2014 - 2020 Interreg V-A

Italy - Croatia CBC Programme

Call for proposal 2019 Strategic

CoAStal and marine waters integrated monitoring systems for ecosystems proteCtion AnD managemEnt

CASCADE

Project ID: 10255941

Priority Axis: Environment and cultural heritage

Specific objective: Improve the environmental quality conditions of the sea and coastal area by use of sustainable and innovative technologies and approaches.

D4.1.1

Equipment implemented/installed by relevant partners.

PP1 – CMCC

Final version

Public document

June, 2023

Project acronym	CASCADE
Project ID number	10255941
Project title	CoAStal and marine waters integrated monitoring systems for ecosystems protection AnD managemEnt
Priority axis	3 - Environment and cultural heritage
Specific objective	3.2 - Contribute to protect and restore biodiversity
Strategic theme	3.2.1 - Marine environment
Word Package number	WP4
Word Package title	Monitoring (observations and modelling) and information system
Activity number	Activity 4.1
Activity title	Set up and testing of the observing system
Partner in charge	PP1 – CMCC
Partners involved	All PPs

Table of contents

Chapter 1. Aims and content of the document

Monitoring instruments, such as flow velocimetry sensors, Acoustic Doppler Current Profilers, waves monitoring, tide gauges, CTD, underwater drones, naval equipment, buoys, multiparametric probes, consumables have been acquired/added/integrated to enhance monitoring network and improve modelling input and system calibration.

Chapter 2. Observing equipments at the Pilot Scale

2.1 Grado and Marano Lagoon, and Gulf of Trieste (IT)

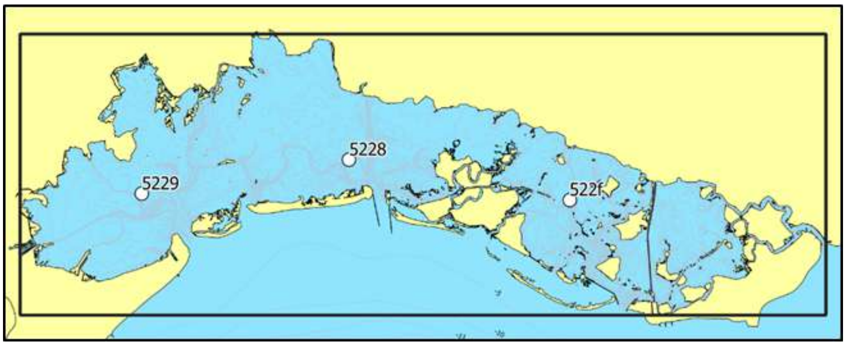
ARPA FVG has implemented two different activities simultaneously on its marine and transitional waters; therefore, they will be treated in two separate chapters to make the description of the activities more understandable.

2.1.1. Grado and Marano Lagoon monitoring equipment

In the past years ARPA FVG had already acquired experience in the use of parametric probes in the lagoon. At the time, the aim was to acquire knowledge of some little-investigated areas of the lagoon and to be able to observe the entire day/night cycle of physical and chemical parameters, primarily regarding dissolved oxygen.
After 7 years of activity, the system began to be dated and its disposal was expected. The CASCADE project provided the opportunity to replace the equipment and allow an upgrade to a more recent model of probes, superior both in terms of engineering and software. Furthermore, the objective in using this equipment has evolved from a simple tool for acquiring new knowledge to a tool for supporting a more in-depth modelling system of the lagoon.
In fact, among the model quality assessment procedures, one regards the comparison with real data collected directly in situ. The probes will acquire hydrological and physical and chemical data in continuous so they will add information required for the model validation in the most resolved domain area.

The continuous monitoring system is composed of 3 multiparametric probes able to work autonomously for long periods and with a relatively high sampling rate (Table 1). For this pilot project it was decided to carry out sampling every 15 minutes. As mentioned above, the system is an evolution of the one previously installed in the lagoon from which we decided to recover the floating system. The flotation system is nothing more than a buoy detachable and consisting of two half-cylinders in high-density plastic (yellow pieces in Figure 1) and a central cylinder (black piece in Figure 1), made of the same material, which houses the instrument and allows it to be locked inside with a padlock. The white piece visible in Figure 1 is a structure that hangs up to the probe and supports it inside the buoy. The half cylinders have ballast boxes to stabilize them and allow them to sink to the desired level. To be reused, the buoys have been suitably modified to accommodate the new probes.

Table 1 Equipment and instrumentation characteristics



Monitored Area	Grado and Marano Lagoon
Monitoring starting date	1/07/2021
Monitoring period	July – November 2021
Number of instruments	3
Total investment	48190,00€
Site localization	Probe 5228 - 13.232107 E 45.730268 N Probe 5229 - 13.128559 E 45.716727 N Probe 522f - 13.343004 E 45.717867 N
Instrumental type	Multiparametric probes onboard an anchored buoy
Dimension	Probe high: 499 mm Probe diameter: 110mm Buoy high: 950mm Buoy diameter: 800mm
Power supply	6 alkaline batteries type D
Communication	Wi-Fi/GPRS
Sampling frequency	every 15 minutes
Sensor installed	Temperature Conductivity Ph Dissolved Oxygen Pressure"

Figure 1. A probe installed on board the buoy.

Each probe is connected to a GPS/GPRS 3/4G modem that allows you to acquire the position of the instrument daily (useful in case of breakage of the anchor). With the same frequency, data is also sent to an FTP server which allows ARPA FVG's technicians to access the data remotely (Figure 2).

The good condition of the sensors is ensured by a wiper that passes every hour over the sensors, removing the fouling that could accumulate.

Figure 2. The probes equipped with 3 sensors and the wiper in the center on the left and the GPS/GPRS modem connected on the right

The probes can host up to 6 sensors (or 7 by removing the wiper) and records a maximum of 16 different parameters at the same time, both from sensors measurement and calculated. The Table 2 below shows the technical specifications of the sensors installed on the probes.

Table 2. All parameters obtained from the probes.

Parameters	Sensor technology	Range	Accuracy	Precision	Equation for calculated
Conductivity	4 carbons electrodes cell	0-100 mS/cm	±0.5% of the reading	0.001 mS/cm	
Temperature	Thermistor	-2°C +35°C	±0.02°C	0.001°C	
Pressure	Piezoresistive	0-25 bars	±0.15%	0.001 bar	
Oxygen concentration	Optical	0-23 mg/L	±0.1 mg/L	0.025 mg/L	
Oxygen saturation	Optical	0-250%	±1%	0.25%	
pH	Electrodes	0-14 pH	±0.1 pH	0.01 pH	
Depth	*calculated	0-250 m	±0.15%	0.001 m	UNESCO equation
Salinity	*calculated	2-42 PSU	±0.1 PSU or ±1% of the reading	<0.001 PSU	n.a.

*Calculated by using equations and other parameters available

2.1.2. Gulf of Trieste monitoring equipment

The activity in the Gulf of Trieste consists of both sampling and monitoring.

Sampling regards the neglected macrozoobenthic communities, living on shallow rocky substrates and, consequently, the conservation status. The fieldwork has been carried out una tantum within April and September 2021, between Villaggio del Pescatore and Lazzaretto (nearby the Slovenian boarder). The total number of sites was 15 (Table 3).

To reach the sampling site, it has been used one of the ARPA FVG's vessels and a small support boat with oars to transport all the equipment directly near the rocky coast. The collection of samples in the two mesolittoral belts was done by snorkelling, while in the upper-infralittoral it has been used scuba gears to remain for the time needed on the sea bottom. The organisms had been scraped from the rocks or the bottom by a rasp, within a metal square 20x20 cm that is the reference sampling area. In the infralittoral belt the collection it was also utilized a small sorbona.

Monitoring activities were also carried out on the same sites, albeit at different times, searching for 2 species of the Gulf:

- A visual census of *Fucus virsoides* noting the presence/absence;
- Identification of the main fish species of littoral by the means of non-invasive methods, in particular, it will be investigated the presence/absence of adults and/or juvenile of the *Gobius cobitis.*

To investigate the presence of the fish species, various action cameras were used to record video and photographic material, both by swimming over the site, shooting the fish species encountered, and by anchoring the action cameras in fixed positions on the sea bottom and leaving them to record for 30-45 minutes at the time.

Table 3. Summary of the sampling activity and equipment used in the Gulf of Trieste

Monitored Area	Rocky shores in the Gulf of Trieste
Monitoring starting date	1/05/2021
Monitoring period	April– September 2021
Number of instruments	n.5 diving gears n.5 action cams with accessories n.1 camera* with waterproof case n.4 metallic collecting squares n.1 sorbona (underwater vacuum cleaner)** n.1 non-motorized support vessel n.1 single point probe**Other various tools used to collect samples
Total investment	12720,00 €
Site localization	CAS1 - 13.594000 E 45.774204 N CAS2 - 13.603198 E 45.771000 N CAS3 - 13.624967 E 45.768552 N CAS4 - 13.637988 E 45.760943 N CAS5 - 13.648307 E 45.754172 N CAS6 - 13.655164 E 45.749612 N CAS7 - 13.668756 E 45.740490 N CAS8 - 13.687355 E 45.727938 N CAS9 - 13.706121 E 45.713690 N CAS10 - 13.711591 E 45.702721 N

	CAS11 - 13.745677 E 45.686797 N CAS12 - 13.736310 E 45.693026 N CAS13 - 13.733119 E 45.610286 N CAS14 - 13.719039 E 45.605776 N CAS15 - 13.720379 E 45.601800 N
Instrumental type	20 single points (vertical profiles) with multiparametric probe?
Dimension	Probe height: 499mm Probe diameter: 110mm
Power supply	-
Communication	-
Sampling frequency	Una tantum campaign
Sensor installed	-

Table 4. Camera specifications

Camera Kit	
Sensor	Effective pixels approx.20.1 megapixels (aspect ratio: 3: 2)
Lens	Focal length 8.8 - 36.8mm (35mm equivalent: 24 - 100mm)
Zoom	Zoom 4.2x optical, 8.4x ZoomPlus
Opening	Maximum opening f / 1.8 - f / 2.8
Focus distance	Minimum focus distance 5 cm (wide angle) from the front of the lens 40 cm (telephoto) from the front of the lens
Shooting	Continuous shooting Approx. 8 shots / sec. up to 19 frames in RAW format and 30 frames in JPEG format with AF: Approx.5.4 shots / sec. up to 46 frames in JPEG format
Compression	JPEG compression (Exif 2.3 [Exif Print] compliant) / Design rule for Camera File system and compliant with DPOF ver. 1.1), RAW (14-bit Canon original RAW 2nd edition), RAW + JPEG
Additional lens	Supermacro lens for underwater use, which can be combined with compacts. Magnification 10 diopters. 70mm diameter x 30mm height. Maximum depth: 100 m. optimized for autofocus. supplied with the common 67mm threaded lens mount.
Lights	Dimensions: length 155mm Diameter: 23mm Weight: 178g on land / 112g in water Max. Immersion depth: 100m Light output: 100'000Lux at 100mm distance

The characteristics of the camera are shown in Table 4, but for the sake of completeness, a list of all the equipment used during the campaign is also provided (Figure 3, 4).

Diving gear:

- Long wet suits
- Wet suits shorty
- Masks
- Snorkels
- Gloves in antigrip fabric
- Thin boots
- Fins
- Belts
- Buoy
- Weights
- Duffel bags
- Anklets
- Backrests
- Thick booties
- Knife
- Carabiners
- Complete regulator
- Net bag
- Bathrobe


Figure 3. Diving gear and the sorbona

Sampling tools kit:

- Sorbona (underwater wacoom connected to an air tank)
- 5 action camera kits with tripods

- Inflatable SUP kit (length 290 cm, width 89 cm, load 140 kg)
- Collecting square in inox (reference area 20x20 cm)
- 500 micrometers-mesh net
- Reels (min 60 m)
- Cotton collecting bag
- Blackboards + pencils
- Spatulas and Pickaxes
- Ropes
- Jars
- Spray bottles

Figure 4. SUP and equipment

Camera equipment

- Camera-case
- Additional macro lens
- Illuminator
- Flip
- Flashlight kit
- Underwater flash

In addition, the material used for identification:

- Stereomicroscope and optical microscope **
- Books for taxonomic ID
- Software (Primer-e)
- N. 2 sieves (500 micrometers mesh)
- Tweezers of different sizes
- Sorting tray

** tools not bought with CASCADE budget

More details regarding the use of the equipment will be reported in the deliverable 4.1.2 which describes the phases developed during the campaign.

2.2 Transitional and coastal areas in Emilia Romagna (IT)

ARPA Emilia-Romagna manages, for many years already, a monitoring network composed by a series of measurements stations listed below:

- 8 multiparametric probes (dissolved oxygen, pH, salinity, and temperature) located in the Sacca di Goro and within the Comacchio Valleys. Stations: Punta Volano, Gorino2, Bocca Scanno and Manufatto (Sacca di Goro), Ponte San Pietro, Bellocchio and Logonovo (Comacchio Valleys).
- 1 international tidal station equipped with: 1 multiparameter probes (dissolved oxygen, pH, salinity, and temperature), 2 sea level sensors (1 radar sensor and 1 float sensor), 1 meteorological sensor (air temperature, precipitation, humidity, wind direction and intensity), located at Porto Garibaldi and it is also a GNSS station and has joined the EUREF EPN network.
- 1 wave gauge in front of Cesenatico (Nausicaa Buoy).

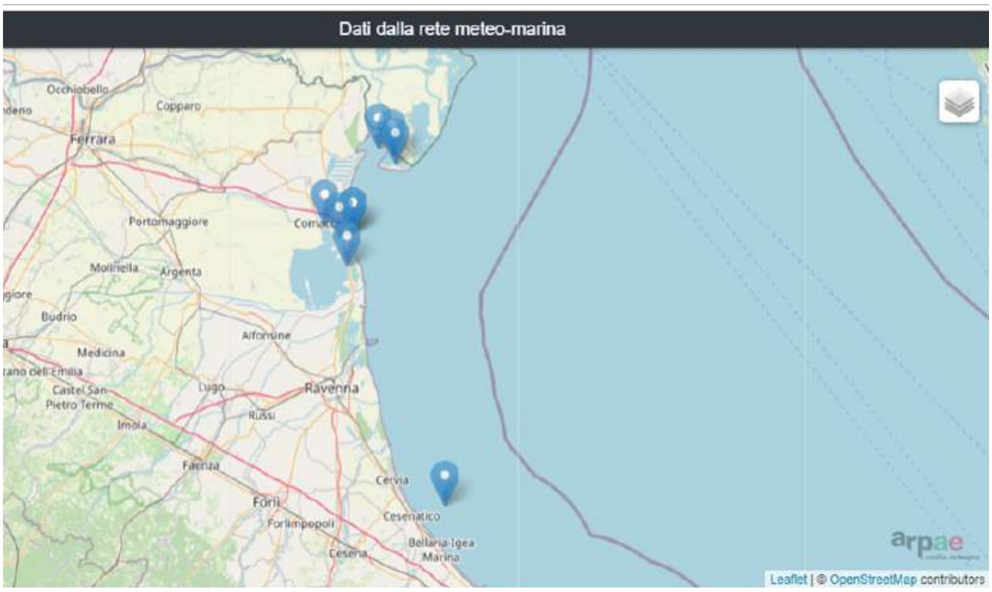


Figure 5 Locations of the existent monitoring network for the Emilia-Romagna Region managed by ARPAE.

As part of the project, ARPA Emilia-Romagna has carried out the installation of new measuring instruments and additional sensors to the stations already in operation, to update and improve the existing monitoring system of the Goro Lagoon and to enhance the monitoring of the physical and geochemical state of the marine waters.

In particular, the following instruments have been installed:

- 1 monitoring station complete with a multiparameter probe with a turbidimeter installed on the “Ponte di barche” bridge over the Po di Goro (FE).
- 3 multiparameter probes (without turbidimeter) installed at the existing monitoring station in Sacca di Goro.
- 4 sea level sensors to be installed at the 4 existing Sacca di Goro gauging stations to implement the compensated pressure measurement at the 4 gauging stations.
- 2 mobile probes for salt wedge monitoring (turbid transport, temperature, and conductivity)

2.2.1. Multi-parameter station at Po di Goro

On 21-03-2023, a multiparameter station for monitoring physical and chemical parameters was installed at Po di Goro, Ferrara (Figure 6). The station is equipped with a multi-parameter probe that measures the following parameters:

- Turbidity (NTU)
- Water Temperature (°C)
- pH (U)
- Specific Conductance at 25° (mS/cm)
- Salinity (ppt)
- Dissolved Oxygen Saturation (%)
- Dissolved Oxygen (mg/L)

Measured data is transferred via FTP to the current data reception and management system. The interval between acquisition and registration and transmission to the server is hourly.

The station was installed on site by specialised personnel, complete with all the necessary instruments, and permanently connected to the structure of the bridge in the correct position identified together with ARPAE's technicians during the inspection phase. At the end of the installation, the correct functioning of all the instruments was verified.

A second multiparameter probe was supplied as a spare for station maintenance.

The station consists of the following elements:

- Watertight box with IP66 degree of protection suitable for containing the assembled parts, complete with key lock and set up for fixing on a pole.

- Pole in AISI 304 stainless steel, complete with base for fixing to the plinth or existing flooring used as a support for the cassette and for the solar panel.
- Probe protection tube in AISI316L stainless steel, for probe, complete with collars for vertical wall mounting to allow immersion and protection of the probe. Closed at the top, padlockable, drilled at the bottom.
- 2 multiparameter probes
- Interchangeable submersible cables
- Bluetooth module with battery to power the probe and connect it to Smartphone, Tablet and PC.
- Photovoltaic panel power supply system
- Data Acquisition
- Integrated 2G/3G/4G/GPRS modem for data logger

Sensor's specifications:

1. Temperature sensor:
    - operating temperature range from -5 to 50 degrees °C
    - Accuracy: ±0.1
    - Resolution: 0.01
    - Unit of measurement: Celsius degrees and Fahrenheit degrees
    - No calibration
2. Conductivity sensor for calculating Salinity:
    - measurement range: 0 to 275 mS/cm
    - Accuracy: ±0.5% over reading range, 0 to 5000 µS/cm
    - ±1% of reading range, 0 to 100 mS/cm
    - ±0.5% of reading range, 0 to 100 mS/cm
    - ±2%, in the range, from 100 mS/cm to 275 mS/cm
    - Resolution: 0.001 (mS/cm), 0.1 µS/cm
    - Unit of measurement: mS/cm or µS/cm
    - Calibration with Standard KCl
3. pH sensor:
    - measurement range: 0 to 14 pH units
    - Accuracy: ±0.1 within 10 degrees C of calibration; 0.2 otherwise
    - Resolution: 0.01
    - Unit of measure: Unit of pH
    - Calibration using a certified pH buffer solution.

4. Dissolved Oxygen Sensor
    - measuring range: 0 to 50 mg/l and 0 to 500% saturation
    - Accuracy: ±0.1 mg/L in reading range (0-20 mg/L)
    - ±0.15 mg/L in reading range (20-30 mg/L)
    - ±5% of reading range (30-50 mg/L)
    - Resolution: 0.01 mg/l and 0.1% saturation
    - Units of measurement: mg/l (ppm), % saturation
    - Calibration measurement of a point in the air
5. Turbidity sensor
    - measurement range from 0 to 4000 FNU
    - Accuracy: ±.3 FNU or ±2% in the range of reading from 0 - 1000 FNU
    - ±4% in the reading range from, 1000 – 4000 FNU
    - Resolution: 0.01
    - Unit of measurement: FNU
    - Calibration: in two points with certified laboratory samples.

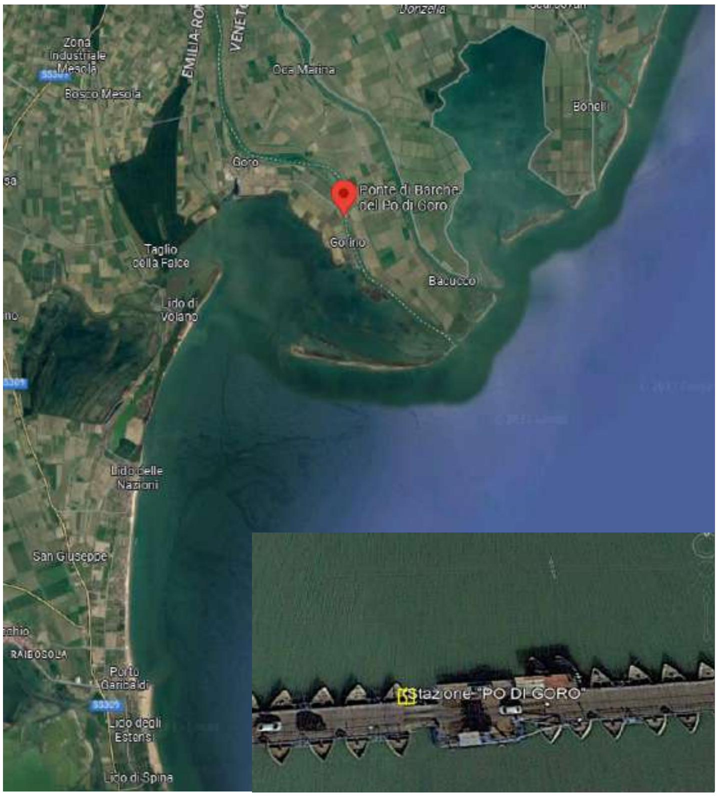


Figure 6. Location of multiparameter station installed at Po di Goro on the bridge “Ponte di Barche”.

Figure 7. Multiparameter station installed at Po di Goro Location

2.2.2. Multiparametric probes for the Sacca di Goro and Bellocchio Valleys

On 16-03-2023 and 21-03-2023, 2 multiparametric probes were installed on 2 already operational measurement stations named Manufatto (in the Sacca di Goro) and Bellocchio (in the Comacchio Valleys), displayed in Figure 8 with violet dots.

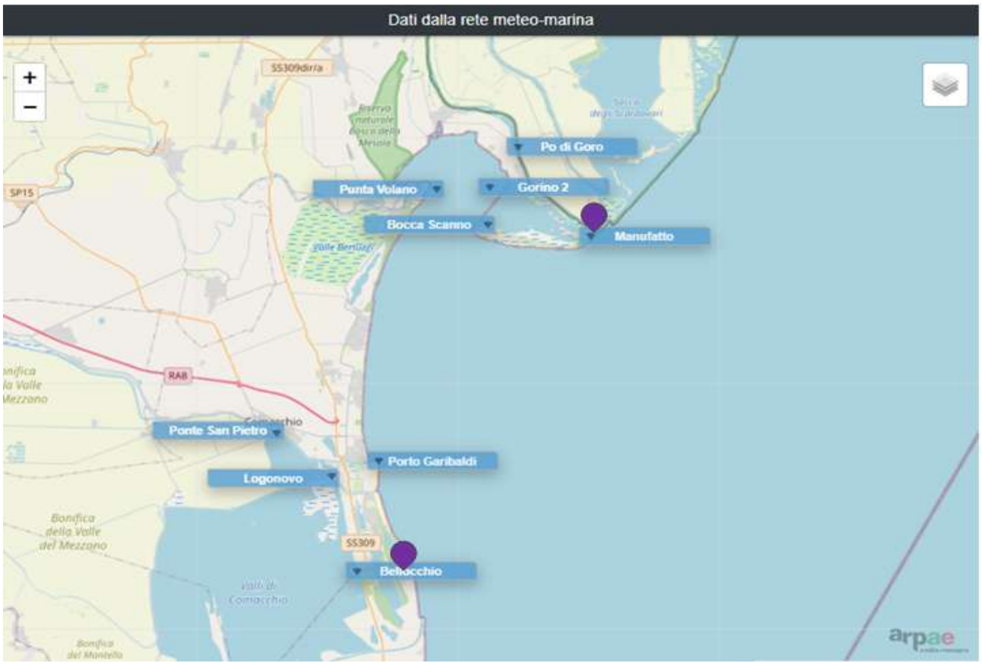


Figure 8. Location of the 2 stations (Bellocchio and Manufatto) equipped with the multiparametric probes (violet dots).

The probes allow to measure these parameters:

- Water Temperature (°C)
- pH (U)
- Specific Conductance at 25° (mS/cm)
- Salinity (ppt)
- Dissolved Oxygen Saturation (%)
- Dissolved Oxygen (mg/L)

The instruments consist of:

- probe body, USB and RS232 communication modules, sensor protection cage with ballast, calibration cable, USB interface, operating manual in electronic format.
- Integrated interface module for connecting probes to OTT neDL500 datalogger present in the Sacca di Goro stations

ARPA provided a boat and a staff technician team to reach the stations inside the Sacca di Goro and allow the installation.

a)


b)


c)


Figure 9. a) Bellocchio installation. b) and c) Manufatto installation.

Sensor's specifications:

1. Temperature sensor:
    - operating temperature range from -5 to 50 degrees °C
    - Accuracy: ±0.1
    - Resolution: 0.01
    - Unit of measurement: Celsius degrees and Fahrenheit degrees

- No calibration

1. Conductivity sensor for calculating Salinity:
    - measurement range: 0 to 275 mS/cm
    - Accuracy: ±0.5% over reading range, 0 to 5000 µS/cm
    - ±1% of reading range, 0 to 100 mS/cm
    - ±0.5% of reading range, 0 to 100 mS/cm
    - ±2%, in the range, from 100 mS/cm to 275 mS/cm
    - Resolution: 0.001 (mS/cm), 0.1 µS/cm
    - Unit of measurement: mS/cm or µS/cm
    - Calibration with Standard KCl
2. pH sensor:
    - measurement range: 0 to 14 pH units
    - Accuracy: ±0.1 within 10 degrees C of calibration; 0.2 otherwise
    - Resolution: 0.01
    - Unit of measure: Unit of pH
    - Calibration using a certified pH buffer solution.
3. Dissolved Oxygen Sensor
    - measuring range: 0 to 50 mg/l and 0 to 500% saturation
    - Accuracy: ±0.1 mg/L in reading range (0-20 mg/L)
    - ±0.15 mg/L in reading range (20-30 mg/L)
    - ±5% of reading range (30-50 mg/L)
    - Resolution: 0.01 mg/l and 0.1% saturation
    - Units of measurement: mg/l (ppm), % saturation
    - Calibration measurement of a point in the air

2.2.3. Sea level sensors integrated in the Sacca di Goro monitoring stations

The measuring stations operating in the Sacca di Goro have been equipped with the installation of 4 sea level sensors, as follows

- Bocca Scanno and Manufatto (on 16/03/2023)
- Punta Volano and Gorino (on 24/03/2023)

The 4 pressure level sensors with ceramic-capacitive cell have the following characteristics:

- Ranges: 0 ÷ 4m, 0 ÷ 10m, 0 ÷ 20m, 0 ÷ 40m, 0 ÷ 100m
- Accuracy: ±0.5% 0.05%fs. Resolution: 1mm.
- Temperature Range: -25°C ÷ 70°C

- Material: seawater resistant stainless steel AISI 904L (1.4539).
- Dimensions (L x Ø): 195mm x 22mm.
- Interfaces: SDI-12, RS-485, 4...20mA
- Power supply: 12V DC

Figure 10. Manufatto station.

Figure 11. Bocca Scanno station.

Figure 12. Punta Volano station.

Figure 13. Gorino station.

2.2.4. Mobile multiparametric probes for monitoring turbid transport, temperature and conductivity and training activities.

On 29.03.2002, the 2 mobile multiparametric probes were delivered at the same time as the training activity planned at the ARPAE office in Goro.

The 2 probes delivered were used to illustrate the maintenance and calibration procedure of the sensors and the operating software for the management of the Manta+30 probes. The communication methods available for displaying data in the field were then illustrated, via Bluetooth with tablet/smartphone devices running Android and/or IOS operating systems, and via cable with tablet/PC running Windows operating systems. The possibility of real-time data visualisation on the H3Ocube web portal for the Sacca di Goro, Comacchio and Porto Garibaldi monitoring network was also illustrated during the training.

2.2.5 Probes for monitoring water column parameters during phytoplankton and benthos sampling campains

CIRSA-UNIBO implemented the integrated monitoring actions in the Sacca di Goro and Lago delle Nazioni. Physical, biotic and abiotic data are collected from the seawater surface in 4 different stations of the Sacca di Goro, chosen to represent areas of the same sub-basins having different hydrographic characteristic (Porto Gorino – Gorino – Foce Volano – Bocca Mare), reached on a monthly base with a fishing boat for the first year, then seasonally in the second year, while Lago delle Nazioni was monitored on a monthly base for two years.
The monitoring activity was aimed at the assessment of the ecological status of the two transitional environments and at obtaining data for the implementation of the BFM biogeochemical model.
Three instruments were acquired to perform in situ point measurements:
a multiparameter probe to measure temperature (°C) and dissolved oxygen (mg/L and saturation %), a probe to measure underwater irradiance and a portable spectrophotometer to measure inorganic nutrients.
Here we report the main characteristics for each sensor/equipment.

Temperature and oxygen HQ30d Portable Meter (Hach-Lange GmbH):

- operating temperature range 0 – 60°C
- Temperature accuracy ± 0,3 °C
- DO concentration (mg/L) 0,01 - 20 mg/l
- DO concentration resolution (mg/L) 0,01 mg/l / 0,1 %

Underwater Quantum Flux (Apogee Instruments)

- Calibration Uncertainty ± 5%
- Measurement Range 0 to 4000 µmol m^{-2} s^{-1}
- Measurement Repeatability Less than 0.05%
- Long-term Drift (Non-stability) Less than 2 % per year
- Non-linearity Less than 1 % (up to 4000 µmol m^{-2} s^{-1})

- Response Time Less than 1 ms
- Field of View 180˚
- Spectral Range 389 to 692 nm ±5 nm
- Spectral Selectivity Less than 10 % from 412 to 682 nm ± 5 nm
- Directional (Cosine) Error Less than ± 5 % at 75˚ zenith angle and 10 % from 412 to 682 nm ± 5 nm
- Azimuth Error Less than 0.5 %
- Tilt Error Less than 0.5 %
- Temperature Response -0.11 ± 0.04 % C^{-1}

Portable spectrophotometer DR 1900 (HACH)

- Operating Mode Transmittance (%), Absorbance and Concentration
- Source Lamp Xenon Flash
- Wavelength Range 340 to 800 nm
- Wavelength Accuracy ± 2 nm (range 340 - 800nm)
- Wavelength Selection Automatic
- Wavelength Reproducibility ± 0.1 nm
- Spectral bandwidth 5 nm
- Photometric Measuring Range 0 to 3 Abs (wavelength range 340 – 800 nm)
- Photometric Accuracy ± 0.003 Abs @ 0.0 - 0.5 Abs
- Photometric Linearity < 0.5 % (0.5 - 2.0 Abs)
- Stray Light < 0.5% T@340nm with NaNO2
- Display Graphical display 240 x 160 pixel (LCD, b/w, backlit)
- Data Logger 500 measured values (Result, Date, Time, Sample ID, User ID acc. to GLP)
- Preprogrammed Methods > 220
- User Programs 50
- Sample Cell 13 / 16 mm and 1 inch
- Compatibility round adapter, 1 inch square and 10x10mm
- Operating Conditions 10 to 40 °C (50 - 104 °F), max. 80 % relative humidity (non-condensing)

2.3 Torre Guaceto-Canale Reale, Punta della Contessa and Melendugno in Puglia (IT)

CMCC, UNISALENTO and Regione Puglia are carrying out a series of activities for the characterization of the pilot area P3, which includes different areas selected with stakeholders and, in particular,

- Marine Protected Area (MPA) of Torre Guaceto,
- Protected land of Salina Punta della Contessa,
- The coastal marine area of Melendugno Municipality.

CMCC equipped a buoy in MPA integrating several oceanographic sensors managed by a low-cost electronic system. In addition, as a spatial integration of the buoy measures, an oceanographic survey was carried out to acquire data for numerical model validation. All these activities are supported by the Marine Protected Area facilities.

Regione Puglia purchased: an Unmanned Surface Vehicle (USV) equipped with a Multibeam Norbit IWBM a Side Scan Sonar Blueprint Starfish 425 F and a sound velocity profile for hydrographic and environmental survey applications; n. 4 hydrophones for noise and sounds monitoring.

The USV is a surface vehicle autonomous that operates without the need for a crew. It is capable of navigating on the surface of water autonomously due to the presence of motors and an operator-programmable navigation. It can perform missions in marine coastal areas, measuring several water parameters, thanks to the instruments it is equipped with.

The hydrophones will be able to detects acoustic signals under the water to acquire long-term data sets of the marine acoustics environment and to identify and study acoustic impacts from both human activities and natural processes and organisms.

UniSalento is in charge to perform campaigns for detecting some organic pollutants, heavy metals and microplastics in P3. Heavy metals have been determined by atomic spectrometry. In addition, speciation analysis of some heavy metals will be attempted on selected samples by home-made portable electrochemical sensors.

2.3.1 Torre Guaceto Marine Protected Area fixed station equipment

One of the delimitation buoy moored in the Torre Guaceto Marine Protected Area was made available for the integration of low-cost measurement instrumentations. The station is based on low-cost and open access technologies and allows to acquire different types of parameters, such as: temperature, conductivity (salinity, density), dissolved oxygen, suspended solids, fluorescence of chlorophyll-a. The data acquired by the buoy will be processed and validated and will be able to be shared with the project community and on MPA website to have a useful time series of the main parameters which will allow to analyse the seasonal trends and potential variations. The main features of the equipment (monitored area, monitoring starting date, monitoring period, number of instruments, total investment, site localization, instrumental type, sensors installed) are reported in Table 5.

Table 5. Equipment and instrumentation characteristics for Torre Guaceto fixed station

Monitored Area	Area Marina Protetta di Torre Guaceto (Carovigno e Brindisi, Puglia, IT)
Monitoring starting date	17/07/2021
Monitoring period	July – November 2021
Number of instruments	1
Total investment	13615,20
Site localization	Lat 40.7227778 E Long 17.7779861 N
Instrumental type	Fixed Buoy
Dimension	Probe high: 400 mm Probe diameter: 40 mm Buoy high: 3300mm Buoy diameter: 1300mm
Power supply	Solar Panel
Communication	GPRS/LoRa
Sampling frequency	every 10 minutes
Sensor installed	Temperature Conductivity Dissolved Oxygen Suspended solids Chlorophyll-a Fluor.

The delimited buoy in Torre Guaceto AMP is shown in Figure 14, including some pictures of the phase of monitoring installation. The fixed buoy will allow a continuous monitoring of the main physical and biogeochemical parameters of marine water. The system is an upgrade of a previous one, with improved electronics that allows to manage a big number of sensors and an improved transmission system. The system was developed to be a low-cost system to be installed in different kind of buoys or fixed infrastructures.

Figure 14. Torre Guaceto MPA delimitation buoy; buoy and monitoring system installation.

The multiparametric probe (Figure 15) was designed to be equipped with different kind of sensors, both in-house developed and commercial ones. The system, based on low-cost electronics, will allow to manage analogic and digital sensors, and will acquire data with a frequency of 10 minutes.

Figure 15. Multiparametric probe developed for P3 buoy

The data are transmitted to a server in .csv format. The first installation integrated the following sensors: AML Xchange CT for conductivity and temperature; Atlas Scientific EZO DO OEM for dissolved oxygen; Pt 100 class A for temperature; SeaTech Turbidimeter for suspended solids.

Here we report the main characteristics for each sensor:

- AML Oceanographics:
  - CT XChange OEM:
    Range: 0 ÷ 90 mS/cm (conductivity)
    -5 ÷ 45°C (temperature)
    Accuracy: ±0.01 mS/cm
    ±0.005 °C
    Precision: ±0.003 mS/cm
    ±0.003°C
    Resolution: 0.001mS/cm
    0.001°C
    Stability: 0.003 mS/cm/month
- Atlas Scientific
  - Lab grade DO DO Ezo OEM:
    Range: 0 ÷ 100 mg/L
    Accuracy: ±0.05 mg/L
  - Pt100 Wika classe A + RTD Ezo OEM:
    Range: -50 ÷ 260 °C (4 cables)
    Accuracy: ±0.03 °C
    Resolution: ±0.001°C
- SeaTech
  - Turbidimeter #116
    Range: 33 mg/L o 100 mg/L (High o Low Gain)
    Output : 0 ÷ 5V analogico

Resolution: ±0.01% FS (3µg/L)

2.3.2 Torre Guaceto Marine Protected Area monitoring survey equipment

The activity in the Torre Guaceto Marine Protected Area consists both of continuous monitoring by fixed station and in-situ surveys. The in-situ survey consists of n. 20 stations, where a multiparametric probe was used allowing to perform a series of vertical profiles and to acquire along the water column the following parameters: depth, temperature, conductivity (salinity, density), dissolved oxygen, pH, chlorophyll a, turbidity. The main features of the equipment (monitored area, monitoring starting date, monitoring period, number of instruments, total investment, site localization, instrumental type, sensors installed) are reported in Table 6. Further specific technical characteristics are reported in Table 7. The station ID and the coordinates of sampling are reported in Table 8.

Table 6. Equipment and instrumentation characteristics for Torre Guaceto monitoring survey

cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

Monitored Area	Area Marina Protetta di Torre Guaceto (Carovigno e Brindisi, Puglia, IT)
Monitoring starting date	17/07/2021
Monitoring period	17 July 2021
Number of instruments	1
Total investment	0
Site localization	Lat_min=40.709451 E Lat_max=40.735239 E Lon_min =17.768416 N Lon_max=17.815624
Instrumental type	20 single points (vertical profiles) with multiparametric probe

Dimension	Probe height: 499mm Probe diameter: 110mm
Power supply	Alakaline batteries
Communication	Wifi/GPRS
Sampling frequency	Una tantum campaign
Sensor installed	Temperature Conductivity Dissolved Oxygen Suspended solids Chlorophyll-a Fluor. Turbidity

Table 7. Multiparameter probe sensors with specific technical details

Parameter	Range	Initial Accuracy	Resolution	Response Time
Pressure	0..1000 dbar (1)	0.05% FS	0.002% FS	50 ms
Temperature	-3..+50 °C	0.002 °C	0.0002 °C	50 ms
Conductivity	0..70 mS/cm	0.003 mS/cm	0.0003 mS/cm	50 ms (2)
Oxygen Polarographic	0..50 ppm	0.1 ppm	0.01 ppm	3 s (3)
	0..500 %sat.	1 %sat.	0.1 %sat.	3 s (3)
Oxygen Optical	0..45 mg/l	0.1 mg/l	0.025 mg/l	3 s (4)
	0..250 %sat.	±0.2 %sat.	0.05 %sat.	3 s (4)
pH	1.. 13 pH	0.01 pH	0.001 pH	3 s

Table 8. Survey stations coordinates.

Station ID	coordinates Lon Lat
stat-1	17.768416 40.725507
stat-2	17.769567 40.730373
stat-3	17.770718 40.735239
stat-4	17.780449 40.732937
stat-5	17.779298 40.728071
stat-6	17.778148 40.723205
stat-7	17.787879 40.720904
stat-8	17.789030 40.725770
stat-9	17.790181 40.730635

stat-10	17.799912 40.728334
stat-11	17.798761 40.723468
stat-12	17.797611 40.718602
stat-13	17.807342 40.716301
stat-14	17.808493 40.721166
stat-15	17.809644 40.726032
stat-16	17.819375 40.723730
stat-17	17.818224 40.718865
stat-18	17.817074 40.713999
bay-1	17.779175 40.720587
bay-2	17.815624 40.709451

2.3.3 Unmanned Surface Vehicle for hydrographic and environmental survey

The Unmanned Surface Vehicle for hydrographic and environmental survey application, purchased by Regione Puglia, can navigate on the water surface autonomously, thanks to the presence of motors and an operator-programmable control and navigation system, and to carry out missions in coastal marine areas. Its equipment is easily modifiable with appropriate instruments depending on the type of investigation to be carried out.

Table 9. Equipment and instrumentation characteristics of Unmanned Surface Vehicle for hydrographic and environmental survey

REGIONE PUGLIA
 Torre Guaceto

Puntarenas

San Basilio

Monitored Area	Torre Guaceto; Melendugno (San Basilio, Puntarenas)
Monitoring starting date	13.04.2023
Monitoring period	Torre Guaceto: 13.04.2023; 20.04.2023 Puntarenas e San Basilio: 24.05.2023
Number of instruments	1
Total investment	€ 208.072,30
Instrumental type	Unmanned Surface Vehicle for hydrographic and environmental survey application with probes
Dimension	Length: 145 cm Height: 45 cm Diameter: 90 cm Weight: < 15 kg
Power supply	n. 8 lithium polymer batteries
Communication	Wifi
Sampling frequency	Una tantum campaign
Sensor installed	• Multibeam Echo sounder (MBE) with Integrated SV Probe and

	Inertial Motion and navigation System • Sound velocity profiler (SVP) • GPS System (GNSS receivers and antenna) Side Scan Sonar

The Unmanned Surface Vehicle is equipped with a software package for navigation in remote pilot and autopilot mode and for data acquisition and management software.

Figure 16. Unmanned Surface Vehicle for hydrographic and environmental survey

On-board technical instrumentation and their technical characteristics are:

- Multibeam echo sounder: It is a complex system composed of multiple sensors and applies the principles of acoustic reflection, scattering, and acoustic interferometry to create bathymetric data that measure depth and allow for the development of a mapping survey of the seafloor. The technical characteristics are shown below:

Table 10. Technical characteristics of multibeam echo sounder

Characteristics	Range
Swath opening	Between 5° and 210°
Minimum number of beam	512
Sidescan and Backscatter output	Present
Maximum detectable depth	270 meters
Operating frequency	Nominal frequency: 400kHz Frequency Agility 200-700kHz optional
Beam dimension (accross X along)	2,0°X 4,0° @200 kHz 0,9°X 1,9° @400 kHz 0,5° X 1,0° @700 kHz;
Depth resolution	1 cm
Update frequency	60Hz

- Sound velocity profiler measures the speed of sound throughout the column of water. Sound velocity in water is measured by either using a small acoustic signal which is sent to a receiver at a known distance or by measuring the variables affecting sound velocity in water, salinity, temperature, and pressure variables.

  Its main characteristics are for the Speed of sound:
  - Measuring range 1,375-1,900 m/s;
  - Accuracy ±0.02 m/s;
  - Resolution 0.001 m/s;

  and for the pression:

  - Measuring range: 50 Bar;
  - Accuracy ±0.01% FS;
  - Resolution 0.001% FS;

Figure 17. Technical characteristics of sound velocity profiler

- Side Scan Sonar Blueprint StarFish 452F PRO is an active sonar system for detecting and imaging objects on the seafloor. The technical characteristics are shown below:

Table 11. Technical characteristics of Side Scan Sonar

Characteristics	Range
Downwards angle	30° from the horizontal
Vertical beam	nominal width = 60°
Horizontal beam	nominal width = 0.8°
Frequency	450kHz Chirp
Range	1-100m
Temperature range	-5 to +40°C

Figure 18. Side Scan Sonar

They were also provided data acquisition and management software, software for post-processing of the acquired data.

Figure 19. Unmanned Surface Vehicle during a survey

2.3.4 Hydrophones

N. 4 hydrophones are purchased by Regione Puglia to detect and record ocean sounds from all directions.

Table 12. Equipment and instrumentation characteristics of hydrophones

REGIONE PUGLIA	
Number of instruments	4
Total investment	€ 13.496,58
Instrumental type	Hydrophones
Dimension	Length: 530mm Diameter: 60mm
Power supply	Lithium polymer batteries
Communication	wireless
Sampling frequency	Una tantum campaign

The technical characteristics are shown below:

Table 13. Technical characteristics of hydrophones

Characteristics	Range
Bandwidth	20 Hz – 60 kHz
Sampling rate	Selectable up to 192 kS/sec
Max working depth	500 meters

Figure 20. N.4 hydrophones

2.3.5 UNISALENTO electrochemical sensor equipment for heavy metals speciation

For developing and applying electrochemical sensors to heavy metal speciation, UNISALENTO has acquired an electrochemical system consisting of a portable potentiostat (Palmsense 4) able to power home-made sensors and to read the relevant outputs. The instrument has been received in April 2021. PalmSens 4 was also equipped with a cable connector for screen-printed electrodes on which are based home-made sensors. The instrument has been used for sensors development and heavy metal speciation analysis on selected samples.

Figure 21. Potentiostat Palmsense 4 equipped with a cable connector for (disposable) screen-printed electrodes

General specifications of the instrument are reported in Tables 14 and 15.

Table 14. Portable potentiostat PalmSens 4 (PalmSens BV Randhoeve 221, 3995 GA Houten (NL) through Thasar Srl – via Larga, 23, 20122 Milano, Italy)

Temperature range	0°C to + 50 °C
Battery time	Up to 16 h
Internal storage space	8 GB (800 000 measurements incl. method info, assuming 200 data points per measurement)
Dc-potential range	± 10 V (or ± 5 V)
Compliance voltage	± 10 V
Maximum current	± 30 mA
Max. acquisition rate	150 000 data points/s

Power supply	USB or Internal LiPro battery
Communication	USB and Bluetooth (dual mode)
Dimension	15.7 x 9.7 x 3.5 cm^3

Table 15. Specifications

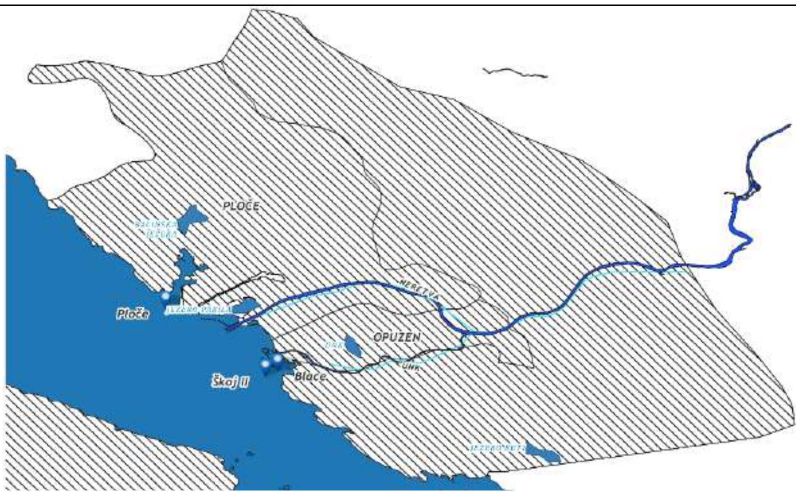
	Potentiostat mode
Applied dc-potential/current resolution	76.3 µV (18-bit)
Applied potential accuracy	≤ 0.1% ± 1 mV offset
Current ranges	100 pA to 10 mA (9 ranges)
Current accuracy	≤ 0.1% (at full scale range)
Measured potential/current resolution	0.005 % of current range (18-bit, 5 fA on 100 pA range) 0.0025% of 10 mA range

2.4 Neretva River mouth (HR)

The activity in the Neretva River includes both sampling and monitoring. Dubrovnik-Neretva County (DNC) has used the underwater drone to find the best locations for sampling. Micro conditions were also taken into consideration. Mussel and sediment samples were collected at the mouth of the Neretva River. The sediment samples were analysed for grain size, organic matter, carbonate, and metals. Temperature, salinity, and oxygen saturation were determined in the seawater samples, while the concentration of metals, PAH, hydrophilic and lipophilic toxins was determined in the mussel samples.

The grain size analysis, organic matter and carbonate were further processed and measured using the laser granulometer. Metals were determined using the AAS instrument, hydrophilic PSP toxins and PAHs were measured using a UHPLC instrument, while lipophilic toxins and hydrophilic ASP toxins were measured using the LC-MS/MS instrument. Temperature and salinity were measured with a CTD probe, while oxygen saturation was determined titrimetrically with thiosulfate.

Table 16. Equipment characteristics for Neretva River mouth monitoring survey



Monitored Area	Neretva river
Monitoring starting date	01/01/2021
Monitoring period	2021 – 2022
Number of instruments	4
Total investment	465.886,00 €
Instrumental type	Monitoring instruments

Figure 22. Ultra-high performance liquid chromatograph (UHPLC, Agilent 1290 Infinity II Fluorescence Detector)

Table 17. Performance specifications of UHPLC

Type	Specification
Flow	0.00 – 5.00 mL/min
Injection range	0.1-120µL
Injection precision	< 0.25% RSD of peak areas from 5 µL to 100 µL
Pressure range	Up to 130 MPa (1300 bar)
Carryover	40 ppm with needle wash
Sample Thermostat	
Temperature range	4°C to 40°C
Multicolumn Thermostat	
Temperature range	4°C to 110°C
Independent Temperature zones	2 (in single device)
Column capacity	4 columns of 300 mm
UV detector	
Detection Type	Double-beam photometer
Light source	Deuterium lamp
Number of signals	Single and dual wavelength detection
Maximum data rate	240 Hz (single wavelength detection)
Drift	< $1*10^{-4}$ AU/h, at 230 nm
Wavelength range	190-600 nm
Wavelength accuracy	$\pm 1\ nm$
Flow cells	14µL volume, 10 mm cell path length
FLD detector	

Detection Type	Multi-signal wavelength fluorescence detector with rapid on-line scanning capabilities and spectral data analysis
Single wavelength operation	RAMAN (H_2O) > 3000 (noise reference measured at dark value)
Light source	Xenon Flash Lamp
Maximum data rate	148Hz
Excitation monochromator	Range: settable 200 nm – 1200 nm
Emission	Range: settable 200 nm – 1200 nm
Wavelength characteristic	Repeatability +/- 0.2 nm Accuracy +/- 3 nm

Figure 23. Direct mercury analyser (DMA 80, Milestone)

Table 18. Technical specifications of DMA

Direct analysis of solid, liquid or gas matrices
Direct analysis does not require any pre-treatment or chemical additions
Double beam spectrophotometer to enhance performance
Detectors: UV enhanced photodiodes
Catalyst tube and gold amalgamator providing full mercury conversion, interference removal, and fast mercury release
Direct analysis does not require any pre-treatment or chemical additions
Double beam spectrophotometer to enhance performance
Detectors: UV enhanced photodiodes
Catalyst tube and gold amalgamator providing full mercury conversion, interference removal, and fast mercury release
Combustion temperature: time-to-temperature and time-at-temperature programs
Autosampler suitable for solid, liquid and gas samples
Software for data handling, data import/export
Autoblank feature to minimize the memory effect problem in mercury analysis
Short time of analysis (less than 6 minutes)
Carrier gas: either compressed air or oxygen
Max. Sample weight (solid): 1,5 grams
Max. Sample weight (liquid): 1,5 ml
Working range from 0.01 ng to 1500 ng Hg
Compliant with multiple official methods such as the US EPA method 7473

Figure 24. Atomic absorption spectrometer (AAS, PinAAcle 900T, PerkinElmer)

Table 19. Technical specifications of AAS

Flame, graphite furnace and mercury hydride mode of analysis
Working range: min. 185-899 nm
8-lamp housing for hollow cathode lamps (hcls) and electrodeless discharge lamps (edls)
Transversely heated graphite atomizer (THGA)
Stabilized temperature platform furnace technique
Either Deuterium or longitudinal Zeeman background correction
Furnace autosampler
Automatic setup (with lamp pre-warming)
Continuous monitoring of lamp usage
Furnace camera for easier autosampler tip alignment and sample dispensing control
Removable burner assembly
Automatic adjustment of the burner head position
Stainless steel or high-sensitivity, corrosion-resistant nebulizer models
Software for instrument setup, method development, sample analysis and report generation

Figure 25. Laser granulometer (Malvern Panalytical Mastersizer 3000 E + Hydro EV + Hydro M).

Table 20. Performance specifications of laser granulometer

Wet dispersion unit for samples
Hydro EV unit with a capacity of 250 - 1000 ml, with integrated mixer and the possibility to set the mixing speed up to 3500 rpm
Hydro EV unit contains an integrated 40 W ultrasonic system with adjustable intensity for disintegration and homogenization
Dry dispersion unit for samples
Light source: 632.8nm laser in the red range, power 4mW
Measurement range from 100 nm to 2100 µm, without changing the optical configuration of the instrument
Speed of data acquisition: 10kHz
Possibility to adjust dispersion pressure from 0-4 bar in steps of 0.1 bar
Ability to precisely adjust the application of samples to the load cell in the range of 0-100% in 1% increments
Oil-free compressor with a capacity of 85 l/min at 6 bar and a 40-liter tank with built-in particle filter down to 0.01 µm
Allows transition from dry to wet measurement and automatic detection of the dispersion unit
Control and analysis software (real-time display: Intensity of scattered light time at each built-in detector, particle size distribution, deviation between individual measurements; overlap/comparison of at least 20 results)

The vessel and marine equipment would be used to protect the coast from possible pollution. The equipment for research and protection includes:

1. Standard marine equipment - outboard engine 20 hp - 4 stroke, 3.5 m auxiliary boat - aluminum flooring, spotlight system (4 pieces 24 V - 2 fixed, 2 portable), "echo sounder";

2. Fire equipment – communication equipment, cleaning chemicals in case of sea pollutions, compressor (blower) for inflating the dam segment, installation of BOMPET fire extinguisher (2 pcs);
3. Special equipment - equipment for combating heavy marine pollution (sets and systems of buoys and suction systems, skimmers), equipment for combating marine pollution – dry suit for 2 persons (set with equipment), high gumboot for flood for 5 persons, diving equipment, storage area container, aluminum path for firefighters to descend and lower the equipment from the ship to shore, an aluminum cage (as a part of a crane) for firefighters to descend and lower the equipment from the ship to shore;
4. Underwater drone.

Figure 26. Ship for prevention water pollution

2.5 Miljašić Jaruga river mouth, Nin Bay (HR)

Table 21. Equipment and instrumentation characteristics

Monitored Area	Characterization of the ecosystem of the coastal bay at the mouth of the river Miljašić in Nin, Croatia
Monitoring starting date	12/07/2021
Monitoring period	30 June 2022
Number of instruments	2
Total investment	Not applicable
Site localization	44°14’48’’ N 15°11’45’’ E
Instrumental type	BRUV systems with GoPro Cameras
Dimension	Height: 120 cm Width: 100 cm
Power supply	Lithium – ion batteries
Communication	Wifi/GPRS
Sampling frequency	1 per month; 2 days in a row
Sensor installed	Temperature

The method of direct **Underwater Visual Census (UVC)** with the use of equipment for autonomous diving (SCUBA), and photo and video documentation were taken, using a CANON G16 camera with underwater housing. For mollusc determination, sediment was collected on the beach itself and after strong storms and winds accompanied by high tide, some individuals were collected by diving, but also by brushing the rocks and shaking the algae.

During April, May, and June 2022 we used the **BRUV method (Baited remote underwater video)** for the monitoring of ichtyo populations around Miljašić Jaruga. We used 2 mono systems, each composed of the GoPro Hero4+ camera with underwater housing (Picture 1). One BRUV system was installed within the Miljašić Jaruga channel, while other was 200 m away from the shore.

Figure 27. BRUV method (Baited remote underwater video)

2.5.1 Measurements of sea currents, sea level dynamics and Miljašić Jaruga flow characteristics

For analysing the pattern of sea circulation within Nin Bay close to the Miljašić Jaruga river mouth as well as the flow pattern in the river itself, a field measurement campaign has been conducted in period from December 16th, 2022 (further referred as Dec 2022) to February 3rd, 2023 (further referred as Feb 2023). The campaign included the measurements of sea current and river flow velocities, sea level dynamics, and wind-generated surface waves dynamics. The measuring equipment consisted of two acoustic Doppler current profilers (further referred as ADCP) and one conductivity-temperature-density probe (further referred as CTD). The conducted measurements will also be used for the calibration of the numerical models what is described as a part of deliverable D.4.1.2.

Below are presented the locations of the used instruments – two ADCPs and one CTD with the specifications applied for this observing campaign.

Figure 28. Plan view of the Nin Bay and Miljašić Jaruga river mouth with presented locations of the installed instruments in period Dec 2022-Feb 2023

Table 22. Measuring equipment characteristics.

Monitored Area	Mouth of the river Miljašić in Nin, Croatia		
Monitoring starting date	16/12/2022		
Monitoring period	49 days		
Number of instruments	3		
Site localization	44°15’07’’ N 15°11’27’’ E	44°14’49’’ N 15°11’48’’ N	
Instrumental type	Acoustic Doppler Current Profiler Sentinel V20	Acoustic Doppler Current Profiler WorkHorse Monitor	Probe Citadel CTD-NH
Dimension	Height: 40 cm (with mount) Width: 50 cm (with mount)	Height: 30 cm (with mount) Width: 50 cm (with mount)	Height: 100 cm (with mount) Width: 50 cm (with mount)
Power supply	Alkaline battery pack		
Communication	Wireless or cable	Cable	
Sampling frequency	currents – 600 pings with frequency of 1 Hz, recorded 1 ensemble per hour waves – 240 pings with frequency of 2 Hz, 3 ensembles per hour	currents – 600 pings with frequency of 1 Hz, recorded 1 ensemble per hour	currents – 1200 pings with frequency of 2 Hz, recorded 1 ensemble per hour
Sensor installed	ADCP Pressure Temperature Compass	ADCP Pressure Temperature Compass	Conductivity Pressure Temperature

ADCP1 was bottom mounted at the depth of -6.7 m at the monitoring starting date (Table 22) and used for measuring the sea current profile and the dynamics of the surface wind-waves at the location above (see Figure 28). The vertical profile in which the profiler measures the sea current velocities was split to 30 cm bin cells. The second profiler – ADCP2 was used for the measurement of the velocity profile at the MIljašić Jaruga river mouth and was bottom mounted at depth of -3.0 m with a vertical profile discretised with 20 cm measuring bin cells. In general, a total number of vertical bin cells varies depending on the dynamics of the sea level. CTD probe was placed upstream of the ADCP2 at the depth of -2.5 m and this device records measurements locally at the depth of deployment. Below are presented the photos of the instruments taken before and during the deployment.

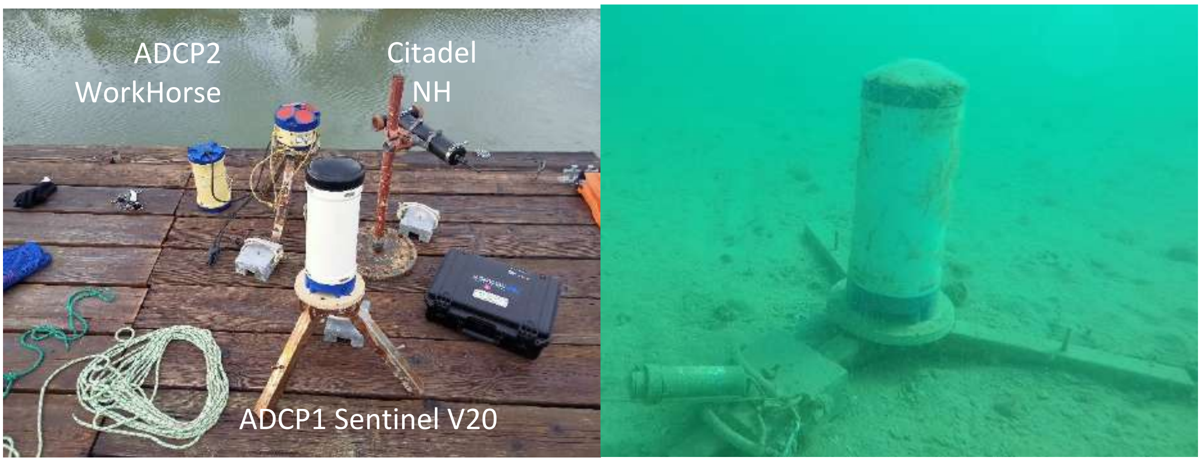


Figure 29. Measuring equipment (Sentinel V20, WorkHorse Monitor and Citadel CTD-NH) before the deployment – left, Sentinel V20 bottom mounted at the location ADCP1 – right

The analysis of the field measurements was conducted by using R programming language while the obtained results will be presented through as it follows:

Surface wind-waves at the location ADCP1 (see Figure 28)

- Time series of the significant wave height, peak wave period and direction

Sea currents and sea level dynamics at the location ADCP1 (see Figure 28)

- General statistic parameters of the total sea current velocity (maximum, average, minimum, standard deviation, and resultant vector)
- Hourly velocity vectors (for three depths d=-1.5m, -4.0m, -6.0m and depth-averaged)
- Velocity components (depth-averaged velocities longitudinal and transversal to the Nin Bay direction of propagation)

- Progressive vector diagram (for three depths d=-1.5m, -4.0m, -6.0m and depth-averaged)
- Spectral density of the sea levels
- Spectral density of velocities

River flow velocities and sea level dynamics at the location ADCP2 (see Figure 28)

- General statistic parameters of the total sea current velocity (maximum, average, minimum, standard deviation, and resultant vector)
- Hourly velocity vectors (for two depths d=-0.2m, -1.2m and depth-averaged)
- Velocity components (depth-averaged velocities longitudinal and transversal to the Miljašić Jaruga main flow direction)
- Progressive vector diagram (for two depths d=-0.2m, -1.2m and depth-averaged)
- Spectral density of the sea levels at the river mouth
- Spectral density of velocities

Temperature and salinity at the location ADCP2 (see Figure 28)

- Time series of the temperature and salinity at the Miljašić Jaruga river mouth

2.5.2 Results of the conducted measurements

Statistical analysis of the measured hourly velocity time series at the locations ADCP1 and ADCP2 (see Figure 28) is presented through five basic statistical parameters presented in the tables below.

Table 23. Statistical parameters of the measured sea current velocities at depths -6.0, -4.0 and -1.5 m, and depth averaged for the location ADCP1 in period Dec 2022 – Feb 2023

Depth	-6.0 m	-4.0 m	-1.5 m	depth-avg
Maximum velocity (cm/s)	18.4	20.1	23.1	21.6
Average velocity (cm/s)	2.9	3.2	4.2	4.0
Standard deviation (cm/s)	2.5	2.8	3.1	2.7
Resultant vector magnitude (m/s)	1.5	1.9	3.7	2.8
Resultant vector direction (°)*	214	236	272	249

*direction is calculated according to the true north

Table 24. Statistical parameters of the measured sea current velocities at depths -1.5 and -0.5 m, and depth averaged for the location ADCP2 in period Dec 2022 – Feb 2023

Depth	-1.5 m	-0.5 m	depth-avg
Maximum velocity (cm/s)	45.6	74.6	62.8
Average velocity (cm/s)	8.2	19.5	13.3
Standard deviation (cm/s)	3.5	12.5	8
Resultant vector magnitude (m/s)	7.1	18.4	10.1
Resultant vector direction (°) *	184	293	253

*direction is calculated according to the true north

Based on the statistical analysis of the measurements obtained at the location ADCP1 (Table 23), maximum, average, and standard deviation of the sea current velocities occur in the subsurface layer (-1.5 m) and continuously decrease as the depth increases. Maximum velocities vary between 18.4 and 23.1 cm/s, average velocities between 2.9 and 4.2 Resultant vector gives the greatest magnitudes in subsurface layer (-1.5 m) with a W as a direction while the lowest values occur at the depth of -6.0 m with direction changed to SSW. Depth averaged resultant vector magnitude is equal to 2.8 cm/s with a WSW direction.

The statistical analysis of the measurements at the location ADCP2 (Table 24) show that in the subsurface layer at depth of -0.5 m recorded velocities obtain maximum of 74.6 cm/s, average 19.5 cm/s and a standard deviation of 12.5 cm/s. Resultant vector obtains value of 18.4 cm/s with a direction of 293° (NW) what is certainly expected considering the main flow direction and the orientation of the river mouth. As the depth increases the resultant vector changes its direction to S at a depth of -1.5 m where its magnitude is equal to 7.1 cm/s. At this depth maximum recorded velocity is 45.6 cm/s while the average and standard deviation are 8.2 and 3.5 cm/s, respectively. Depth averaged velocities obtain a maximum of 62.8 cm/s while the average and standard deviation are equal to 13.3 and 8.0 cm/s, respectively. The resultant vector is directed towards WSW (253°) with a magnitude of 10.1 cm/s.

The analysis of velocity vector time series per each depth as well as depth averaged ones gives the most intuitive graphical representation of the dominant magnitudes and directions of the sea currents. Therefore, for the ADCP1 a velocity vector time series is provided for the depths -6.0, -4.0 and -1.5 m along with depth averaged values. At the location of ADCP2 besides the depth averaged velocity vectors, this graphical presentation is provided for depths of -1.5 m and -0.5 m. Below are presented hourly velocity vectors for two locations (ADCP1 and ADCP2, see Figure 28) for the whole period of field measurement campaign (Dec 2022 – Feb 2023).

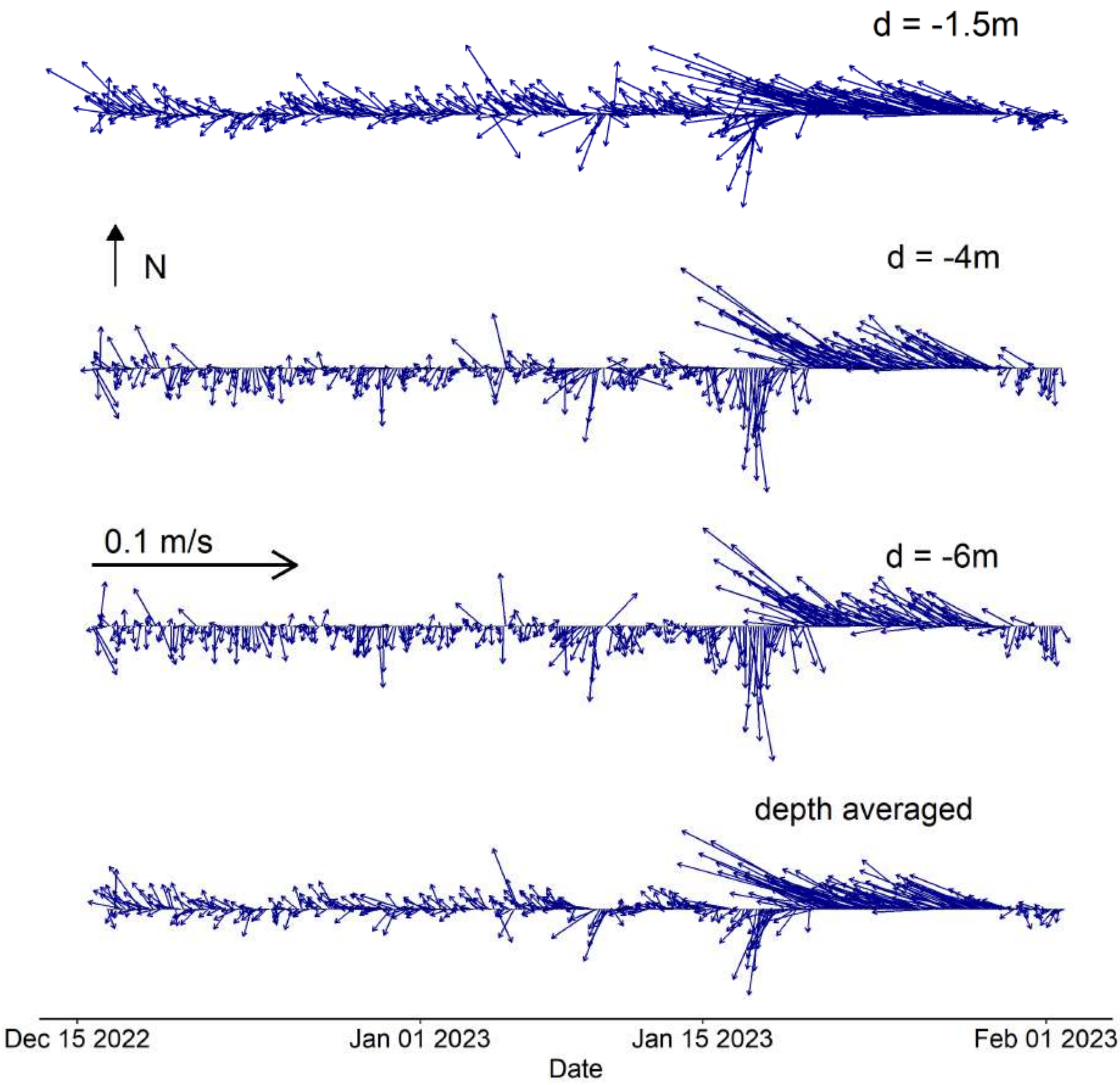


Figure 30. Hourly velocity vectors obtained from the measurements at ADCP1 location in period Dec 2022 – Feb 2023 for depths -6.0, -4.0 and -1.5 m, and depth averaged.

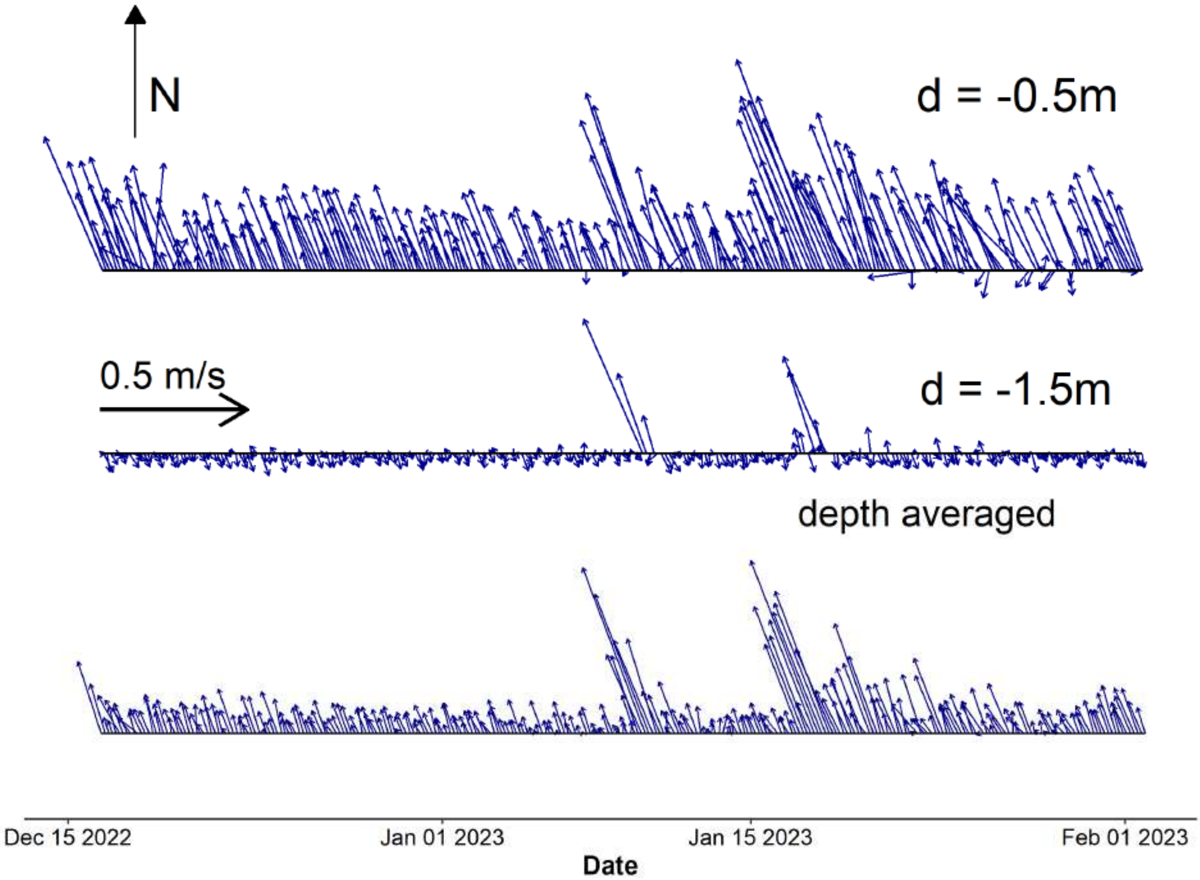


Figure 31. Hourly velocity vectors obtained from the measurements at ADCP2 location in period Dec 2022 – Feb 2023 for depths -1.5 and -0.5 m, and depth averaged.

Based on the measurements recorded on ADCP1, the most intense circulation occurs in the subsurface layer in W-NW direction what is mainly influenced by the shape of the Nin Bay as well as the influence of the Miljašić Jaruga flow due to the vicinity of ADCP1 to the river mouth. As the depth increases, in the mid-December to mid-January period sea circulation changes its direction to S and afterwards follows the circulation pattern of the subsurface layer. Depth averaged hourly velocity vector show that the sea circulation pattern dominantly follows the circulation pattern of surface layers.

Measurements at the location ADCP2 show that the highest river flow velocities are present in subsurface layer while they decrease as the depth increases. Furthermore, flow direction changes from NW at depth of -0.5 m to SE at -1.5 m. Depth averaged velocity vector time series generally follow the pattern of the hourly vectors in the subsurface layer (Figure 30).

Following paragraph provides the insight in the velocity components in the longitudinal and transversal direction for the two locations. For the location of ADCP1 a longitudinal direction corresponds to the direction of propagation of Nin Bay (322° according to true north) while for the ADCP2 a longitudinal direction is considered as the main river flow direction (345° according to true north). The schematic of the considered velocity components is presented below in Figure 32.

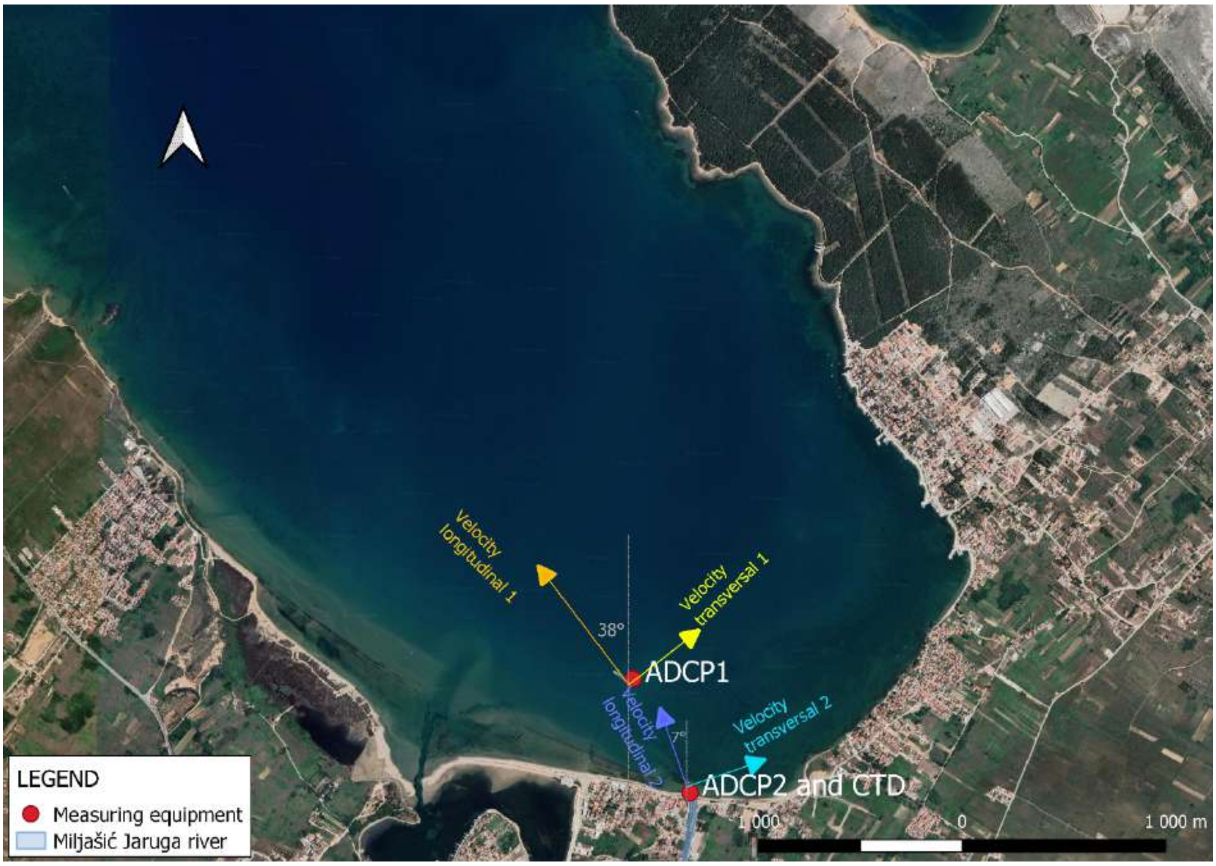


Figure 32. Schematic of the longitudinal and transversal velocity components for ADCP1 and ADCP2 location presented in plain view of the study area.

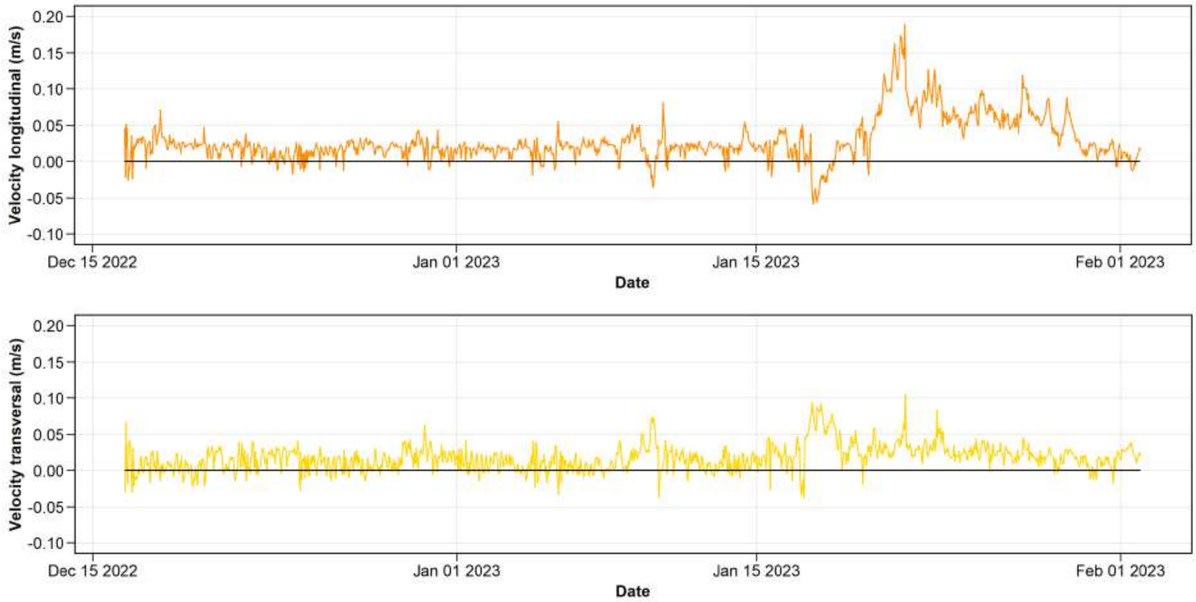


Figure 33. Hourly longitudinal and transversal velocity components time series for ADCP1 in period Dec 2022 – Feb 2023

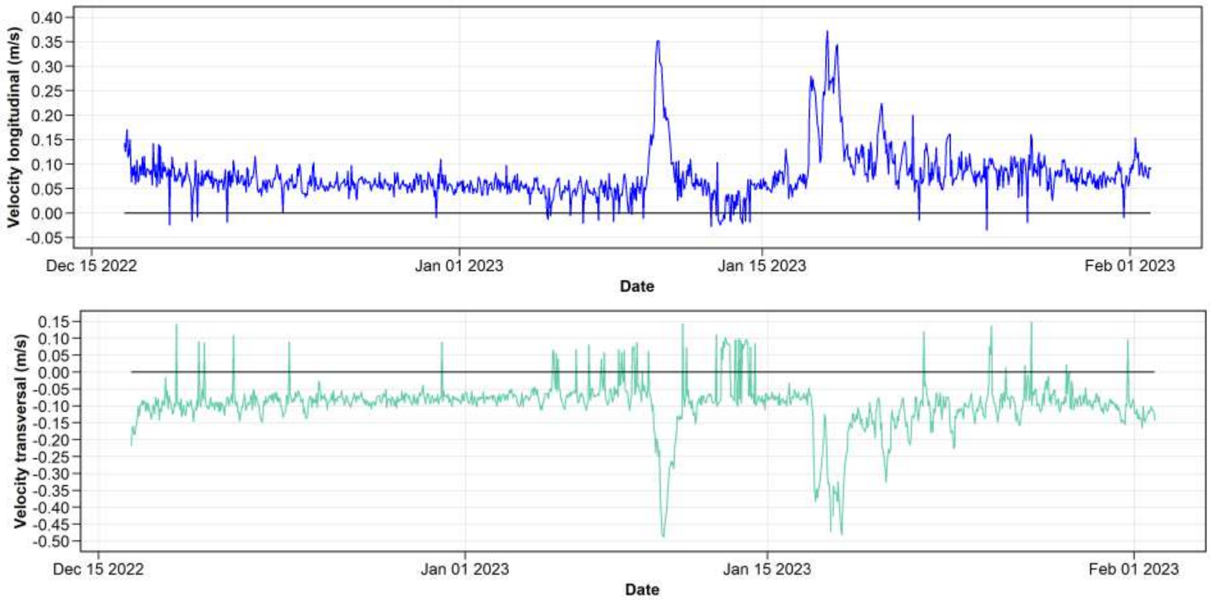


Figure 34. Hourly longitudinal and transversal velocity components time series for ADCP2 in period Dec 2022 – Feb 2023

The time series of the longitudinal and transversal velocity components at the location ADCP1 follows the previously discussed results as the Figure 33 shows that dominant sea current occurs in the W-NW direction with maximum longitudinal velocity equal to 18.9 cm/s.

Similarly, the time series of the longitudinal and transversal velocity components at the location ADCP2 follows the previously discussed results as the Figure 34 shows that dominant river flow occurs in the NW direction with maximum longitudinal velocity equal to 35.0 cm/s.

Progressive vector diagram is calculated and presented under the assumption that a particle dispersed in a liquid would travel constantly with the measured velocity within the period of one hour. Under this assumption, the particle displacement within a period of one hour can be calculated for any depth as well as depth averaged. By calculating a cumulative sum of the previously calculated hourly displacements, a trajectory of a particle is drawn, providing useful insight into the main flow direction for the depth average and velocities at different depths. Below are presented the progressive vector diagrams for the two location of velocity measurements – ADCP 1 and ADCP2 (see Figure 28).

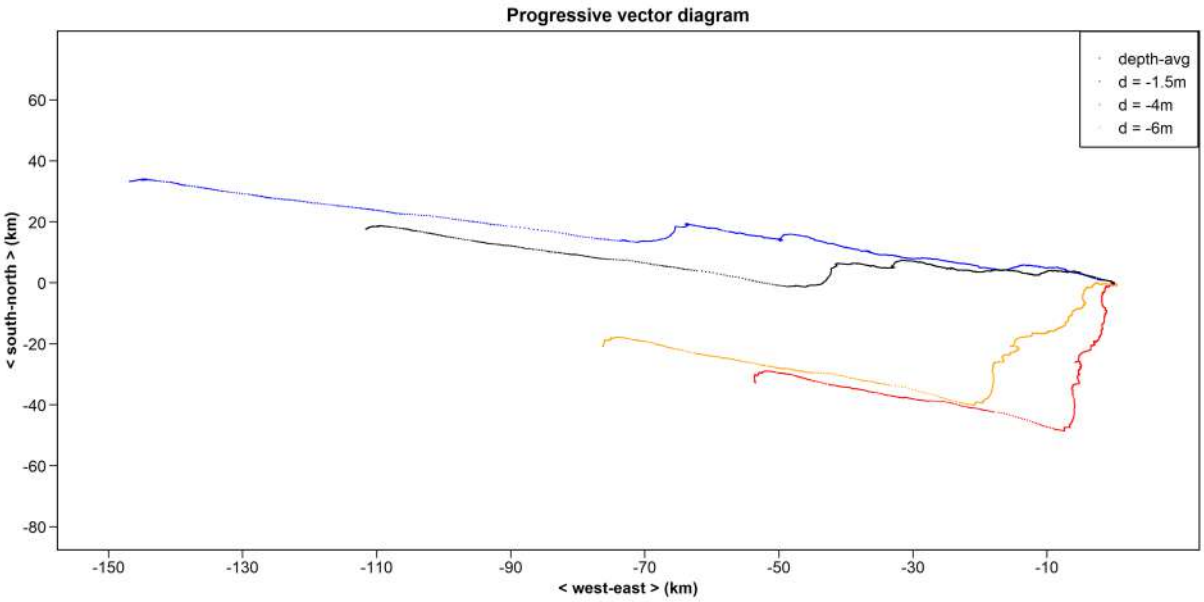


Figure 35. Progressive vector diagram for velocities on three depths (-6.0, -4.0 and -1.5 m) and depth averaged velocities measured at the location ADCP1 in period Dec 2022 – Feb 2023

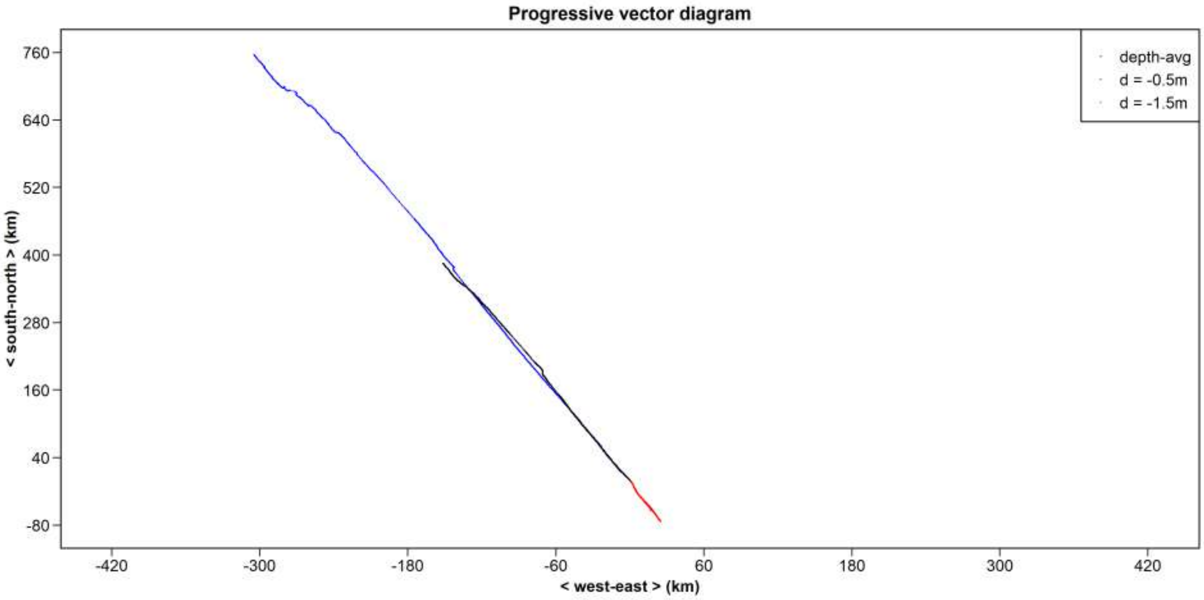


Figure 36. Progressive vector diagram for velocities on two depths (-1.5 and -0.5 m) and depth averaged velocities measured at the location ADCP2 in period Dec 2022 – Feb 2023

Progressive vector diagrams for ADCP1 (Figure 35) and ADCP2 (Figure 36) confirm the previously discussed results of the analysed measurements. For both locations highest velocities occur in subsurface area (ADCP1 at -1.5 m and ADCP2 at -0.5 m) with dominant direction in WNW for ADCP1 and NW for ADCP2. Depth averaged progressive vector diagrams generally follow the previously described pattern. At lower depths (-4 m and -6 m) two directions stand out as dominant – SW and WNW what is in line with the previously discussed results and plots (Table24, Table 25, Figure 30, Figure 31, Figure 34, Figure 35).

The following section provides information on spectral analysis of sea level and velocities. It is important to note that the spectral analysis of sea level is only calculated for the dynamics of sea level change recorded with ADCP1. It is considered that it is not necessary to show the results of this analysis for the sea level measurements at both profilers, as there is a negligible difference for this parameter at the two sites. Below is presented a sea level time series obtained at the ADCP1 location (see Figure 28) for the whole recording period (Dec 2022 – Feb 2023). Also, the results of the calculated power spectrum density of the sea level are provided below.

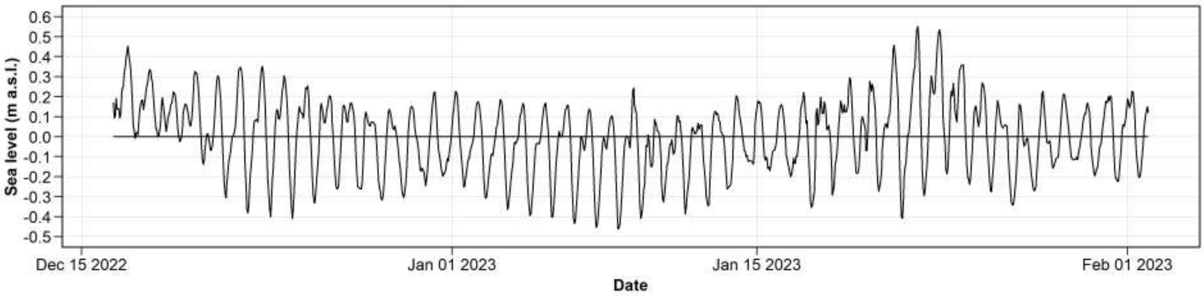


Figure 37. Hourly sea level time series recorded on ADCP1 in period Dec 2022 – Feb 2023

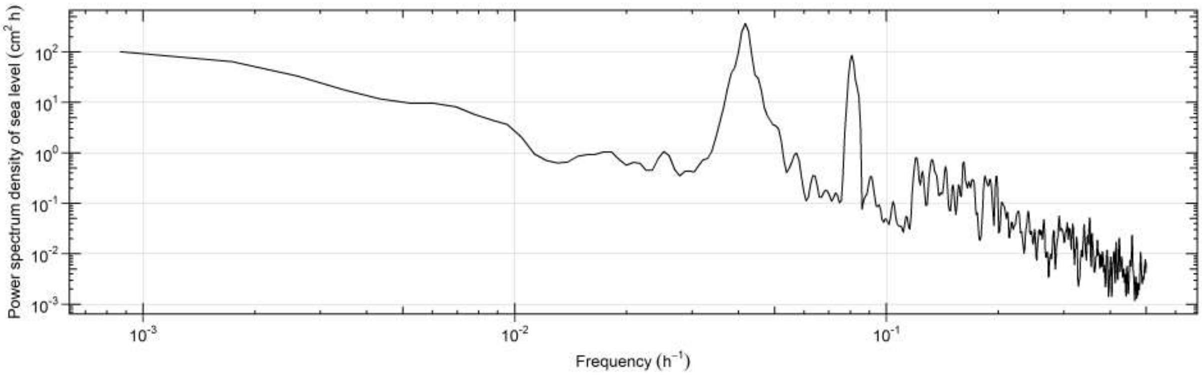


Figure 38. Power spectrum density of sea level recorded on ADCP1 in period Dec 2022 – Feb 2023

Power spectrum density of the recorded sea level shows two peak in 24 h and 12 h tidal which refers to the diurnal and semidiurnal periods. For this period of measurement, most of the energy is generated by the effect of tidal oscillations.

Below are presented the power spectrum densities for the velocities measured on ADCP1 and ADCP2. As it was discussed earlier, the spectral analysis is conducted for depth averaged as well as for velocities at the depths of -1.5, -4.0 and -6.0 m for ADCP1 and at the depths of -0.5 and -1.5 m for ADCP2.

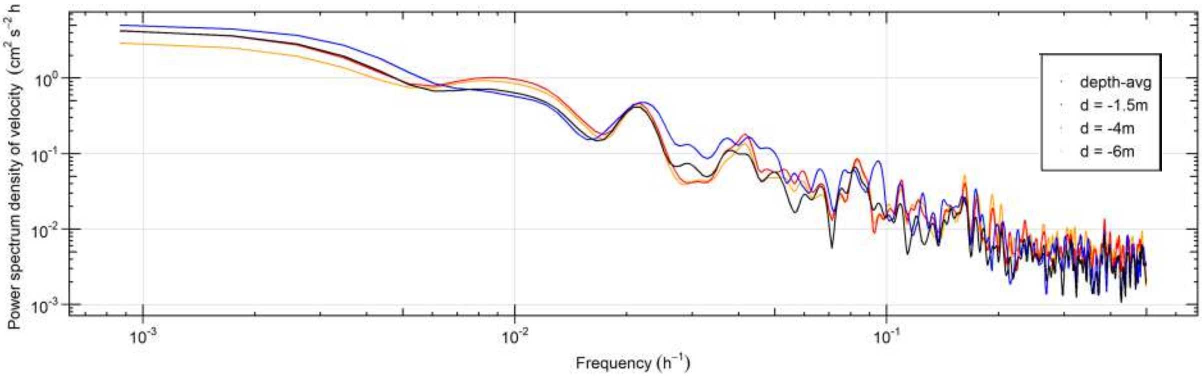


Figure 39. Power spectrum density of velocities recorded on ADCP1 in period Dec 2022 – Feb 2023

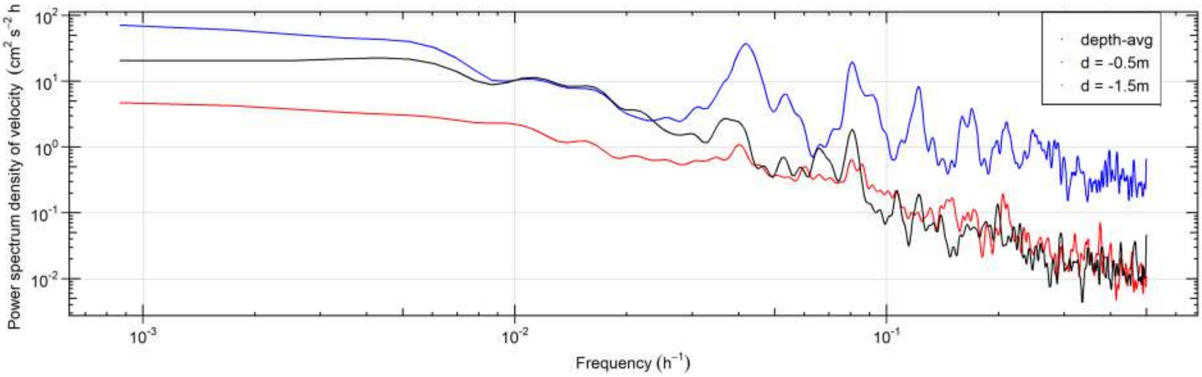


Figure 40. Power spectrum density of velocities recorded on ADCP2 in period Dec 2022 – Feb 2023

Spectral analysis of the velocities recorded at the ADCP1 location shows no significant differences between different depths as well as for depth averaged values. At depths of -4.0 and -6.0 m both diurnal (24 h) and semidiurnal (12 h) components of tidal oscillation are noticeable. For the ADCP2 location subsurface velocities (-0.5m) provide significantly higher power spectral density values when compared to bigger depths what is mainly related to the continuous flow from Miljašić Jaruga to Nin Bay and highest velocities at this depth. Also, both diurnal and semidiurnal components are evident at this location at depth of -0.5 m during period between Dec 2022 and Feb 2023. These components of tidal oscillations are noticeable for spectral analysis of depth average velocities at this location.

The following paragraph gives the description of the measured parameters that describe dynamics of the surface wind-waves. The results will be presented through the time series of the measured significant wave height, peak wave period and direction.

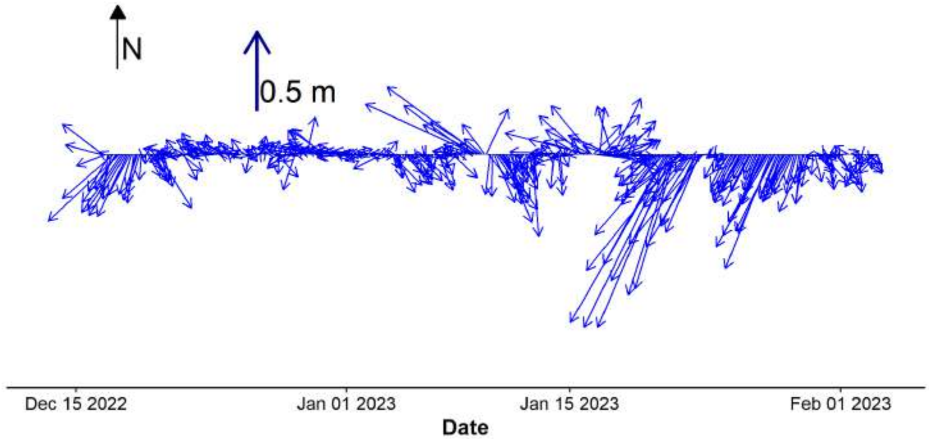


Figure 41. Hourly significant wave height vectors obtained from the measurements at ADCP1 location in period Dec 2022 – Feb 2023

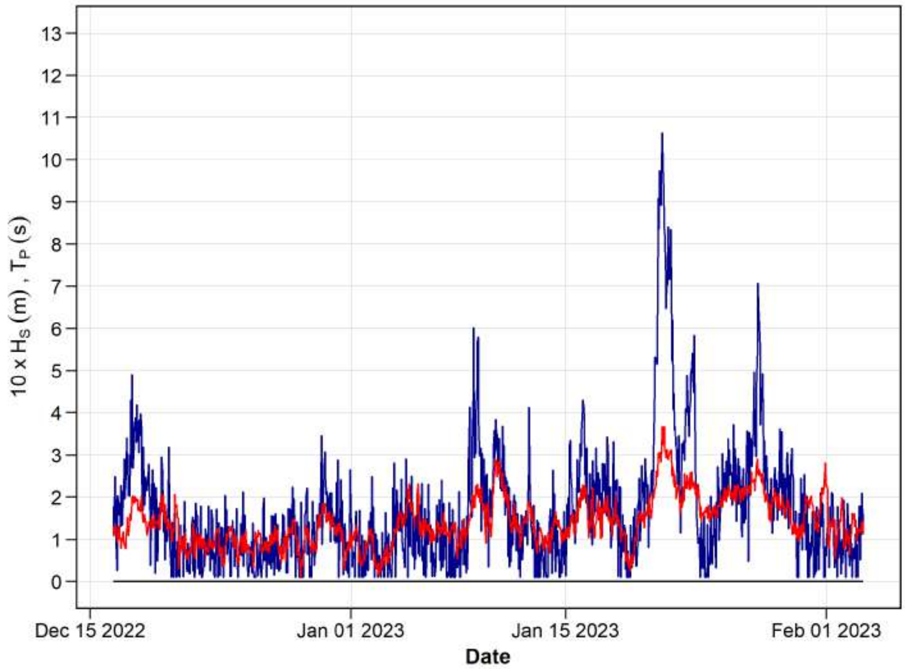


Figure 42. Time series of significant wave height multiplied by 10 (dark blue line) and peak wave period (red line) recorded on ADCP1 in period Dec 2022 – Feb 2023

The graphs above show that a wave event that was recorded on January 21st, 2023, from direction NNE with a maximum significant wave heigh $H_S = 1.06$ m and a peak wave period of 3.67s (see Figure 41, Figure 42).

The last paragraph of the field measurement campaign includes the description of temperature and salinity data that was measured by CTD probe at the location presented in Figure 28. Below are presented the time series of the two parameters.

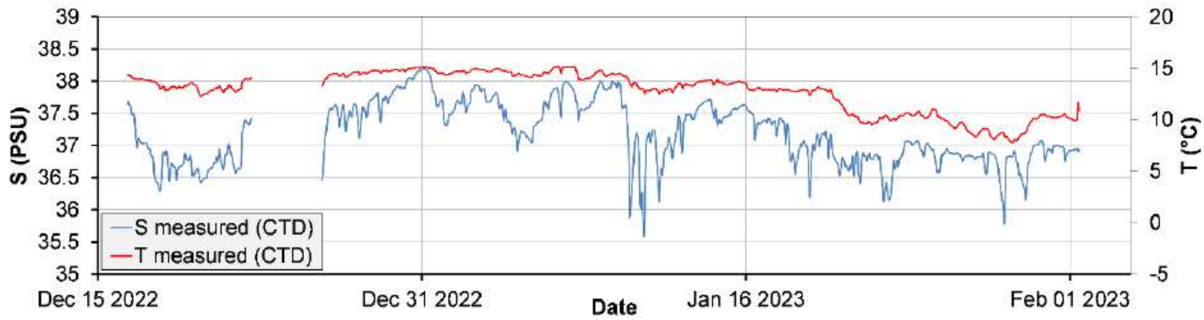


Figure 43. Time series of temperature and salinity measured with CTD probe at depth of -2.5 m and location ADCP2

The previous graph points out that there was a malfunction in CTD probe operation in period Dec 22nd – Dec 26th. The salinity time series shows a significant drop which during January 10th, 2023, when an increase in discharge rate in Miljašić Jaruga river was present after a precipitation episode on the river basin. As it can be seen salinity varies between 35.5 and 38.3 PSU what leads to conclusion that dominantly sea water was present at the depth of the probe deployment.

The short-term variations in temperature are not so significant as for the salinity. Two periods of temperature change can be seen from the Figure 43. – one from the start of measuring period to 19th January 2023 where temperature varied around the average of 13 °C what is followed with a temperature drop and variation around 10 °C until the end of the measurements.

2.6 Northern-eastern Adriatic in Croatia (HR)

Center for Marine Research, Ruder Boskovic Institute had an old oceanographic buoy installed at the similar position as the new buoy installed in the CASCADE project and it was integrated in the long-term monitoring of the eastern Adriatic in the period from year 2003 to 2020. New oceanography buoy enabled significant improvements of the measuring parameters and data collection and will also be integrated in the monitoring system of the eastern Adriatic.

New oceanographic buoy (Figure 44) is installed in the north-eastern Adriatic Sea on the position 5nm from the coast of Croatia (Lat: 45° 4' 31.7712'' N, Lon: 13° 35' 56.3208'' E). In the automatic identification system (AIS) of marine safety and traffic, the installed buoy was named CIM ODAS II. The buoy is 3 m in diameter and has a platform large enough for two people to work on the buoy. The platform allows access to all installed maintenance and measurement instruments. Buoy provides fixed structure for attaching underwater sensors and placing other sensors, electrical and communication equipment at sea. The buoy is adapted to power systems of solar and wind charging and includes charge regulators and batteries. Oceanographic buoy is equipped with meteorological sensors (wind direction and speed, air temperature, relative humidity, atmospheric pressure, solar irradiation, precipitation, air visibility sensor), compass, 360 ° camera, GPS and GSM system and LED marine lantern for visibility at night (intensity of 5 NM). Measurements of physical and chemical sea parameters on the buoy include Acoustic Doppler Current Profiler (ADCP), wave sensor, surface current measurement sensor, PCO_2 sensor, sea temperature, conductivity (salinity), dissolved oxygen, light transmission meter sensor, pH sensor, soluble organic fluorescence (FDOM), phytoplankton pigment sensors (phycocyanin, phycoerythrin, Chlorophyll A and backscatter Red sensor, backscatter blue sensor).

Data collection is near-real-time and will be shared for Cascade project activities and provided free of charge on the Center for Marine Research (RBI) specific web page. Oceanographic buoy measurements provide an integrated dataset across all platforms and datatypes.

Table 25. Screen shot from AIS with the position of the buoys and measuring sensors/equipment characteristics.

<table>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Monitored Area</td><td>Northern Adriatic
(1 and 5 nm, Rovinj, HR)</td></tr>
</table>

Monitoring starting date	17/11/2022
Monitoring period	December 2022 – June 2023 (2 per day)
Number of instruments	7 meteorological camera, compass, 12 oceanographic sensors (CTD, ecc)
Total investment	1 200 000 Euro (4 projects together Cascade part 270 000)
Site localization	Lat = 45.07394 E Lon = 13.5144 N
Instrumental type	Oceanographic buoy- multiple sensors
Dimension	Probe height: Probe diameter: 3 m
Power supply	batteries
Communication	WiFi/GPRS
Sampling frequency	Several times per day
Sensor installed	Acoustic Doppler Current Profiler (ADCP), wave sensor, surface current measurement sensor, PCO_2 sensor, sea temperature, conductivity (salinity), dissolved oxygen, light transmission meter sensor, pH sensor, soluble organic fluorescence (FDOM), phytoplankton pigment sensors (phycocyanin, phycoerythrin, Chlorophyll A and backscatter Red sensor, backscatter blue sensor). meteorological sensors (wind direction and speed, air temperature, relative humidity, atmospheric pressure, solar irradiation, precipitation, air visibility sensor), compass, 360 ° camera, GPS and GSM system and LED marine lantern for visibility at night (intensity of 5 NM).

Figure 44. CIM ODAS 2 Oceanographic buoy

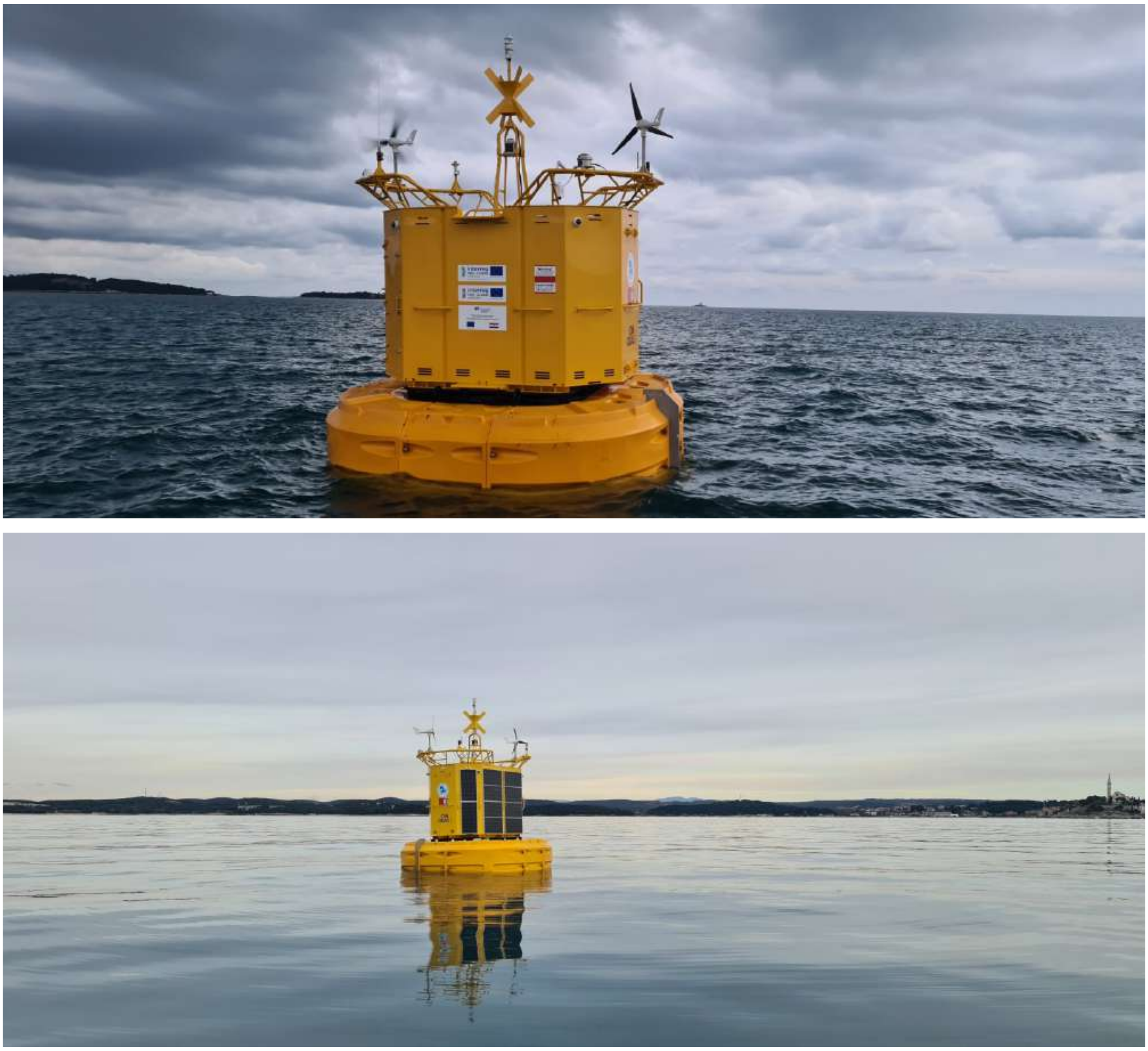


Figure 45. CIM ODAS 1 Oceanographic buoy

2.7 Cetina River mouth (HR)

Table 26. Equipment and instrumentation characteristics of multiparametric sonde onboard an anchored buoy

PP15 - PUBLIC INSTITUTION FOR THE MANAGEMENT OF PROTECTED AREAS IN THE AREA OF SPLIT-DALMATIA COUNTY SEA AND KARST

Monitored Area	Cetina Estuary (HR3000126)
Monitoring starting date	*to be set up*
Monitoring period	*to be set up*
Number of instruments	1
Total investment	4.356,16€
Site localization	*to be set up*
Instrumental type	Multiparametric sonde onboard an anchored buoy
Dimension	Length: 46 cm (18.145”) (includes connector) With bail: 59 cm (23.25”) Diameter: 4.7 cm (1.860”) *Buoy high: to be set up* *Buoy diameter: to be set up*
Power supply	6 alkaline batteries type D
Communication	Wireless
Sampling frequency	*to be set up*
Sensor installed	Temperature Conductivity/Salinity Dissolved Oxygen

Table 27. General characteristics and all parameters obtained from the Aqua troll 500 multiparameter sonde.

GENERAL	AQUA TROLL 500 MULTIPARAMETER SONDE		
OPERATING TEMP. (NON-FREEZING)	-5 to 50°C (23 to 122°F) ISE: Ammonium and Nitrate 0 - 40°C, Chloride 0 - 50°C	EXTERNAL POWER VOLTAGE EXTERNAL POWER CURRENT[1]	8-36 VDC; Required for normal operation Sleep: < 0.2 mA typical; Measurement: 40 mA typical, 75 mA Max
STORAGE TEMP.	Components Without Fluid -40°C to + 65°C (Non Freezing Water) pH/ORP Sensors -5°C to +65°C Ammonium/Nitrate: 0 - 40°C Chloride: 0 - 50°C	INTERNAL MEMORY AND DATA LOGGING	Use external datalogger or telemetry
DIMENSIONS	Length: 46 cm (18.145") (includes connector). With bail: 59 cm (23.25") Diameter: 4.7 cm (1.860")	READING RATES	1 reading every 2 seconds
WEIGHT	0.978 kg / 2.15 lbs. (includes instrument, sensors, restrictor and bumpers)	COMMUNICATION DEVICE	Wireless TROLL Com
WETTED MATERIALS (SONDE AND SENSORS)	PC, PC alloy, Delrin, Santoprene, Inconel, Viton, Titanium, Platinum, Ceramic, Nylon, PVC, Graphite	CABLE OPTIONS	Vented or non-vented polyurethane or vented Tefzel®
SENSOR HEX SCREW DRIVER	0.050, 1.3 mm	LCD DISPLAY	Integrated display shows status of sonde, sensor ports, power voltage and connectivity, enable/disable BT.
ENVIRONMENTAL RATING	IP68 with all sensors and cable attached IP67 without the sensors or cable attached	SOFTWARE	Android: VuSitu through Google Play Windows: Win-Situ 5 Data Services: HydroVu
MAX PRESSURE RATING	Up to 150 PSI Ammonium/Nitrate up to 30PSI	INTERFACE	Android 4.4, requires BlueTooth 2.0
OUTPUT OPTIONS	RS-485/MODBUS, SDI-12, Bluetooth	CERTIFICATIONS	CE, FCC, WEEE, RoHS Compliant

STANDARD SENSORS	ACCURACY	RANGE	RESOLUTION /PRECISION	RESPONSE TIME	UNITS OF MEASURE	METHODOLOGY
TEMPERATURE[2]	+/- 0.1°C	-5 to 50°C (23 to 122°F)	0.01°C	T63<2s, T90<15s, T95<30s	Celsius or Fahrenheit	EPA 170.1
CONDUCTIVITY[5] -TDS (TOTAL DISSOLVED SOLIDS) -SALINITY	±0.5% of reading plus 1 µS/cm from 0 to 100,000 µS/cm; ±1.0% of reading from 100,000 to 200,000 µS/cm; ±2.0% of reading from 200,000 to 350,000 µS/cm	0 to 350,000 µS/cm 0-350 ppt 0-350 PSU	0.1 µS/cm 0.1 ppt 0.1 PSU	T63<1s, T90<3s, T95<5s	Actual conductivity (µS/cm, mS/cm); Specific conductivity (µS/cm, mS/cm); Salinity (PSU, ppt); Total dissolved solids (ppt, ppm); Resistivity (Ohms-cm); Density (g/cm3)	Std. Methods 2510, EPA 120.1 Std. Methods 2520A
RUGGED DISSOLVED OXYGEN (RDO) WITH RDO-X OR FAST CAP[6]	±0.1mg/L +/-2% of reading	0 to 20 mg/L 20 to 60 mg/L	0.01 mg/L	RDO-X: T63<15s, T90<45s, T95<60s Fast Cap: T63<1s, T90<15s, T95<30s	mg/L, %saturation, ppm	EPA-approved In-Situ Methods: 1002-8-2009, 1003-8-2009, 1004-8-2009

To acquire information on the hydrodynamics between freshwater and coastal water an in situ multiparameter probe Aqua TROLL 500 was placed at the Shallow mark at 5 m depth (Fig. 46). It acquires data on temperature, salinity, and dissolved oxygen. Data are continuously transmitted to Public Institution Sea and Karst through a set of elements for telemetric data download from an in situ multiparameter probe. Data stored on Pileus server (https://meteo.pileus.si/) can be accessed, processed, and downloaded through internet. Measurements are taken next to the Cymodocea nodosa meadow and in vicinity of resistant Noble Pen shell (Pinna nobilis) individual, and at the location under strong influence of the Cetina River freshwater.

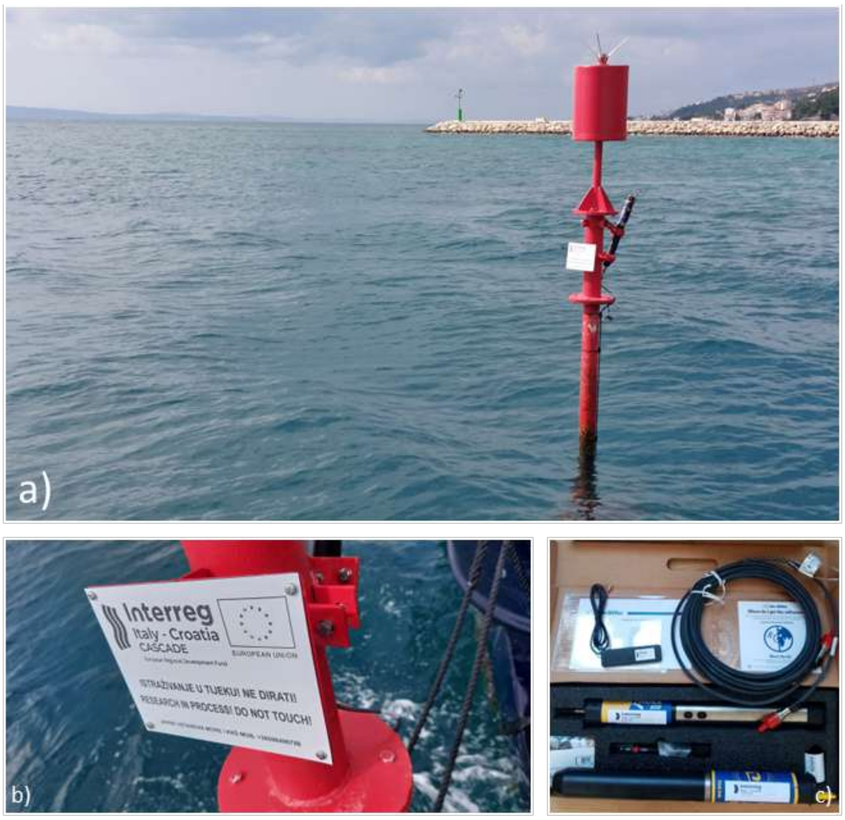


Figure 46. Aqua troll 500 multiparameter sonde: vu-link system of the sonde mounted onboard Velika plaža shallow mark (a), visibility elements of CASCADE project displayed at the shallow mark (b) and (c) all the elements of the sonde (from the bottom to the up: vu-link system, multiparametric sonde, cable, and antenna). Photo credit: J. Kurtović Mrčelić

Table 28. Equipment and instrumentation characteristics of HOBO Pendant

PP15 - PUBLIC INSTITUTION FOR THE MANAGEMENT OF PROTECTED AREAS IN THE AREA OF SPLIT-DALMATIA COUNTY SEA AND KARST

SITE DISPLAY

Monitored Area	Cetina Estuary (HR3000126)
Monitoring starting date	July 16 2022 at 1 am
Monitoring period	1 year
Number of instruments	12
Total investment	1.053,51€
Site localization	Mala Luka (Balića rat) 43.414947, 16.717642
Instrumental type	HOBO Pendant® Temperature/Light 64K Data Logger
Dimension	58 x 33 x 23 mm (2.3 x 1.3 x 0.9 inches)
Power supply	1 CR2032 Type Lithium Battery
Communication	Optic USB interface
Sampling frequency	1 hour
Sensor installed	Temperature Light

Table 29. General characteristics and all parameters obtained from the HOBO Pendant

Measurement Range	**Temperature:** -20° to 70°C (-4° to 158°F) **Light:** 0 to 320,000 lux (0 to 30,000 lumens/ft^2)
Accuracy	**Temperature:** ± 0.53°C from 0° to 50°C (± 0.95°F from 32° to 122°F), see Plot A in manual **Light intensity:** Designed for measurement of relative light levels, see Plot D for light wavelength response
Resolution	**Temperature:** 0.14°C at 25°C (0.25°F at 77°F), see Plot A in manual **Drift:** Less than 0.1°C/year (0.2°F/year)

Response Time	**Airflow of 2 m/s (4.4 mph):** 10 minutes, typical to 90% **Water:** 5 minutes, typical to 90% **Time accuracy:** ± 1 minute per month at 25°C (77°F), see Plot B in manual
Operating Range	**In water/ice:** -20° to 50°C (-4° to 122°F) **In air:** -20° to 70°C (-4° to 158°F) **Water depth rating:** 30 m from -20° to 20°C (100 ft from -4° to 68°F), see Plot C in manual **NIST traceable certification:** Available for temperature only at additional charge; temperature range -20° to 70°C (-4° to 158°F) **Battery life:** 1 year typical use **Battery Type:** CR2032
Memory	**UA-002-08:** 8K bytes (approximately 3.5K combined temperature and light readings or events) **UA-002-64:** 64K bytes (approximately 28K combined temperature and light readings or events)
Other	**Materials:** Polypropylene case; stainless steel screws; Buna-N o-ring **Weight:** 18 g (0.6 oz) **Dimensions:** 58 x 33 x 23 mm (2.3 x 1.3 x 0.9 inches **Environmental Rating:** IP68

HOBO® Pendant temp/light dataloggers were launched using the base station with the appropriate coupler connected to the computer and set up to record seawater temperature every hour, starting from July 16 2022 at 1 am. In total 6 data loggers were placed from 5 m down to a 30 m depth (Figure 47-53), last one 2 m below the lower depth limit of the cushion coral *Cladocora caespitosa* reef. A serial number of each data logger fixed at a specified depth is indicated in Table 30. First recovery (and placement back into the sea) of the dataloggers will be done in July 2023.

Table 30. Serial numbers of HOBO® Pendant temp/light data logger placed at 6 depths, from 5 to 30 m at the site Mala Luka (Balića rat) close to Omiš.

Depth (m)	Data logger's serial number
5	21237184
10	21237185
15	21237183
20	21237190
25	21237188
30	21237193

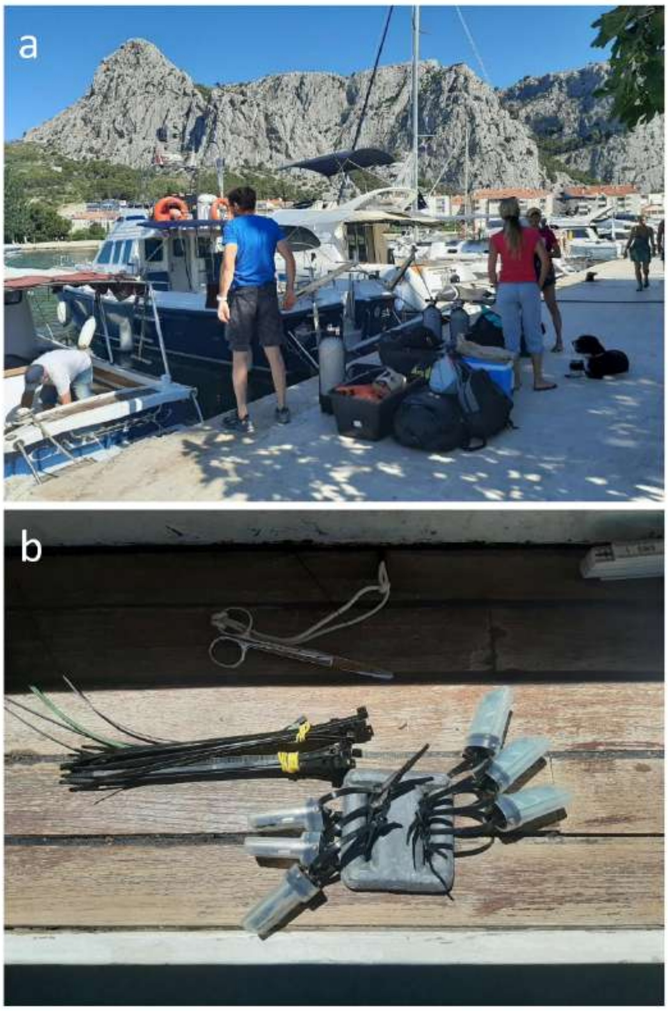


Figure 47. Initial phase to set up a new seawater temperature monitoring site: a) embarking SCUBA equipment on the boat, b) preparing necessary material to place data loggers underwater - zip ties were used to attach them to the rocky bottom or concrete blocks. Note: data loggers have positive buoyancy and should be handled with care. Photo credit: S. Kipson.

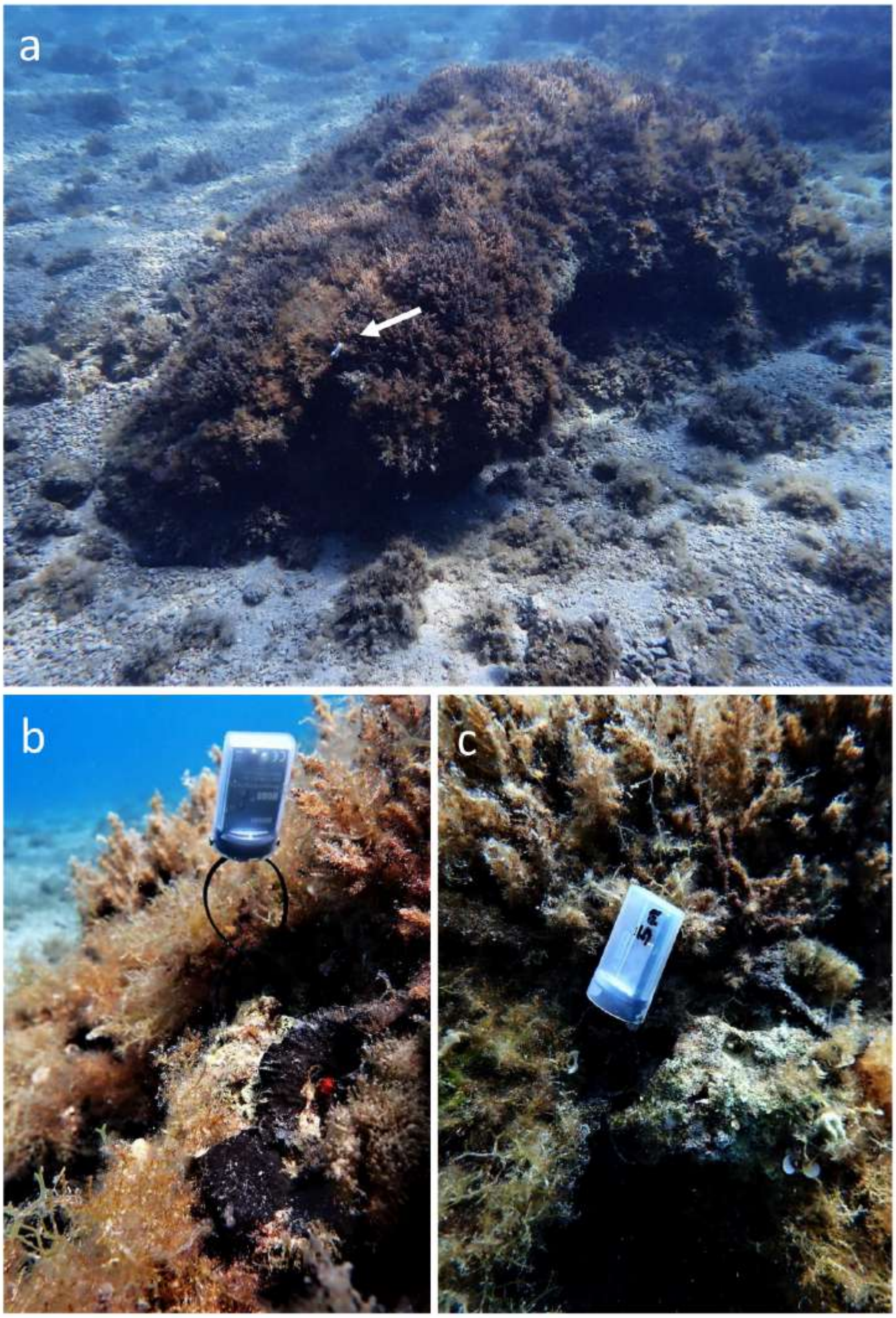


Figure 48. HOBO® Pendant temp/light data logger placed at 5 m depth: a) position of the data logger on the boulder (white arrow, image taken from approx. 6 m depth), b) black keratose sponge (lower right corner) thriving next to the data logger, c) detail of the data logger with a serial number 21237184. Photo credit: S. Kipson.

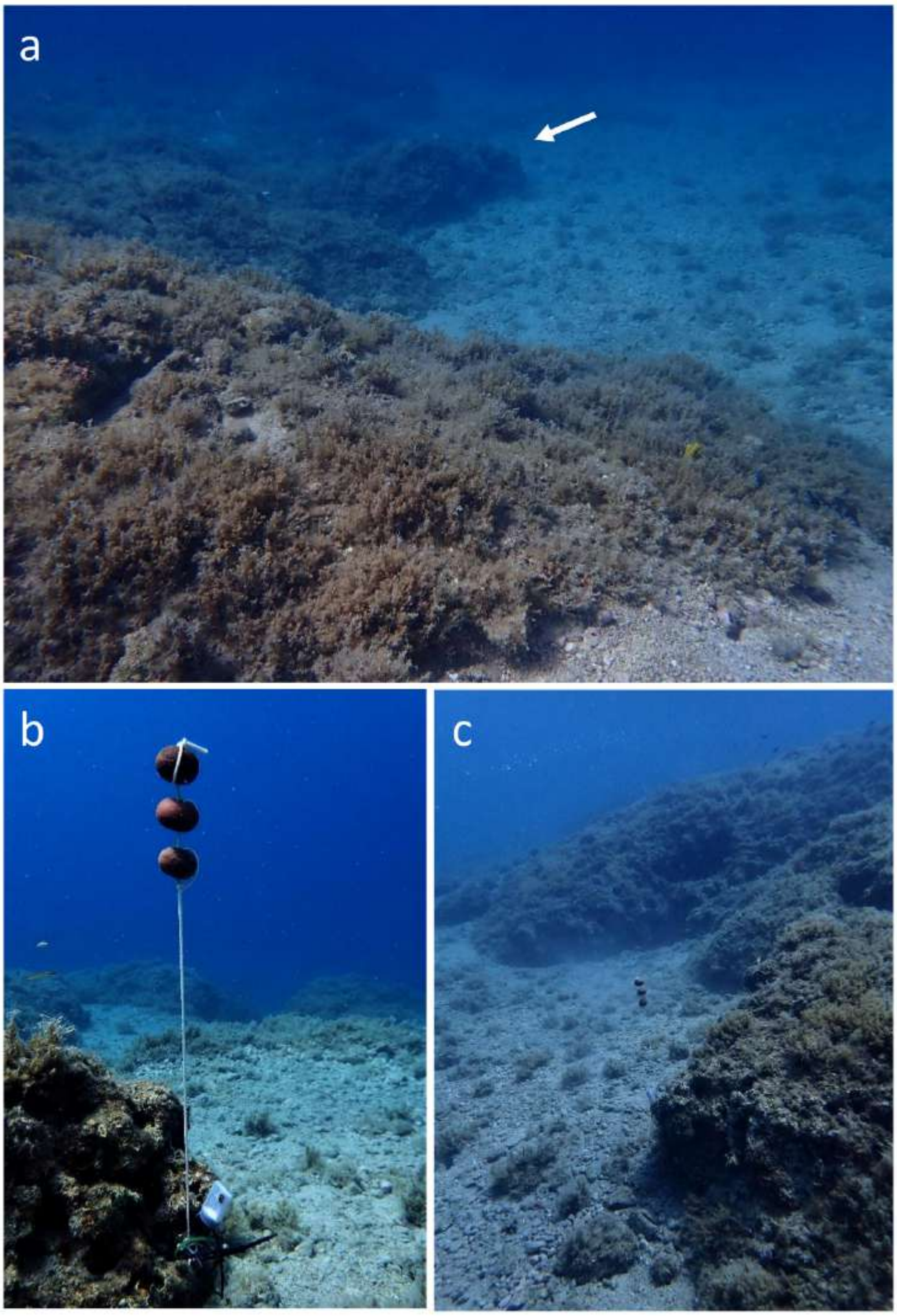


Figure 49. HOBO® Pendant temp/light data logger placed at 10 m depth: a) a view of the rocky substrate on descends towards the data logger position (white arrow), b) a small buoy left to mark the data logger with a serial number 21237185, c) a view of the data logger from approx. 11 m depth. Photo credit: S. Kipson.

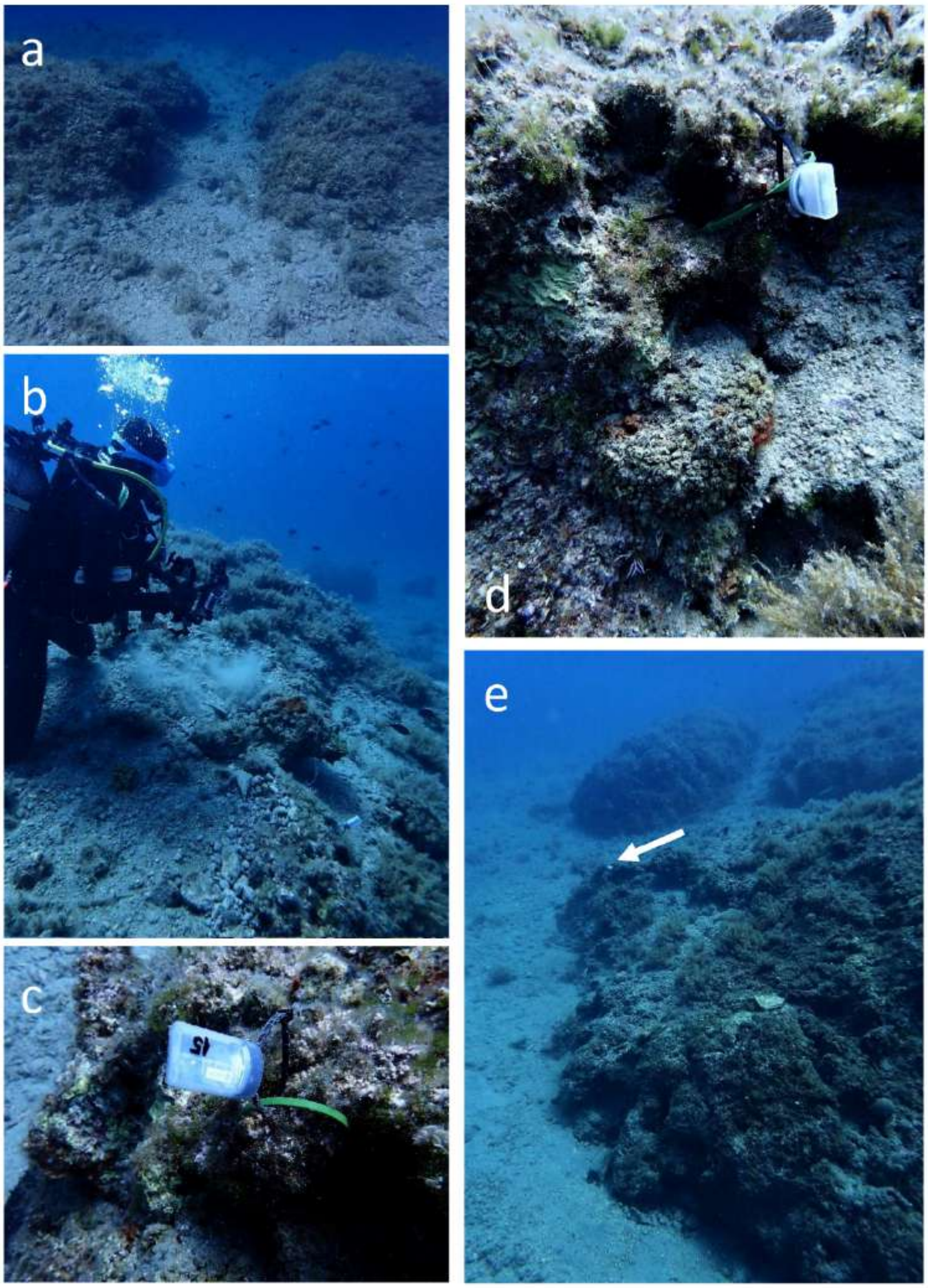


Figure 50. HOBO® Pendant temp/light data logger placed at 15 m depth: a) two characteristic rocks on descend towards the position of the datalogger at 15 m depth, b) position of the datalogger on the rock, c) detail of the data logger with the serial number 21237183, d) a small colony of Cladocora caespitosa below the data logger fixation point, e) view of the data logger (white arrow) and two characteristic rocks in the background (image taken from a position at 16-17 m depth). Photo credit: S. Kipson.

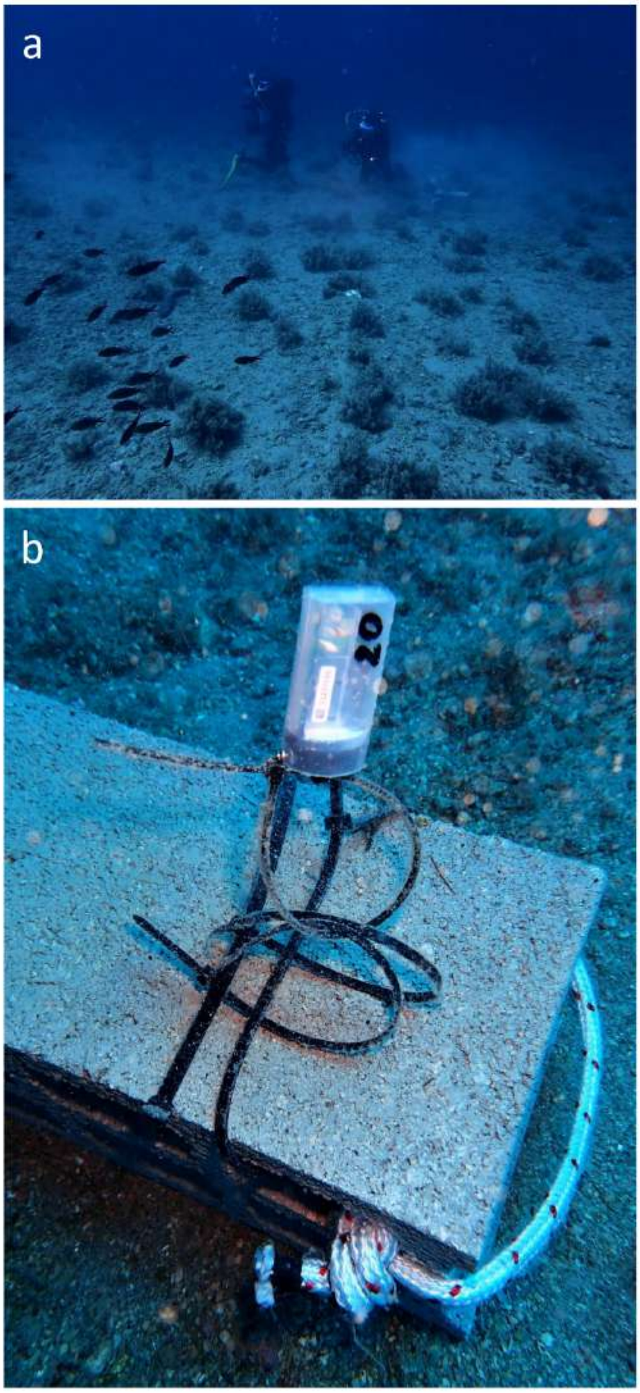


Figure 51. HOBO® Pendant temp/light data logger placed at 20 m depth: a) the sea bottom below 18 m depth is devoid of larger rocks, hence a concrete block was placed as a fixation point for the data logger, b) detail of the data logger with a serial number 21237190. Photo credit: S. Kipson.

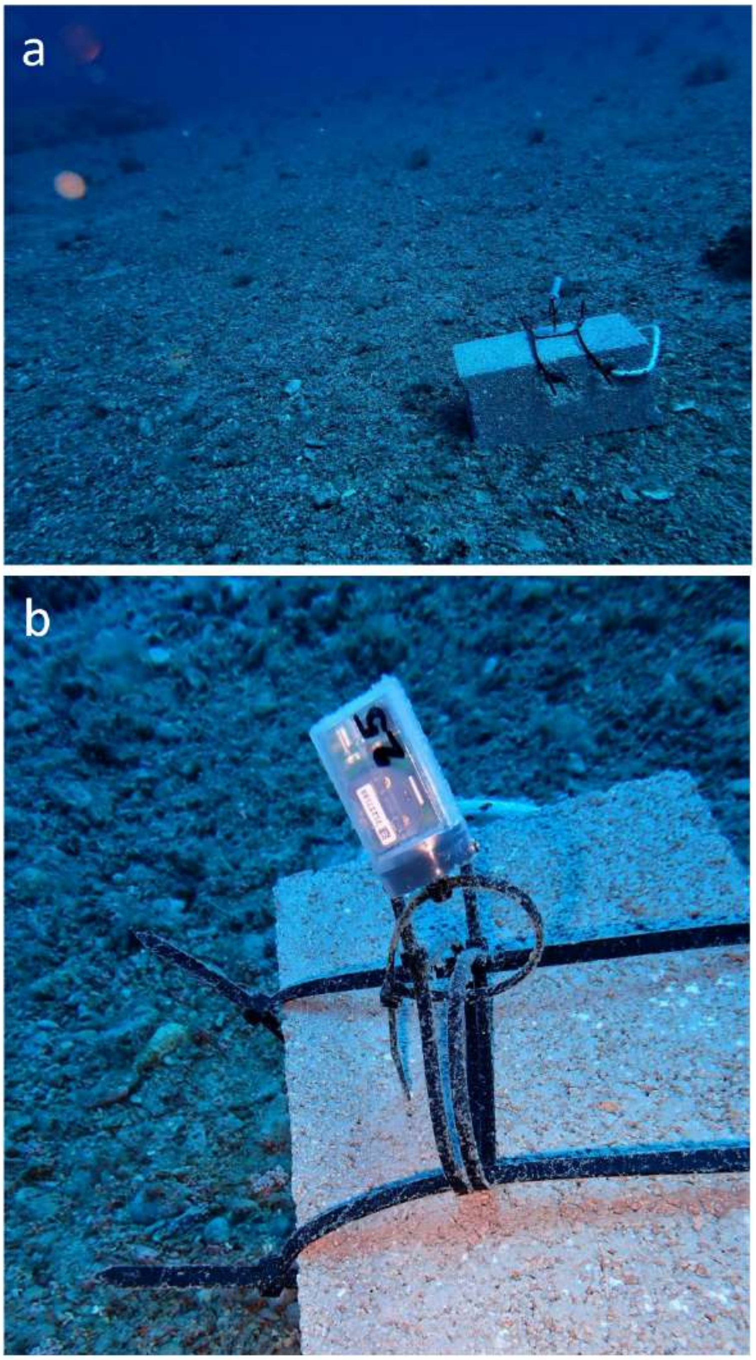


Figure 52. HOBO® Pendant temp/light data logger placed at 25 m depth: a) the position of the data logger in relation to the upper part of the Cladocora caespitosa reef (in the upper left corner), b) detail of the data logger with a serial number 21237188. Photo credit: S. Kipson.

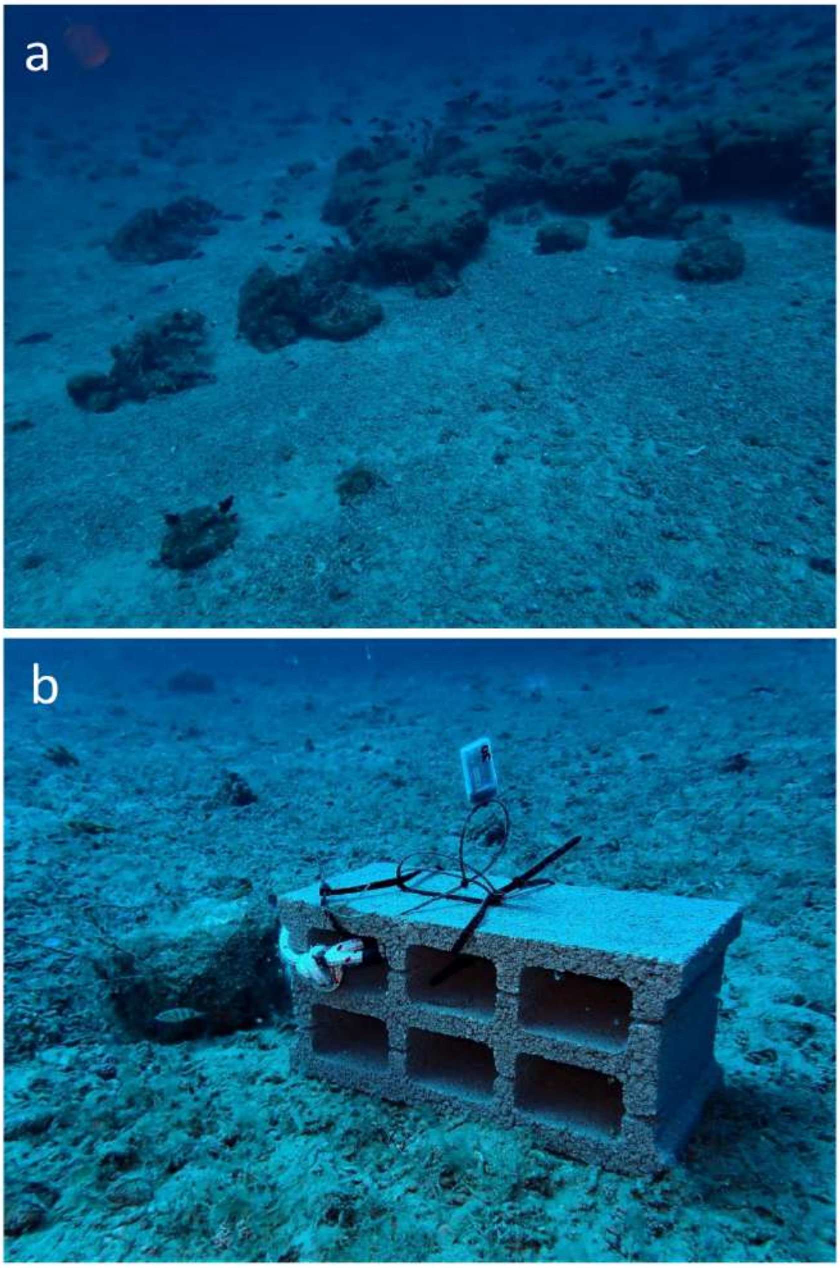


Figure 53. HOBO® Pendant temp/light data logger placed at 30 m depth: a) lower part of the Cladocora caespitosa reef – datalogger is placed several meters away from it, b) concrete block as a fixation point for the data logger with the serial number 21237193. Photo credit: S. Kipson.

Chapter 3. Conclusion

3.1 - Grado and Marano Lagoon, and Gulf of Trieste (IT)

Project CASCADE has given the opportunity to improve the agency's capacity to better investigate the marine ecosystems. As far as the probes, they provide an expandable platform capable of accommodating additional sensors in the near future, improving efficiently data acquisition capability and increasing its value over time.

3.2 – Transitional and coastal areas in Emilia Romagna (IT)

ARPAE managed to increment its monitoring capacities by installing multiparametric probes for a range of applications. The new probes provide measurements that improve knowledge related to biogeochemical and physical variables which allow for a better comprehension of processes taking place in the targeted areas. Furthermore, a better characterization of the transitional waters, especially the inputs from Po di Goro, allow for more reliable modelling/forecasting implementations.

Monitoring instruments have been used to enhance monitoring network and improve modelling input and system calibration in transitional areas of Emilia-Romagna region. Such instrumentation represents a step forward for the monitoring activities and allow a rapid and precise environmental characterization.

3.3 – Torre Guaceto-Canale Reale, Punta della Contessa and Melendugno in Puglia (IT)

The availability of new low-cost and user-friendly technologies which can be adaptable to existing platforms and allow continuous physical, optical, and biogeochemical data acquisition is fundamental to create distributed coastal observing systems.

3.4 – Neretva River mouth (HR)

The main aim was to monitor the ecological status of the Neretva estuary. For this purpose, IOF and DNC acquired different types of equipment such as UHPLC, AAS, DMA, laser granulometer and underwater drone to find the best locations for sampling and measure different parameters such as metals, lipophilic and hydrophilic toxins and perform grain size analysis.

3.5 – Miljašić Jaruga River mouth, Nin Bay (HR)

The use of the BRUV method proved to be very successful for use in monitoring the ichtyo population of the mouth of the Miljašić ravine, especially in combination with the visual survey that was used earlier. Although the same number of species was determined as with the visual examination by diving, a very large diversity of ichthyopopulations was observed in a relatively small research area.

3.6 – Northern-eastern Adriatic in Croatia (HR)

Ruder Boskovic Institute improved the capacity to better investigate the marine ecosystems. As far as the oceanographic buoys, they provide an expandable platform capable of accommodating additional sensors in the near future, improving efficiently data acquisition capability and increasing its value over time.

3.7 – Cetina River mouth (HR)

For the first time it has been possible to do in-situ continuous high-resolution sea water temperature monitoring along depth gradient at the border of Cetina estuary Natura 2000 site and in-situ continuous high-resolution sea water temperature, salinity, and oxygen monitoring in the centre of Cetina estuary Natura 2000 site near Cetina River freshwater inflow. In the long-term, these data series will build robust baselines and track hydrological and environmental changes (e.g., warming, heat waves, shifts in seasonality, stratification) to better understand the impacts of climate warming on the local marine coastal biodiversity. By joining the Mediterranean observational network T-MEDNet the Public institution Sea and Karst will contribute to better understanding of thermal regimes and consequences of climate-induced changes across the Mediterranean Sea.