D.5.2.3. Sensors solutions with full documentation ready for end-users' applications

InnovaMare project

Blue technology - Developing innovative technologies for sustainability of Adriatic Sea

WP5 – Cooperation in innovation on robotic and sensors solution (TT) – pilot actions

Project References

Call for proposal 2019 Strategic – InnovaMare
Project number: 10248782
Work package: WP5 Cooperation in innovation on robotic and sensors solution (TT) – pilot actions
Activity title: A2 Pilot I. - creating a prototype that is innovative robotic solution
Deliverable title: D.5.2.3. Sensor solutions with full documentation ready for end-users' applications
Expected date: 28/02/2022
Deliverable description D.5.2.3. This deliverable presents the specifications of sensors chosen in INNOVAMARE project to address the monitoring of different environmental variables accordingly with some of the use cases presented in D 5.2.1.
Partner responsible for the deliverable: [PP4-CNR]
Dissemination level: CO - Confidential
Status: Final
Version: V1
Date: 21/06/2021

Contents

INTRODUCTION

Within the WP5 activities of InnovaMare project the autonomous platforms developed were equipped with a full set of sensors useful to monitor and measure different kind of variables and, specifically, to those related with different descriptors of Marine Strategy Framework Directive (MSFD). This deliverable presents and describes the different sensors and their functioning, useful as reference for the end users in several typologies of application, as described in deliverable 5.2.1.

SENSORS SOLUTIONS WITH FULL DOCUMENTATION READY FOR END-USERS' APPLICATIONS

MBES R2 Sonic

Characteristics

A Multibeam echosounder (MBES) is a type of sonar sounding system that is used to map the depths of the seabed in respect to the sea surface. Multibeam systems emit acoustic waves in a fan shape beneath the transceiver and the length of time it takes for the sound waves to reflect off the seabed and return to the receiver is used to calculate the water depth. Unlike other sonars, multibeam systems use beamforming to extract directional information from the returning soundwaves, producing a swath of depth readings from a single ping. Therefore, further to the bathymetric information, the instrument is capable to detect the acoustic seafloor and water column backscatter. Backscatter data are intensity data (image) of the seafloor and (density) of the water column but do not have the same quality and resolution of side-scan sonar data, however are still useful for, for example, seabed classification, i.e. identifying the type of seabed (sand, rock, etc.) or habitat (seagrass, rocks, etc.).

The MBES available on the market are constantly evolving as technology advances but current products and trends belong to quite a small group of high-end sonar producers that constantly upgrade their products in terms of efficiency and resolution. After an accurate market analysis, the MBES chosen for the applications envisaged within the Innovamare project is a R2Sonic 2020. The choice fell mostly in the range of available size and portability. The R2Sonic 2020 is a highly portable, compact (140 x 161 x 133.5 mm), light (4.4 kg) and low power consumption (20 W average) equipment, that makes it the best choice to be mounted on an autonomous vehicle and the most compact high performance broadband shallow water multibeam echo sounder currently on the market.

The R2Sonic 2020 MBES is based on a Sonar Architecture that networks all of the modules and embeds the processor and controller in the sonar head to make for a very simple installation. The Sonic Control Graphical User Interface (GUI) is a simple program that can be installed on any Windows based computer and allows the surveyor to control the operating parameters of the Sonic 2020. Sonic Control communicates with the Sonar Interface Module (SIM) via Ethernet. The SIM supplies power to the sonar head, synchronises multiple heads, time tags sensor data, relays commands to the sonar head, and routes the raw multibeam data to the user's computer.

The sounding depth of R2Sonic 2020 is 200 m, the range resolution is down to 1.25 cm and the sounding for ping are 1024 thanks to the Ultra High Density (UHD) option.

The selectable frequencies range 200 –450 kHz with an additional high-resolution frequency of 700 kHz (Ultra High Resolution, UHR) so it is adaptable to a wide range of survey depths and conditions. These frequencies can be selected "on-the-fly" by the user via the Sonic Control GUI, without having to shut down the sonar system or change hardware or halt recording data. Changes can be done in steps of 1 kHz giving much more operational flexibility to optimize to the application, depth or environment and to control interference from other active acoustic systems. R2Sonic has a variable swath coverage capability (from 10° to 130°), with ability to electronically steer beams to a user defined sector. When a narrow sector is selected, all soundings are concentrated within the swath for increased sampling density over small scale bottom features (for example, to increase the definition of seafloor litter). In addition, the UHD (see above) option enlarges the number of independent bottom samples per ping (the standard is 256), increasing further the sampling density.

System Feature	Specification
Frequency	450kHz to 200kHz (700kHz optional)
Beamwidth – Across Track (at nadir)	2.0°@ 450kHz / 4.0° @ 200kHz
Beamwidth – Along Track (at nadir)	2.0° @ 450kHz / 4.0° @ 200kHz
UHR Beamwidth (at nadir)	**1.0° x 1.0°**
Number of Beams	256
Swath Sector	10° to 130° (user selectable) (optional 160°)
UHR Swath Sector	**10° to 70°** (user selectable)
Maximum Slant Range	1200 metres
Pulse Length	15µSec – 1000µSec
Pulse Type	Shaped Continuous Wave (CW)
Depth Rating	100 metres (3000 metres optional)
Operating Temperature	-10° C to 40° C
Storage Temperature	-30° C to 55° C

Table 1: R2Sonic 2020 system specifications

Another two interesting options adding to this MBES are the multispectral mode and the TruePix™ Compressed Water Column. TruePix™ is an exclusive, unique functionality developed by R2Sonic that has the benefit of simultaneously reporting backscatter and water column imagery.

The multispectral mode allows to simultaneously acquire data at different frequencies (up to five) which means having different applications e.g. for sea bottom classification in a single pass of the same survey, thus reducing the survey time and optimizing the final results.
TruePix™provides highly compact water column imagery and backscatter. It's a process independent from the bottom detection and, just like a side scan sonar, assembles the imagery record with one sample per range bin per side, so water column file sizes, which are normally very large to handle, are smaller. In addition, TruePix™ returns amplitude, range and angle for each target, which ensures unmatched accuracy and precision.
A multibeam survey system is comprised of more components than just the R2Sonic 2020 described. These components are the auxiliary sensors, which are required to provide the necessary information for a multibeam survey.
The R2Sonic 2020 multibeam is integrated with a I2NS tipe III (Integrated Inertial Navigation System) with includes:

- SIM (Sonar Module Interface), to integrate and harmonize all data sources and all outputs (see below).
- IMU (Inertial Measurement Unit), to compensate and correct three axis movements (attitudes). The R2Sonic I2NS (Inertial Navigation System) option integrates the Applanix Position and Orientation System POS Computing System and is comprised of the enhanced Sonar Interface Module (SIM), which contains the Applanix boards, and connections for the antennas and IMU.
- 2 GNSS (global navigation satellite system) antennas, for precise positioning.
- a Sound Velocity Probe (Valeport MiNi SVs) to detect the sound velocity of water near the sonar head and that should be mounted together.

Additionally, the acquisition system is completed by a Sound Velocity Profiler (Valeport SWIFT) equipped with Bluetooth transmission that can be deployed at specific times and locations to provide more accurate sound velocity profiles along the water column for refraction correction to be applied in post-processing.

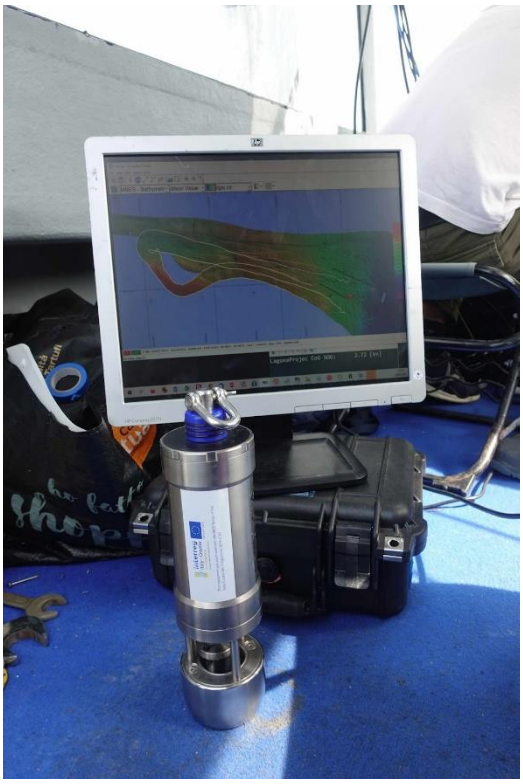


Figure 1: Sound Velocity Profiler (Valeport SWIFT) on board the vessel used to test the MBES acquisition system.

Mode of operation/Standard Operation Procedure

The sonar operation is controlled from a graphical user interface on a PC or laptop typically equipped with a navigation, data collection and storage applications software (working station).

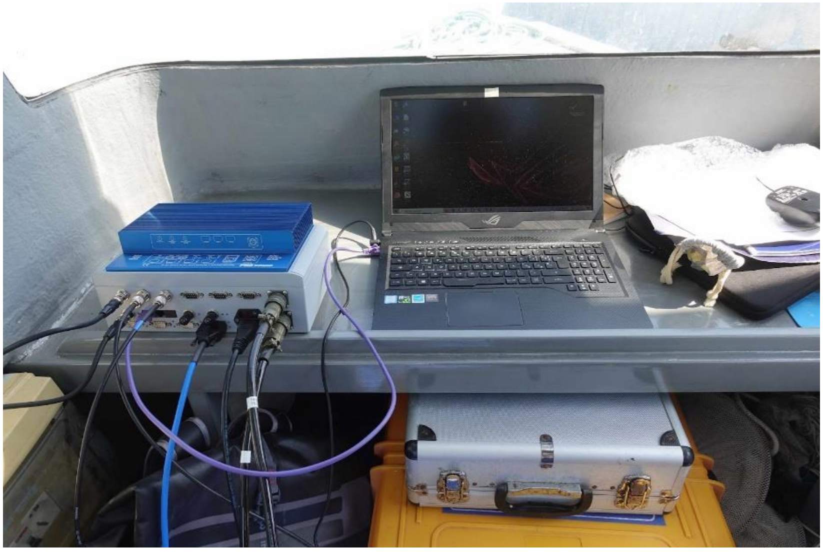


Figure 2: Working station mounting the acquisition software connected with SIM (on the right)

The operator sets the sonar parameters in the sonar control window, while depth, imagery and other sensor data are captured and displayed by the applications software.
The application software chosen for this MBES and this project is Qinsy (QPS, Quality Positioning Services B.V.) a very stable, powerful and flexible software for survey planning, acquisition and real-time data processing. In addition to this commercial package, an in-house software for survey automation and control was developed and described at the end of this section.
The commands from the operator through the software are transmitted via an Ethernet interface to the Sonar Interface Module (SIM - see figure above). The Sonar Interface Module supplies power to the sonar heads, synchronizes multiple heads if they are present, time tags sensor data, and releases data to the workstation and commands to the sonar head.
The receiver head decodes the sonar commands, triggers the transmit pulse, receives, amplifies and beam forms thus performing bottom detection and transmission of data packages through the Sonar Interface Module via Ethernet to the working station.
To protect the single components of the full installation (sonar head, SIM, MRU and mini-SVP), a special mounting frame made of plastics and polyurethane foam was designed exclusively for the sea testing and trials of the instrumentation purchased for the Innovamare project.

Figure 3: Single components of MBES installation, from left to right: sonar head, I2NS, MRU, mini SVP.

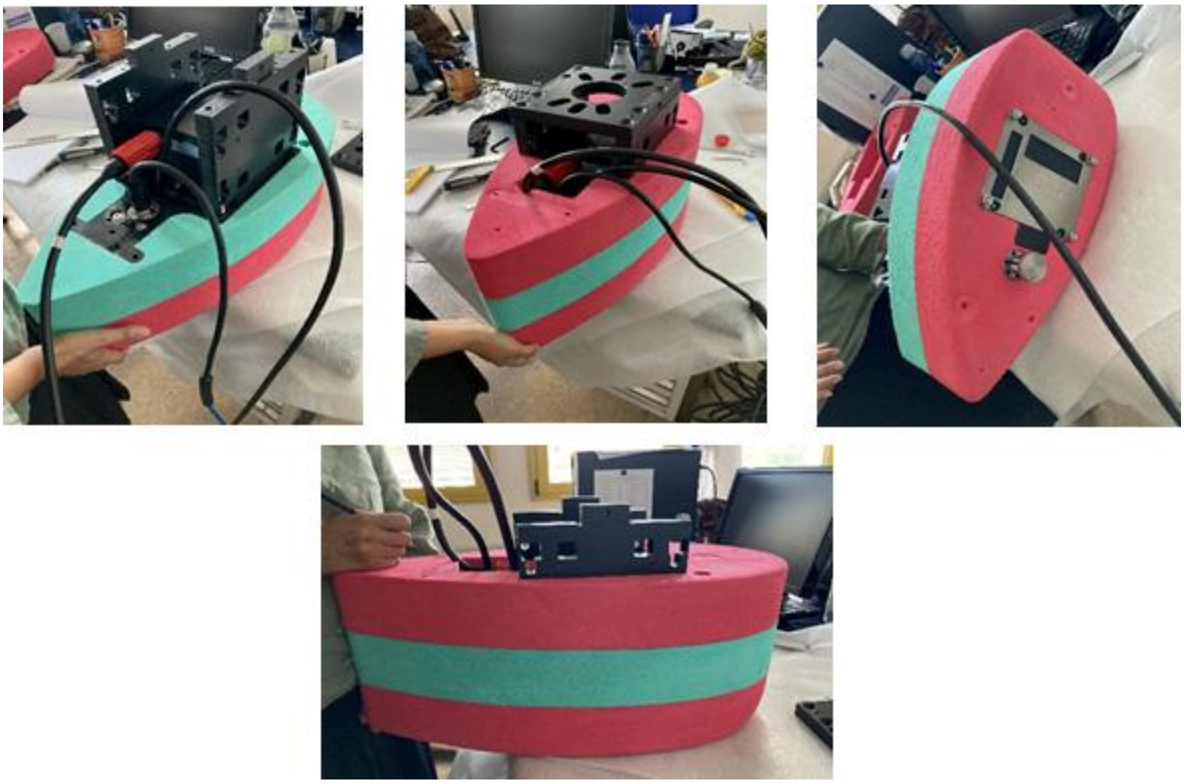


Figure 4: A PE-FOAM (closed cell polyethylene foam) and HDPE (High Density Polyethylene) mounting frame created by CNR-INM to protect MBES and easily mounted on a pole.

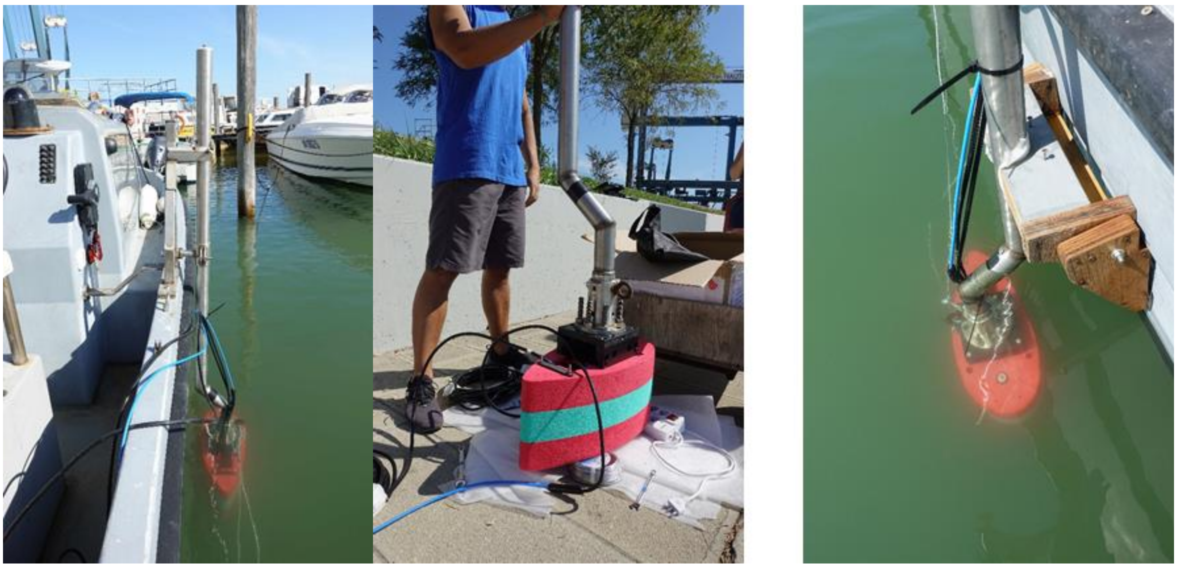


Figure 5: Operation test for R2Sonic 2020 in a pole-mounted configuration.

Figure 6: MBES acquisition sea trials.

New software for automatic control

A software tool for the automated control of the MBES has been specifically customized, in order to be executed on board the SWAMP vehicle, with the following functionalities:

- configuration of the MBES operating parameters
- management of data acquisition activation and deactivation commands;
- data storage on a storage medium based on a micro-SD card;
- data transmission via the vehicle's WiFi communication system;
- simple user interface for displaying the acquired data.

The software tool consists of three components:

- R2Commander - responsible for sending MBES configuration parameters and sending of the acquisition start/stop commands;
- R2Collector - component managing the acquisition and persistence of data produced by the MBES;
- R2GUI - provide a user interface for assessing the quality of the (raw) data produced during acquisition.

Possible applications

All three types of data produced by MBES can be used to create high resolution bathymetric 3D model, for monitoring erosion near structures, for marine litter detection on mosaics, for benthic habitat mapping, for monitoring of submerged archeological sites and for inspection of buildings and structures conditions.

Moreover, the water column backscatter signal can be useful to map and detect biofouling in aquaculture cages.

Guard1 cameras

Characteristics

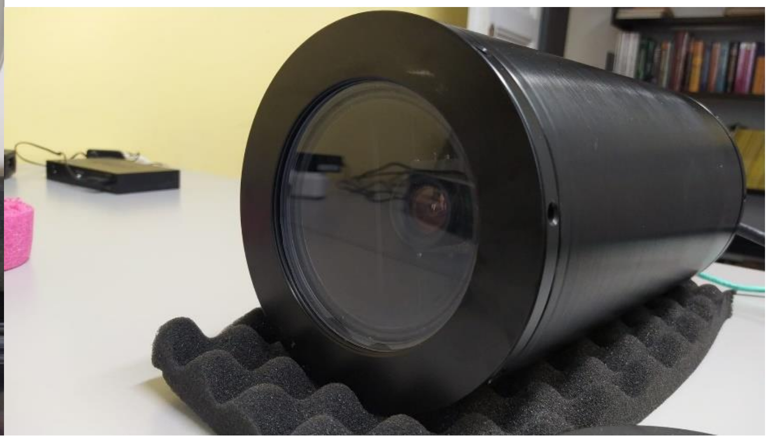
The GUARD1 is an intelligent imaging device for the autonomous monitoring of remote marine environments and infrastructures, specifically designed for actions extended in time (> 6 months). It is conceived as equipment for mobile platforms (e.g. sea gliders, vertical profilers, drifter buoys, AUVs, USVs) as well as stand-alone and wired observatories (e.g. oceanographic moorings, landers, cabled observatories). It acquires underwater images at a programmable time rate, provides on board content-based image recognition based on customizable software and communicates the information extracted from the acquired images, discarding not relevant data.

The device can be programmed according to different application contexts. The program optimises the image acquisition and processing actions according to the specific characteristics of the subjects that have to be automatically recognized (e.g. lighting conditions, image acquisition frequency, sensibility of the recognition performance, periodic data transmission). The embedded software manages the logical and temporal flow of the system behaviour to reduce the energy consumption for extending the device autonomy. The application software executes image processing and recognition algorithms for analysing the image content and for encoding such a content into an alphanumeric format (e.g. number and type of relevant detected objects).

The content extracted from the images can be easily transmitted to an external station through satellite, acoustics, Ethernet communication links or by releasing floating component equipped with communication facilities.

In particular, the two imaging devices GUARD1 that will be used within the InnovaMare project include:

- An underwater case rated for 100m depth operative work;
- An illuminator consisting of a ring including four high efficiency LEDs;
- A battery pack sized for a mission lasting 24 hours;
- Ethernet connection for data transfer

Technical details on the GUARD1 imaging device can be found at the following link:
https://www.oengineering.eu/guard-1/

Possible applications

The possible applications of this device deal with:

- Visual inspection and monitoring of aquaculture ecosystems
- Visual inspection and monitoring for harbours and marinas including marine litter detection
- Benthic habitat mapping
- Cultural heritage visual inspection and monitoring

ROX spectrometer

Characteristics

The RoX, developed and produced by JB Hyperspectral Devices (Germany), is a field spectrometer designed to acquire continuous hyperspectral measurements in the visible and near infrared (VNIR) spectral region. The instrument employs two Ocean Optics spectroradiometers that simultaneously collect the incoming and the upwelling irradiance/radiance in the wavelength interval between 400–950 nm, with a spectral resolution of 1.5 nm and acquisition time of about 30 seconds /1 minute, depending on illumination conditions. The RoX consists of a small waterproof rugged case (dimensions: 30 × 25 × 13 cm) with a low weight (about 3 kg). These characteristics, paired with the low power consumption, make the RoX a perfect field spectrometer for INNOVAMARE applications.
The two spectroradiometers of RoX are mounted on the SWAMP in a way that the first one points upward to collect the incoming irradiance (Ed) reaching the target and the second one points downward to measure the upwelling radiance (Lu) rising from the water body. The Ed optic is placed on a fiber levelling gimbal to ensure the measurements are always perpendicular to the water surface regardless of the SWAMP oscillations. To avoid the solar glint from the water

surface, the sensor collecting Lu is placed below the water surface (ca. 15 cm) and pointed downward. Finally, the two sensors are installed far enough from the vehicle in order to avoid any shadow. Moreover, some arrangements will be adopted during the SWAMP route to reduce the possibility of unintentional shadows from the surrounding area.
In view of satellite remote sensing applications, the above-surface water-leaving radiance (Lw) will be calculated from the Lu measured by the RoX below the water surface. Lu will be multiplied by a correction factor to account for the water-air interface. The calculated Lw will be divided by the Ed, to obtain the remote sensing reflectance Rrs. Since Lw is measured in Wm^{-2} nm^{-1} sr^{-1} and Ed in Wm^{-2} nm^{-1}, the Rrs is reported in sr^{-1}.
Rrs data will be filtered considering several quality flags that are automatically evaluated on the ROX spectral measurements. These quality flags allow detecting spectral measurements collected in not optimal illumination conditions, as it can occur during cloudy conditions. Measurements that will not satisfy the quality flag imposed will be deleted from the time series.

Possible applications

Autonomous and continuous hyperspectral acquisitions will be carried out by the ROX spectrometer sensor mounted on the SWAMP. The vehicle will be set to move at a speed adequate to sample spectral measurements with a suited spatial resolution, in relation to the investigated parameters. When the target of investigation is the benthic habitat mapping, spectral measurements will be collected over optically shallow waters along a transect, where different bottom substrate coverage are present (e.g. seagrasses, macroalgae, sand). In the case of monitoring of water parameters, the vehicle will be located far enough from the shallow zone to avoid the bottom contribution in the measured spectral signal. If necessary, continuous spectral measurements can be collected in the same location for some time, to evaluate optical water dynamics (e.g. turbidity, coefficient of attenuation, etc.).

SUNA V2 (OGS)

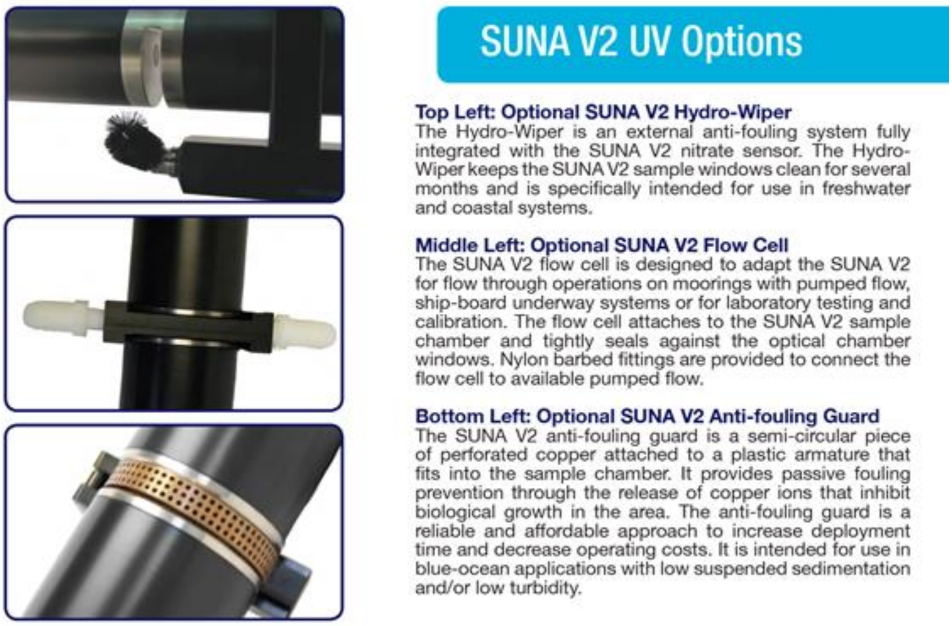
Characteristics

The Sea-Bird Scientific SUNA V2 (Submersible Ultraviolet Nitrate Analyzer) is an optical UV nitrate sensor based on In Situ Ultraviolet Spectroscopy (ISUS) technology for measuring UV nitrates, originally developed by Dr. Ken Johnson and Luke Coletti of the Monterey Bay Aquarium Research Institute (MBARI).
With improved optics and integrated logic, SUNA V2 measures nitrate with industry-leading accuracy and stability under a wide range of environmental conditions, from nitraclines in deep oceans to runoff in rivers and streams following flash floods.
The instrument uses the proven ultraviolet absorption spectroscopy technology to measure dissolved chemical species and consists of four key components: a stable UV light source, a UV spectrometer, a fiber optic sampling probe and a processing computer.
All components are housed in a single pressure case. The instrument can be set to produce real-time nitrate concentrations at a frequency of 1 Hz for profiling applications, or it can be programmed to sample on a defined schedule and record data internally for mooring applications.

Standard Features
• Accuracy and stability over a wide range of environmental conditions

• Adaptive sampling intelligence
• Universal real-time nitrate processing algorithm
• 10 mm optical plathlength
• Serial data output
• Titanium housing with a 500 m depth rating
• Simple, software-based, in-field reference checks
• User-friendly UCI software (Windows and Mac OS X compatible)

SUNA – V2



SUNA – V2 configurations

Possible applications

Assessment of nutrient concentrations in aquatic systems provide to understand the coupling between hydrological, geochemical and biological processes. From lakes and rivers to deep oceans, nutrient monitoring is increasingly being used to understand ecosystem dynamics on time scales that capture daily processes, trends, and events.
The enrichment of natural water bodies with nutrients, usually of anthropogenic origin, results in the occurrence of eutrophication, which causes significant changes in ecosystem structures.
The two major sources of nutrient additions to lakes, rivers and coastal oceans are:
- runoff from fertilizers used in land-based agricultural applications;
- discharge of wastewater, either directly or from treatment plants.
The unnatural increase of macronutrients, particularly nitrate and phosphorus, in coastal water bodies leads to the stimulation of algal blooms that can be harmful and disruptive for fish and

humans. Once harmful algal blooms decay and sink into the deeper layers, anoxic conditions can occur as bacteria decompose the dead organic material. As the severity and frequency of these events increase, it becomes increasingly important to monitor and understand nutrient cycles with in situ nutrient sensors.

In INNOVAMARE, the sensor will be installed on the SWAMP ASV vehicle, hence the choice to use a compact system, with purely optical technology and without the use of reagents, limited in size and weight and compatible with the payload available on the AUV vehicle.
The Flow-Cell configuration was preferred for this type of application. Being able to have a pumped system and thus an inlet tube, allows the positioning of the instrument on the AUV to be independent of the point of water uptake and thus to move that point away from the AUV propellers, which by generating turbulence and bubbles could disturb the measurement.
It should also be noted that this tool is already widely used on mobile platforms, particularly on floats that are autonomous profiling vehicles that are part of the worldwide ARGO International program for ocean monitoring and in that context also used by the ARGO Italy program.

Sensors on Korkyra ASV

A short summary of the simple set of sensors included in the Korkyra ASV follows. For more information on these sensors and mode of operation please refer to D5.2.2 Swarm of autonomous vehicles with full documentation ready for variety of end-users' applications.

Characteristics

Multibeam sonar system (MBES): NORBIT iWBMSc with integrated INS, 400 kHz, 80 kHz bandwidth, 140º nominal aperture
GNSS: GNSS system with inertial measurement unit (IMU) and possibility of base station corrections leading to < 10 cm accuracy
Camera: pan-tilt-zoom (PTZ) Hikvision IP mounted on the top of the vehicle
Acoustic positioning: WaterLinked Underwater GPS (UWGPS) G2 Short-BaseLine (SBL) system (with IMU)

Possible applications (see table on scenarios of D 5.2.1 below)

- Inspection and monitoring of aquaculture ecosystems
- Inspection and monitoring for harbours and marinas including marine litter detection
- Benthic habitat mapping
- Cultural heritage inspection and monitoring

Mode of operation/Standard Operation Procedure

Most of the sensors on Korkyra ASV are functional to navigation or to the localization of Blueye Pro ROV and do not collect environmental data. More info on the mode of operation can be found in D5.2.2 Swarm of autonomous vehicles with full documentation ready for variety of end-users' applications.

Sensors on Buoys

A multi-platform system is composed of one moored Smart Buoy (plexiglass enclosure in moulded expanding polyurethane hull with water-resistant coating, Fig. 7) and three Sensor Units

(plexiglass enclosure with variable-radius mooring point attachments, Fig. 8) deployed along mooring line at different depths. These can be used to monitor water quality parameters such as Temperature, Salinity/conductivity, Dissolved oxygen and Chlorophyll.
The system includes the following communication capabilities:

- LoRa transmitter/receiver (NOTE: requires matching transmitter/receiver unit on land)
- LTE Cat-M1/NB-IoT/EGPRS modem - https://wiki.teltonika-networks.com/view/TRM250
- Wi-Fi (Raspberry Pi Zero W on-board)
- Underwater acoustic communication between buoy and sensor units

It also includes several features such as solar panels (5 panels of 6V/3.5W per buoy unit), sleep modes and power management for long-term autonomy, SD card data logging and Data collection and display on IoT dashboard.

Characteristics

On the buoy:

- GPS: LoRa/GPS_HAT for buoy localisation
- RTD temperature probe: Atlas Scientific PT-1000 for water temperature monitoring
- Camera: IR-CUT B camera on top of buoy for day and night
- IMU for wave estimation and disturbance detection

On the sensor units:

- Temperature probe: Maxim Integrated DS18B20 temperature probe
- Conductivity probe: Atlas Scientific conductivity probes K 10 (for salt water) and K1.0 (for brackish water)
- Dissolved oxygen: Atlas Scientific dissolved oxygen probe
- Chlorophyll: Turner Cyclops-7F submersible fluorometer for chlorophyll *in vivo* (blue excitation)
- Pressure sensor: for depth measurement TE Connectivity MS5837-30BA

Possible applications (see table on scenarios of D 5.2.1 below)

- Inspection and monitoring of aquaculture ecosystems
- Inspection and monitoring for harbours and marinas including marine litter detection
- Cultural heritage inspection and monitoring

Mode of operation/Standard Operation Procedure

The buoy is active immediately upon plugging the power bank into the power management board and can be sealed by closing the top cap (Fig. 7). By default, it is set to turn on every 22 minutes and work for 8 minutes, gathering any sensor data and acoustic data transmitted during that time window, uploading it to the online dashboard. The main board (Raspberry Pi Zero) of the buoy connects to WiFi upon boot and SSH can be used to modify any behaviours. The sensor probe and acoustic transducer at the bottom of the buoy must be submerged in order to function as intended.

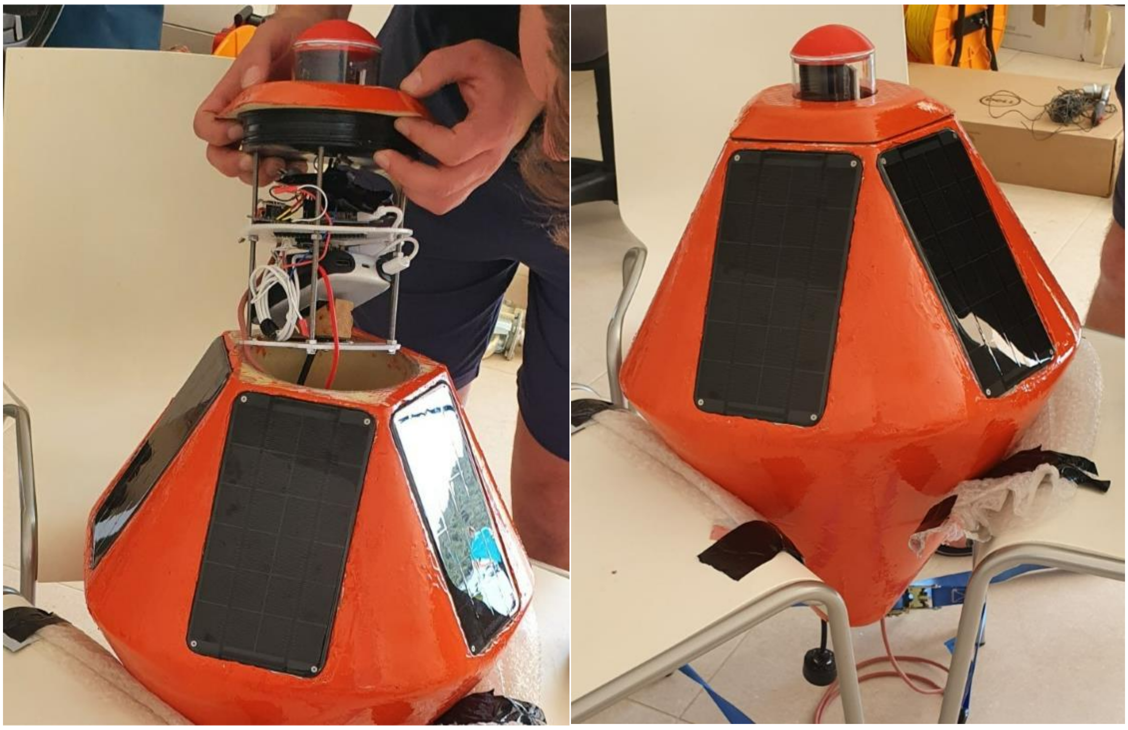


Figure 7. Preparing Smart Buoy for deployment

Sensor units are switched on using the switch on their top cap and are ready for parallel deployment, as each has a RTC module and is programmed to use an acoustic communication timeslot based on their unique ID, preventing interference. It is not necessary to open up the sensor units. Probes attached to sensor units and buoy units have been calibrated using calibration solutions (where necessary) and should not need further calibration.

Figure 8. Sensor units ready for deployment

The sensor units can be deployed along the seabed or hung off the buoy mooring line using variable radius ring attachment points (Fig 9).

Figure 9. Sensor units attached to mooring line

The buoy dashboard is available at https://labustbuoy.ddnsfree.com/ . The dashboard includes an admin account as well as a view-only customer account.
Customer login: bove@bove.hr
Customer password: bovetest

Sensors on Blueye Pro ROV

A short summary of the simple set of sensors included in the Blueye Pro ROV follows. For more information on these sensors and mode of operation please refer to D5.2.2 Swarm of autonomous vehicles with full documentation ready for variety of end-users' applications.

Characteristics

- HD camera: [-30°, 30°] tilt angle mechanism, 25 - 30 fps.
- Lights: 3300 lum with 90 CRI LEDs
- IMU: 3-axis gyro and 3-axis accelerometer
- Depth sensor
- Magnetometer: compass
- Temperature sensors: both indoor (inside the ROV) and outdoor sensors are present
- Internal pressure sensor.

Possible applications (see table on scenarios of D 5.2.1 below)

- Inspection and monitoring of aquaculture ecosystems
- Inspection and monitoring for harbours and marinas including marine litter detection
- Cultural heritage inspection and monitoring

Mode of operation/Standard Operation Procedure

Most of the sensors on Blueye Pro ROV are functional to navigation and do not collect environmental data. However, the HD camera can be used in the applications mentioned above and more info on the mode of operation can be found in D5.2.2 Swarm of autonomous vehicles with full documentation ready for variety of end-users' applications.

Sensors on GEOMAR Surface vessel

Characteristics

- Vessel: LOA 8.55m, cabin, outboard engine 225 HP, MinnKota bow electric 36V motor for positioning and survey, diesel generator 220V/AC, 6 kW
- MBES: Teledyne SeaBat T20-P, high resolution 1024 beams, 190-420 kHz wide-band multi-detect option (up to 5 depth recordings in water column). Sound Velocity Profiler for speed of sound observations in water column.
- SBP: Innomar SES 2000 light, transmitter frequencies: 4, 5, 6, 8, 10, 12, 15 kHz layer resolution up to 5 cm, depth range: 0.5m-400m, penetration up to 40m
- ROV: Ageotech SIRIO + USBL ROV positioning system, observation class, 40 kg, 4 motors, 2 reflectors, electric arm, camera HDI 7000 TVL, depth range 300m
- RTK: Trimble navigation system (Applanix IMU + Trimble GNSS antennas) RTK CROPOS precise positioning (subdecimeter)
- Drone: DJI Phantom 4 PRO + 24 Megapixel camera with RTK precise positioning. Software for developing DTM and orthophoto situation plan

Possible applications (see table on scenarios of D 5.2.1 below)

- Inspection and monitoring of aquaculture ecosystems
- Inspection and monitoring for harbours and marinas including marine litter detection

Mode of operation/Standard Operation Procedure

- Hydrographic bathymetric survey using MBES or geological sediments SBP survey; equipment mounted on surface vessel; drone for photogrametry detection and mapping
- ROV inspections using surface vessel with Applanix/Trimble and Tritech USBL positioning

CONCLUSIONS

This deliverable presents several sensor solutions available for end-users produced or acquired within INNOVAMARE Activity 5.2. The deliverable presents solutions from different partners that can be used in a series of use cases defined in Deliverable 5.2.1. Sensors covered a wide range of scenarios and variables to be measured addressing several of MSFD descriptors. Moreover, the deliverable explains in detail the mode of operation of each sensor which can be very useful for an interested end-user.