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DEC	Websites, patents, filing, etc.	
DEM	Demonstrator	
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NAUTILOS - New Approach to Underwater Technologies for Innovative, Low-cost Ocean observation is an H2020 project funded under the Future of Seas and Oceans Flagship Initiative, coordinated by the National Research Council of Italy (CNR, Consiglio Nazionale delle Ricerche). It brings together a group of 21 entities from 11 European countries with multidisciplinary expertise ranging from ocean instrumentation development and integration, ocean sensing and sampling instrumentation, data processing, modelling and control, operational oceanography and biology and ecosystems and biogeochemistry such, water and climate change science, technological marine applications and research infrastructures.

NAUTILOS will fill-in marine observation and modelling gaps for chemical, biological and deep ocean physics variables through the development of a new generation of cost-effective sensors and samplers, the integration of the aforementioned technologies within observing platforms and their deployment in large-scale demonstrations in European seas. The fundamental aim of the project will be to complement and expand current European observation tools and services, to obtain a collection of data at a much higher spatial resolution, temporal regularity and length than currently available at the European scale, and to further enable and democratise the monitoring of the marine environment to both traditional and non-traditional data users.

NAUTILOS is one of two projects included in the EU´s efforts to support the European Strategy for Plastics in a Circular Economy by supporting the demonstration of new and innovative technologies to measure the Essential Ocean Variables (EOV).

More information on the project can be found at: http://nautilos-h2020.eu/.

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Executive Summary

This deliverable is the result of the work carried out in Task 7.1 (Fisheries and Aquaculture Observing Systems) up to M40. The main objectives were to start demonstrating the use of the dissolved oxygen and Chlorophyll *a* sensors, developed in ST3.1.2, on commercial fishing vessels and in aquaculture facilities, lay the foundation for a new Aquaculture Observing Systems integrated approach and to trial the deployment of Acoustic Marine Mammal Monitoring System by fishermen.

This document provides details on the implementation of demonstrations involving the AdriFOOS infrastructure, commercial fishing vessels, ferries and aquaculture facilities; it also illustrates any problems encountered, the solutions developed to improve the functioning of the sensors involved and the phases to implement the data exchange with the NAUTILOS data stream services.

Therefore, it is organised in 6 main sections:

Chapter I: Introduction, provides a brief description of the idea behind the planned activities, some references to the state of the art and a list of the carried-out activities;

Chapter II: Fisheries Observing Systems Demonstration Report, contains details on demonstrations relating to the use of commercial fishing vessels, carried out by CNR and Ifremer in the Adriatic Sea and the Bay of Biscay respectively, with the support of NKE;

Chapter III: Novel approach to Aquaculture Observing Systems Demonstration Report, describes updates and plans related to demonstrations with aquaculture operations carried out by NIVA in coastal Norway and HCMR in the Aegean Sea, as well as machine learning-based event detection carried out by DFKI;

Chapter IV: Demonstration of Acoustic Marine Mammal Monitoring System Report details the demonstration plans, involving the use of fishing and a research vessel in Swedish and Italian waters, to assess the effectiveness of the AQUAclick Sound passive acoustic recorder in detecting marine mammals under different conditions;

Chapter V: Ethical Considerations, reports some considerations on some ethical aspects relevant to the activities described in this deliverable;

Chapter VI: Summary, closes the report, highlighting the main achievements obtained in T7.1 up to M40.

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List of Acronyms and Abbreviations

Abbreviation	Definition
AdriFOOS	Adriatic Fisheries and Oceanography Observing System
AOS	Aquaculture Observing System
APN	Access Point Name
CFP	Common Fisheries Policy
Chl-*a*	Chlorophyll *a*
CMEMS	Copernicus Marine Service
CSV	Comma-separated values
CTD	Conductivity, Temperature, and Depth
DC	Direct Current
DCF	Data Collection Framework
DO	Dissolved Oxygen
EAF	Ecosystem Approach to Fishery
EMODnet	European Marine Observation and Data Network
EOVs	Essential Ocean Variables
EU	European Union
EUSAIR	European Union Strategy for the Adriatic and Ionian Region
FOOS	Fisheries and Oceanography Observing System
FOOS	Fishery and Oceanography Observing System
FTP	File Transfer Protocol
FTPS	File Transfer Protocol Secure
GPS	Global Positioning System
IATA	International Aviation
IR	Infrared
ITAR	International Traffic in Arms Regulations

JSON	JavaScript Object Notation
M/S	Motor ship
MEDIAS	Pan-Mediterranean Acoustic Sampling
MHWs	Marine Heat Waves
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
NetCDF	Network Common Data Form
NRT	Near Real Time
QC	Quality Control
QR	Quick Response
R/V	Research Vessel
REST-API	Representational State Transfer - Application Programming Interface
RoHS	Restriction of Hazardous Substances in Electrical and Electronic Equipment
ROV	Remotely Operated Vehicle
RT	Real Time
TRL	Technology Readiness Levels
VOOs	Vessels Of Opportunity
WEEE	Waste Electrical and Electronic Equipment
WFD	Water Framework Directive
Wi-Fi	Wireless Fidelity
WP	Work Package
WT	Water Tracer
AIM	Adriatic-Ionian Macroregion

I. INTRODUCTION

The NAUTILOS project aims to fill existing gaps in marine observation and modelling through the development of new technologies and their deployment on different observational platforms. One of the specific objectives of the project is to promote innovative and cost-effective methods in a wide range of critical environmental contexts and European Union (EU) policy applications as for example the Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC) and the Common Fisheries Policy (CFP; EU REGULATION 1380/2013).

Based on the experience of the CNR Adriatic Fisheries and Oceanography Observing System (AdriFOOS; Patti et al. 2016, Penna et al. 2023) and Ifremer RECOPESCA (Leblond et al. 2010, Lamouroux et al., 2016) programs, a new generation of sensors has been designed, implemented and tested within NAUTILOS to collect measurement of Essential Ocean Variables (EOVs) by exploiting the capacity of commercial fishing vessels as emerging platforms for ocean observation (Van Vranken et al. 2020, 2023). Data collected through fishing vessels demonstrated to be useful to feed oceanographic models and advance knowledge on climate change, as well as to improve the Ecosystem Approach to Fishery management (Carpi et al. 2015, Aydoğdu et al. 2016, Mourre et al. 2019, Penna et al. 2023).

To improve the "Fisheries Observing Systems" approach, specific sensors for some of the main environmental variables related to fisheries resources, specially designed to be installed on commercial fishing vessels, are demonstrated in the Adriatic Sea and the Bay of Biscay.

In order to provide a new means for sustainable aquaculture management, a similar approach is planned to be used for new “Aquaculture Observing Systems” (AOS), with observations carried out from other classic Vessels Of Opportunity (VOOs) such as ferries equipped with FerryBox systems (Rosa et al. 2021) operating touristic or commercial routes nearby aquaculture facilities. Sensors are also to be deployed within mariculture and fish farm plants and on fishery research vessels operating in the areas. This novel integrated approach is planned to be trailed in coastal regions of Norway and Greece. The data stream from underway sensor operations is meant to be used to enable real-time event detection with an adaptive machine learning approach.

To further extend the potential of commercial or artisanal fisheries as an observation platform, some vessels will also be used to test new underwater passive click & sound recorders for the assessment of echo-locating marine mammal abundance. Assessment and demonstration activities will be held all over Europe, including Atlantic and Mediterranean sites. In particular, acoustic monitoring systems will be deployed in the Swedish Sound/Kullaberg/Lysekil waters, with the collaboration of local commercial fishermen. Additionally, further demonstrations are scheduled to occur within the Portofino Marine Protected Area, designated as a sanctuary for cetaceans.

II. Fisheries Observing Systems Demonstration Report

1 Background

As part of NAUTILOS WP3, NKE developed prototype sensors for measuring Dissolved Oxygen (DO) and Chlorophyll *a* (Chl-*a*), designed specifically for use in fisheries and aquaculture applications; each sensor also measures depth and temperature and communicates via Wi-Fi with an automatic data recovery and transmission system (WiHub), which also records the Global Positioning System (GPS) track (Malardé et al. 2022). Prototypes were factory calibrated respectively for DO (3 sensors) and Rhodamine WT (initially 3 sensors, plus an additional prototype; see below in the Demonstration Plan section) and the sensor specifications declared by the manufacturer are reported in D3.2 (Malardé et al. 2022) and D5.6 (Martinelli et al. 2023). Specifications updated after the first demonstration phase described below are also reported in Appendix 2. The prototypes underwent laboratory calibrations at the Ifremer, CNR and SYKE facilities reported in ST6.1.1 (Ntoumas et al. 2023) and field validation tests in the North Sea, the Adriatic Sea, the Baltic Sea and the Bay of Biscay reported in D5.6 (Martinelli et al. 2023). Tests included comparisons with traditional oceanographic instruments, measurements at different salinity/temperature/dissolved oxygen combinations, and comparative experiments with fluorescein and algae cultures.

The acquisition rates of the DO and Chl-*a* sensors suggest their employment in relatively stable conditions and/or for prolonged use at fixed depths, making them suitable for use on fixed fishing gear such as pots, set nets, longlines or on towed gears to record measurements as fishing operations take place at stable depths. The prototypes demonstrated good performance for both depth and temperature even during the downcast or upcast profiling phases. The possibility of setting a known salinity of seawater internally in the DO sensor allows its use in known conditions of stable salinity without the need for post-processing. Instead, in possibly variable conditions it would be preferable to use sensors with internal salinity set at 0, together with other available commercial sensors in order to obtain useful information for data post-processing (e.g. correction values for some combinations of temperature and salinity in D6.1 and D5.6). The Chl-*a* prototypes showed a linear response compared to other traditional instruments but showed broader noise recording at low concentration levels. Therefore, the acquired Chl-*a* trends could be considered reliable, but if accurate measurements are needed, the dataset can be post-processed.

2 Demonstration Plan

After laboratory calibration (ST6.1.1) and field validation (ST5.3.1), the DO and Chl-*a* sensors, developed in ST3.1.2, were mechanically and electronically integrated, together with their WiHub, into the CNR AdriFOOS infrastructure and on a commercial fishing vessel selected by Ifremer (Martinelli et al. 2023). Subsequently, a demonstration phase was planned with sensors that collect data autonomously in the Adriatic Sea and the Bay of Biscay, respectively under the constant monitoring of the CNR and Ifremer. The two demonstration sites were selected to verify the functioning of the sensors under different conditions, both in environmental and operational terms (for example installing them on different types of fishing vessels); the two demonstrations were also designed to allow different aspects of the sensors' operational behaviour to be tested simultaneously. All the produced datasets will be

showcased on NAUTILOS data services (i.e. through ERDDAP[1] and GeoServer[2]; see D8.3 and D8.7) and also made publicly available through relevant EU data portals such as European Marine Observation and Data Network (EMODnet).
The consent forms developed in WP13 and described in D13.7 were made available and signed by commercial fishermen involved before installing the sensors on board and are stored in the archives of the partners who lead each demonstration (Pieri et al. 2022).

a. Demonstration on Fisheries Observing Systems in the Adriatic Sea (CNR)

- **Specific Objectives**

This demonstration was specifically designed to allow verification of sensor robustness, battery life and communication protocols and to showcase data collected in Near Real Time (NRT) on NAUTILOS data portals.

- **Platform involved**

The involved platform is the CNR-IRBIM AdriFOOS infrastructure operating in the Adriatic Sea (Mediterranean basin). AdriFOOS consists of Fishery and Oceanography Observing Systems (FOOSs; Patti et al. 2016) installed on commercial fishing vessels and a multifunctional dedicated on land datacenter, located at CNR-IRBIM Ancona (Penna et al. 2023). AdriFOOS includes in its fleet various kinds of fishing vessels (e.g. bottom trawlers and mid pelagic trawlers), targeting different resources, and producing a huge amount of data useful both for oceanographic and fishery biology purposes. The datacenter receives daily data sets of environmental parameters (e.g. temperature, salinity, etc.) collected along the entire water column and on the seabed during ordinary fishing operations using oceanographic sensors installed directly on the fishing gear; this information comes along with GPS haul tracks, catch amounts per haul, target species sizes and meteorological information (Martinelli et al. 2016, Penna et al. 2023).
AdriFOOS platform has previously been involved in various European projects (i.e., EU FP7 JERICO "Towards a Joint European Research Infrastructure network for Coastal Observatories" and NeXOS "Next generation Low-Cost Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management" projects, H2020 JERICO NEXT "Joint European Research Infrastructure network for Coastal Observatory – Novel European eXpertise for coastal observaTories"; Puillat et al. 2014; Gaughan et al. 2015; Sparnocchia et al. 2017).
In this case, a bottom trawler based in the port of Ancona was selected to participate in NAUTILOS demonstrations on Fisheries Observing Systems in ST7.1.1. The vessel was already part of the AdriFOOS architecture and the FOOS installed on board included a previous generation NKE sensor installed on the fishing gear to record pressure, temperature and salinity (Penna et al. 2023). In the Adriatic Sea, trawlers fish for demersal species (mainly crustaceans and fish) and are equipped with otter doors to keep the mouth of the dragged net open during fishing operations that take place on the seabed (Lucchetti et al. 2012).
This type of fishery allows the sensors to be installed directly on fishing gear dragged along the seabed (namely on the otter doors), normally at constant speed and stable depth, which offers adequate operational conditions for the DO and Chl-*a* sensors especially considering

[1] https://coastwatch.pfeg.noaa.gov/erddap
[2] http://geoserver.org/

their minimum acquisition rate (i.e. 2 sec). Furthermore, the possibility of recording data close to the seabed allows to obtain useful information to correlate with the target demersal resources. Otter doors provide good support for installing sensors, which offers some degree of protection from contacts with other objects; however, due to their impact with the seabed at the beginning of the fishing operations and their subsequent continuous contact which can generate vibrations and shocks, the positioning of the probes as described above is a proper condition for testing their robustness. The daily execution of fishing operations and the subsequent deployment of the sensors allows the battery life to be tested.

- **Deployment configuration**

On 7 July 2023, the following equipment was installed on board the selected fishing vessel:
- DO sensors serial number 2222 (First Factory calibration Date 11-22),
- Chl-*a* sensors serial number 8888 (First Factory calibration Date 09-22),
- WiHub systems serial number 23 0002.

This instrumentation was integrated into the FOOS on board following all the mechanical and electronic integration phases and precautions described in Chapter II of D5.6 (Martinelli et al. 2023). In this case the DO and Chl-*a* prototypes, covered by their plastic protections, were both fixed to the internal surface of the same otter door (with detection cells facing the water flow during towing) on threaded steel rods, using nuts and anti-shock rubber rings (Fig. 1A,B), as the sensor recording salinity was already installed on the other one. The WiHub was fixed on a steel rod in an open field to prevent any possible interference with other on-board instruments or the ship's structure (Fig. 1C) and was connected via Ethernet communication with the previously updated FOOS e-logbook to allow communication, storage and data management (see D5.6). The WiHub configuration in use is the same reported in D5.6.

Figure 1: A) Fixing of the prototypes on the otter door with visible plastic protections, threaded steel bars, nuts and anti-shock rubber rings; B) DO and Chl-a prototypes fixed on the otter door of the selected commercial fishing vessel; C) WiHub position with visible Ethernet and power cable.

The DO and Chl-*a* prototypes settings were determined through their web application by means of a cellular phone. The communication with the WiHub was enabled and the acquisition was set to *fishing sampling regime* (Fig. 2). This configuration allows two distinct data acquisition intervals within the same fishing haul: i) the sensors were configured to start data recording once immersed in water at a pressure greater than 0.2 bar, with a frequency of 2 seconds (the highest allowed by the sensors), for 10 minutes; ii) subsequently, the recording intervals were extended to 1 minute until the pressure drops below 0.2 bar (corresponding to the conclusion of the fishing operation; Fig. 2). Within the DO sensor, the internal salinity value was set at 38.67; this was selected as the average salinity value recorded by the FOOS sensor (NKE STPS 300m PR n.31002-15123) on board the same vessel between 20 June and 27 June 2023.

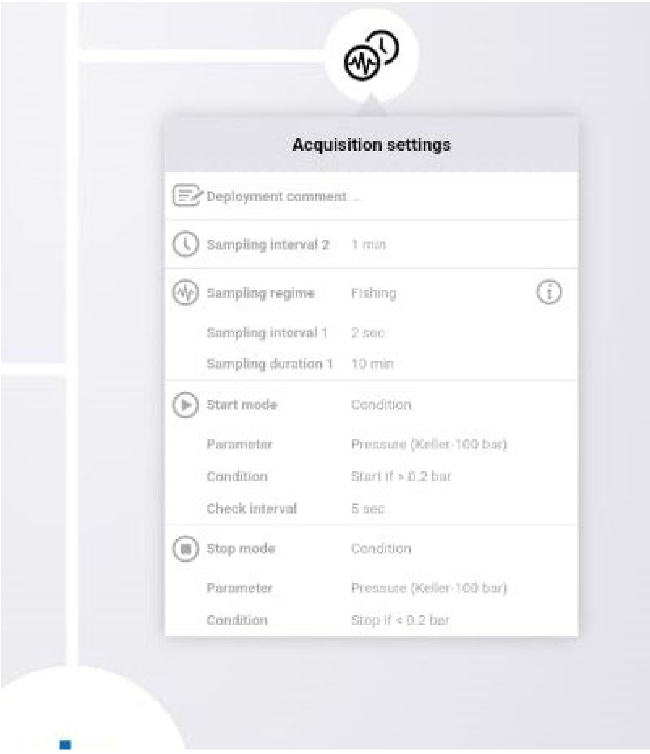


Figure 2: Sensor acquisition settings for the fisheries sampling regime as of 7 July 2023.

- **Location**

The commercial fishing vessel selected for this demonstration is routinely operating in the so-called "Off Ancona" fishing ground (Zacchetti et al. 2022; Fig. 3), straddling between the Northern and the Central Adriatic subbasins. The Adriatic Sea is a semi-enclosed basin within the Mediterranean Sea, located between the Italian peninsula and the Slovenian–Croatian–Montenegro–Albanian coasts (Fig. 3). The northern Adriatic is the shallowest area with maximum depth around 100 m, while the central part has a maximum depth of 270 m (Marini et al. 2016). The general circulation is cyclonic, strongly influenced by atmospheric conditions and driven mainly by the dominant winds (Bora NE-ENE and Scirocco SE), also presenting seasonal basin-scale cyclonic eddies (Artegiani et al. 1997; Poulain 2001). The Po River flows into the northern sub-basin, representing about a third of the total river freshwater input into the Adriatic and introducing large amounts of nutrients which flow south along the Italian coast (Marini et al. 2008; Cozzi and Giani 2011; Grilli et al. 2020). The Adriatic Sea is therefore characterized by an extensive continental shelf and eutrophic shallow waters in its central-northern part which make it a very productive area, one of the most intensively fished of the Mediterranean (Campanelli et al. 2011; Eigaard et al. 2017; FAO 2020).

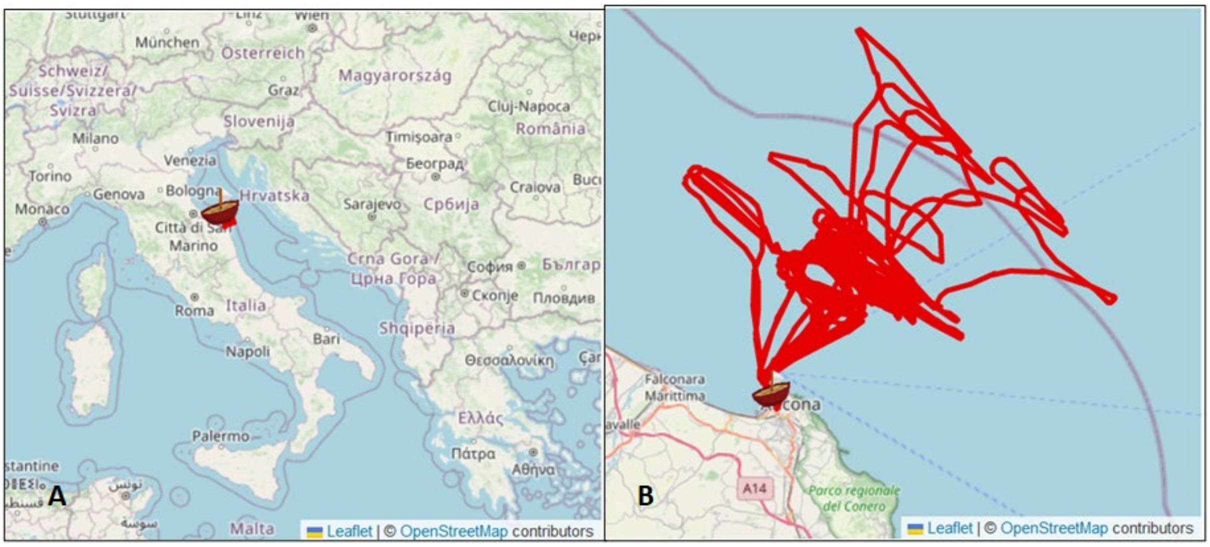


Figure 3: A) Position of the Ancona harbour within the Adriatic Sea, B) GPS route tracks for one month of fishing activity of the selected commercial vessel as visible in the AdriFOOSweb interface (Penna et al. 2023); maps are generated by means of © OpenStreetMap[3].

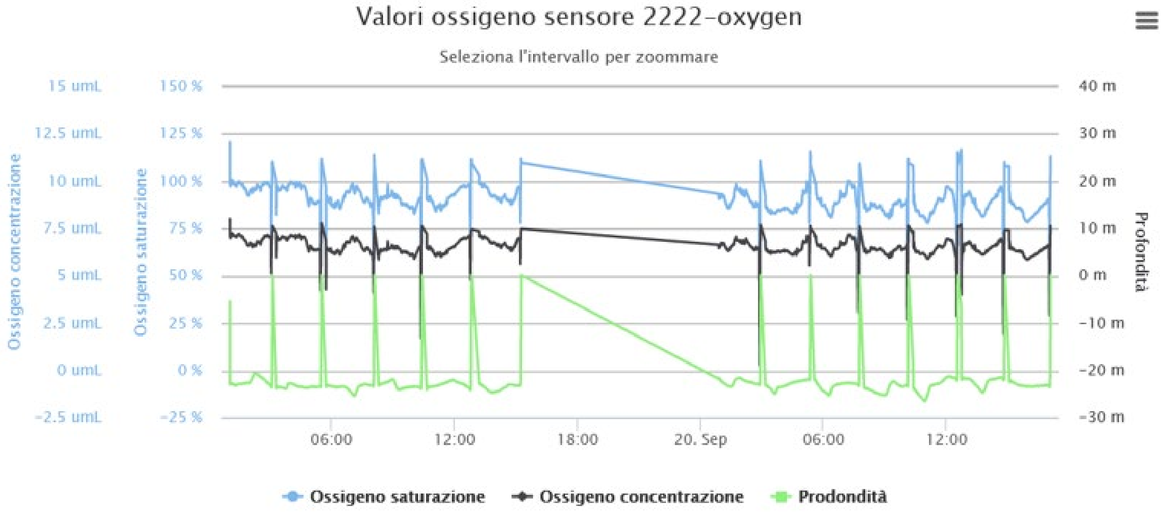
- **Period of occurrence**

After installation on the commercial fishing vessel in July 2023, a trial period followed until the annual fishing closure (from August to mid-September) to verify the functioning of the system; CNR and NKE were in constant contact. Since mid-September, CNR staff have constantly monitored the functioning of the prototypes and the transmission of data. The vessel is expected to remain equipped until at least summer 2024.

- **Maintenance, events/issues occurred and actions taken**

Constant monitoring of the equipment functioning and of the entire data ingestion process is carried out using the AdriFOOS web viewer, which was appropriately modified for the purpose as reported in D5.6 (Martinelli et al. 2023).
The sensors' battery level is displayed only in the footer of the produced data file which, for operational reasons, is not processed by the AdriFOOS web viewer, then to check the power consumption it is necessary to manually download samples of data files or use the sensors' web application.
On 20 September 2023, the Chl-*a* prototype showed incorrect functioning by not recording data for hauls detected by the other on-board sensors (Fig. 4). An intervention on board by CNR staff revealed that the battery was completely discharged (Tab. 1). In fact, the sensors started recording data during the commercial fishing operations on 16 July 2023, but batteries were previously consumed also during testing that took place in ST6.1.1 and ST5.3.1.
Following the instructions provided by NKE, CNR staff procured the appropriate battery and replaced it as quickly as possible, also considering the possibility of access to the vessel (Fig. 5). Subsequently, after being reinstalled on board, the Chl-*a* prototype 8888 resumed its correct functioning. At the same time the DO 2222 probe showed 43% battery life remaining (Tab. 1).

[3] https://www.openstreetmap.org/copyright



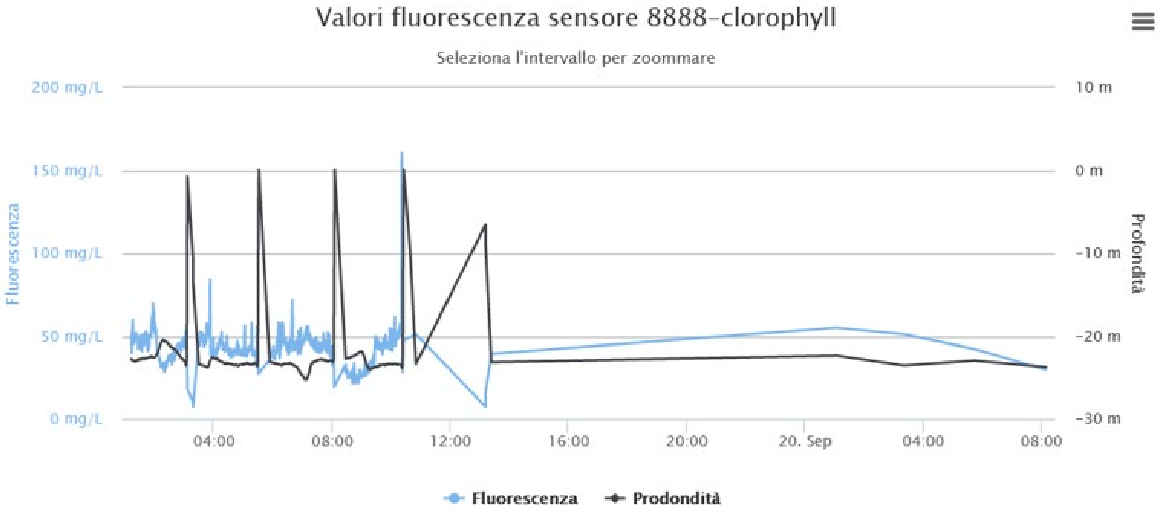


Figure 4: AdriFOOS web viewer shows the hauls recorded in the same period by the DO 2222 (top) and Chl-a 8888 (bottom) sensors on 20 September 2023, highlighting for the latter a failure to record data, caused by the flat battery.

Table 1: status of sensors' battery life over time as reported via their web application.

	07/07/23	**12/10/23**	**20/10/23**	**22/11/23**	**17/01/24**	**26/01/24**
DO 2222	76%	43%	-	-	100%	98%
Chl-*a* 8888	72%	-	100%	69%	100%	98%

Figure 5: Chl-a prototype 8888 power level after battery replacement on the 20/10/2023.

During the month of November 2023, the Chl-*a* 8888 prototype showed erratic behaviour upon activation (Fig. 6), i.e. it occasionally failed to activate during the fishing hauls or showed activations inconsistent with the 0.2 bar threshold set in the configuration (Fig. 2).

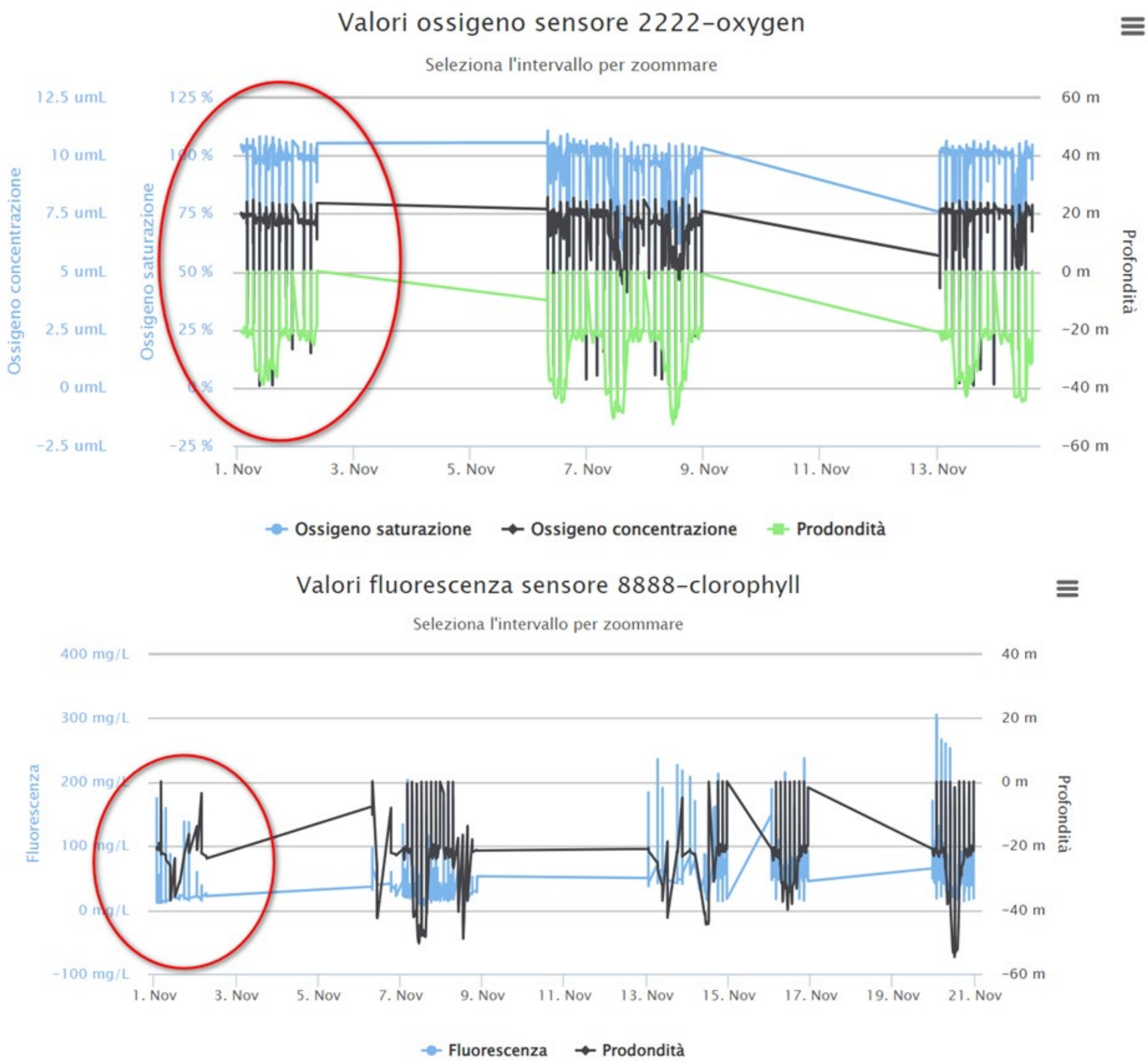


Figure 6: AdriFOOS web viewer shows the hauls recorded in the same period by the DO 2222 (top) and Chl-a 8888 (bottom) sensors in November 2023, highlighting for the latter inconsistent activation behaviour.

Constant monitoring via the AdriFOOS web viewer also allowed detecting a lack of data for the DO 2222 prototype around 16 November 2023 (Fig. 6). While on-board the CNR staff found the sensor off and it was not possible to manually turn it on; therefore it was decided to proceed with replacing the battery assuming that this was probably caused by a lack of power. However, on 22 November 2023, while carrying out the battery replacement procedures, CNR staff instead observed a structural problem, probably due to some physical impacts that occurred during fishing activity (Fig. 7).

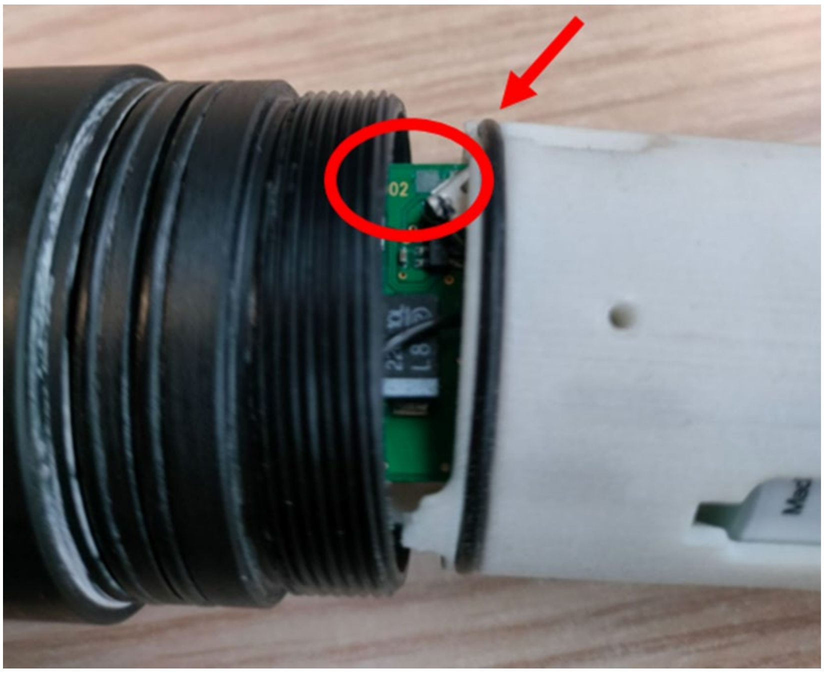


Figure 7: Structural issue observed on the DO 2222 prototype while carrying out battery replacement on 22 November 2023.

Therefore, following communications between the partners, on 29 November 2023 both probes had their batteries removed and were sent back to NKE facilities for a general check.
The DO 2222 prototype needed an internal membrane replacement and following the issues encountered during the demonstration and above described, the sensor's battery housing was redesigned to strengthen the battery fixing mechanism and avoid shifting during strong vibrations (Fig. 8A). Furthermore, to prevent the user from configuring the sensor with identical pressure thresholds on the way up and down, a firmware upgrade was made which sets some pressure limit thresholds for the activation settings. A new QR code label was also attached to the prototypes which allows to directly open the web application for settings configuration (Fig. 8B).
On 17 January 2024, the probes were received back at the CNR-IRBIM office in Ancona and equipped with new batteries following NKE instructions (Fig. 9) provided in an updated version of the sensor quick guide (see D5.6 Appendix 2.2).

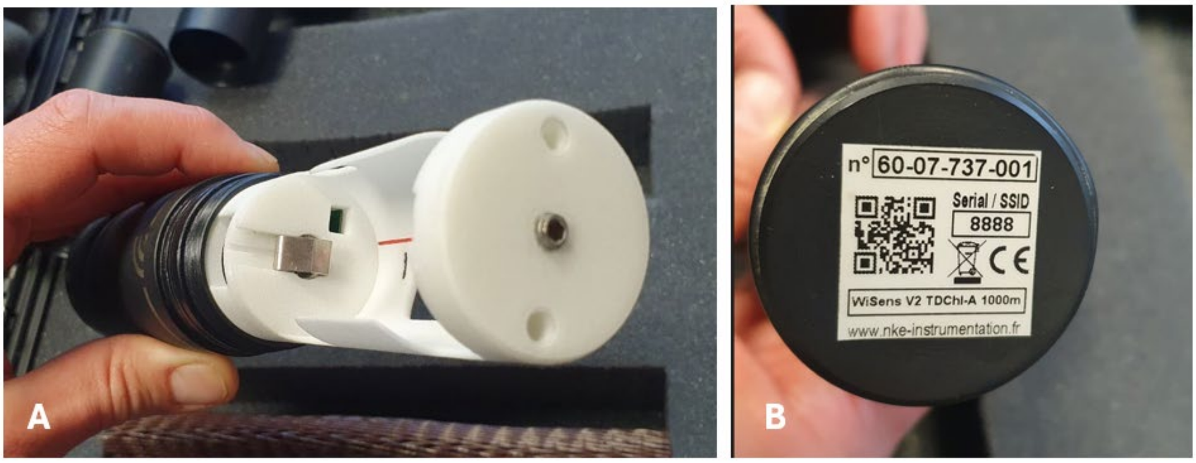
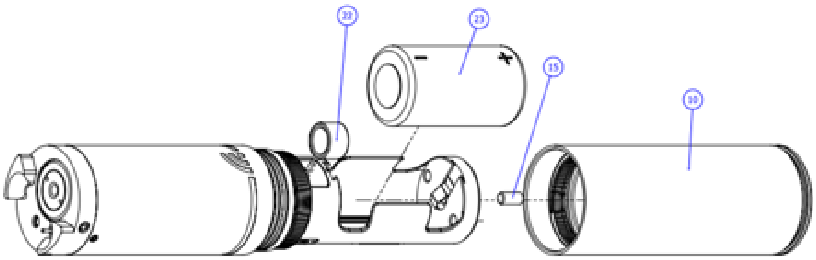


Figure 8: A) new more robust battery housing; B) label with QR code allowing to directly open the web application for settings configuration.



1. Unscrew the battery container (item 10) and check that the two seals are in good condition.
2. To release the pressure on the battery spring, unscrew the screw (item 15) using a 2.5 hexagonal key.
3. Check that the battery (item 23) is fitted the right way round and insert it into its housing with the negative pole first.
4. The sensor emits 3 vibrations and a double beep to confirm correct operation.
5. Tighten the screw (item 15) moderately until it is flush with the chassis.
6. Optionally, add the desiccant tablet (item 22) to its housing.
7. Screw in the container (item 10) completely

Figure 9: Sensor battery replacement instructions provided by NKE in an updated version of the Sensor Quick Start Guide.

Upon checking the settings on 18 January 2024, the probes were reassembled on board the commercial fishing vessel. In particular, following NKE recommendations, the activation and stop settings of the sensors were set to start if the pressure is > 0.2 and stop if < 0.3 (Fig. 10A). Based on the average values of the previous month, the salinity setting internally to the DO sensor was changed to 38.5 (Fig. 10B). Afterwards the sensors restarted working properly.

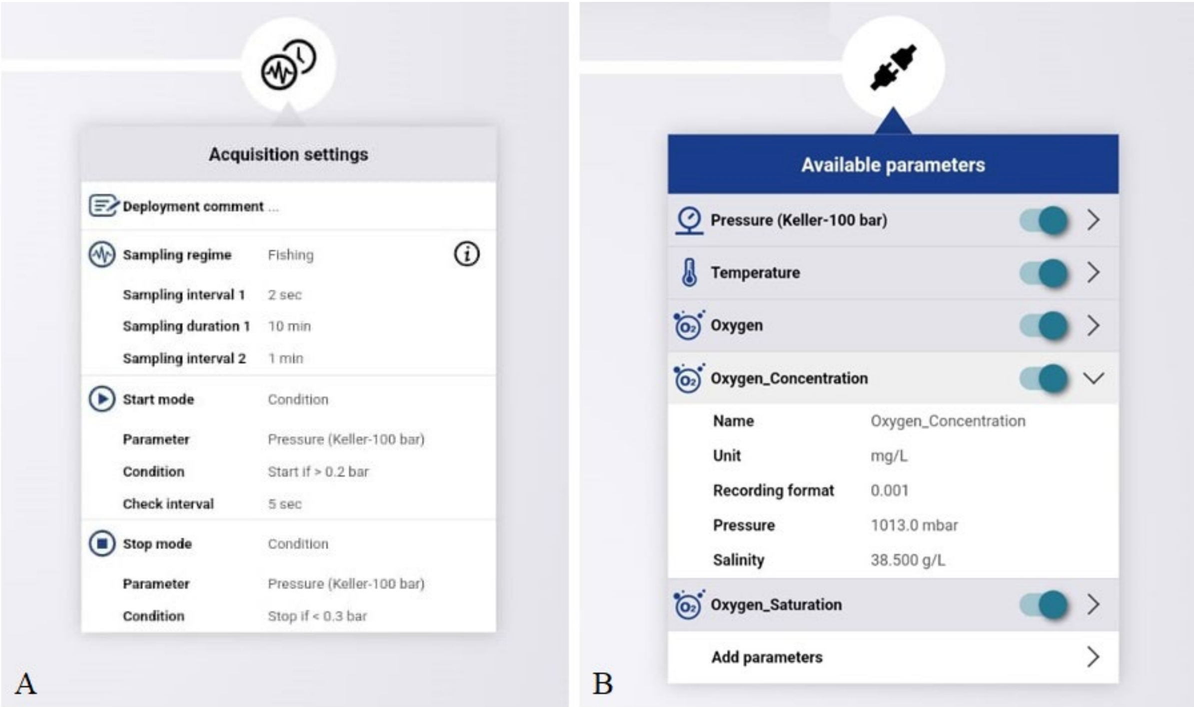


Figure 10: A) Sensor acquisition settings for the fisheries sampling regime as of 18 January 2024; B) Internal salinity setting salinity of the DO 2222 sensor.

- **Data recovery**

To prepare the NRT data flow to be implemented during the demonstration phase, in the previous months some sample data[4,5] generated by the AdriFOOS infrastructure were shared with the ETT staff and used to populate the NAUTILOS ERDDAP server and test the data transfer to the EMODnet platform.

The data acquired and collected on board are sent to the AdriFOOS cloud database in NRT via specific REST-API (Representational State Transfer - Application Programming Interface) procedures as detailed in D5.6 (section 2.1.5). The raw data (i.e. oceanographic data and GPS positions) are then synchronised by timestamp. Subsequently, a series of automatic controls are carried out to verify the data quality (e.g. pressure increasing check, range and spikes checking) and to assign Quality Control (QC) flags according to the standard vocabulary L20 (Seadatanet, 2022). Between September and November 2023 CNR and ETT finalised NRT data transmission to NAUTILOS services. Comma-separated values (CSV) data files are transferred to the ERRDAP server (see D8.3) via File Transfer Protocol Secure (FTPS). Figure 11 shows a pre-agreed data format with the measured parameters and their respective quality flags. A JavaScript Object Notation (JSON) file (Fig. 12) is associated with each data file, which contains the header with the metadata[6] and information about the properties of the parameters measured by the sensor (i.e. accuracy, precision, resolution, range, etc.). An automatic procedure was developed by the CNR staff to perform this task. A script runs every 5 minutes on the AdriFOOS database (Penna et al. 2023) and performs the following actions: it checks

[4] https://data-nautilos-h2020.eu/erddap/tabledap/AdriFOOS_profiles_2012-2020.html

[5] https://www.emodnet-ingestion.eu/submissions/submissions_details.php?menu=39&tpd=1080&step_more=8_11_17

[6] https://data-nautilos-h2020.eu/erddap/info/adrifoos_test/index.html

the local database for new validated data, transforms the data in the agreed format, saves a local copy and sends the files via FTPS to the NAUTILOS (Fig. 13). A diagram of the general data and metadata flow between data provider (CNR-IRBIM) and the NAUTILOS ERDDAP server (managed by ETT) is shown in Figure 14.

Then an automatic service gets metadata from the JSON file and data from the CSV file, merging them in a single Network Common Data Form (NetCDF) file (one file for each data package). The NetCDF files are uploaded and made available through the ERDDAP server (Fig. 15).


```
SN;Date_Time;LAT;LAT_QC;LON;LON_QC;depth;depth_QC;temperature;temperature_QC;fluorescence;fluorescence_QC
8888-clorophyll;2023-11-14_17:03:00;43.70065;1;13.50982;1;20.5;1;17.633;1;55.928;0
8888-clorophyll;2023-11-14_17:04:00;43.69987;1;13.5106;1;20.4;1;17.626;1;69.161;8
8888-clorophyll;2023-11-14_17:05:00;43.69911;1;13.51151;1;20.2;1;17.619;1;62.337;1
8888-clorophyll;2023-11-14_17:07:00;43.69845;1;13.51254;1;20.4;1;17.611;1;58.341;1
8888-clorophyll;2023-11-14_17:08:00;43.69754;1;13.51497;1;20.2;1;17.608;1;61.583;1
8888-clorophyll;2023-11-14_17:09:00;43.69718;1;13.51622;1;20.3;1;17.607;1;58.642;1
8888-clorophyll;2023-11-14_17:10:00;43.69683;1;13.51746;1;20.3;1;17.608;1;65.994;8
SN;Date_Time;LAT;LAT_QC;LON;LON_QC;depth;depth_QC;temperature;temperature_QC;oxygen_sat;oxygen_sat_QC;oxygen_conc;oxygen_conc_QC
2222-oxygen;2023-11-14_12:35:02;43.74247;1;13.56469;1;5.8;1;18.281;1;106.26;0;7.923;0
2222-oxygen;2023-11-14_12:35:04;43.74247;1;13.56469;1;7.7;1;18.283;1;106.084;1;7.91;1
2222-oxygen;2023-11-14_12:35:06;43.74247;1;13.56469;1;9.9;1;18.269;1;105.875;1;7.896;1
2222-oxygen;2023-11-14_12:35:08;43.74247;1;13.56469;1;11.9;1;18.163;1;105.024;1;7.849;1
2222-oxygen;2023-11-14_12:35:10;43.74247;1;13.56469;1;13.9;1;17.971;1;104.452;1;7.834;1
2222-oxygen;2023-11-14_12:35:12;43.74247;1;13.56469;1;15.7;1;17.844;1;103.663;1;7.794;1
2222-oxygen;2023-11-14_12:35:14;43.74247;1;13.56469;1;17.3;1;17.695;1;102.99;1;7.765;1
```


Figure 11. Examples of data files produced in the agreed format for the Chl-a (up) and DO (below) sensors; the QC columns report the QC flags adopted for each parameter.


```
{
    "institution": "NATIONAL RESEARCH COUNCIL - INSTITUTE FOR MARINE BIOLOGICAL RESOURCES AND BIOTECHNOLOGIES (CNR IRBIM)",
    "wmo_platform_code": "AdriFOOS",
    "site_code": "Adriatic",
    "title": "AdriFOOS CNR-IRBIM Ancona",
    "institution_references": "http://www.irbim.cnr.it",
    "contact": "Pierluigi Penna CNR IRBIM Ancona Largo Fiera della Pesca 2 60125 Ancona (Italy) pierluigi.penna@cnr.it",
    "author": "CNR IRBIM Ancona Largo Fiera della Pesca 2 60125 Ancona (Italy)",
    "data_assembly_center": "CNR IRBIM-AN",
    "pi_name": "Michela Martinelli CNR IRBIM Ancona Largo Fiera della Pesca 2 60125 Ancona (Italy) michela.martinelli@cnr.it",
    "distribution_statement": "These data follow NAUTILOS standards they are public and free of charge. User assumes all risk
    "citation": "These data were collected by means of the AdriFOOS platform and made freely available as a contribution to NA
    "time_coverage_start": "2023-11-14 17:03:31",
    "time_coverage_end": "2023-11-14 17:45:00",
    "vessel code": "AN-04",
    "brand": "NKE",
    "model of sensor": "8888-clorophyll",
    "temperature accuracy": "0.02 °C",
    "temperature range": "-2 - 35 °C",
    "temperature precision": "",
    "temperature resolution": "0.01 °C",
    "depth accuracy": "1.5 % of full scale",
    "depth range": "0 - 600 dBar",
    "depth precision": "",
    "depth resolution": "",
    "fluo accuracy": "",
    "fluo range": "0 - 140 ppb RWT",
    "fluo precision": "0.03 %",
    "fluo resolution": ""
}
```


Figure 12. A sample JSON file containing the header with the metadata associated with the corresponding CSV data file.

Nome file	Dimensione ...	Tipo file	Ultima modifica	Permessi	Proprieta...
NRT_test_AdriFOOS_8888-clorophyll_20231114_174500.json	1.7 KB	File JSON	14/11/2023 21:00:03	-rw-r--r--	root root
NRT_test_AdriFOOS_8888-clorophyll_20231114_174500.csv	2.8 KB	File CSV	14/11/2023 21:00:03	-rw-r--r--	root root
NRT_test_AdriFOOS_8888-clorophyll_20231114_170200.json	1.7 KB	File JSON	14/11/2023 20:00:04	-rw-r--r--	root root
NRT_test_AdriFOOS_8888-clorophyll_20231114_170200.csv	39.7 KB	File CSV	14/11/2023 20:00:04	-rw-r--r--	root root
NRT_test_AdriFOOS_2222-oxygen_20231114_150500.json	1.7 KB	File JSON	14/11/2023 19:00:05	-rw-r--r--	root root
NRT_test_AdriFOOS_2222-oxygen_20231114_150500.csv	30.3 KB	File CSV	14/11/2023 19:00:05	-rw-r--r--	root root
NRT_test_AdriFOOS_2222-oxygen_20231114_122500.json	1.7 KB	File JSON	14/11/2023 16:00:04	-rw-r--r--	root root
NRT_test_AdriFOOS_2222-oxygen_20231114_122500.csv	28.1 KB	File CSV	14/11/2023 16:00:04	-rw-r--r--	root root

Figure 13. Image of the local folder that contains the .json and .csv files created and mirrored to NAUTILOS server folder by the AdriFOOS data export procedure.

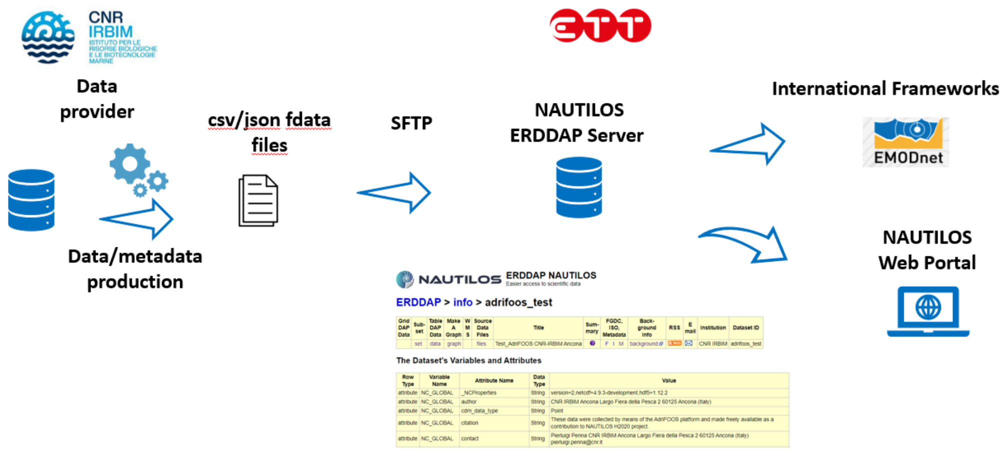


Figure 14. General data flow between the data provider (AdriFOOS) and NAUTILOS ERDDAP server.

NAUTILOS ERDDAP NAUTILOS
Easier access to scientific data

ERDDAP > Files > adrifoos_test

ERDDAP's "files" system lets you browse a virtual file system and download source data files.
WARNING! The dataset's metadata and variable names in these source files may be different than elsewhere in ERDDAP! You might prefer using the dataset's Data Access Form instead.
("files" documentation, including "How can I work with these files?")

Dataset Title: **Test_AdriFOOS CNR-IRBIM Ancona** RSS
Institution: CNR IRBIM (Dataset ID: adrifoos_test)
Information: Summary | License | FGDC | ISO 19115 | Metadata | Background | Subset | Data Access Form | Make a graph

Name	Last modified	Size	Description
Parent Directory	-	-	
NRT_test_AdriFOOS_2222-oxygen_20230914_180455.nc	22-Nov-2023 11:16	462578	
NRT_test_AdriFOOS_2222-oxygen_20230918_003058.nc	22-Nov-2023 11:16	88546	
NRT_test_AdriFOOS_2222-oxygen_20230919_104442.nc	22-Nov-2023 11:16	190299	
NRT_test_AdriFOOS_2222-oxygen_20230919_144900.nc	22-Nov-2023 11:16	207274	
NRT_test_AdriFOOS_2222-oxygen_20230920_102448.nc	22-Nov-2023 11:16	265086	
NRT_test_AdriFOOS_2222-oxygen_20230921_110100.nc	22-Nov-2023 11:16	239478	
NRT_test_AdriFOOS_2222-oxygen_20230927_062000.nc	22-Nov-2023 11:16	261012	
NRT_test_AdriFOOS_2222-oxygen_20230928_061858.nc	22-Nov-2023 11:16	220272	
NRT_test_AdriFOOS_2222-oxygen_20231002_024038.nc	22-Nov-2023 11:16	180696	
NRT_test_AdriFOOS_2222-oxygen_20231003_020700.nc	22-Nov-2023 11:16	221242	
NRT_test_AdriFOOS_2222-oxygen_20231003_130158.nc	22-Nov-2023 11:16	178465	
NRT_test_AdriFOOS_2222-oxygen_20231004_110258.nc	22-Nov-2023 11:16	16738	
NRT_test_AdriFOOS_2222-oxygen_20231004_230600.nc	22-Nov-2023 11:16	35703	
NRT_test_AdriFOOS_2222-oxygen_20231004_230622.nc	22-Nov-2023 11:16	61580	
NRT_test_AdriFOOS_2222-oxygen_20231008_223758.nc	22-Nov-2023 11:16	16738	
NRT_test_AdriFOOS_2222-oxygen_20231009_005200.nc	22-Nov-2023 11:16	33637	
NRT_test_AdriFOOS_2222-oxygen_20231009_005211.nc	22-Nov-2023 11:16	64490	
NRT_test_AdriFOOS_2222-oxygen_20231009_010226.nc	22-Nov-2023 11:16	16738	
NRT_test_AdriFOOS_2222-oxygen_20231009_032100.nc	22-Nov-2023 11:16	64878	
NRT_test_AdriFOOS_2222-oxygen_20231009_033104.nc	22-Nov-2023 11:16	16738	
NRT_test_AdriFOOS_2222-oxygen_20231009_055100.nc	22-Nov-2023 11:16	62162	

Figure 15. NetCDF files generated and uploaded to the NAUTILOS ERDDAP.

b. Demonstration on Fisheries Observing Systems in the Bay of Biscay (Ifremer)

- **Specific Objectives**

This demonstration was specifically conceived to quantify the Dissolved Oxygen (DO) and Chlorophyll a (Chl-*a*) prototypes drift (every 3 months after their 1st immersion) and evaluate probe measurement cycles.

- **Platform involved**

The two prototypes were installed together with the standing alone WiHub (developed in ST3.1.2) onboard a fishing vessel equipped to fish by means of pots (Fig. 16). Inside pots offer good support for installing sensors, some degree of protection from contacts with other objects, and minimise the risk of loss.
The captain is a long time partner of Ifremer, namely involved in the ex-RECOPESCA program (Lamouroux et al. 2016; Leblond et al. 2010 - ended in January 2023).

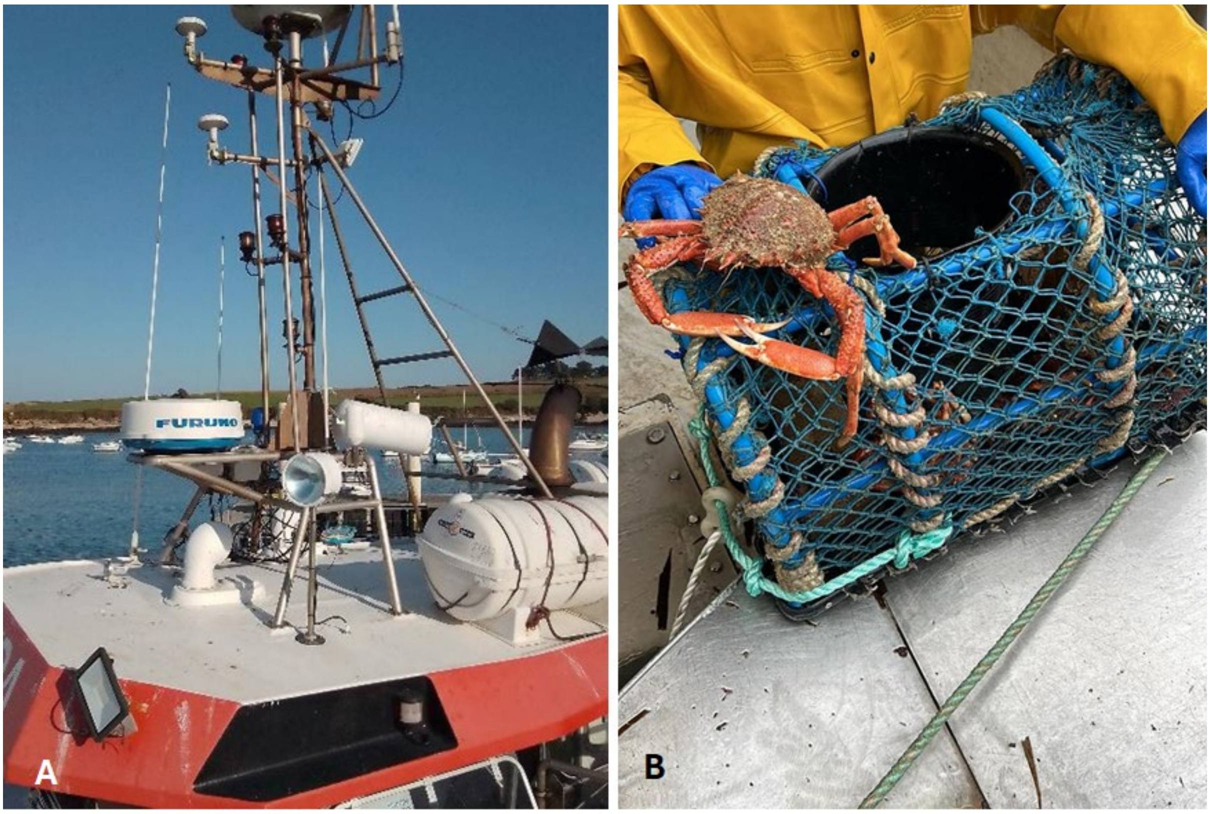


Figure 16: A) WiHub position, B) pot.

The vessel is based in a port near the city of Brest, so that the Ifremer staff can constantly verify the correct functioning. The vessel operates at depths ranging from 50 m (~2 min to be reached) to 150 m (~15 min to be reached). In general, pots are hauled every 3 days and stay onboard about 10 min before the setting process. Obviously, this depends on the weather: pots can stay underwater longer or put back on board until the next fishing trip when the weather is bad, namely during winter. In that case, or when the vessel is undergoing a technical shutdown, it may remain docked for several days and consequently not provide data.

- **Deployment configuration**

On 19 July 2023, the following equipment was installed on board the selected fishing vessel:
- DO sensor serial number 1111 (First Factory calibration Date 11-22);
- WiHub systems serial number 23 0009.

As reported in D5.6, Chl-*a* prototype 6666 failed during the field testing and in May 2023 was returned to NKE for inspection; the new Chl-*a* 59dd prototype was built in July 2023 (First Factory calibration Date 08-23), received in August by Ifremer and then tested with fluorescein in the Ifremer metrology laboratory (see Appendix 3). Protections have been received at the end of September, so this Chl-*a* 59dd prototype was installed in a pot by the fisherman at the end of October.

This instrumentation was integrated on board as described in Chapter II of D5.6 (Martinelli et al. 2023).

The sensors and WiHub settings were determined through their web application by means of a cellular phone as follows:

A) <u>DO sensor</u>

The acquisition was set to the fishing sampling regime. This configuration allows two distinct data acquisition intervals within the same fishing haul.

From late July 2023 to early November 2023 the sensor was configured to start data recording once immersed in water at a pressure greater than 0.2 bar and stop data recording when pressure was less than 0.2 bar, with a frequency of 2 seconds (the highest allowed by the sensors) for 10 minutes, then with a frequency of 1 min (Fig. 17).

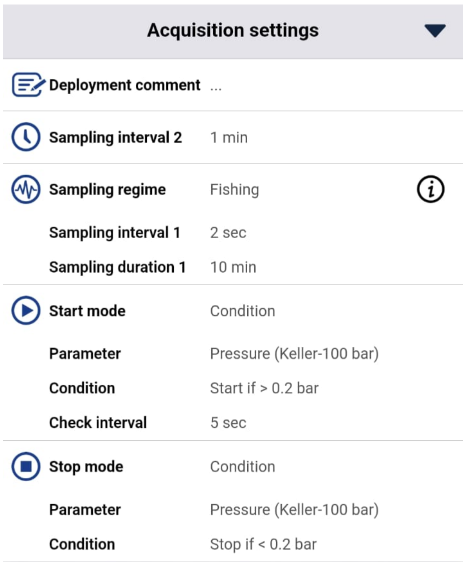
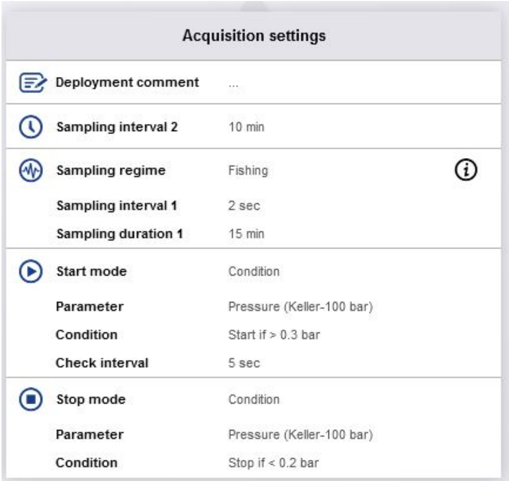


Figure 17: First DO sensor acquisition settings.

Since mid-December 2023 the sensor was configured to start data recording once immersed in water at a pressure greater than 0.3 bar and stop data recording when reaching a pressure less than 0.2 bar (this was suggested by NKE to avoid dysfunction), with a frequency of 2 seconds (the highest allowed by the sensors) for 15 minutes, then with a frequency of 10 min (Fig. 18).



Acquisition settings	
Deployment comment	...
Sampling interval 2	10 min
Sampling regime	Fishing
Sampling interval 1	2 sec
Sampling duration 1	15 min
Start mode	Condition
Parameter	Pressure (Keller-100 bar)
Condition	Start if > 0.3 bar
Check interval	5 sec
Stop mode	Condition
Parameter	Pressure (Keller-100 bar)
Condition	Stop if < 0.2 bar

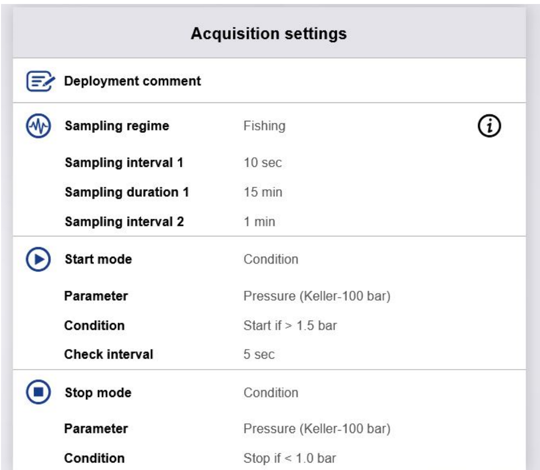
Figure 18: Second DO sensor acquisition settings.

Within this sensor, the internal salinity value was set at 0 because it was deployed in variable conditions (see *Location* part) and in the absence of other instruments for measuring salinity on board.

B) <u>Chl-*a* sensor</u>

The acquisition was also set to fishing sampling regime.

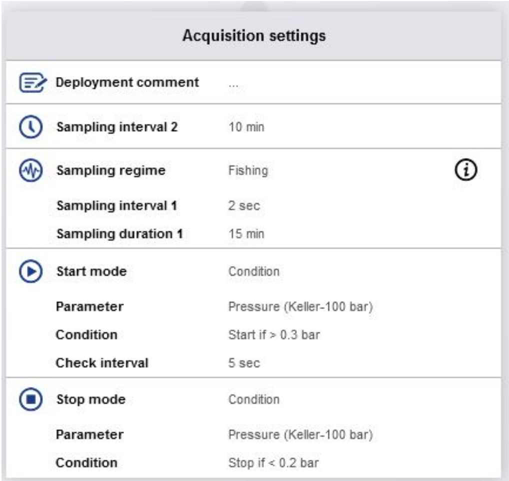
During November 2023 the sensor was configured to start data recording once immersed in water at a pressure greater than 1.5 bar and stop data recording when pressure becomes less than 1 bar, with a frequency of 10 seconds for 15 minutes, then with a frequency of 1 min (Fig. 19).



Acquisition settings	
Deployment comment	
Sampling regime	Fishing
Sampling interval 1	10 sec
Sampling duration 1	15 min
Sampling interval 2	1 min
Start mode	Condition
Parameter	Pressure (Keller-100 bar)
Condition	Start if > 1.5 bar
Check interval	5 sec
Stop mode	Condition
Parameter	Pressure (Keller-100 bar)
Condition	Stop if < 1.0 bar

Figure 19: First Chl-a sensor acquisition settings.

Since December 2023, the Chl-*a* sensor was also configured as well as the DO sensor (Fig. 20).



Acquisition settings

Deployment comment	...
Sampling interval 2	10 min
Sampling regime	Fishing
Sampling interval 1	2 sec
Sampling duration 1	15 min
Start mode	Condition
Parameter	Pressure (Keller-100 bar)
Condition	Start if > 0.3 bar
Check interval	5 sec
Stop mode	Condition
Parameter	Pressure (Keller-100 bar)
Condition	Stop if < 0.2 bar

Figure 20: Second Chl-a sensor acquisition settings.

C) <u>WiHub</u>

From late July 2023 to early October 2023 the GPS acquisition was set every 15 min (to save memory because of problems with the data transmission, see *Maintenance, events/issues occurred and actions taken* section), and from early October 2023 to early November 2023, the GPS acquisition was set every 5 min.

In early November 2023, NKE updated the WiHub firmware and set the GPS acquisition to every 1 min.

- **Location**

The selected vessel mainly operates in the Iroise Sea (North Bay of Biscay) located at the western end of Brittany in the north-west of France (Fig. 21).

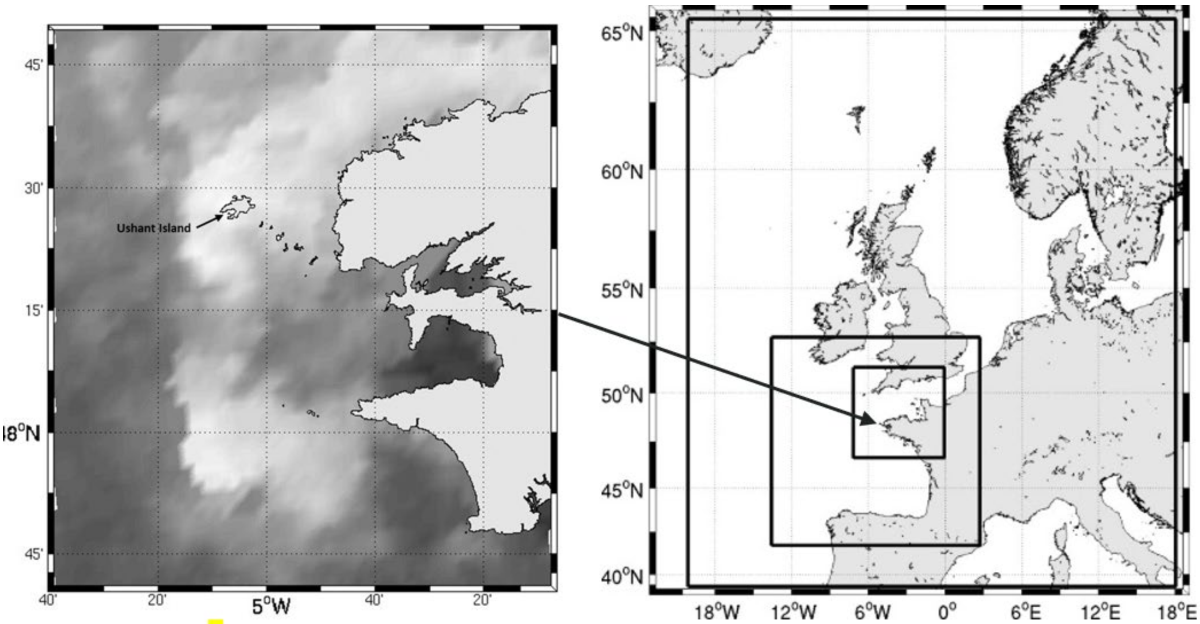


Figure 21: Location of the French demonstration area (modified from Muller et al., 2007).

It is a shallow area with a mean depth of 110 m. With regard to the hydrodynamics, the tidal wave is semi-diurnal and propagates northwards at the extreme end of Brittany. The tidal range varies between 3 m at neap tide and 7 m at exceptional spring tide. The interaction with the coastline and bathymetry causes strong currents (Muller et al. 2007), leading to coastal homogeneous waters, mixed by tides. In contrast, offshore Celtics waters are well thermally stratified in summer and autumn, due to external forcings (air/sea heat flux and wind tension, spring/slack tide cycles; Cambon G. 2008). The separation between stratified and mixed waters is called the "Ushant tidal front" (from the Ushant Island name), whose dynamics structure the hydrological specificity of the Iroise Sea.

The activity area of the vessel selected for the sensors' demonstration is mostly coastal (es. Fig. 22), therefore subject to variations in temperature and salinity. Figure 23 shows the salinity at the surface and at the bottom during the first 6 months of the demonstration phase.

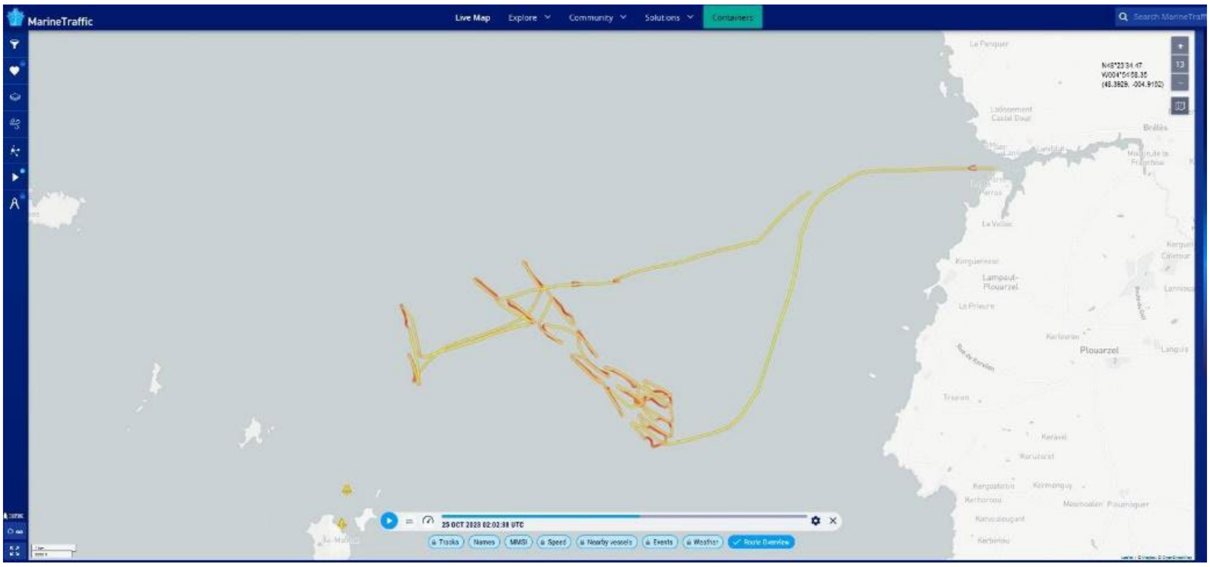


Figure 22: Main activity area of the vessel involved in the demonstration (source: AIS data from Marine traffic[7]).

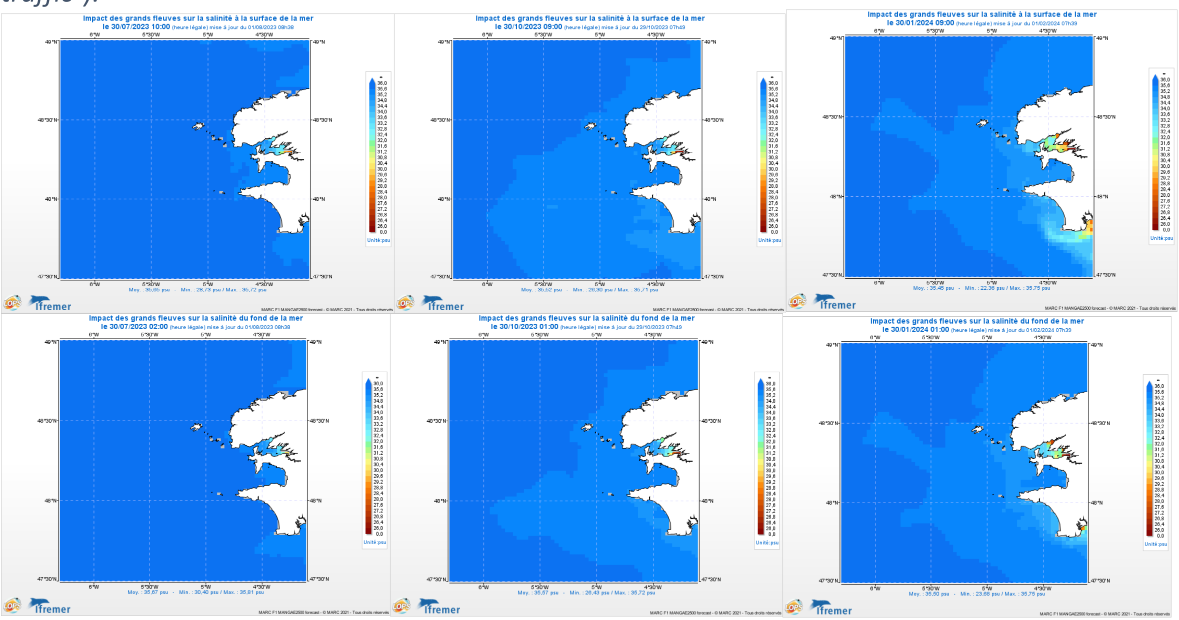


Figure 23: Salinity at the surface (up) and at the bottom (bottom) during the first 6 months of the demonstration phase (Source: MARC Modeling and Analysis for Coastal Research[8]).

[7] https://www.marinetraffic.com

[8] https://marc.ifremer.fr/en/

- **Period of occurrence**

Ifremer received training on the WiHub use in June 2023 and tested integration and data flow in July 2023, together with installation of DO 1111 prototype. Chl-*a* 59dd prototype built in July 2023 was installed at the end of October 2023. Vessel should remain equipped until summer 2024.

- **Maintenance, events/issues occurred and actions taken**

A) <u>DO sensor</u>

Sensors are not accessible in the same way as the CNR, as they are most of the time underwater. So, in order to communicate with the sensors to check configuration for example, it is necessary to ask the professional to take the pot out of the water.

The 1111 sensor on board since late July 2023 was accessed in early November 2023. It did not provide data after early September 2023 whereas the vessel was active. The battery level was 12% (Fig. 24A). This low level did not permit to record more data. NKE replaced the battery.

Figure 24 shows some biofouling on the DO sensor; however, passive protection is introduced around the active sensor membrane (black circle in Figure 24B) which passively prevents dirt deposits and fouling of this membrane.

The 1st drift check occurred in mid-November 2023 (see *Drift check procedure* section).

The sensor was put back in a pot in mid-December 2023 (with 99% battery level).

Figure 24: DO sensor's low battery level indication (A) and fouling (B) after 3 months underwater.

B) <u>Chl-*a* sensor</u>

The 59dd sensor put onboard at the end of October 2023 was retrieved in mid-February. It did not record any data since mid-December 2023) (Fig. 25). The battery level was at 12%.

The 1st drift monitoring after 3 months will be carried out in mid-February 2024.

The tables 2 and 3 below summarise the sensors events and batteries levels.

Figure 25: Last Chl-a sensor's file recorded after the 1st setting period.

Table 2: DO 1111 sensor events and battery level from July 23 to January 24.

DO 1111 sensor events		
Configuration: fishing mode with start>0.2 bar/stop<0.2 bar): T1=2 s/10 min - T2=1 min		
Date	**Events**	
26/07/2023	1st deployment	
05/09/2023	No data record	
09/11/2023	Battery change	
20/11/2023	1st drift check	
Configuration: fishing mode with start>0.3 bar/stop<0.2 bar): T1=2 s/15 min - T2=10 min		
Date	**Events**	
14/12/2023	2nd deployment	
Battery level information in DO 1111 sensor data file		
Configuration on fishing mode with start>0.2 bar/stop<0.2 bar): T1=2 s/10 min - T2=1 min		
Date	**% battery (eS1 indicator)**	**records nb (eD3 indicator)**
[26/07/2023-29/07/2023]	94.1 %	4 527
[29/07/2023-01/08/2023]	88.8 %	4 355
[01/08/2023-09/08/2023]	83.6 %	11 897
[09/08/2023-11/08/2023]	68.8 %	3 348
[11/08/2023-14/08/2023]	64.9 %	4 596
[14/08/2023-16/08/2023]	59.4 %	2 947
[16/08/2023-29/08/2023]	56.0 %	18 932
[29/08/2023-05/09/2023]	32.2 %	10 249
[05/09/2023-05/09/2023]	19.5 %	300
Configuration on fishing mode with start>0.3 bar/stop<0.2 bar): T1=2 s/15 min - T2=10 min		
Date	**% battery (eS1 indicator)**	**records nb (eD3 indicator)**
[16/12/2023-26/12/2023]	98.9 %	1 877
[26/12/2023-08/01/2024]	87.5 %	2 317
[08/01/2024-10/01/2024]	72.6 %	749
[10/01/2024-13/01/2024]	70.2 %	871
[13/01/2024-15/01/2024]	66.9 %	734

Table 3: Chl-a 59dd sensor events and battery level from November 23 to January 24.

Chl-a 59dd sensor events		
Configuration: fishing mode with start>1.5 bar/stop<1 bar): T1=10 s/15 min - T2=1 min		
Date	**Events**	
31/10/2023	1st deployment	
Configuration: fishing mode with start>0.3 bar/stop<0.2 bar): T1=2 s/15 min - T2=10 min		
Date	**Events**	
15/12/2023	No data record	
Battery level information in Chl-a 59dd sensor data file		
Configuration on fishing mode with start>1.5 bar/stop<1 bar): T1=10 s/15 min - T2=1 min		
Date	**% battery (eS1 indicator)**	**records nb (eD3 indicator)**
[31/10/2023-07/11/2023]	89.3 %	10 156
[07/11/2023-11/11/2023]	74.7 %	5 637
[11/11/2023-15/11/2023]	66.6 %	5 973
[15/11/2023-23/11/2023]	58.0 %	11 477
[23/11/2023-25/11/2023]	41.4 %	3 024
Configuration on fishing mode with start>0.3 bar/stop<0.2 bar): T1=2 s/15 min - T2=10 min		
Date	**% battery (eS1 indicator)**	**records nb (eD3 indicator)**
[30/11/2023-30/11/2023]	36.5 %	367
[02/12/2023-15/12/2023]	36.3 %	2 316
[15/12/2023-15/12/2023]	13.1 %	450

C) WiHub

From the end of July to early November 2023, there was no automatic transmission of data to the NKE FTP server (Fig. 26) *via* the telephone network; this issue was investigated and corrected by NKE in early November (the port for the FTP server did not support the national mobile operator associated with the SIM card inserted in the WiHub by Ifremer staff).

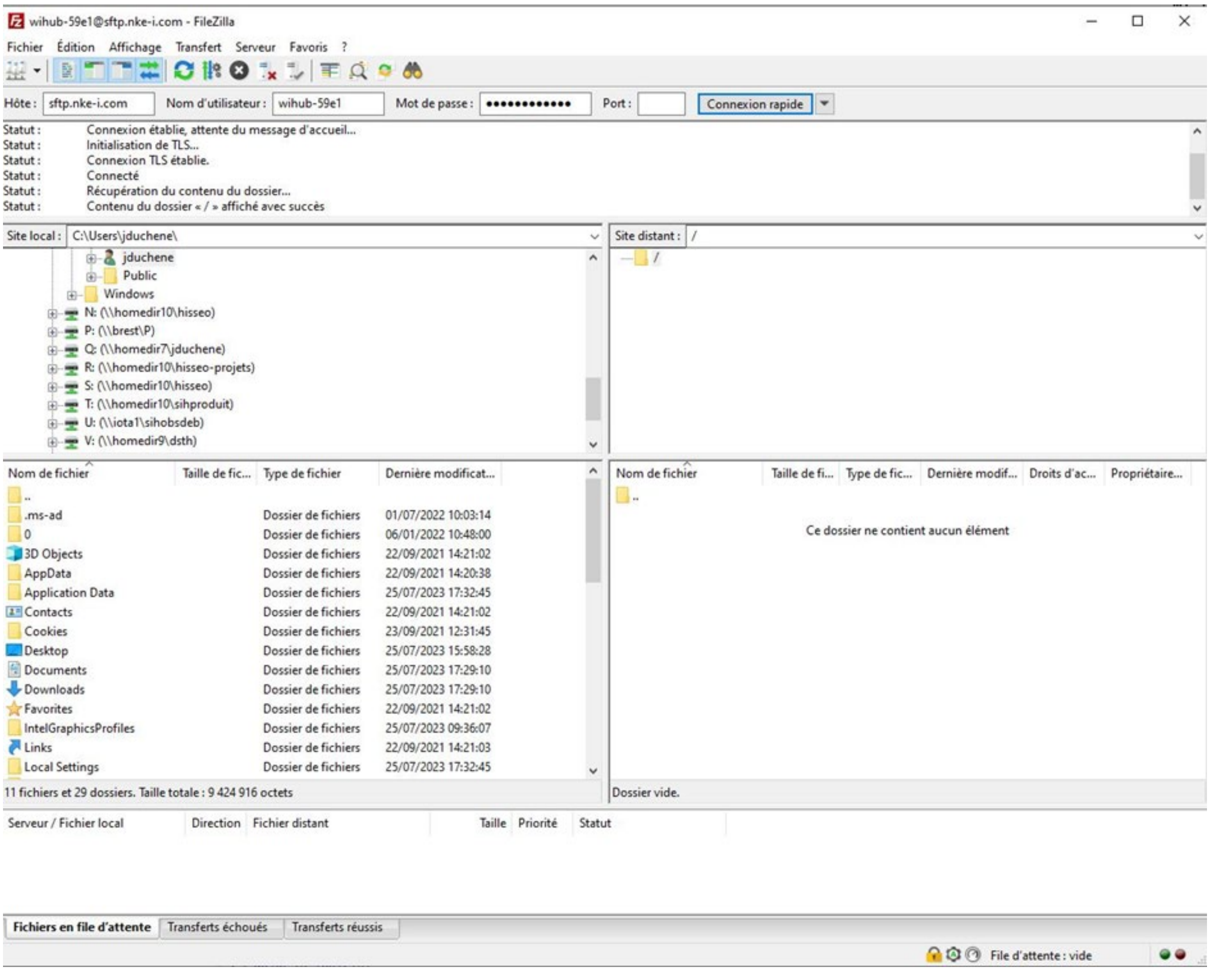


Figure 26: NKE FTP server interface for users.

GPS and DO sensor data were retrieved manually *via* Wi-Fi until the automatic transmission started to work.

Tests to identify the problem led to a GPS reception interruption from the end of July to mid-October 2023: change of Access Point Name (APN) configuration from websfr (data option) to sl2sfr (voice and data option) led to an abnormal reset and erased GPS data, whereas data from DO sensor were still automatically offloaded to the WiHub. This issue has been identified by NKE and resolved by a software update in early November 2023.

- **Drift check procedure**

Sensors drift check was done according to the procedures detailed in D6.1.

A) <u>DO sensor</u>

Analyses were performed according to the Winkler method described in Aminot & Kérouel (2004) with 100 % oxygen saturation and internal salinity setting at 0, in Ifremer testing facilities.

B) <u>Chl-*a* sensor</u>

This sensor was tested with different practical concentration ranges of Fluorescein solution in Ifremer testing facilities.

- **Data recovery**

Once out of the water after the fishing operations, sensors sent the data acquired during the fishing phase to the WiHub *via* Wi-Fi. During the 1st part of the demo, the sensor's dataset and the GPS time stamp produced by the latter were retrieved manually *via* Wi-Fi from the WiHub and sent to ETT directly in October 2023. Then, the WiHub started to transfer automatically to the NKE FTP server (as a first step) using file transfer protocol FTP port 2221. In a second step, Ifremer staff put the raw data progressively in the data-nautilos-h2020.eu FTP for ETT access as Ifremer downloads them from the NKE FTP server. The metadata related to the produced dataset should indicate that the internal salinity setting for the DO 1111 sensor is set at 0, therefore data should be post processed before usage for purposes external to the project.

3 RESULTS – COMMENTS – CONCLUSIONS

- **Results**

From July 2023 to January 2024 the DO 2222 prototype registered 18524 records during 140 trawl hauls carried out in the Adriatic Sea, while the Chl-*a* 8888 one registered 12397 records in 121 hauls in the same area.

Recorded data were transferred to the NAUTILOS data services and are accessible both through ERDDAP[9] and GeoServer[10] interfaces (Figs. 27 and 28).

The number of deployments (i.e. trawl hauls) occurred in the Adriatic Sea was associated with the recorded battery consumption levels (Table 1). The DO 2222 prototype showed a battery consumption of 33 % (from 76% to 43%) after 94 hauls (38764 records), while Chl-*a* 8888 revealed faster battery consumption with a decrease of 31% (from 100% to 69%) after 48 hauls (22234 records). Deployments had an average duration of 141.5 minutes. According to the set sampling regime (Fig. 10), for each haul there are 300 initial records taken every 2 seconds, then in the second phase the number of records registered every minute depends on the haul duration; this may also influence the battery consumption.

Each fishing operation in the Iroise Sea can last a few days (setting-fishing-hauling). The DO 1111 sensor registered 67700 records during 14 fishing operations in July, August, September, December 2023 and January 2024. The table 4 below shows an extract of a DO sensor's file.

The Chl-*a* 59dd sensor registered 39400 records during 8 fishing operations in October, November and December 2023. The table 5 below shows a full Chl-*a* sensor's file and the figure 29 the data. In the Chl-*a* 59dd sensor files, there is no column "CH3:Depth(m)" as instead in the files produced by the other prototypes.

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[9] https://data-nautilos-h2020.eu/erddap/tabledap/adrifoos_test.graph

[10] https://nautilos-h2020.eu/data-portal/

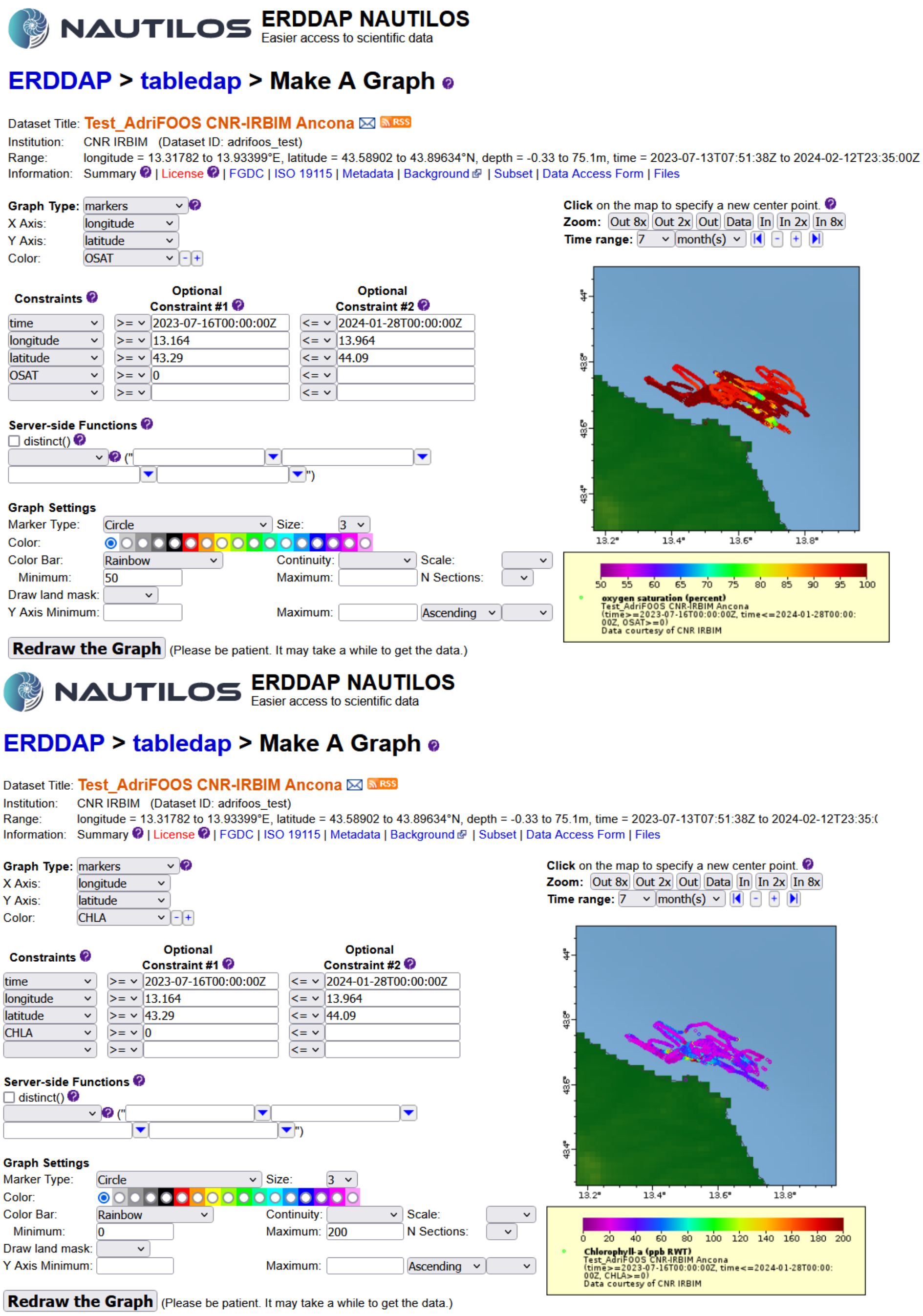

Figure 27: DO 2222 (top) and Chl-a 8888 (bottom) datasets recorded in the Adriatic Sea via AdriFOOS infrastructure and available through the NAUTILOS ERDDAP.

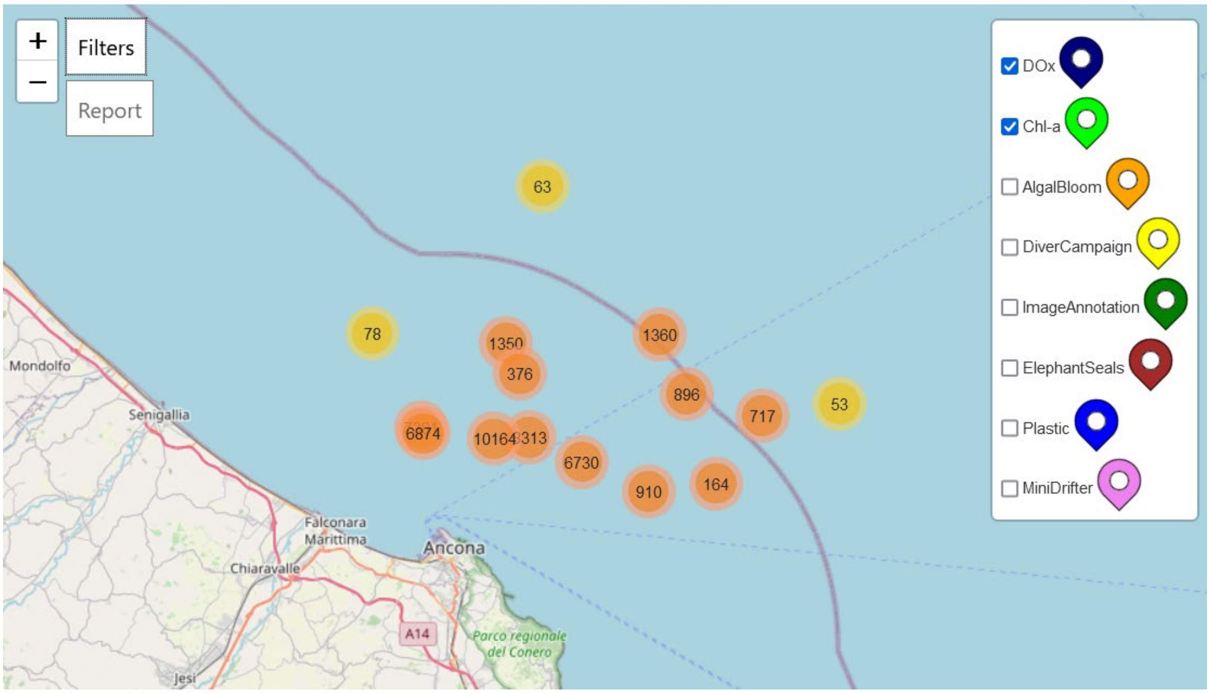

Figure 28: DO 2222 (top) and Chl-a 8888 (bottom) datasets recorded in the Adriatic Sea via AdriFOOS infrastructure and available through the NAUTILOS data portal on the project website.

Table 4: DO 1111 sensor's data extracted from a file.

Timestamp(Standard)	CH0:Pressure (bar)	CH1:Temperature (degC)	CH2:Oxygen (deg)	CH3:Depth (m)	CH4:Oxygen_Concentration (mg/L)	CH5:Oxygen_Saturation (%)
26/07/2023 09:26:02	1,11	15,112	23,078	11	9,827	**97,832**
26/07/2023 09:26:04	1,18	15,058	23,114	11,7	9,814	**97,584**
26/07/2023 09:26:06	1,25	14,959	23,116	12,4	9,842	**97,658**
26/07/2023 09:26:08	1,33	14,885	23,202	13,1	9,793	**97,016**
26/07/2023 09:26:10	1,41	14,756	23,157	13,9	9,871	**97,507**
26/07/2023 09:26:12	1,49	14,589	23,262	14,7	9,835	**96,798**
26/07/2023 09:26:14	1,56	14,417	23,299	15,4	9,857	**96,653**
26/07/2023 09:26:16	1,64	14,368	23,304	16,2	9,868	**96,658**
26/07/2023 09:26:18	1,71	14,375	23,35	16,9	9,827	**96,275**
26/07/2023 09:26:20	1,78	14,356	23,25	17,6	9,917	**97,113**
26/07/2023 09:26:22	1,86	14,314	23,256	18,4	9,925	**97,103**
26/07/2023 09:26:24	1,93	14,256	23,27	19,1	9,931	**97,042**
26/07/2023 09:26:26	2	14,197	23,322	19,8	9,906	**96,67**
26/07/2023 09:26:28	2,06	14,168	23,382	20,4	9,865	**96,207**
[...]						

Table 5: Chl-a 59dd sensor's file.

Timestamp(Standard)		CH0:Pressure(bar)	CH1:Temperature (degC)	CH2:Chlorophyll_*a*(ppb)
23/11/2023	07:22:50	1,706	13,913	221,305
23/11/2023	07:23:00	2,092	13,915	218,157
23/11/2023	07:23:10	2,533	13,915	231,065
23/11/2023	07:23:20	2,956	13,916	248,835
23/11/2023	07:23:30	3,406	13,917	242,328
23/11/2023	07:23:40	3,839	13,918	239,11
23/11/2023	07:23:50	4,259	13,917	245,407
23/11/2023	07:24:00	4,605	13,917	254,327
23/11/2023	07:24:10	4,968	13,917	252,018
23/11/2023	07:24:20	5,376	13,917	255,446
23/11/2023	07:24:30	5,725	13,918	254,711
23/11/2023	07:24:40	5,922	13,918	270,173
[...]				

The Chl-*a* 59dd signal seems quite high considering this period of the year (November month), but as already reported in D5.6 this is factory calibrated with Rhodamine as a proxy of Chlorophyll, therefore data would need a post-processing to be compared with other acquisitions. Furthermore, the sensor position in a meshbag could influence the beam and provide incorrect data.

<u>Ifremer DO sensor drift check n°1</u>

All the results for the tests performed at Ifremer lab are expressed in % of O_2 saturation (Tab. 6). Tap water was used to carry out the tests and internal salinity was set at 0. The drifts for the O_2 saturation showed to be ~ 5% while that for temperature was almost zero.

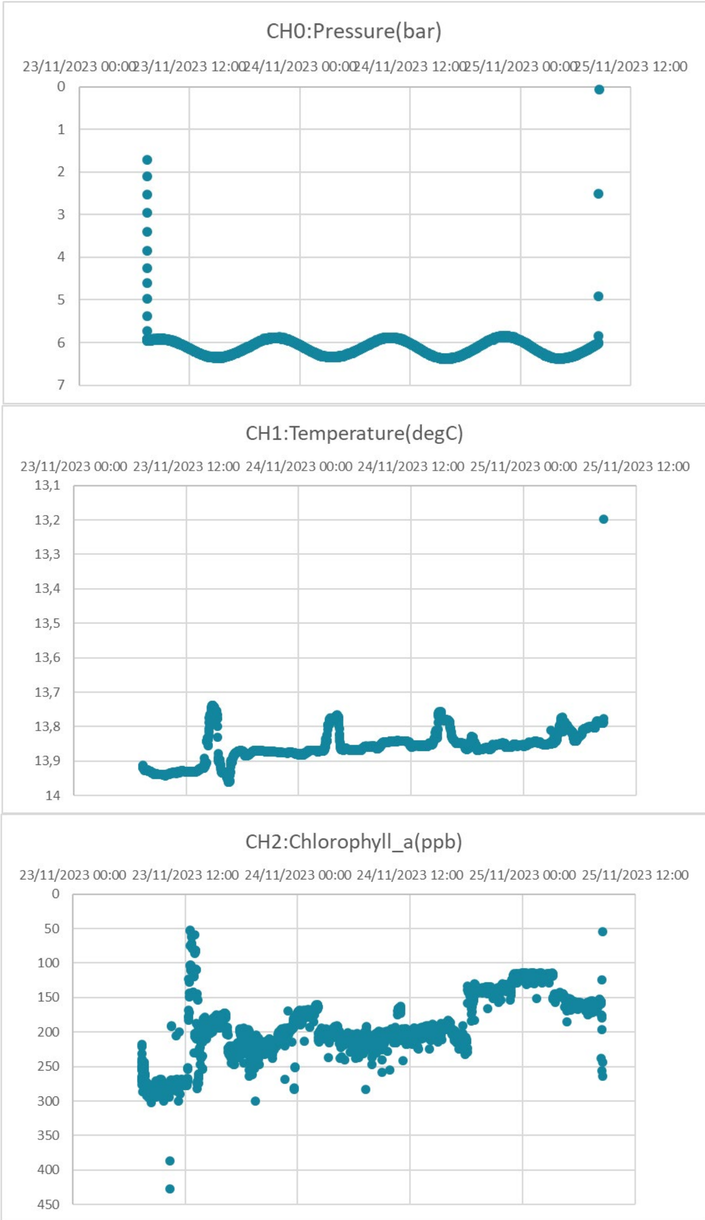

Figure 29: Chl-a 59dd sensor's data extracted from a file.

Table 6: DO sensor reference values (up) and 1st drift check.

Wisens O2 SN 1111 01/2023 (calibration and validation references D6.1)

Winkler Reference				Temperature	Salinity	O2 sensor 1111									
[O2] (mg/L)		O2 % sat		°C	PSU	internal salinity setting	$[O_2]$ en mg/L		Correction (mg/L)	$[O_2]$ en % sat		Correction (%)	T en °C		Correction (°C)
Moyenne	Ecart-type						Moyenne	Ecart-type		Moyenne	Ecart-type		Moyenne	Ecart-type	
9,83	0,02	97,88	0,19	15,20	0,00	0	9,83	0,00	0,00	98,2	0,1	-0,3	15,20	0,02	0,00

Wisens O2 SN 1111 18/11/2023 (drift check n°1)

Winkler Reference				Temperature	Salinity	O2 sensor 1111									
[O2] (mg/L)		O2 % sat		°C	PSU	internal salinity setting	$[O_2]$ en mg/L		Correction (mg/L)	$[O_2]$ en % sat		Correction (%)	T en °C		Correction (°C)
Moyenne	Ecart-type						Moyenne	Ecart-type		Moyenne	Ecart-type		Moyenne	Ecart-type	
10,20	0,01	101,6	0,1	15,19	0,00	0	9,60	0,04	0,60	95,7	0,3	5,9	15,18	0,00	0,01

- **TRL achievement level and project SOP**

After the installations on board, some maintenance interventions and mechanical and software refinements were carried out in order to optimise the entire process of oceanographic data acquisition and data transmission to the inland datacenters.
Based on the technical issues encountered during the first part of the demonstration phase, the battery housing has been redesigned, the sensor firmware has been upgraded as well as the quick start guides related to the sensor's use.
A software update occurred in the WiHub to allow the port for the FTP server to support the mobile operator selected by Ifremer.
These improvements justify an upgrade of the declared Technology Readiness Levels (TRL) from 6 in D5.6 to 7 at this stage.

- **Future plans and Recommendations**

In the coming months the CNR-IRBIM staff will continue to constantly monitor the correct functioning of the sensors and the WiHub installed on the commercial bottom trawler operation in the Adriatic Sea, and the transmission of NRT data to the NAUTILOS data services. Furthermore, after the last battery replacement occurred simultaneously for both prototypes, power consumption levels will also be constantly monitored.
Ifremer will proceed to the 2nd DO 1111 sensor and the 1st Chl-*a* 59dd sensor drift checks in mid-February before the vessel stops the pot fishing activity until the end of March/early April. Then Ifremer will proceed to the DO sensor 3rd drift check and Chl-a sensor 2nd drift at the end of June/early July (the final checks before the end of the NAUTILOS Project). For this last stage, the Chl-*a* 59dd sensor will not be placed in a meshbag and different mounting positions will be tested so that the field in front of the sensor will be free. In fact, when the sensor is placed inside a pot, it is possible that organisms will pass in front of it.
As well as for the other prototypes, the indication of depth in Chl-*a* 59dd files would have been practical, therefore it is recommended to consider this in all future sensor products. Care must be taken in the production of the WiHub to ensure that all national telephone operators in the countries where the instruments are deployed are properly supported.

III. Novel approach to Aquaculture Observing Systems Demonstration Report

1. Background

In Aquaculture Observing Systems demonstration (ST7.1.2), NIVA and HCMR will implement DO, Chl-*a*, Infrared (IR) temperature sensor and carbonate system sensors from T3.1, T3.2 and T4.1, respectively, in coastal regions of Norway and Greece with mariculture and fish farming. The sensors are described in Deliverables 3.2: Report on the development of Dissolved Oxygen and Chlorophyll-*a* sensors for fishery vessels, 3.3: Report on laboratory tests of downward looking sensors and 4.1: Report on the development of carbonate chemistry/ocean acidification sensors; and calibration/validation of the sensors are documented in Deliverables 6.1 and 6.2: Report on results and methodology of calibration/validation experiments performed in T6.1 and T6.2, respectively. The sensors will be deployed both at the mariculture/fish farm locations as well as integrated and demonstrated on FerryBoxes and fishery research vessels that operate in the vicinity of the mariculture/fish farm locations to provide a higher degree of spatial and temporal data coverage. The integration of the sensors with the observing platforms was primarily documented and described in Deliverable 5.6: Validation and integration report on ships of opportunity. Data will be collected in NRT and DFKI will utilise the data stream from the sensors for event detection and concept change detection (as described in D4.6: Report on development of event-based sampling).

The carbonate chemistry and ocean acidification sensors that will be used in ST7.1.2 include pH and pCO_2 sensors that were further developed in NAUTILOS: a Honeywell Durafet III ISFET pH electrode and a Franatech CO_2-HR sensor. The commercial-off-the-shelf sensors were improved in several ways: 1) customised pressure case for the pH sensor, 2) Tris-buffer calibration protocols for improved accuracy for the pH sensor, 3) integration of the pH sensor with a Raspberry Pi for data logging and visualisation of pH measurements, 4) gas calibration cap and protocols for improved accuracy of the CO_2 sensor, and 5) addition of pump head to the CO_2 sensor to improve response time.

Technical specifications:
NAUTILOS Honeywell Durafet III ISFET pH electrode
Dimensions: Ø80mm * L~400mm
Weight: ~2kg
Power: 12VDC
Telemetry: internal logger, RT capable
Measurement range: 0-14 pH
Measurement precision: 0.025

NAUTILOS Franatech CO_2-HR sensor
Dimensions: Ø90mm * L~300mm
Weight: 2.6kg
Power: 24VDC
Telemetry: internal logger, RT capable
Measurement range: 0 - 50000 ppmv
Measurement precision: 74 µatm

2. Demonstration Plan

a. Demonstration on Aquaculture Observing Systems in Coastal Norway (NIVA)

- **Specific Objectives**

Mariculture, specifically salmon aquaculture, is a major coastal industry in Norway with >1 million metric tons and valued at >11 billion Euros. The survival and success of salmon in open mariculture pens can be influenced by various coastal ocean processes. For example, high biomass algal blooms and harmful algal blooms can negatively affect fish health. For instance, a bloom of fish-killing phytoplankton, haptophyte *Chrysochromulina leadbeateri*, occurred in spring 2019 which resulted in 8 million salmon died in a one week timespan (~50 million Euro in lost revenue) in mid-northern Norway (John et al. 2022). A similar bloom occurred in 1991 and also had devastating impacts on salmon aquaculture. Low-cost and user-friendly sensors for DO, Chl-*a*, and CO_2 can be used to detect phytoplankton bloom events and inform aquaculture operators when conditions may be unfavourable for salmon. Based on the conditions, operators can then decide to move operations to an area with better conditions or carry out an early harvest before mass mortalities occur. For carbonate chemistry sensors, salmon can be negatively affected by high CO_2 and low pH conditions, primarily due to CO_2 accumulation and overall negative growth performance (e.g., Mota et al. 2020). Aquaculture operations therefore need quick, reliable, and accurate measurements of CO_2 and pH to ensure that the density of smolt/adult fish and CO_2 concentrations do not reach critical levels. At present, low-cost and relatively accurate sensors (with the ability to carry out calibrations) for CO_2 and pH measurements in seawater are not readily available to the aquaculture community.

- **Location and Period of occurrence**

The demonstration will take place in late spring/early summer 2024. Measurements with NAUTILOS DO, Chl-*a*, and carbonate chemistry sensors will be carried out in cooperation with Campus BLUE, the former Norwegian Aquaculture Academy, in Brønnøysund, Norway. Campus BLUE has salmon pens nearshore as well as salmon pens that are operated with collaborators ~3-5 km offshore with the possibility of sensor deployments at the pens or on buoy installations nearby (Fig. 30 below). Complementary measurements of salinity, temperature, DO, Chl-*a*, and carbonate chemistry (pH, pCO_2) will also be carried out on M/S Trollfjord and M/S Richard With that pass by within ~2 km of the salmon pens once every ~5 days (Fig. 30 below). Ethics related forms developed in WP13 will be distributed and signed by participants before commencement of activities.

- **Platform/equipment**

The primary demonstration will be carried out at the aquaculture facility in Brønnøysund, Norway where NAUTILOS researchers from NIVA will deploy the DO, Chl-*a*, and carbonate chemistry sensors together with Campus BLUE students. The sensors will be demonstrated for approximately 1 month in which time NAUTILOS researchers will train the students how to deploy, collect data, and analyse data. The complementary measurements on board the M/S Trollfjord and M/S Richard With FerryBoxes will be made using additional sensors including SeaBird SBE38 and SBE45 sensors for temperature and salinity, Aanderaa 4835 optodes (DO), Turner Designs C3 sensors for Chl-*a*, coloured dissolved organic matter, and turbidity, a NIVA spectrophotometric pH sensor using meta-cresol purple, and a NIVA-Franatech flow-through membrane equilibrator pCO2 sensors with an infrared detector.

- **Deployment configuration**

The NAUTILOS sensors will be deployed manually at the aquaculture facility, so no additional integration will be required beyond the development already performed and documented in WP3, WP4, and WP5 deliverables.
The manual deployment of the NAUTILOS sensors will involve tethering the sensors to a line and lowering the sensors into surface waters. Alternatively, the tethered sensors can be deployed for multiple days by tying off the line onto a cleat or other permanent structure. The DO and Chl-*a* sensors will be powered by battery packs. For the carbonate system sensors, 220 V power is available at the aquaculture facility that will provide power via cable to the sensors. The carbonate sensors will also undergo regular calibration (e.g., weekly). This will be carried out with Tris pH buffer and air: CO2 calibration gases by NIVA researchers and also the aquaculture students will be trained to carry out the calibration. The complementary sensors on the FerryBoxes will be deployed in a NIVA-developed FerryBox system that is already in operation. This pumps seawater in at ~5 m depth and which then circulates in series through the various sensors for Essential Ocean Variables.

- **Recovery**

Recovery of sensors at the aquaculture farm will be done manually as the sensors will be tethered via line. No recovery of sensors is required for the sensors on the FerryBoxes.

- **Other activities**

The demonstration will be carried out at an aquaculture academy where coursework is taught to ~50 high school students and ~15 vocational (2 year college) students focused on salmon aquaculture techniques, fishing, fish biology, and aquaculture operations. NAUTILOS researchers will interact with students for sensor deployment and data collection/analysis, and also provide some informal lectures and practical guidance for oceanography and oceanographic research techniques.

- **Data recovery/analysis**

Data from NAUTILOS sensors will be logged locally onto data loggers and transferred to a cloud database for further analysis and interpretation. NIVA's FerryBox data is transferred near-real-time via satellite connection to NIVA's cloud database and eventually to Copernicus Marine Service (CMEMS) and EMODnet. Visualisation, data annotation, and automated and manual quality control can be carried out via NIVA's Grafana-based cloud database viewing software. DKFI will also have access to the cloud database and quality controlled data for event-based detection that will provide early warnings for changes in environmental conditions that may be deleterious for fish well-being.

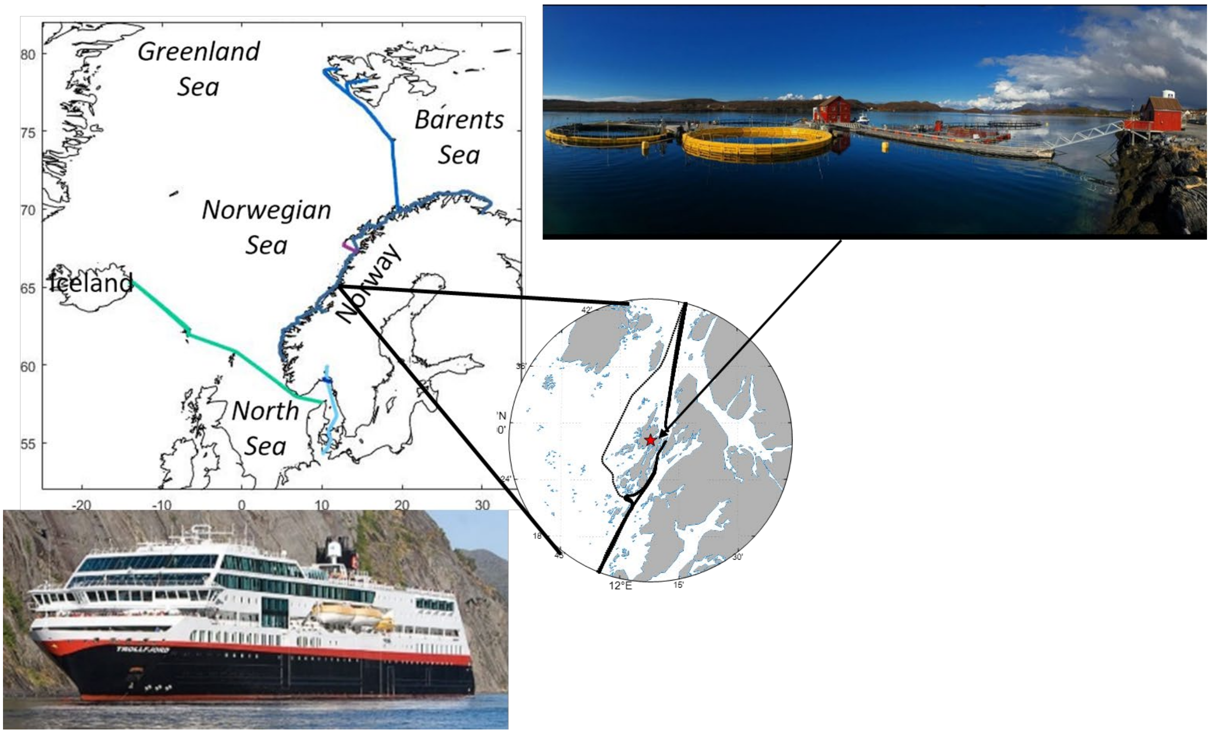

Figure 30: Campus BLUE located in mid-Norway indicated by the red star in the zoomed in map of coastal Norway (circle inset map). Campus BLUE operates salmon pens attached to shore facilities as well as in collaboration with offshore salmon pens ~3-5 km offshore. NAUTILOS sensors will be deployed at Campus BLUE salmon pens and complementary observations of Essential Ocean Variables will also be made by FerryBoxes on M/S Trollfjord and M/S Richard With that transect in vicinity of the salmon pens every ~5 days. Local data collected at Campus BLUE and the extended spatial and temporal coverage by FerryBoxes will be used for event detection and early warning.

b. Demonstration on Aquaculture Observing Systems in Coastal Greece (HCMR)

- **Specific Objectives**

Aquaculture is a key sector for the blue economy in the Adriatic-Ionian Macroregion (AIM), with a significant potential for increasing development. In the European Union Strategy for the Adriatic and Ionian Region (EUSAIR) aquaculture is considered as one of the most promising activities of all coastal countries of the region. The total aquaculture production in the AIM was 300,853 tonnes in 2020, slightly reduced by 1.64% compared to 2019 figure (305,870 tons). The largest producer in 2020 was Greece, although Italy was steadily the first Country until 2019. Greece has developed a large aquaculture sector, representing a major share of national seafood production with finfish and mussels being the main groups of species produced. In recent decades, marine heat waves (MHWs) occurring in the Mediterranean Sea have led to mass-mortality events across diverse marine species and significant losses for seafood industries (Lattos et al. 2022). It is anticipated that these MHWs will increase in intensity, duration, and frequency due to anthropogenic warming (Darmaraki et al. 2019). In waters off Greece, where the coastal zone accounts for about 69% of the national economy, a marine heatwave in 2021 ravaged the country’s mussel harvest, halving production and wiping out 80% of the baby mussel seed for this year as reported by several new agencies. The objective of this task is to test the IR sensor deployed in the HCMR R/V

Philia as a data source contribution to the study of marine heat waves affecting the aquaculture industry.

- **Location and Period of occurrence**

The demonstration of the IR sensor will take place in summer 2024 during the R/V Philia surveys in coastal areas of Greece (Ionian and Cretan Sea). This area hosts several aquaculture facilities. The IR temperature sensor will operate continuously during the surveys and CTD casts will be performed in predefined coordinates.

- **Platform/equipment**

The R/V PHILIA (Fig. 31) was built in 1986 in Piraeus, Greece. Operates from her home port of Heraklion, not only in Cretan waters, but also throughout the Aegean and Ionian sea and in the wider area of the Eastern Mediterranean sea. It is a multipurpose research vessel with an emphasis on experimental fishing. Because of its size it is very flexible and besides the open sea is ideal for coastal and shallow research. It has travelled thousands of miles by conducting exploratory oceanographic and fishing missions as well as technical work. It was rebuilt in 1997 and 2022 and supplied with modern equipment offering scientific services such as:

· supports European and national research programs for fisheries ecosystem based management, for environmental monitoring, in order to investigate the effect of climate change on marine biological resources;

· supports the HCMR's equipment for underwater monitoring and research (ROVs, sleds underwater photography and maintenance of the floats of the POSEIDON system);

· operates in all Greek seas covering the needs of all regions on (i) the state of fish stocks, (ii) the monitoring of water quality, marine organisms and pollution, and (iii) the integrated management of coastal zones;

· is used by other entities, such as universities (Univ. Athens, Crete, Patras, Thessaloniki, Aegean), research institutions and fishermen cooperatives for research purposes;

· is used to serve the country's consistent research and policy needs such as sampling and data collection required by national and Community policies such as the Common Fisheries Policy, the Fisheries Data Collection Program (DCF, EC 198/2008), the Marine Strategy Framework Directive (MSFD, 2008/56 / EC) and the Water Framework Directive (WFD, 2000/60 / EC). It is part of the Mediterranean fleet of research vessels that has undertaken the implementation of the Pan-Mediterranean Acoustic Sampling (MEDIAS).

Figure 31: The HCMR R/V Philia during operations in the Cretan sea.

The Calex PyroMiniBus (PMB201) is a non-contact infrared sensor operating at 8 to 14 µm spectral range, measuring temperatures from -20 °C to 1000 °C with a 0.5 °C repeatability. It is capable of measuring sea surface temperature from above water. It has the advantages of being easy to operate, produce a limited amount of data that is relatively easier to work with compared to the multi- and hyper-spectral cameras, is very light and compact (18x45 mm and ~70 g) and is inexpensive.

- **Deployment configuration**

For power supply, the sensor will draw power from a 12 V DC power supply unit, located within the main laboratory of the ship. Already existing cable channels connecting the laboratory and the external decks of the ship will be used. In terms of data storage and telemetry, data will be transmitted and stored on the data storage computer through the RS485 Modbus serial protocol via a DB9 connector. Furthermore, an automated timestamp will accompany the data to facilitate correlation with the time-stamped coordinates provided by the GPS module during the ship's transect.

- **Recovery**

Recovery of the sensors will take place after the finalisation of the project.

- **Data recovery/analysis**

Data from NAUTILOS IR temperature sensor and CTD casts during the surveys will be logged locally in the ship on board data station and will be available through mobile network connection or in delayed mode. The analysis of the data will be included in the final report of the task.

c. Event detection (DFKI)

Sensor equipment of the respective platform will be used to observe environmental parameters in real-time. Historic data of FerryBoxes is currently being annotated by domain experts from NIVA, so suitable machine learning models can be fitted. Anomaly detection methods (Li and Jung 2023; Yilmaz and Kozat 2020) and concept drift detection methods (Gemaque et al. 2020) can be suitable methods, depending on the desired behaviour and properties of the environment (see also Deliverable 4.6). If lasting changes in data patterns are to be expected, concept drift detection can be preferable over online anomaly detection. A selection of missing value imputation approaches is available and can be evaluated once historic data becomes available, to select both the best methods and limitations, as event detection might become unreliable once a gap in the data becomes too large. Prior experiments at DFKI have shown that front filling and decision tree regression are promising solutions for this issue. Finally, suitable evaluation metrics have been researched, with the publication by Paparizzos et al. (2022) summarising possible metrics and their strengths and weaknesses. Most importantly, this publication provides evaluation metrics for both point-based anomalies and events as well as range-based or interval-based events.

3. Results – Comments – Conclusions

1. <u>Coastal Norway</u>

-Grafana based interface for data annotation of NIVA's ferryBox has been set up. The dataset is being annotated by NIVA's scientists.

-No field measurement from NAUTILOS sensors yet, demonstration will be carried out in spring/summer 2024. The ferryBox is operational.

-TRL 5 at present - all sensors and platforms have been tested in relevant environments, primarily as part of WP5 and WP6 activities. Final TRL is expected to be TRL7 by the end of the demonstration period.

-Recommendations: In general, early discussions with the aquaculture operator has been key for establishing a plan for the demonstration. As the demonstration has not yet begun, recommendations will be provided in D7.2: Fisheries and Aquaculture Observing Systems demonstration final report.

Figure 32: Example of annotation of algae blooms on NIVA FerryBox installed on board of MS Richard With, sailing through a large distance of coast of Norway, between Bergen and Kirkenes.

2. Coastal Greece

No data/results obtained during this reporting period.

3. Event detection

Regarding the event detection there are no results yet, as there is no data available yet. Methods have partly been already evaluated on data of related domains (German Bight and rivers). Final results will be part of D7.2.

IV. Demonstration of Acoustic Marine Mammal Monitoring System Report

1. Background

- **Introduction to Technology**

The AQUAclick Sound represents a pioneering advancement in passive acoustic recording technology, specifically tailored for observing echo-locating marine mammals. Developed to address the increasing demand for accurate and versatile marine mammal monitoring systems, this device integrates a 150kHz bandwidth sound recorder capable of capturing the full waveform of various marine mammal signals, including frequency-modulated whale clicks, broadband dolphin clicks, narrow-band high-frequency porpoise-like clicks, and dolphin communication whistles.

One of the primary motivations behind the development of this technology was the need for enhanced species classification and monitoring capabilities in marine environments. By providing detailed acoustic data, the AQUAclick Sound facilitates better understanding and tracking of marine mammal behaviour and distribution, thereby contributing to conservation efforts and ecosystem management.

The device includes the design and development of a custom-made hydrophone with a flat frequency response over the full recording bandwidth.

Building both instruments (Click and Sound recorder) on one configurable electronics platform provides a common architecture with simplified firmware and hardware. The design covers all aspects in terms of deployment, data uploading and post-processing with a user-friendly software.

- **Technical Specifications**

Dimensions: 460mm (height) x 98mm (diameter)
Weight: 3.6 kg (slightly negative buoyancy of 0.79 kg)
Power: Internal battery (Standalone sensor)
Measurement Range: Underwater sound from 5Hz to 150kHz

This technology's development aligns closely with the objectives of Work Packages 3 and 4, which focus on enhancing marine mammal monitoring systems and developing innovative instrumentation for underwater observation.

2. Demonstration Plan

- **Objectives**

The demonstration aims to show the efficiency and effectiveness of the AQUAclick Sound in detecting and identifying marine mammals in their natural habitats. The objective of the demonstration is to showcase the enhanced Acoustic Marine Mammal Monitoring System developed under ST 3.3.2, performing all the deployment (onboard), underwater measuring as standalone device with internal battery and post-analysis of the recorded Audio data. Also, verification of battery duration, Firmware & Software development (subject to updates during the demonstration time) and sensor performance.

The recorded Audio data can provide valuable insights into the distribution and abundance of marine mammals in these areas, which can inform management decisions and

conservation efforts. In parallel, the sensor is intended to address the needs of underwater soundscape observations, including the study of sea ice dynamics, detection of seismic events, and monitoring of acoustic impact of different human activities across a wide range of water environments.
In addition, the demonstration aims to assess its broader applicability in monitoring underwater soundscapes. By collecting data on sea ice dynamics, seismic events, and human activities acoustic impact, the demonstration seeks to highlight the device's versatility and potential contributions to various marine research fields.

- **Demonstration**

The demonstration will involve deploying the AQUAclick Sound in two distinct marine environments: the Swedish Sound/Kullaberg/Lysekil waters and the Portofino MPA cetaceans sanctuary. Through these deployments, the device's performance will be evaluated under different ecological conditions and cetacean populations' presence variations.

- **Location and Period of occurrence**

The Swedish Sound/Kullaberg/Lysekil waters (Fig. 33) are located in the Kattegat and Skagerrak areas of the North Sea, between the west coast of Sweden and the east coast of Denmark. This region is known for its diverse marine ecosystem, including a wide range of fish species and marine mammals. The waters have depths ranging from 10 to 200 metres, with some areas close to shore having a depth of only a few metres. The commercial fishermen will deploy the AQUAclick Sound from their fishing vessels, which will serve as a platform for the deployment. Demonstrations in Swedish waters will start in April 2024.

Figure 33: Swedish Sound/Kullaberg/Lysekil waters (located in the Kattegat and Skagerrak areas of the North Sea).

The Portofino MPA cetaceans sanctuary (Fig. 34) is located off the coast of Italy and is a protected marine area designated for the conservation of cetaceans, including dolphins and whales. The waters in the sanctuary are relatively shallow, with a maximum depth of around 100 metres. The demonstration will be carried out by ETT, who will deploy the AQUAclick Sound from a research vessel. Demonstrations in the Portofino area will start in June 2024.

Figure 34: Portofino MPA cetaceans sanctuary (located off the coast of Italy).

- **Platform / Equipment**

Commercial fishing vessels will serve as the deployment platform in the Swedish Sound/Kullaberg/Lysekil waters, providing accessibility and logistical support for deploying the AQUAclick Sound. In the Portofino MPA cetaceans sanctuary, a dedicated research vessel will facilitate deployment, ensuring compliance with sanctuary regulations and research protocols.

- **Deployment Configuration**

Pre-deployment checks will verify sensor performance, firmware reliability, and software interface usability, minimising potential issues during operation.
The device will be configured to operate in passive click recorder mode, optimised for detecting and recording marine mammal acoustic signals. Deployment configurations will consider factors such as sensor placement, depth profiling, and recording duration to maximise data collection efficiency and accuracy.

- **Recovery**

Upon completion of the deployment period, the AQUAclick Sound will be recovered from the water, and collected data will be securely transferred for analysis. Recovery procedures will involve careful handling of the device to prevent damage and ensure data integrity.

- **Other Relative Activities**

In addition to acoustic data collection, supplementary activities may include sampling of water and plankton to provide context for acoustic recordings. These activities aim to enhance understanding of the marine ecosystem and its relationship with marine mammal behaviour and distribution.

- **Data Recovery / Analysis**

Recorded audio data will undergo comprehensive analysis to evaluate the device's performance in detecting and identifying marine mammals. Data analysis will involve processing recorded signals, species classification, and assessing environmental noise levels. Feedback on software user interface and system performance will inform potential updates and improvements for future deployments.

3. Results – Comments – Conclusions

No data/results obtained during this reporting period.

V. Ethical Considerations

1. Data Protection

Within T7.1, raw and processed data are exchanged among partners to carry out joint evaluation on the behaviour of the prototypes encountered during the demonstration phases. All the information publicly shared outside the project for the purposes of project dissemination, will follow the procedures already established in D13.2 and all relationships with people or private companies external to the project followed and will follow in further developments what was recommended in D13.7.

In particular, the consent forms developed in WP13 and described in D13.7 were made available and signed by the involved commercial fishermen before installing the sensors on board and are stored in the archives of the partners who lead each demonstration (Pieri et al. 2022). Activities that will be carried out in the future will also utilise consent forms with participants.

Stored acoustic data fall outside the purview of data protection regulations. Nevertheless, users of the instrument possess the capability to annotate data with unstructured text during the configuration of a data logging session. This unstructured text may encompass personal or commercial information, such as names and geo-tagging details.

2. Environmental Protection

As regards the impact on the seabed (and on marine life) of the fishing gears deployed at sea by the commercial fishing vessels involved in the demonstrations, this is part of the normal fishing activities occurring in the demonstration sites and each fishing vessel operates in agreement and with the authorizations of the management bodies.

The use of NAUTILOS sensors in ST7.1.2 will be in line with potential impacts addressed and mitigation actions in D3.2, D3.3 and D4.1.

The standalone instruments typically rely on batteries for power, which may consist of primary cells such as Alkaline Manganese Dioxide or various Lithium formulations, or rechargeable options like Nickel Metal Hydride. In accordance with EU regulations, it is imperative to dispose of all battery types in designated recycling facilities. Disposal in general waste or, worse, in the marine environment is strictly prohibited. In the event of instrument loss, the exposure of batteries to the marine environment could lead to significant environmental harm and prolonged pollution. However, precautions have been taken to avoid the loss of the instruments at sea (e.g. particular attention was paid to effectively fixing the sensors to the fishing gears, to reduce the possibility of loss during demonstrations) and the sensors have a waterproof pressure housing which should prevent leakage towards the outside.

Compliance with the Waste Electrical and Electronic Equipment (WEEE) Directive is essential for commercial users of NAUTILOS products and accessories, including batteries.

3. Health and Safety

The instrument or sensor may be equipped with either primary (non-rechargeable) batteries or rechargeable batteries, depending on user preference. It is crucial to verify the type of battery installed before attempting to recharge, particularly as recharging primary batteries can lead to fire or explosion risks. This caution is especially pertinent with lithium batteries,

where certain actions such as attempting to recharge, tampering with the battery pack assembly, or exposing them to heat, fire, water, or short circuits must be strictly avoided.
For instruments equipped with lithium batteries, users involved in shipping these batteries by air or road must adhere to the latest International Aviation (IATA) or Dangerous Goods Regulations. It is imperative to consult the IATA regulations[11] to ensure compliance with shipping requirements.
When handling pressure cases, it is essential to adhere to safety guidelines to mitigate risks. Leaking cases can pose hazards upon surfacing, and if a hissing noise is detected, it is advisable to wait until it ceases before cautiously opening the case. Allowing cases to reach ambient temperature before opening is recommended, as cold cases may have internal pressure lower than outside pressure, potentially causing water ingress.
All components chosen for the sensors are compliant with Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS) regulations, ensuring adherence to environmental standards.

4. Protection of Marine Life

No harms to marine life were identified (except for fishery catches).
Some prototypes emit a flashing blue light for a very short time, as already discussed in D3.1.
The passive anti-fouling protection introduced around the active membrane of the DO and Chl-*a* sensors does not release substances into the water that can harm marine life.
For what may concern the passive acoustic sensor, the instrument operates entirely passively, without any transmission. However, there are plans for future capabilities to utilise very low-power active tones for self-calibration or synchronisation. These levels are expected to be negligible in open water conditions. Furthermore, in scenarios involving captive animals in small, enclosed spaces, such active tones would be disabled to ensure silence during these instances.

5. Dual Use Potential

No dual use potential has been identified for the DO and Chl-*a* sensors, the WiHub could potentially be used for GPS tracking of vessels.
In the context of the passive sensor, it's worth noting that hydrophone technology is addressed within Part 121, Category XI, Part (c)(12) of the International Traffic in Arms Regulations (ITAR). However, the particular acoustic technology under development here falls outside the purview of these regulations, as none of the specified criteria from (i) to (vi) are applicable. This exemption is primarily attributed to the passive nature of the product. Additionally, it's essential to highlight that the design depth of this system extends to a maximum of 500 metres.

[11] http://www.iata.org/lithiumbatteries

VI. SUMMARY

In summer 2023, ST7.1.1 demonstrations on Fisheries Observing Systems, involving the DO and Chl-*a* prototypes developed by NKE in ST3.1.2, started both in the Adriatic Sea and the Bay of Biscay respectively conducted by CNR-IRBIM and Ifremer. The functioning of the instruments is constantly monitored by the NAUTILOS partners involved. This has already allowed further mechanical and software updates to the previously designed and tested instruments. The data produced during these demonstrations are showcased on NAUTILOS data portals. The activities of ST7.1.1 are expected to continue until summer 2024 (e.g. battery duration verification, sensor drift check etc.).

In ST7.1.2, preparations and initial plans have been made for demonstrating DO, Chl-*a*, carbonate chemistry, and IR temperature sensors at and in the vicinity of aquaculture sites in coastal Norway and Greece. The sensors will be demonstrated at the actual aquaculture sites with supporting observations with FerryBoxes (Norway) and on a fisheries research vessel (Greece). The Norway demonstration will be focused on Campus BLUE, an aquaculture academy in coastal mid-Norway addressing water quality issues related to finfish health. The Greek demonstration will be focused in the Aegean Sea addressing marine heat waves and mass mortality. Data collected from the Aquaculture Observing Systems will be ingested real-time for event detection and early warning. The demonstrations are expected to be carried out in spring and summer 2024.

In ST7.1.3, plans have been made to showcase the AQUAclick Sound passive acoustic recorder's capabilities in detecting marine mammals during demonstrations scheduled for April 2024 in Swedish waters and June 2024 in Italian waters. These demonstrations will evaluate the device's performance under diverse ecological conditions and varying cetacean populations. Deployment will be facilitated by commercial fishing vessels and a research vessel, ensuring adherence to regulations and ease of access. Prior to deployment, comprehensive pre-deployment checks will validate sensor functionality and post-recovery procedures will uphold data integrity. Subsequent thorough analysis of recorded audio data will assess the device's efficacy and guide potential enhancements for future deployments.

Appendix 1: References and Related Documents

ID	Reference or Related Document	Source or Link/Location
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APPENDIX 2: UPDATED SPECIFICATIONS FOR THE DO AND CHL-*A* SENSORS

Specifications for the WiSens DO and Chl-*a* sensors as updated after the first demonstration phase described in this document.

WiSens DO:

Parameters	*Range of Measurement*	*Accuracy*	*Resolution*	*Drift*
%Saturated Air (%a.s.)	*0 - 200*	*1%*		
DO concentration (mg/L)	*0 - 20*	*+/- 0.1*		
Temperature (°C)	*-2 to 35*	*+/- 0.020*	*0.001 °C*	*0.020 °C/year*
Pressure (bar)	*0 - 100*	*0.015% full scale*	*1 cm*	*0.15 %/year*

WiSens Chl-a:

Parameters	*Range of Measurement*	*Accuracy*	*Resolution*	*Drift*
Chlorophylle-a (ppb RWT)	*0 - 500*	*0.03 µg/l*		
Temperature (°C)	*-2 to 35*	*+/- 0.020*	*0.001 °C*	*0.020 °C/year*
Pressure (bar)	*0 - 100*	*0.015% full scale*	*1 cm*	*0.15 %/year*

Appendix 3: Chl-a 59DD sensors Laboratory Calibration

Wisens Nautilos Chl-*a* sensor SN 59DD test

Date: 31/08/2023
Ifremer

Fluorescein	sensor 59DD	
µg/L	Average	SD
0	0.617	0.296
25	77.978	1.180
50	152.848	1.875
75	226.787	1.686
100	299.203	1.741
125	373.935	1.864
150	444.341	2.536
175	533.882	1.745
200	627.958	0.999