducted (Fossile *et al.*, 2021), along with an analysis of how multiple environmental variables affect foraminiferal community composition through machine learning techniques (Rostami *et al.*, 2023). To investigate the spatial and temporal evolution of the environmental contamination revealed by the previous research campaign, nine sampling stations of the PERTRE expedition were included in the PER24 campaign sampling program.

2. Aim of the research

The aim of the PER24 campaign was to determine the extent of anthropogenic alterations in the Southern Adriatic Sea and in the Otranto Strait, focusing on human-induced contamination (*i.e.* organic and inorganic pollutants) and on the pathways of these substances from coastal areas to deep basins. All the collected data will be released as Open Science following the FAIR principles (Findable, Accessible, Interoperable, and Reusable).

A multidisciplinary approach was employed to obtain a comprehensive understanding of the complex land-sea-sediment system, which included the following main objectives of the PER24 campaign:

1. Determination of the concentration of legacy (heavy metals, PAHs, NPs) and emerging contaminants (PFASs, PPCPs, BPA) in surface and sub-surface sediments (with a maximum depth of 10 cm) and sediment cores, considering their transport and deposition processes.
2. Analysis of elemental carbon and nitrogen, along with their stable isotopes, in surface sediments and sediment cores to evaluate the different anthropogenic sources affecting the surveyed area.
3. Characterization of microbiological composition in surface sediments.
4. Survey of the bathymetry and geomorphological characterization of the seafloor.
5. Sedimentological investigation (*e.g.*, grain size, porosity) of the surveyed area.
6. Benthic foraminiferal assemblage taxonomical classification to understand alterations in the benthic communities.
7. Oceanographic characterization of the water masses and circulation patterns, assessing pollutant transport through measurements of thermohaline and biochemical properties, as well as currents.

3. Geological and oceanographic settings

The Adriatic Sea is a semi-enclosed basin located in the northernmost part of the Mediterranean Sea, bordered by the Apennines to the West and the Dinaric Alps to the East. It extends approximately 800 km in length and 200 km in width, oriented NW-SE. The basin is divided into three sub-basins based on bathymetry: the Northern Adriatic Sea, limited by the 100 m isobath; the Central Adriatic Sea, with an average depth of about 140 m; and the Southern Adriatic Sea, which connects to the Ionian Sea *via* the Otranto Sill (780 m) and contains the basin's deepest point: the South Adriatic Pit, reaching a depth of 1233 m (Russo & Artegiani, 1996; Artegiani *et al.*, 1997; Cushman-Roisin *et al.*, 2001). The South Adriatic Pit, bordered by the shallower Otranto Sill, restricts exchanges with the Ionian Sea, influencing sediment accumulation and driving deepwater convection processes that likely also affect pollutant transport (Gloginja & Mitrović, 2021).

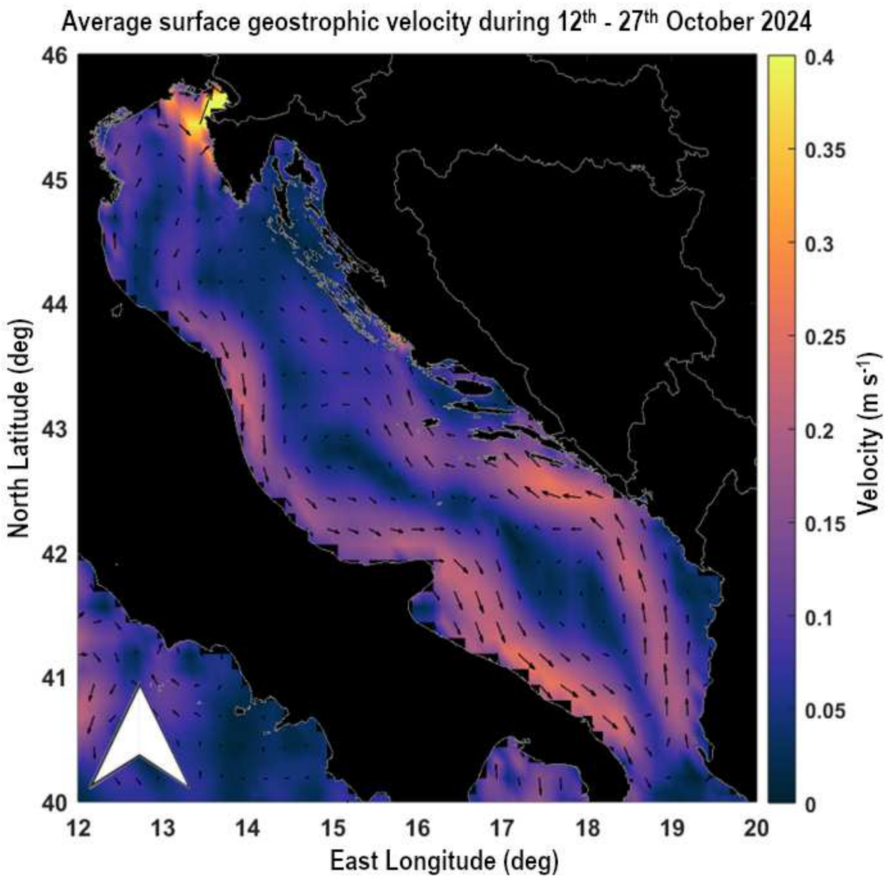

Figure 1. Overview of the average surface geostrophic circulation during the PER24 campaign activities, computed from the satellite-derived surface currents of the Copernicus Marine Environment Monitoring Service (https://marine.copernicus.eu).

The Adriatic general circulation is primarily cyclonic, with a northwestward flow along the Eastern coast and a return southeastward flow on the Western side (Orlić *et al.*, 1992; **Fig. 1**). Seasonal variations drive three distinct cyclonic gyres in each sub-basin, with the Southern Adriatic gyre exhibiting persistent year-round circulation. Wind forcing, especially from the Bora and Sirocco winds, impacts both surface and deepwater flow, creating strong currents and localized gyres that are expected to play a significant role in pollutant dispersal (Artegiani *et al.*, 1997).

The Southern Adriatic Sea contains key water masses: Adriatic Surface Water (AdSW), Levantine Intermediate Water (LIW), and Adriatic Deep Water (AdDW), which undergoes dense water formation in winter due to intense cooling, further contributing to deepwater exchanges with the Ionian Sea through the Otranto Strait. This dense water formation is essential for oxygenating the deep basin and can also influence the movement of contaminants toward the deep sea (Mihanović *et al.*, 2021).

It seems that the Southern Adriatic Sea's bathymetric and hydrographic properties create areas where pollutants are likely to settle or recirculate. The region was found to experience periods of high salinity, especially during dry years with low river input and high evaporation rates (Mihanović *et al.*, 2021). This saline stratification can trap pollutants in specific water layers, impacting biogeochemical cycles and potentially reintroducing contaminants to surface waters through convective processes.

4. Study area

The study area is located in the Southern Adriatic basin, part of the Mediterranean Sea, and holds significant ecological and geological importance, serving as a natural repository for materials transported from both natural and anthropogenic sources.

Within this region, rivers, industrial activities, and coastal runoff deposit a wide range of organic and inorganic contaminants, including heavy metals and persistent organic pollutants such as PAHs, NPs, PFASs, PPCPs, and BPA. These pollutants are often embedded in sediment layers through sedimentation and diagenesis processes and can migrate to deeper marine environments. Once deposited in these depths, contaminants might persist or undergo biogeochemical transformations, potentially re-entering the water column and affecting the food chain through bioaccumulation.

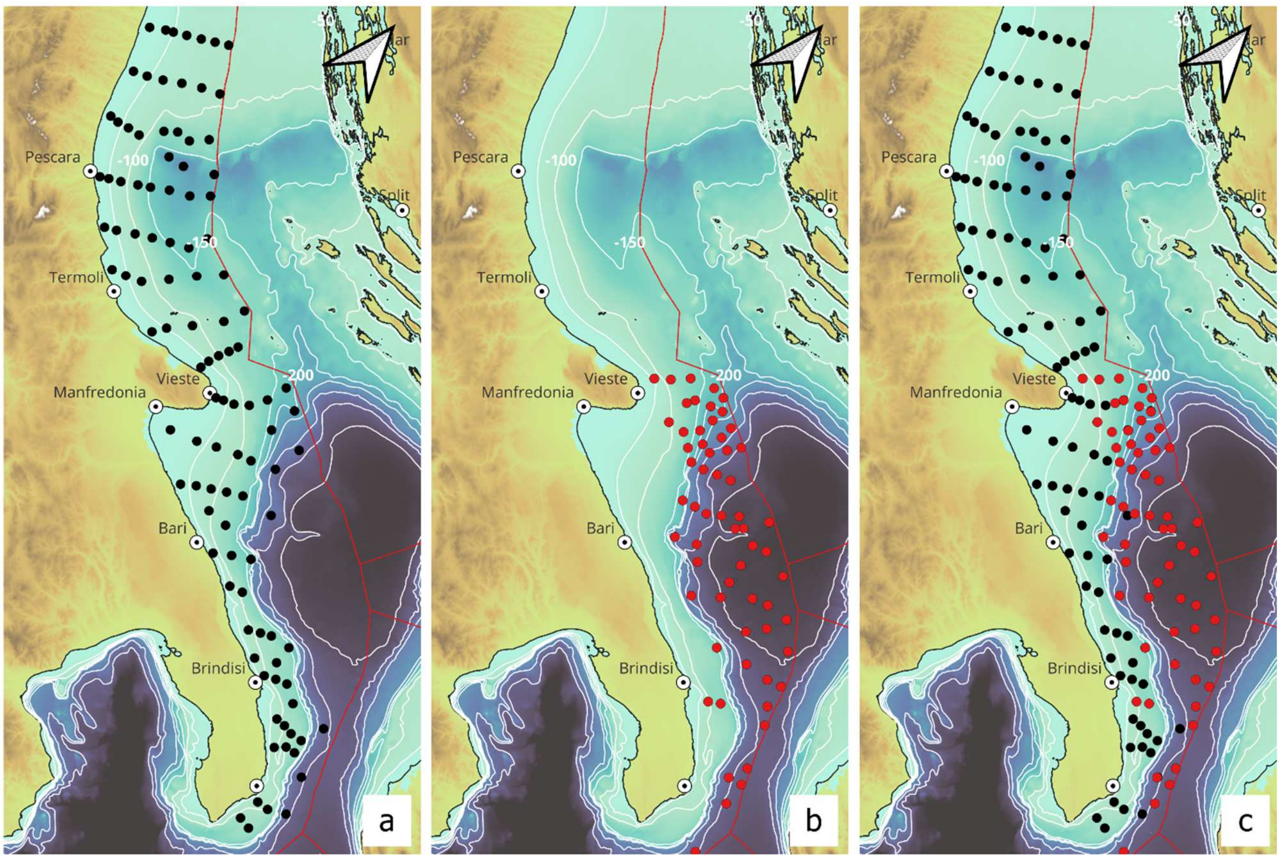

Figure 2. Box corer sampling stations: **a)** PERTRE campaign; **b)** PER24 campaign; **c)** combined area.

The PER24 campaign surveyed the Italian EEZ in the Southern Adriatic and Northern Ionian seas (**Fig. 2b**). The sampled area extended the PERTRE campaign study area (**Fig. 2a**), also revisiting nine sampling stations. The comprehensive coverage, combining the two campaigns, results in more than 150 sampling points (**Fig. 2c**).

5. Participants

Table 1. The PER24 campaign scientific crew.

Participant	Role	Affiliation	Leg
De Marco Rocco	Head of Mission	CNR-IRBIM	Both
Avanzato Gaspare	SBP/MBES/Navigation	CNR-IRBIM	Both
Berto Daniela	Laboratory	ISPRA Chioggia	2nd
Calace Nicoletta	Laboratory	ISPRA Roma	2nd
Cristallo Carla	Activity report/Dry Lab	UNIURB	2nd
Di Cola Alessandro	Navigation	CNR-IRBIM	1st
Evangelista Chiara	Laboratory	CNR-IRBIM	Both
Fanelli Matteo	Box corer/Laboratory	UNIVPM	Both
Freddi Angela	Laboratory	UNIURB/CNR-IRBIM	1st
Krauzig Naomi	CTD/L-ADCP/ADCP	UNIVPM/FMC	Both
Massi Lorenzo	Box corer/Laboratory	UNIVPM/UNIVE	Both
Minetti Loris Emanuele	Activity report	UNICAM	1st
Patrolecco Luisa	Laboratory	CNR-ISP Roma	2nd
Pizzini Sarah	Laboratory	CNR-IRBIM/FMC/UNIVE	2nd
Prosciutti Giulia	Activity report	UNICAM	1st
Rampazzo Federico	Box corer/Laboratory	ISPRA Chioggia	2nd
Rebecchi Federica	Activity report/Dry Lab	UNIURB	2nd
Rossi Francesco	Navigation	UNIURB	Both
Zambrano Miller	SBP/MBES	UNICAM	Both

Figure 3. The PER24 campaign scientific crew of the first and second leg, respectively.

6. Materials and methods

The field activities of the PER24 campaign were carried out using the CNR's R/V "Gaia Blu". The campaign lasted 18 days, including Mob/Demob, transit time to reach the target areas, and time for swapping both the scientific crew and the onboard scientific instruments.

The cruise was organized in two legs (**Table 1**; **Fig. 3**):

- Leg 1 from October 11th to October 18th, 2024 (Bari/Vieste area);
- Leg 2 from October 18th to October 28th, 2024 (Bari/Santa Maria di Leuca area).

During the PER24 campaign, the following sampling/scientific instruments were used:

- MarineTech Edelstahlhandel MT-OBC50 Oceanic Box Corer;
- Sea-Bird Scientific SBE 9plus Conductivity, Temperature, Depth (CTD) Unit and SBE 11plus V2 Deck Unit;
- Teledyne RD Instruments (TRDI) Workhorse II (300 kHz) Lowered-Acoustic Doppler Currents Profilers (L-ADCPs);
- Vessel-mounted TDRI Pinnacle (45 kHz) and Workhorse II Mariner (300 kHz) Acoustic Doppler Currents Profilers (ADCPs);
- Vessel-mounted Knudsen Systems CHIRP (Compressed High-Intensity Radiated Pulse) signal 3260 Sub-Bottom Profiling (SBP) echosounder;
- Vessel-mounted Kongsberg Discovery EM 712 (1° x 0.5° beam width) and EM 304 MKII (1° x 1° beam width) MultiBeam Echo Sounders (MBESs);
- Carl Zeiss Stemi 508 Stereo Microscope with Axiocam 208 color camera.

In addition to the above-mentioned activities, an experimental sample management method has been developed using an automated labeling system (see **Paragraph 6.3**).

6.1. Sediment sampling

The PER24 campaign primarily focused on acquiring surface sediment samples. A total of 61 sampling stations have been surveyed, nine of which have already been sampled during the PERTRE campaign. Sediment samples were collected using a cylindrical box corer. At each station, a 58 cm-length PVC liner with a diameter of 10 cm was inserted along the full sampled length to retrieve a sediment core to perform stratigraphic analysis and dating. Additionally, at some selected stations, a second PVC liner was collected to conduct further analyses along the core sedimentary profile (see **Paragraph 7.2**).

6.1.1. Box corer

The box corer is one of the most used tools for marine geological sampling when it comes to unconsolidated sediments. It allows the collection of samples of the seafloor sediment surface with minimum disturbance and contamination. It is useful for biological (micro- and macrofauna), geochemical, and stratigraphic analysis. It is lowered vertically until it impacts the seabed where the box will penetrate because of its own weight. Closing lids (or water vents), working as valves, prevent the sediment compression during its penetration and preserve undisturbed the water-sediment interface (allowing, in many cases, also for the bottom water collection) during recovery of the box corer.

A MT-OBC50 oceanic box corer (MarineTech Edelstahlhandel GmbH & Co. KG, Bremen, Germany) has been used in the sampling tasks. Its structure is made of hot-dip galvanized steel, with dimensions of 1535 x 2040 mm for the base and 2635 mm in height, with an approximate weight of 550 kg. The ballast (six unit used) is made of hot-dip galvanized steel, with dimensions of 300 x 300 x 50 mm and an approximate weight of 35 kg. The overall weight was about 760 kg. The sampling bucket has a round base in AISI 304 stainless steel, measuring 300 x 300 x 550 mm in height, with a thickness of 5 mm, a capacity of approximately 50 L, and an approximate weight of 26 kg (**Fig. 4**).

The aim of the sediment sampling was to cover the entire area of the Italian EEZ not sampled during the PERTRE campaign conducted in 2016, particularly the deeper areas of the basin. However, nine stations, already sampled in the 2016 campaign, have been re-sampled to assess the environmental evolution occurred over these 8 years.

Figure 4. The box corer used on board for the sediment sampling.

6.2. Oceanographic and geophysical surveys

All the instruments employed for the oceanographic and geophysical surveys conducted during the PER24 campaign are listed below.

6.2.1. CTD and L-ADCP casts

A combination of CTD and L-ADCP measurements was used to assess oceanographic properties and current structures. This was based on the classic Sea-Bird Scientific (Bellevue, WA, USA) combination SBE 9plus CTD Unit and SBE 11plus V2 Deck Unit for real-time georeferenced sampling with primary and secondary sensors and downward- and upward-looking TRDI (Teledyne Marine Technologies Inc., Poway, CA, USA) Workhorse II ADCPs (**Fig. 5**).

All the sensors were mounted on a classic rosette frame and were deployed using an electro-mechanical cable on an IBERCISA Deck Machinery SA (Pontevedra, Spain) ocean winch, equipped with a Launch and Recovery System (LARS) to ensure real-time transmission and handling, as well as a safe deployment and retrieval.

The CTD system provides high-resolution vertical profiles of essential physical properties of seawater, specifically conductivity (from which salinity is derived), temperature, and depth. During the PER24 campaign, the SBE 911plus CTD system was further enhanced with auxiliary sensors (**Table 2**), which measured dissolved oxygen, turbidity, fluorescence (to estimate chlorophyll-*a* concentration), and Photosynthetically Active Radiation (PAR).

Table 2. Components and auxiliary sensors of the utilized Sea-Bird Scientific (Bellevue, WA, USA) SBE 911plus CTD (Conductivity, Temperature, Depth) system.

Component	Description
SBE 4C	Conductivity sensor
SBE 3plus	Premium temperature sensor
Digiquartz®	Pressure sensor
SBE 5T	Submersible pump
SBE 43	Dissolved oxygen sensor
WET Labs* ECO**	Turbidity sensor
WET Labs* ECO**-AFL/FL	Fluorescence sensor
PAR	Photosynthetically Active Radiation (PAR) sensor
04-C	Altimeter for bottom detection

*WET Labs Inc., Philomath, OR, USA.
**ECO: Environmental Characterization Optics.

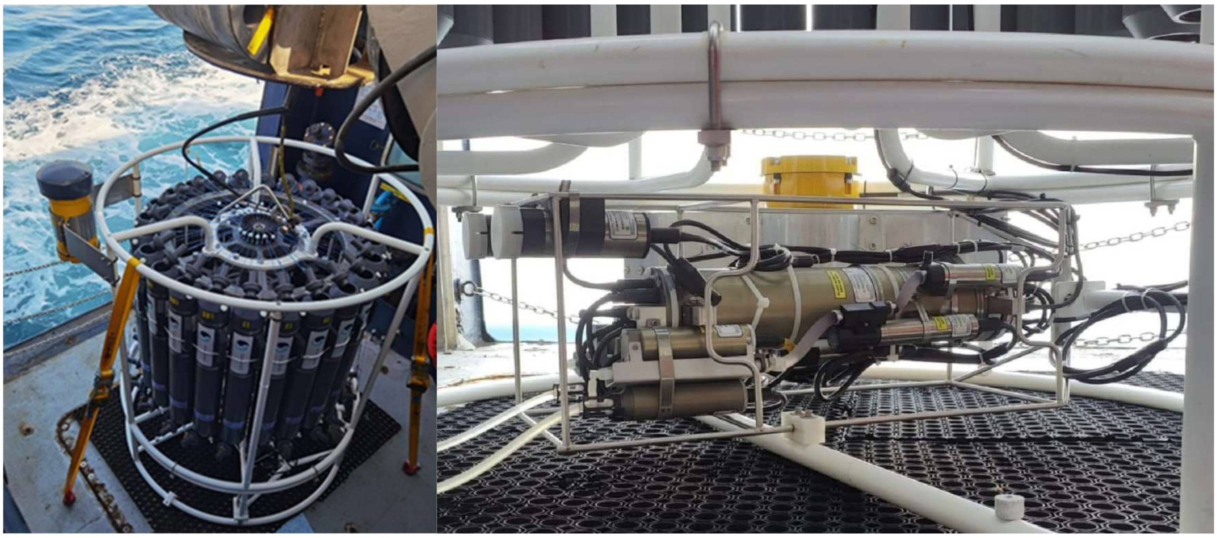

Figure 5. On the left, rosette CTD (Conductivity, Temperature, Depth) and L-ADCP (Lowered-Acoustic Doppler Currents Profiler) used on board for the characterization of the water column. Details of the CTD probe on the right.

The L-ADCP system was based on two 300 kHz Workhorse II ADCPs, set up with Water Mode 15 (WM15) for L-ADCP deployment. In this configuration, the two ADCPs were mounted on the rosette frame in both downward- and upward-looking orientations, allowing them to capture a detailed profile of water column currents. By synchronizing the pinging sequences of the downward- and upward-looking ADCPs, the L-ADCP setup extended the profile range, enabling a comprehensive vertical view of current velocities throughout the water column. This dual orientation maximized spatial coverage and resolution, providing crucial insights into the circulation patterns and vertical structure of currents, aiding the analysis of mixing, stratification, and pollutant transport within the Southern Adriatic Sea.

<u>CTD processing</u>

Regarding the CTD measurements, raw 24 Hz profiles were processed using Sea-Bird Scientific's SBE Data Processing software to produce quality-controlled data on a regular 1-m vertical grid. This processing workflow incorporates key modules essential for generating data that meet international quality standards:

Data Conversion: Converts raw binary data to engineering units (conductivity, temperature, pressure).

Wild Edit: Detects and removes extreme outliers in the data.

Filter: Applies a low-pass filter to reduce high-frequency noise, typically used on pressure data.

Align CTD: Aligns conductivity data with temperature and pressure, correcting for any sensor lag.

Cell Thermal Mass: Corrects for the thermal mass effect in the conductivity cell, improving salinity accuracy.

Window Filter: Applies a moving average or other window-based filter to smooth data while preserving key-profile features.

Loop Edit: Removes data affected by ship heave or oscillations in the downcast profile.

Derive: Calculates additional oceanographic variables (*e.g.*, salinity, density, sound velocity) based on standard equations.

TEOS-10 (Thermodynamic Equation of Seawater, 2010): Converts data to thermodynamic variables using the Gibbs SeaWater (GSW) Oceanographic Toolbox for improved accuracy (*e.g.*, absolute salinity and conservative temperature).

Bin Average: Averages data at regular depth or pressure intervals (*e.g.*, 1-m bins) for a smoothed vertical profile.

The primary variables measured include seawater conductivity (mS cm^{-1}), temperature (°C), and pressure (decibar). Salinity (Practical Salinity Units, PSU) was initially calculated by the software, inferred from conductivity and temperature, using TEOS-10 equations. During further data processing, salinity and other derived parameters were recalculated using the GSW Oceanographic Toolbox for improved accuracy and consistency with modern standards.

L-ADCP processing

The processing workflow for the L-ADCP measurements incorporates the following steps in order to produce accurate velocity profiles that meet international quality standards:

Data Synchronization: Aligning L-ADCP data with corresponding CTD measurements and navigational information to ensure temporal consistency across datasets.

Sound Speed Correction: Accurate sound-speed calculations, derived from CTD-measured salinity, temperature, and pressure, essential for precise velocity measurements.

Coordinate Transformation: Transforming velocity data from the instrument coordinate system to Earth-referenced coordinates, which requires precise heading, pitch, and roll information. Incorporating external sensors can enhance the accuracy of these measurements.

Velocity Inversion: Employing the velocity-inversion method, as implemented in the LDEO (Lamont-Doherty Earth Observatory; Columbia University, New York, NY, USA) MATLAB software (Thurnherr *et al.*, 2017; Thurnherr, 2024), integrating various data sources, including ship drift, bottom tracking, and water tracking, to compute absolute velocity profiles.

Quality Control and Editing: Identifying and removing erroneous data points, such as those caused by instrument malfunctions or environmental interferences, crucial for maintaining data integrity.

Depth and Range Correction: Adjusting for instrument depth and accounting for range limitations, which ensures that velocity profiles accurately represent the entire water column.

L-ADCP measurements were post-processed using the IX.15 version of the LDEO MATLAB software, developed by Thurnherr (2024) and based on the velocity-inversion method originally proposed by Visbeck (2002). This processing approach relies on both ADCP and navigational data collected for each L-ADCP cast to enhance profile accuracy. Additionally, creating high-quality L-ADCP profiles requires precise depth and sound-speed information, derived from the CTD's salinity, temperature, and pressure data. For this scope, the CTD down- and up-cast data were processed and bin-averaged on a regular 5-m vertical grid.

6.2.2. Vessel-mounted ADCPs

During the PER24 campaign, two vessel-mounted ADCPs, the TRDI Pinnacle (45 kHz) and the Workhorse II Mariner (300 kHz) ADCPs, were utilized to capture detailed current velocity profiles along two key transects in the Southern Adriatic Sea (**Fig. 6**). Each ADCP operated at a different frequency, allowing for optimized depth coverage and resolution across the upper ~300 m and ~1200 m of the water column.

The Pinnacle ADCP, a 45 kHz phased-array ADCP, was specifically chosen for its capability to profile currents down to 1000 m in a compact footprint typically associated with ADCPs reaching only half of this range. Its design improves portability and simplifies deployment, making it well-suited for capturing deeper current structures while maintaining ease of use on a research vessel.

Figure 6. Locations of the two vessel-mounted ADCPs (Acoustic Doppler Currents Profilers): the Teledyne RD Instruments (TRDI; Teledyne Marine Technologies Inc., Poway, CA, USA) Pinnacle (45 kHz) and Workhorse II Mariner (300 kHz), on the hull of the R/V "Gaia Blu".
Photo credit: Giovanni De Vita, Argo S.r.l.

In contrast, the Workhorse II Mariner 300 kHz ADCP was selected to focus on high-resolution profiling in shallower waters. With a conventional transducer design that uses a separate ceramic element for each beam, the Workhorse II Mariner is capable of profiling mid-depth currents with broad spatial coverage, making it ideal for resolving circulation patterns and assessing water transport in the upper region of the water column. For improved resolution in the upper ocean, it was configured with a 4-m bin size, providing enhanced data quality at depths under 100 m. Together, the Pinnacle and Workhorse II Mariner ADCPs allowed a comprehensive assessment of horizontal current patterns across various depths, aiding in the analysis of transport mechanisms and pollutant dispersion pathways.

The combined use of the Pinnacle and Workhorse II Mariner ADCPs is expected to provide high-resolution velocity data over a broad depth range, allowing for detailed mapping of circulation dynamics, critical to understanding oceanographic processes and transport mechanisms in the Southern Adriatic Sea.

Vessel-Mounted Data Acquisition System (VMDAS)

Data acquisition was managed using the TRDI VMDAS, which facilitated the configuration of key ADCP parameters, including depth cell size and number of cells, and provided synchronized data recording from both ADCPs and ancillary sensors. VMDAS organizes data storage with a consistent file-naming system, simplifying retrieval and ensuring all the data are tagged with a common time base that can be converted to UTC. The platform's real-time access to data allowed adaptive sampling during the survey, enabling adjustments in response to current structures observed along the transects.

Vessel-mounted ADCP post-processing

Data post-processing was conducted using the CODAS3 Software System, which supports data extraction, coordinate assignment, and velocity data editing and correction. This processing step includes adjustments for variations in sound velocity, as well as correction for any misalignment of the ADCPs with the vessel's axis, ensuring the highest accuracy in the final velocity profiles.

6.2.3. Vessel-mounted CHIRP-SBP surveys

SBP provides return high-resolution stratigraphic information of the first 10 to 40 m of sediment (**Fig. 7**). The main interest of seismic imaging was focused on areas characterized by the presences of contourites generated by bottom currents, likely controlled by the morphology of the marine bottom. During the PER24 campaign, the main submarine landslide scarp areas have been mapped in detail, since they help the current to erode sediments, generating moat structures and deposition areas called drift. Contourites have a particular interest due to the remobilization of the sediments due to the bottom currents. In addition to this, areas of the basin characterized by ripples or dunes have been imaged. Finally, areas affected by MTDs (Mass Transport Deposits) and faults in shallow sediments have also been detected.

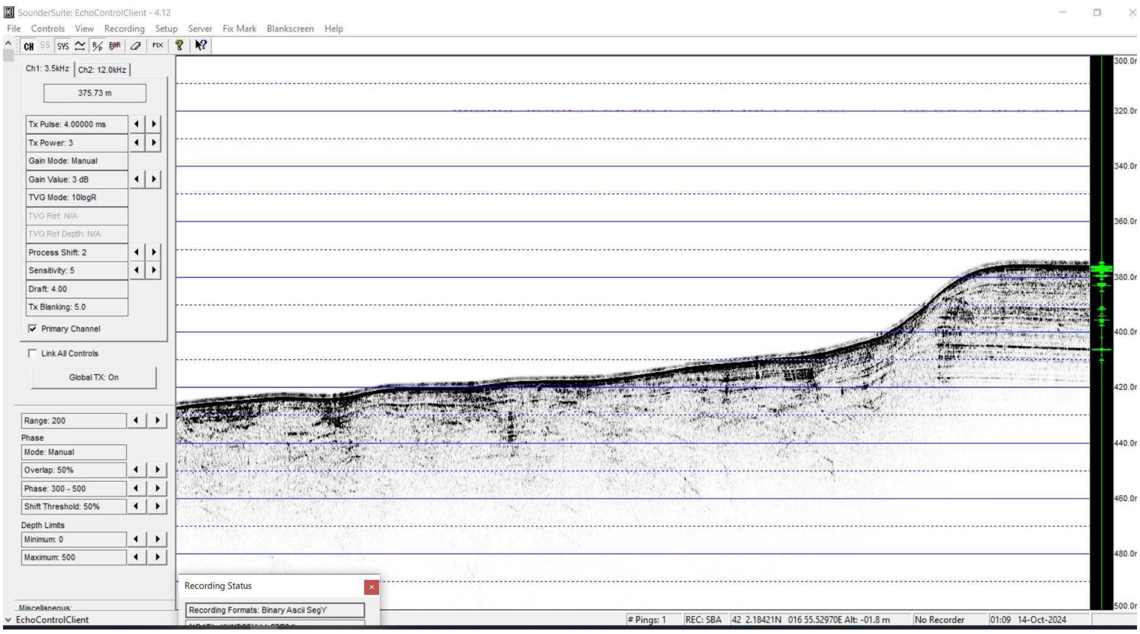

Figure 7. Screenshot of the software acquisition of the vessel-mounted Knudsen Systems Inc. (Perth, ON, Canada) CHIRP (Compressed High-Intensity Radiated Pulse) signal 3260 SBP (Sub-Bottom Profiling) echosounder.

High-resolution seismic reflection data of the sub-bottom were acquired using the vessel-mounted Knudsen Systems Inc. (Perth, ON, Canada) 3.5-12 kHz 3260 SBP echosounder. For the acquisition, a CHIRP signal for pulse generation and correlation processing was selected, that permits to have a broad bandwidth. Since the operational depth was in the range of 300-1200 m, the nominal operational central frequency was adjusted to 3.5 kHz and the bandwidth to 8 kHz. There are two modes of envelope detection available on the CHIRP 3200 series echosounders, amplitude and square-law detection modes. The amplitude mode is used when the background noise level is of interest, whereas the standard square-law detection mode improves the signal-to-noise ratio of the echogram data by helping to pull out the signal return level from the background noise. Under this consideration and after implementing a test, the square-law detection mode was selected. As digital filters, the same window type (rectangular) for the main signal filter and the transmit filter was used, to ensure the best correlation results since the transmitted pulse will more closely match the anticipated correlation signal. The Kongsberg Discovery (Kongsberg Gruppen ASA, Horten, Norway) K-sync software was used to synchronize the multibeam and SBP acquisitions. The multibeam was the master unit as the longest transmitting-receiving system, the CHIRP was subordinated to the listening window of the multibeam.

6.2.4. Vessel-mounted MBES surveys

The MBES is an active sonar system used mainly to map the seafloor. It comprises a transducer array (mounted under the ship's hull), that sends and receives multiple sound pulses (beams) at once in a fan-shaped pattern. Multibeam collects two types of data: seafloor depth and backscatter. The seafloor depth (*i.e.* bathymetry) is computed by measuring the two-way travel time of the pulse from the array to the seafloor and back again to the array. Backscatter is a measurement of the intensity of the sound echo that reflects to the multibeam array. Multibeam is useful for both water column and seafloor characterization.

Throughout the entire PER24 campaign, the MBES was used to support the other scientific activities. Additionally, several seafloor mapping surveys were conducted to characterize the main geomorphological features surrounding the sampling stations. Moreover, during nighttime pauses in primary sampling activities, the available ship time was used to conduct MultiSpectral BackScatter (MSBS) tests, measuring the intensity of reflected signals in response to acoustic pulses at different frequencies over small areas (~2 x 1 nautical miles). In particular, the Kongsberg Discovery EM 712 and EM 304 MKII, two of the three vessel-mounted MBESs on the R/V "Gaia Blu" (**Fig. 8**), were used to support the various scientific activities (**Table 3**), while only the first one was employed for conducting MSBS tests (**Table 4**).

Figure 8. Location of the vessel-mounted Kongsberg Discovery (Kongsberg Gruppen ASA, Horten, Norway) EM 304 MKII and EM 712 MBESs (MultiBeam Echo Sounders), on the hull of the R/V "Gaia Blu".
Photo credit: Giovanni De Vita, Argo S.r.l.

A Kongsberg Discovery Seapath 380 system was incorporated on board the R/V, using a Fugro Marinestar™ NV (Leidschendam, The Netherlands) HP Differential Global Positioning System (DGPS) which provided Global Navigation Satellite System (GNSS) positioning accuracy better than 10 cm. To improve navigational precision, a Kongsberg Discovery Motion Reference Unit (MRU) 5 and a Dual Antenna GPS were integrated into the Seapath 380 setup, allowing for real-time corrections of roll, pitch, heave, and yaw attitudes.

A miniSVS (Sound Velocity Sensor) was employed close to the transducers to continuously monitor the sound velocity during the survey and Sound Velocity Profiles (SVPs) were acquired daily using a Valeport Ltd. (Totnes, UK) MIDAS SVP system to ensure comprehensive data collection, accounting for variations in sound propagation due to changes in water density and temperature throughout the day. The Kongsberg Discovery Seafloor Information System (SIS) 5 was used for raw data acquisition during surveys conducted to support CHIRP data collection and MSBS testing.

Simultaneously, both these surveys and the lines acquired for navigation support were recorded with a Quality Positioning Services (QPS BV, Zeist, The Netherlands) QINSy software.

Table 3. Technical specifications of the vessel-mounted Kongsberg Discovery (Kongsberg Gruppen ASA, Horten, Norway) MBESs (MultiBeam Echo Sounders) used.

Technical specifications	EM 712	EM 304 MKII
Frequency	40-100 kHz	30 kHz
Depth	3200 m	11.000 m
Beam width	1° x 0.5°	1° x 1°
Max number of soundings	512	1600
Max ping rate	50 Hz	10 Hz
Max swath angle	140°	150°

Table 4. Configuration settings of the Kongsberg Discovery (Kongsberg Gruppen ASA, Horten, Norway) EM 712 MBES (MultiBeam Echo Sounder) used for multispectral backscatter tests.

Configuration setting	EM 712
Frequency	40 kHz / 70-100 kHz
Angular coverage mode	Auto
Swath angle	70°
Beam spacing	High density
Dual swath mode	Dynamic
Depth setting	Medium/Deep/Very deep
FM disable	On
Max ping rate	2 Hz

6.3. Automated labeling system

During the PER24 campaign, a software tool specifically developed for the R/V "Gaia Blu" was designed and tested to efficiently and accurately manage the collection of physical samples during oceanographic cruises by means of an automated labeling system (**Fig. 9**).

Figure 9. Label printing system for labeling sediment samples.

6.3.1. Overview of the software tool

The platform is centered around a database that stores and tracks details of scientific activities, collected samples, tasks performed, and the cruise's logistical information (see **Table 8**, **Paragraph 8.1**). This software employs two distinct frontends, optimized for the specific needs of the different operational environments: the ship's control room and the laboratory, where sample management takes place. The database contains well-structured tables that store details of the cruise, types of collected samples, and activities performed. It allows for accurate monitoring of location, time, and scientific details. It supports real-time data collection and can be easily consulted for reporting operations and preparing the sample inventory (**Annex A**).

7. Sediment sample treatment

7.1. Surface sediment sub-sampling

Once the box corer was secured on the aft deck, and after the central pin was inserted and the bucket released, this latter was placed on a pallet truck and moved to the designated operational area. After the removal of the supernatant, one or two PVC liners were inserted for the entire depth of the recovery. Once the necessary liners were inserted, the bottom of the bucket was unlocked, and surface sub-sampling was performed as described below. The bucket was then removed by lifting it upwards, ensuring the liners were kept in a vertical position. The liners were removed by inserting a 12 x 10 cm metal spatula at their base and transported to the laboratory. The box corer and bucket were then cleaned and prepared for the next station. Any remaining sediment was discarded at sea (**Fig. 10**).

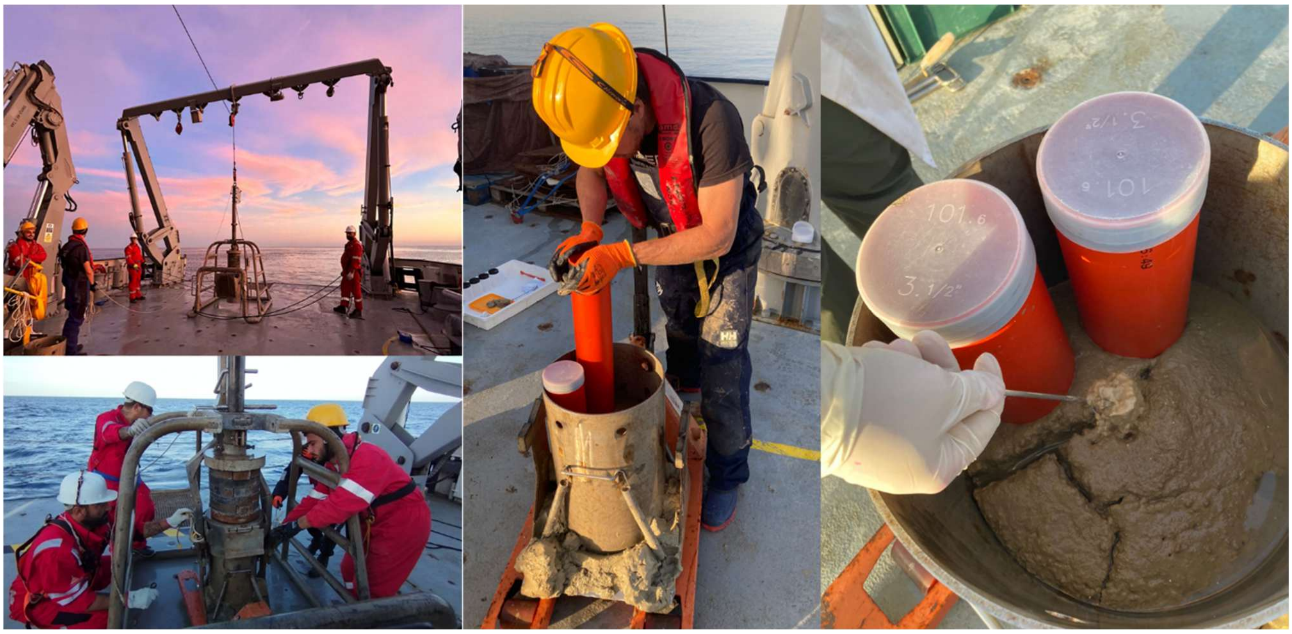

Figure 10. Box corer recovery and sub-sampling protocol.

At each sampling station, the surface sediment has been sub-sampled, immediately after the insertion of the liners, into different aliquots for the planned analyses (**Table 5**). The details of the followed protocol are described below.

PFASs, PPCPs, BPA, NPs, and PAHs

Samples for organic contaminant analysis were collected directly from the box corer bucket in the 0-2 cm layer for the PAHs and down to a maximum depth of 10 cm for all the other pollutants. The sampling was carried out using a metal spoon pre-cleaned with methanol, avoiding any contact with the PVC liner. About 20-40 g of sediment for PAHs and ~50 g for the other contaminants were collected and stored at -20°C in 250 mL glass jars.

Microbiology

Samples for microbiology analysis were collected directly from the box corer bucket in the 0-2 cm layer. The sampling was carried out using a sterile metal spoon pre-cleaned with alcohol, avoiding any contact with the PVC liner. About 50 g of sediment were collected in two sub-replicates and stored at -20°C in 50 mL PP centrifuge tubes.

Total and organic carbon, total nitrogen, $\delta^{13}C$, $\delta^{15}N$

Samples for carbon, nitrogen, and their relative stable isotopes analysis were collected directly from the box corer bucket in the 0-2 cm layer. The sampling was carried out using a plastic spoon pre-cleaned with water. About 10 g of sediment were collected and stored at -20°C in a 50 mL PP centrifuge tube.

Porosity, grain size, heavy metals, X-Ray Diffraction, X-Ray Fluorescence

Samples for geochemical and inorganic contaminant analysis were collected directly from the box corer bucket in the 0-2 cm layer. The sampling was carried out using a plastic spoon pre-cleaned with water. About 5 g of sediment for porosity and 10 g for all the other considered parameters were collected and stored at 4°C for porosity and grain size, at -20°C for all the other considered parameters, in 30, 120 or 250 mL HDPE jars.

Benthic foraminifera

Samples for benthic foraminifera analysis were collected directly from the box corer bucket in the 0-2 cm layer. The sampling was carried out using a plastic spoon pre-cleaned with water. About 20 g of sediment was collected and stored at room temperature in a 250 mL HDPE jar after staining with 100 mL of Rose Bengal.

Qualitative characterization of the sediment and the associated communities

The surface and bottom layers were carried to the onboard Dry Lab for the qualitative characterization of the sediment samples. Once there, a qualitative grain size characterization was followed by an observation of the planktonic and benthic communities by means of a Carl Zeiss AG (Oberkochen, Germany) Stemi 508 Stereo Microscope equipped with an Axiocam 208 color camera (**Fig. 11**).

Table 5. Details of all the collected surface sediment sub-samples.

Measurement	Label	Quantity	Container	Storage
Per- and Polyfluorinated alkyl substances, Pharmaceuticals and Personal care products, Bisphenol A, Nonylphenols	PFAS	~50 g	250 mL glass jar	-20°C
Polycyclic aromatic hydrocarbons	IPA	~20-40 g	250 mL glass jar	-20°C
Microbiology	MICRO	~50 g x 2	50 mL PP centrifuge tubes	-20°C
Total and organic carbon, total nitrogen, $\delta^{13}C$, $\delta^{15}N$	CNI	~10 g	50 mL PP centrifuge tube	-20°C
Porosity	POR	~5 g	30 mL HDPE jar	+4°C
Grain size	GRAN	~10 g	120 mL HDPE jar	+4°C
Heavy metals	MET	~10 g	250 mL HDPE jar	-20°C
X-Ray Diffraction	MIN	~10 g	250 mL HDPE jar	-20°C
X-Ray Fluorescence	XRF	~10 g	250 mL HDPE jar	-20°C
Benthic foraminifera	FORA	~20 g	250 mL HDPE jar	Room temperature after the addition of 100 mL of Rose Bengal

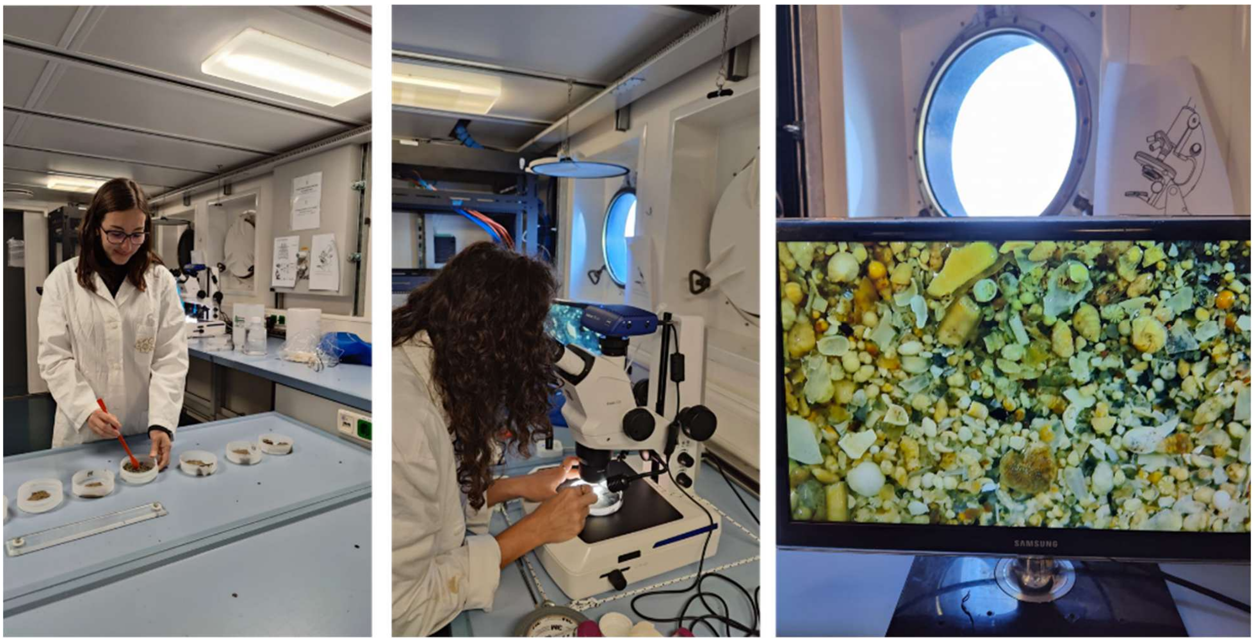

Figure 11. Dry Lab activities: qualitative grain size characterization, stereomicroscope observation, foraminiferal assemblage characterization.

7.2. Sediment cores

As described above, at each sampling station, a sediment core for stratigraphic analysis and geochronology was collected using a 58 cm-length PVC liner with a diameter of 10 cm. The entire core was kept in an upright position and preserved at 4°C.

A further sediment core was retrieved at 22 selected sampling stations (**Table 6**) chosen based on the following criteria:

- Bathymetry of the investigated area;
- Presence of peculiar morphological features of the seafloor such as canyons or continental slopes;
- To obtain the maximum spatial coverage of the investigated area.

The second liner retrieved at these stations was extruded with a resolution of 1 or 2 cm (**Table 6**). The choice of resolution degree was based on the potential sedimentation rate that, in the surveyed area, is found to range between 0.1 to 0.4 cm y^{-1} (Frignani *et al.*, 1997).

Table 6. The selected stations for sediment core extrusion, with relative resolution and recovery.

Station number	Resolution	Box corer recovery
1	1 cm	24 cm
3	1 cm	28 cm
8	2 cm	26 cm
10	1 cm	26 cm
13	2 cm	30 cm

Station number	Resolution	Box corer recovery
17	2 cm	34 cm
18	2 cm	38 cm
19	1 cm	30 cm
21	2 cm	30 cm
23	2 cm	44 cm
24	2 cm	12 cm
25	2 cm	38 cm
27	2 cm	14 cm
35	2 cm	20 cm
37	2 cm	20 cm
44*	2 cm	20 cm
47	2 cm	28 cm
65	1 cm	28 cm
72*	2 cm	28 cm
75*	2 cm	24 cm
79*	2 cm	34 cm
91	2 cm	32 cm

*Station already sampled during the PERTRE campaign (2016).

Sediment extrusion involves the upward movement of sedimentary core from deeper layers to the surface and was carried out on board by means of a manual PTFE extruder equipped with a PVC extrusion puck. After the removal of the supernatant by means of a disposable PP syringe, slices of 2 cm (1 cm in five cores, namely 1, 3, 10, 19, and 65) have been measured using a PVC sampling ring with the appropriate thickness and cut by inserting a 12 x 10 cm metal spatula between the top of the liner and the sampling ring. After the removal of the outer sediment layer, which has come in contact with the liner, each slice has been homogenized and sub-sampled into different aliquots for the planned analyses (**Table 7**) using metal and plastic spoons (**Fig. 12**).

Table 7. Details of all the collected sediment sub-samples along the core stratigraphy.

Measurement	Label	Sampling depth	Container	Storage
Per- and Polyfluorinated alkyl substances	ORG_PFAS	0-10 cm	50 mL PP centrifuge tube	-20°C
Pharmaceuticals and Personal care products, Bisphenol A, Nonylphenols	ORG_LUISA	0-10 cm	50 mL PP centrifuge tube	-20°C
Total and organic carbon, total nitrogen, $\delta^{13}C$, $\delta^{15}N$	SCNI	0-20 cm	50 mL PP centrifuge tube	-20°C
Porosity, grain size	GRAN-POR	2 cm up to the bottom	30 mL HDPE jar	+4°C

Measurement	Label	Sampling depth	Container	Storage
Heavy metals, X-Ray Diffraction, X-Ray Fluorescence	INO	2 cm up to the bottom	30 mL HDPE jar	-20°C

Figure 12. Wet Lab activities: core extrusion and slicing for physico-chemical analyses, Rose Bengal staining for foraminiferal analysis, aliquot subdivision, and storage.

8. Summary report of the activities

8.1. Task history

Table 8. Chronological report of the performed activities.

Date	Time (UTC)	Task	Activity label	Station number
12/10/2024	08:30:00	Departure from Bari port		
	12:48:13	CTD+L-ADCP	T001_CTD+LADCP	63
	14:43:20	CTD+L-ADCP	T002_CTD+LADCP	58
	15:46:11	CTD+L-ADCP	T003_CTD+LADCP	59
	17:37:43	CTD+L-ADCP	T004_CTD+LADCP	60
	19:00:52	CTD+L-ADCP	T005_CTD+LADCP	61
	21:00:34	CTD+L-ADCP	T006_CTD+LADCP	3
	23:20:04	MBES	T007_MBES	MBES 1-4
	23:20:24	SBP	T008_SBP	CHIRP1
13/10/2024	00:42:27	MBES	T009_MBES	MBES2
	00:42:52	SBP	T010_SBP	CHIRP2
	02:06:46	SBP	T011_SBP	CHIRP3
	02:08:26	MBES	T012_MBES	MBES3
	06:04:56	BOXCOR	T013_BOXCOR	58
	06:40:55	BOXCOR	T014_BOXCOR	58
	08:27:47	BOXCOR	T015_BOXCOR	59
	10:57:54	BOXCOR	T016_BOXCOR	54
	11:48:34	CTD+L-ADCP	T017_CTD+LADCP	54
	13:27:40	BOXCOR	T018_BOXCOR	50
	15:02:31	BOXCOR	T019_BOXCOR	49
	15:02:36	BOXCOR	T020_BOXCOR	49
	16:17:09	BOXCOR	T021_BOXCOR	53
	17:42:18	CTD+L-ADCP	T022_CTD+LADCP	53
	20:00:27	CTD+L-ADCP	T023_CTD+LADCP	92
	22:23:07	CTD	T024_CTD	51
14/10/2024	00:26:10	SBP	T025_SBP	CHIRP4-5
	05:39:13	CTD	T026_CTD	48
	06:23:57	BOXCOR	T027_BOXCOR	48
	07:55:42	BOXCOR	T028_BOXCOR	45
	08:17:42	CTD+L-ADCP	T029_CTD+LADCP	45
	09:38:42	BOXCOR	T030_BOXCOR	47
	09:57:42	CTD+L-ADCP	T031_CTD+LADCP	47
	12:41:44	CTD+L-ADCP	T032_CTD+LADCP	30
	12:58:31	BOXCOR	T033_BOXCOR	30
	14:17:39	CTD+L-ADCP	T034_CTD+LADCP	31
	14:33:41	BOXCOR	T035_BOXCOR	31
	15:51:34	BOXCOR	T036_BOXCOR	32
	16:12:06	CTD+L-ADCP	T037_CTD+LADCP	32
	17:47:36	CTD+L-ADCP	T038_CTD+LADCP	33
	18:32:20	SBP	T039_SBP	CHIRP6
	22:47:17	SBP	T040_SBP	CHIRP7

Date	Time (UTC)	Task	Activity label	Station number
	23:55:49	SBP	T041_SBP	CHIRP8
15/10/2024	05:53:42	BOXCOR	T042_BOXCOR	33
	07:25:06	BOXCOR	T043_BOXCOR	34
	08:21:57	BOXCOR	T044_BOXCOR	35
	08:51:16	CTD+L-ADCP	T045_CTD+LADCP	35
	10:47:13	CTD+L-ADCP	T046_CTD+LADCP	44
	11:06:15	BOXCOR	T047_BOXCOR	44
	12:25:18	CTD+L-ADCP	T048_CTD+LADCP	43
	12:42:15	BOXCOR	T049_BOXCOR	43
	13:56:23	BOXCOR	T050_BOXCOR	39
	15:09:35	BOXCOR	T051_BOXCOR	37
	15:29:52	CTD+L-ADCP	T052_CTD+LADCP	37
	16:38:10	CTD+L-ADCP	T053_CTD+LADCP	36
	17:42:56	CTD+L-ADCP	T054_CTD+LADCP	39
	19:39:18	CTD+L-ADCP	T055_CTD+LADCP	45
	20:45:33	CTD+L-ADCP	T056_CTD+LADCP	53
	21:27:33	CTD+L-ADCP	T057_CTD+LADCP	48
	22:29:46	SBP	T058_SBP	CHIRP9
	22:32:32	MBES	T059_MBES	CHIRP9
16/10/2024	00:23:18	SBP	T060_SBP	CHIRP10
	00:23:33	MBES	T061_MBES	CHIRP10
	05:21:39	CTD+L-ADCP	T062_CTD+LADCP	42
	06:09:04	BOXCOR	T063_BOXCOR	42
	07:42:29	BOXCOR	T064_BOXCOR	52
	08:14:12	MBES	T065_MBES	Test
	10:43:53	BOXCOR	T066_BOXCOR	51
	11:55:01	BOXCOR	T067_BOXCOR	92
	13:20:04	BOXCOR	T068_BOXCOR	91
	15:00:50	CTD+L-ADCP	T069_CTD+LADCP	57
	16:35:55	CTD+L-ADCP	T070_CTD+LADCP	91
	18:16:45	CTD+L-ADCP	T071_CTD+LADCP	52
	19:21:47	CTD+L-ADCP	T072_CTD+LADCP	51
	20:35:00	CTD+L-ADCP	T073_CTD+LADCP	92
	21:34:46	SBP	T074_SBP	CHIRP11
	21:35:06	MBES	T075_MBES	MBES11
	23:36:54	MBES	T076_MBES	MBES12
	23:37:14	SBP	T077_SBP	CHIRP12
17/10/2024	01:04:23	MBES	T078_MBES	MBES13
	01:04:43	SBP	T079_SBP	CHIRP13
	02:57:35	MBES	T080_MBES	MBES14
	02:57:50	SBP	T081_SBP	CHIRP14
	05:49:48	CTD+L-ADCP	T082_CTD+LADCP	1
	06:56:05	BOXCOR	T083_BOXCOR	1
	08:25:39	BOXCOR	T084_BOXCOR	55
	11:07:21	BOXCOR	T085_BOXCOR	60
	12:31:10	BOXCOR	T086_BOXCOR	61
	14:21:02	BOXCOR	T087_BOXCOR	3
	15:31:24	BOXCOR	T088_BOXCOR	5

Date	Time (UTC)	Task	Activity label	Station number
	16:05:18	CTD+L-ADCP	T089_CTD+LADCP	5
	17:54:54	ADCP	T090_ADCP	ADCP-01
	22:18:07	CTD+L-ADCP	T091_CTD+LADCP	59
	22:52:10	ADCP	T092_ADCP	ADCP-02
18/10/2024	02:08:26	CTD+L-ADCP	T093_CTD+LADCP	55
	06:07:51	BOXCOR	T094_BOXCOR	7
	11:00:00	Personnel shift at Bari port		
19/10/2024	Delayed departure due to rough sea			
20/10/2024	07:00:00	Departure from Bari port		
	07:30:00	Standby due to rough sea		
	22:24:41	CTD+L-ADCP	T095_CTD+LADCP	24
21/10/2024	00:07:12	CTD+L-ADCP	T096_CTD+LADCP	25
	02:14:16	CTD+L-ADCP	T097_CTD+LADCP	11
	04:34:35	CTD+L-ADCP	T098_CTD+LADCP	8
	05:52:54	BOXCOR	T099_BOXCOR	8
	07:55:47	CTD+L-ADCP	T100_CTD+LADCP	2
	08:50:38	BOXCOR	T101_BOXCOR	2
	11:12:23	BOXCOR	T102_BOXCOR	6A
	13:22:06	BOXCOR	T103_BOXCOR	65
	15:58:38	BOXCOR	T104_BOXCOR	10
	17:30:38	CTD+L-ADCP	T105_CTD+LADCP	10
	18:35:30	CTD+L-ADCP	T106_CTD+LADCP	10bis
	20:21:36	CTD+L-ADCP	T107_CTD+LADCP	64
	22:04:42	CTD+L-ADCP	T108_CTD+LADCP	65
22/10/2024	01:27:09	MBES	T109_MBES	MBES15
	01:27:29	SBP	T110_SBP	CHIRP15
	03:06:59	MBES	T111_MBES	MBES16
	03:07:19	SBP	T112_SBP	CHIRP16
	04:38:24	BOXCOR	T113_BOXCOR	
	04:39:39	SBP	T114_SBP	CHIRP17
	04:39:44	BOXCOR	T115_BOXCOR	
	04:40:44	MBES	T116_MBES	MBES17
	06:12:14	BOXCOR	T117_BOXCOR	12
	08:06:21	BOXCOR	T118_BOXCOR	13
	09:53:52	BOXCOR	T119_BOXCOR	69
	11:59:05	BOXCOR	T120_BOXCOR	15
	14:10:04	BOXCOR	T121_BOXCOR	73
	14:56:04	CTD+L-ADCP	T122_CTD+LADCP	73
	16:43:25	CTD+L-ADCP	T123_CTD+LADCP	23
	18:50:08	CTD+L-ADCP	T124_CTD+LADCP	72
	20:43:35	MBES	T125_MBES	23
	21:11:43	MBES	T126_MBES	BS3
	21:37:46	MBES	T127_MBES	
	21:42:01	MBES	T128_MBES	MBES25
	22:13:25	MBES	T129_MBES	MBES27
	22:48:33	MBES	T130_MBES	MBES28
	23:20:27	MBES	T131_MBES	MBES29

Date	Time (UTC)	Task	Activity label	Station number
	23:56:00	MBES	T132_MBES	MBES30
23/10/2024	00:14:02	BOXCOR	T133_BOXCOR	
	00:19:48	MBES	T134_MBES	MBES31
	00:31:44	MBES	T135_MBES	MBES32
	01:19:44	MBES	T136_MBES	MBES34
	01:48:12	MBES	T137_MBES	MBES35
	02:05:34	MBES	T138_MBES	MBES36
	03:51:25	CTD+L-ADCP	T139_CTD+LADCP	17
	04:09:47	CTD+L-ADCP	T140_CTD+LADCP	17
	05:26:50	BOXCOR	T141_BOXCOR	17
	07:16:22	BOXCOR	T142_BOXCOR	89
	08:43:56	BOXCOR	T143_BOXCOR	18
	11:29:36	BOXCOR	T144_BOXCOR	75
	12:45:19	CTD+L-ADCP	T145_CTD+LADCP	74
	12:57:55	BOXCOR	T146_BOXCOR	74
	13:54:21	CTD+L-ADCP	T147_CTD+LADCP	75
	20:00:39	CTD+L-ADCP	T148_CTD+LADCP	21
	21:11:07	MBES	T149_MBES	
	21:36:04	MBES	T150_MBES	
	21:49:11	MBES	T151_MBES	
	22:14:33	MBES	T152_MBES	
	22:24:15	MBES	T153_MBES	
	22:44:07	MBES	T154_MBES	
	22:56:03	SBP	T155_SBP	CHIRP18
	23:01:54	MBES	T156_MBES	
	23:23:56	SBP	T157_SBP	CHIRP19
	23:25:36	MBES	T158_MBES	
	23:35:57	MBES	T159_MBES	
24/10/2024	00:03:05	MBES	T160_MBES	
	00:10:36	BOXCOR	T161_BOXCOR	
	00:10:51	MBES	T162_MBES	
	00:32:48	MBES	T163_MBES	
	00:44:49	MBES	T164_MBES	
	01:01:06	MBES	T165_MBES	
	01:08:17	SBP	T166_SBP	CHIRP20
	01:10:22	MBES	T167_MBES	
	01:36:45	MBES	T168_MBES	
	01:37:20	SBP	T169_SBP	CHIRP21
	02:05:28	BOXCOR	T170_BOXCOR	
	02:07:43	SBP	T171_SBP	CHIRP22
	02:11:53	MBES	T172_MBES	
	02:41:07	SBP	T173_SBP	CHIRP23
	02:41:12	MBES	T174_MBES	
	03:08:04	MBES	T175_MBES	
	03:08:34	SBP	T176_SBP	CHIRP23A
	03:20:41	MBES	T177_MBES	
	03:21:01	SBP	T178_SBP	CHIRP24
	03:47:24	MBES	T179_MBES	

Date	Time (UTC)	Task	Activity label	Station number
	05:25:34	BOXCOR	T180_BOXCOR	21
	07:41:28	CTD+L-ADCP	T181_CTD+LADCP	83
	09:07:12	BOXCOR	T182_BOXCOR	83
	10:56:23	BOXCOR	T183_BOXCOR	79
	12:16:47	BOXCOR	T184_BOXCOR	80
	12:50:30	BOXCOR	T185_BOXCOR	80
	14:15:19	BOXCOR	T186_BOXCOR	19
	16:48:41	CTD+L-ADCP	T187_CTD+LADCP	76
	18:04:54	CTD+L-ADCP	T188_CTD+LADCP	18
	20:22:28	MBES	T189_MBES	
	20:22:48	SBP	T190_SBP	CHIRP25
	21:56:08	SBP	T191_SBP	CHIRP26
	21:56:18	MBES	T192_MBES	
	22:54:14	MBES	T193_MBES	
	22:54:29	SBP	T194_SBP	CHIRP27
	23:52:25	SBP	T195_SBP	CHIRP28
	23:52:40	MBES	T196_MBES	
25/10/2024	00:31:59	MBES	T197_MBES	
	00:32:24	SBP	T198_SBP	CHIRP29
	01:33:41	MBES	T199_MBES	
	01:34:01	SBP	T200_SBP	CHIRP30A
	05:34:21	BOXCOR	T201_BOXCOR	23
	07:44:40	BOXCOR	T202_BOXCOR	72
	09:37:47	BOXCOR	T203_BOXCOR	16
	12:02:27	BOXCOR	T204_BOXCOR	14
	14:09:50	BOXCOR	T205_BOXCOR	66
	15:59:47	CTD+L-ADCP	T206_CTD+LADCP	14
	17:38:12	CTD+L-ADCP	T207_CTD+LADCP	12
	19:35:40	CTD+L-ADCP	T208_CTD+LADCP	13
	21:54:34	SBP	T209_SBP	CHIRP17A
26/10/2024	00:00:48	MBES+SBP	T210-223_MBES	
	05:56:43	CTD+L-ADCP	T224_CTD+LADCP	28
	05:27:43	BOXCOR	T225_BOXCOR	28
	08:44:06	BOXCOR	T226_BOXCOR	27
	09:19:06	CTD+L-ADCP	T227_CTD+LADCP	27
	11:34:06	BOXCOR	T228_BOXCOR	26
	13:01:37	BOXCOR	T229_BOXCOR	25
	14:39:10	BOXCOR	T230_BOXCOR	24
	15:26:30	SBP	T231_SBP	CHIRP35
	19:08:48	SBP	T232_SBP	CHIRP36
	19:58:32	SBP	T233_SBP	CHIRP37
	19:58:32	MBES	T234-240_MBES	
27/10/2024	06:45:42	MBES	T241_MBES	
	16:30:00	Entering Bari port		

8.2. Box corer sediment sampling activity summary

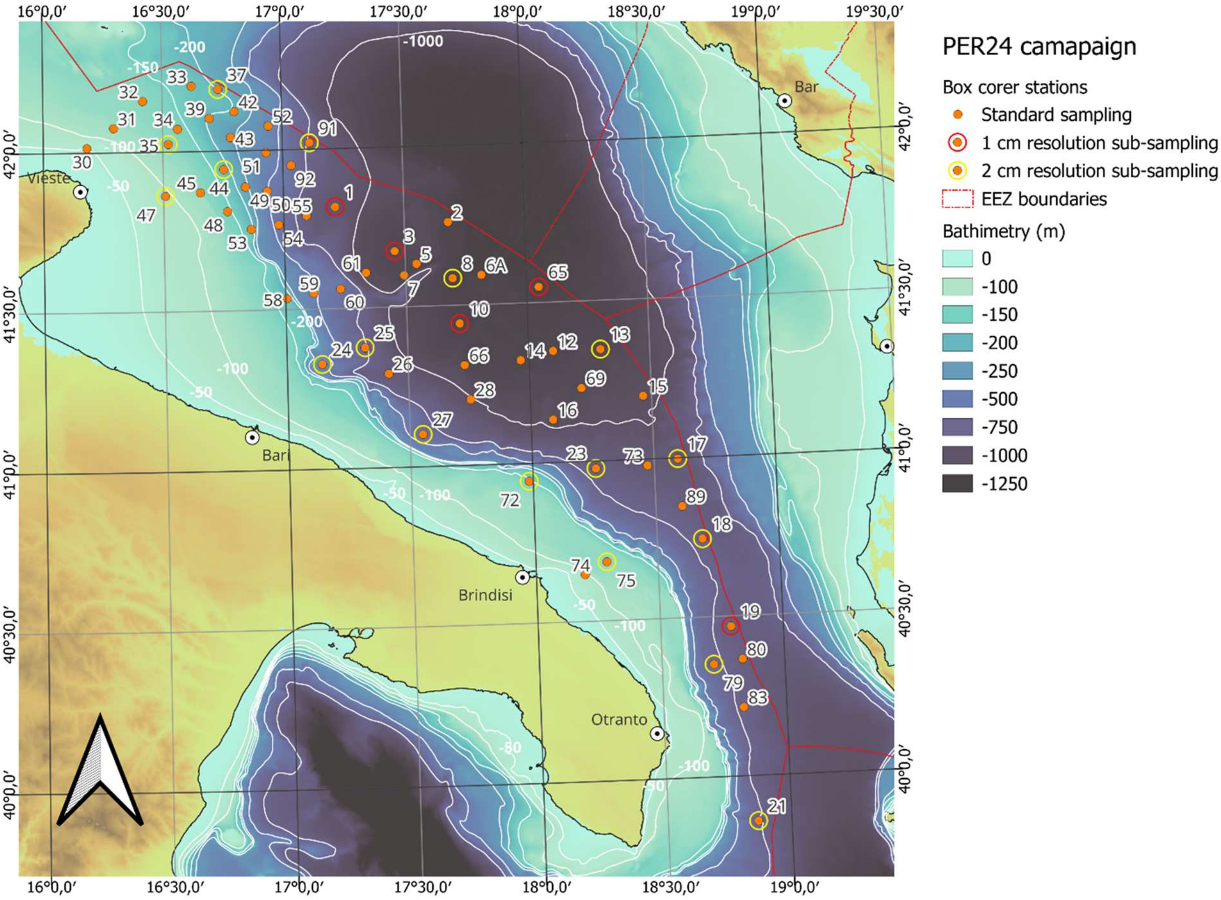

Figure 13. Map of the box corer sampling stations.
EEZ: Exclusive Economic Zone.

Table 9. List of successfully performed box corer sampling.

Station number	Activity label	Timestamp (UTC)	Bottom depth (m)	North Latitude	East Longitude
1	T083_BOXCOR	17/10/2024 06:56	956	41.8183	17.2133
2	T101_BOXCOR	21/10/2024 08:50	1199	41.7614	17.6816
3	T087_BOXCOR	17/10/2024 14:21	1143	41.6757	17.4564
5	T088_BOXCOR	17/10/2024 15:31	1165	41.6340	17.5459
6A	T102_BOXCOR	21/10/2024 11:12	1190	41.5933	17.8134
7	T094_BOXCOR	18/10/2024 06:07	1171	41.5998	17.4931
8	T099_BOXCOR	21/10/2024 05:52	1185	41.5860	17.6946
10	T104_BOXCOR	21/10/2024 15:58	1166	41.4427	17.7177
12	T117_BOXCOR	22/10/2024 06:12	1149	41.3477	18.1003
13	T118_BOXCOR	22/10/2024 08:06	1111	41.3477	18.2962
14	T204_BOXCOR	25/10/2024 12:02	1143	41.3221	17.9650
15	T120_BOXCOR	22/10/2024 11:59	1029	41.1976	18.4653
16	T203_BOXCOR	25/10/2024 09:37	1032	41.1336	18.0908
17	T141_BOXCOR	23/10/2024 05:26	877	40.9976	18.5969
18	T143_BOXCOR	23/10/2024 08:43	801	40.7454	18.6846

Station number	Activity label	Timestamp (UTC)	Bottom depth (m)	North Latitude	East Longitude
19	T186_BOXCOR	24/10/2024 14:15	825	40.4683	18.7859
21	T180_BOXCOR	24/10/2024 05:25	756	39.8585	18.8642
23	T201_BOXCOR	25/10/2024 05:34	814	40.9769	18.2591
24	T230_BOXCOR	26/10/2024 14:39	386	41.3271	17.1447
25	T229_BOXCOR	26/10/2024 13:01	738	41.3758	17.3231
26	T228_BOXCOR	26/10/2024 11:34	875	41.2923	17.4184
27	T226_BOXCOR	26/10/2024 08:44	605	41.1008	17.5527
28	T225_BOXCOR	26/10/2024 06:45	1002	41.2047	17.7533
30	T033_BOXCOR	14/10/2024 12:58	50	42.0147	16.1822
31	T035_BOXCOR	14/10/2024 14:33	112	42.0758	16.2947
32	T036_BOXCOR	14/10/2024 15:51	134	42.1591	16.4179
33*	T042_BOXCOR	15/10/2024 05:53	179	42.2035	16.6231
34*	T043_BOXCOR	15/10/2024 07:25	141	42.0706	16.5627
35	T044_BOXCOR	15/10/2024 08:21	128	42.0241	16.5227
37	T051_BOXCOR	15/10/2024 15:09	211	42.1923	16.7341
39	T050_BOXCOR	15/10/2024 13:56	214	42.1025	16.6961
42*	T063_BOXCOR	16/10/2024 06:09	208	42.1224	16.8003
43	T049_BOXCOR	15/10/2024 12:42	241	42.0419	16.7830
44*	T047_BOXCOR	15/10/2024 11:06	180	41.9425	16.7525
45	T028_BOXCOR	14/10/2024 07:55	128	41.8713	16.6535
47	T030_BOXCOR	14/10/2024 09:38	98	41.8622	16.5072
48	T027_BOXCOR	14/10/2024 06:23	145	41.8113	16.7653
49	T019_BOXCOR	13/10/2024 15:02	231	41.8864	16.8416
50	T018_BOXCOR	13/10/2024 13:27	500	41.8718	16.9321
51	T066_BOXCOR	16/10/2024 10:43	407	41.9924	16.9307
52	T064_BOXCOR	16/10/2024 07:42	408	42.0749	16.9418
53	T021_BOXCOR	13/10/2024 16:17	191	41.7541	16.8626
54*	T016_BOXCOR	13/10/2024 10:57	573	41.7664	16.9779
55	T084_BOXCOR	17/10/2024 08:25	844	41.7932	17.0943
58	T014_BOXCOR	13/10/2024 06:40	181	41.5353	17.0049
59	T015_BOXCOR	13/10/2024 08:27	484	41.5520	17.1168
60	T085_BOXCOR	17/10/2024 11:07	598	41.5622	17.2282
61	T086_BOXCOR	17/10/2024 12:31	1026	41.6109	17.3355
65	T103_BOXCOR	21/10/2024 13:22	1191	41.5500	18.0499
66	T205_BOXCOR	25/10/2024 14:09	1115	41.3128	17.7324
69	T119_BOXCOR	22/10/2024 09:53	1081	41.2289	18.2117
72*	T202_BOXCOR	25/10/2024 07:44	143	40.9444	17.9829
73	T121_BOXCOR	22/10/2024 14:10	892	40.9803	18.4720
74	T146_BOXCOR	23/10/2024 12:57	92	40.6473	18.1994
75*	T144_BOXCOR	23/10/2024 11:29	123	40.6852	18.2899
79*	T183_BOXCOR	24/10/2024 10:56	705	40.3515	18.7102
80	T185_BOXCOR	24/10/2024 12:50	843	40.3650	18.8279
83	T182_BOXCOR	24/10/2024 09:07	781	40.2145	18.8243
89	T142_BOXCOR	23/10/2024 07:16	826	40.8496	18.6070
91	T068_BOXCOR	16/10/2024 13:20	764	42.0201	17.1124
92*	T067_BOXCOR	16/10/2024 11:55	615	41.9508	17.0334

*Station already sampled during the PERTRE campaign (2016).

Box corer sediment samples were taken at 61 sampling stations out of the 92 initially planned in the PER24 campaign proposal due to reduced operational time during daylight hours (approximately from 07:30 to 17:30), allowing for an average of 5-6 box corer samplings per day. On Saturday 19th and Sunday 20th October 2024, adverse weather and sea conditions prevented sampling, as also outlined in the Project Execution Plan (PEP).

The selected sampling stations were chosen based on their geographical and/or bathymetric significance, with a primary focus on excluding coastal stations, which had already been sufficiently covered by the PERTRE campaign. It was also deemed unnecessary to extend the study into the Ionian Sea, with sampling limited to a single significant point, relevant to the circulation analyzed using the L-ADCP sensors. The number of samples taken is considered more than sufficient to ensure comprehensive coverage of the study area (**Table 9**; **Fig. 13**).

8.3. CTD and L-ADCP activity summary

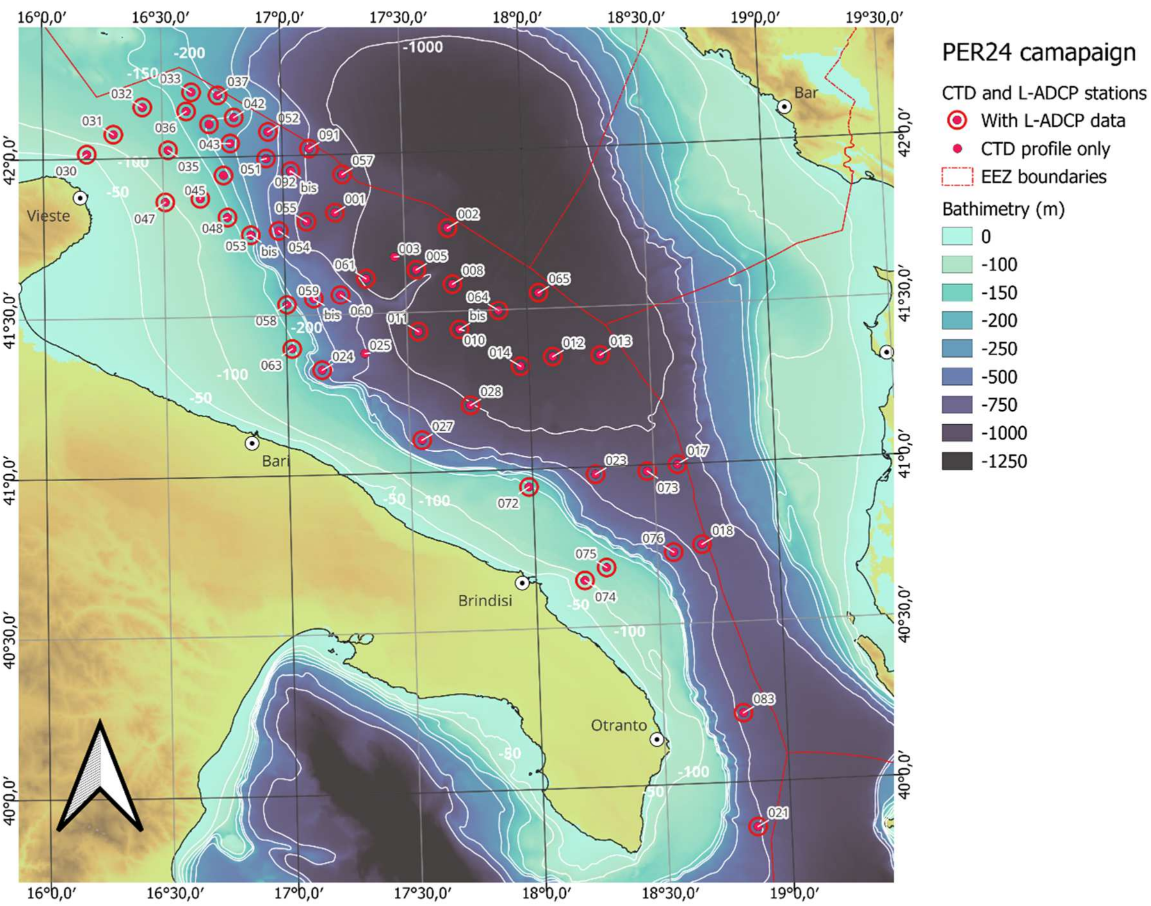

Figure 14. Map of the CTD (Conductivity, Temperature, Depth) and L-ADCP (Lowered-Acoustic Doppler Currents Profiler) sampling stations, aligned with the naming convention of box corer sampling locations. EEZ: Exclusive Economic Zone.

Table 10. List of CTD (Conductivity, Temperature, Depth) and L-ADCP (Lowered-Acoustic Doppler Currents Profiler) sampling stations.

Station number	Bottom depth (m)	North Latitude	East Longitude	L-ADCP measurements
CTD_001	956	41.8185	17.2138	Yes
CTD_002	1198	41.7615	17.6815	Yes
CTD_003	*1143*	*41.6758*	*17.4562*	*No*
CTD_005	1166	41.6340	17.5458	Yes
CTD_008	1186	41.5860	17.6945	Yes
CTD_010	*1166*	*41.4427*	*17.7175*	*No*
CTD_010bis	1166	41.4427	17.7175	Yes
CTD_011	1100	41.4398	17.5477	Yes
CTD_012	1016	41.3483	18.1002	Yes
CTD_013	1112	41.3480	18.2962	Yes
CTD_014	1145	41.3217	17.9657	Yes
CTD_017	877	40.9978	18.5968	Yes
CTD_018	803	40.7458	18.6842	Yes
CTD_021	758	39.8588	18.8635	Yes
CTD_023	817	40.9770	18.2590	Yes
CTD_024	384	41.3275	17.1448	Yes
CTD_025	*739*	*41.3757*	*17.3237*	*No*
CTD_027	606	41.1010	17.5497	Yes
CTD_028	1002	41.2050	17.7533	Yes
CTD_030	50	42.0147	16.1822	Yes
CTD_031	113	42.0757	16.2947	Yes
CTD_032	134	42.1590	16.4180	Yes
CTD_033	180	42.2035	16.6237	Yes
CTD_035	128	42.0242	16.5227	Yes
CTD_036	165	42.1443	16.6013	Yes
CTD_037	211	42.1923	16.7342	Yes
CTD_039	213	42.1025	16.6963	Yes
CTD_042	209	42.1223	16.8003	Yes
CTD_043	240	42.0418	16.7830	Yes
CTD_044	181	41.9425	16.7525	Yes
CTD_045	*128*	*41.8715*	*16.6535*	*No*
CTD_045bis	127	41.8713	16.6538	Yes
CTD_047	97	41.8622	16.5073	Yes
CTD_048	*145*	*41.8112*	*16.7655*	*No*
CTD_048bis	145	41.8112	16.7657	Yes
CTD_051	*410*	*41.9920*	*16.9317*	*No*
CTD_051bis	407	41.9925	16.9318	Yes
CTD_052	410	42.0753	16.9423	Yes
CTD_053	*191*	*41.7550*	*16.8622*	*No*
CTD_053bis	191	41.7547	16.8613	Yes
CTD_054	573	41.7662	16.9780	Yes
CTD_055	849	41.7930	17.0952	Yes
CTD_057	932	41.9373	17.2480	Yes
CTD_058	182	41.5347	17.0053	Yes
CTD_059	*485*	*41.5517*	*17.1173*	*No*

Station number	Bottom depth (m)	North Latitude	East Longitude	L-ADCP measurements
CTD_059bis	486	41.5515	17.1172	Yes
CTD_060	599	41.5618	17.2282	Yes
CTD_061	1028	41.6107	17.3357	Yes
CTD_063	140	41.3960	17.0227	Yes
CTD_064	1164	41.4982	17.8823	Yes
CTD_065	1192	41.5505	18.0503	Yes
CTD_072	144	40.9445	17.9833	Yes
CTD_073	892	40.9803	18.4720	Yes
CTD_074	92	40.6472	18.1992	Yes
CTD_075	124	40.6850	18.2898	Yes
CTD_076	664	40.7247	18.5667	Yes
CTD_083	781	40.2145	18.8243	Yes
CTD_091	763	42.0200	17.1122	Yes
CTD_092	*614*	*41.9517*	*17.0325*	*No*
CTD_092bis	617	41.9515	17.0332	Yes

The station numbers follow the naming convention used for box corer sampling stations. Italicized rows indicate stations where L-ADCP measurements were not taken, while stations marked with "bis" denote repeated measurements, including both CTD and L-ADCP data.

A total of 60 CTD and 51 L-ADCP casts were completed, exceeding the initial plan of approximately 50 stations (**Table 10**; **Fig. 14**). Station selection was strategically prioritized to capture key oceanographic processes and pollutant dynamics in the Southern Adriatic Sea, ensuring that measurements were taken in areas of high relevance to the PER24 campaign's objectives. Moreover, their prioritization considered the available ship time and oceanographic relevance: dynamic regions, vortices, and hydrographic fronts were chosen for their role in driving water mass movement; deep basins and canyons, prone to sediment accumulation, were targeted due to their likelihood of harboring pollutant deposits; coastal regions were included for their high potential in receiving terrestrial contaminant influx.

Using a Sea-Bird Scientific SBE 911plus CTD system with auxiliary sensors for dissolved oxygen, turbidity, fluorescence, and PAR, the casts provided high-resolution profiles of water properties, critical for analyzing thermohaline structure, pollutant pathways, and mixing processes. These measurements were complemented by L-ADCP profiles as often as possible, using dual 300 kHz ADCPs in downward- and upward-looking orientations to capture detailed vertical current structures. This combined setup was essential for estimating pollutant transport pathways and identifying dynamic areas that affect their dispersion.

In conclusion, comprehensive oceanographic characterization of water masses and circulation patterns was achieved to assess pollutant transport, drawing on high-resolution measurements of thermohaline and biochemical properties as well as current dynamics. These oceanographic data support the main objectives of the PER24 campaign, offering essential environmental context for the broader suite of sampling activities, which together aim to evaluate anthropogenic impacts in the Southern Adriatic Sea and the Otranto Strait.

8.4. CHIRP-SBP activity summary

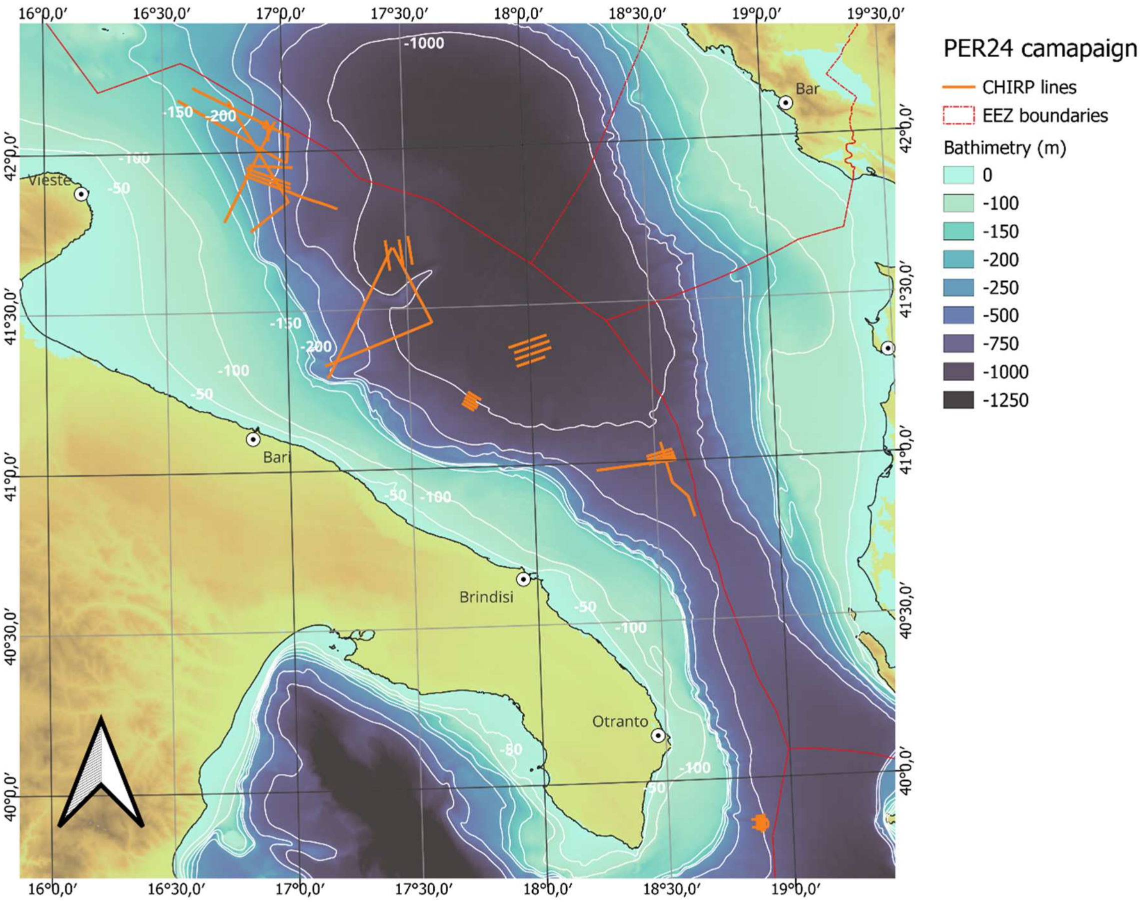

Figure 15. Map of the CHIRP (Compressed High-Intensity Radiated Pulse) signal SBP (Sub-Bottom Profiling) echosounder sampling activities.
EEZ: Exclusive Economic Zone.

The vessel-mounted Knudsen Systems 3260 SBP echosounder was used with a CHIRP signal at a central frequency of 3.5 kHz, using square-law detection mode to maximize the signal-to-noise ratio for clearer echogram data. A synchronized acquisition with multibeam systems *via* the Kongsberg Discovery K-sync software ensured efficient data collection and enhanced spatial resolution. The main applications of this acoustic tool were:

1. **Stratigraphic Profiling:** The CHIRP-SBP was used to obtain high-resolution stratigraphic information from the top 10-40 m of sediment. Areas of interest included submarine landslides, contourite deposits, and MTDs. This profiling helped to identify erosion and deposition zones shaped by bottom currents, enhancing our understanding of sedimentary dynamics and seafloor morphology.
2. **Contourite and Seafloor Mapping:** The CHIRP-SBP data were integrated with the MBES ones to map contourites, ripples, and faults. This integration enabled detailed morphological interpretation of the seafloor, particularly in areas with distinctive features shaped by bottom currents, such as moats and drift deposits.

The details of the CHIRP-SBP sampling activities (**Fig. 15**) are available as shapefile (**Annex B**).

8.5. MBES activity summary

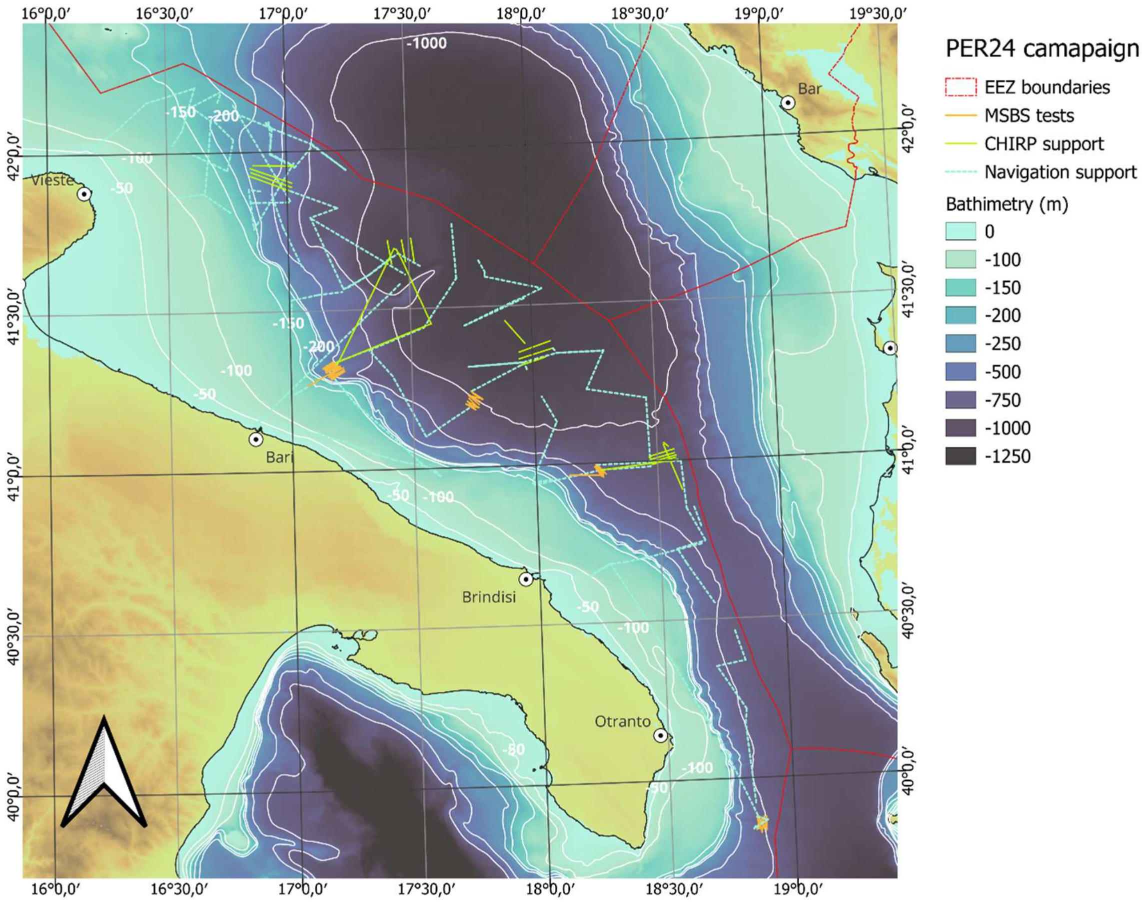

Figure 16. Map of the MBES (MultiBeam Echo Sounder) sampling activities.
EEZ: Exclusive Economic Zone; MSBS: MultiSpectral BackScatter; CHIRP: Compressed High-Intensity Radiated Pulse.

The vessel-mounted Kongsberg Discovery MBES systems (EM 304 MKII and EM 712) were used across three key activities:

1. **MSBS Testing:** The Kongsberg Discovery EM 712 MBES device was deployed to assess backscatter responses over the same area using two different frequency settings. Surveys were conducted across five geomorphologically distinct sites, chosen to represent a range of depths and substrate characteristics. For each area, repeated transect surveys were carried out with the system set at 40 kHz and 70-100 kHz, allowing for comparative analysis of backscatter response across varied frequencies.
2. **CHIRP Support:** The MBESs were used in conjunction with the CHIRP-SBP to provide high-resolution morphological context for stratigraphic data. This integration aims to enrich post-processing data interpretation by correlating surface stratigraphy with precise bathymetric and morphological information.
3. **Navigation Support:** The MBESs supported critical navigation tasks, particularly during station-keeping procedures while deploying sensitive equipment such as the box corer and the CTD. This approach ensured continuous and precise monitoring of the equipment's distance from

the seafloor. Additionally, the MBESs were used during transit among sampling stations to identify areas of interest for others CHIRP-SBP and MBES acoustic activities and to enhance the availability of high-resolution bathymetric data for this region.

The details of the MBES sampling activities (**Fig. 16**) are available as shapefile (**Annex C**).

9. Expected outputs and results

The sampling activities conducted during the PER24 campaign will extend the study area of the PERTRE campaign, achieving comprehensive coverage of the Adriatic Sea from Ancona to the Ionian Sea, with over 160 sampling points in total. This will allow further in-depth studies on geochemistry, pollutant transport, microbiology, and foraminifera analysis.

Currently, the sediment samples are stored at the CNR-IRBIM facility at Lesina (FG), and freeze-drying procedures for a portion of these samples will begin shortly. Unprocessed cores, as with those from the PERTRE campaign, will be preserved for long-term storage.

The use of an automated labeling system also enabled the creation of an online catalog of the retrieved samples, making it possible to track their processing status and facilitating collaboration with other national and international research entities interested in analyzing them. A successful trial of exporting catalog elements has been conducted using the D4Science data infrastructure.

Instrumental data from CTD, L-ADCP and ADCPs, CHIRP-SBP, and MBESs will be processed and released in designated repositories, such as EMODnet (European Marine Observation and Data Network), and may be supplemented with data papers where applicable.

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The PER24 campaign was made possible through the dedicated work of numerous individuals, institutions, and companies behind the scenes.

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