Dataset of Depth/Temperature profiles obtained fromin the period 2012 to -2020 using commercial fishing vessels of the AdriFOOS fleet in the Adriatic Sea (Mediterranean Sea).

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Abstract. **In the last decade, CNR IRBIM's AdriFOOS has collected an enormous amount of georeferenced oceanographic and catch data through the use of commercial fishing vessels operating in the Adriatic Sea. This data is co-located with catch data.** This document describes the dataset of depth (pressure)/temperature profiles collected by means of the fishing fleet infrastructure (AdriFOOS) infrastructure in the period 2012-2020 and briefly illustrates the structure of this facility, the oceanographic dataset validation procedures, some of the results achieved, and also lists some possible operational applications. In fact, in the last decade, CNR IRBIM's AdriFOOS has collected an enormous amount of georeferenced oceanographic and catch data through the use of commercial fishing vessels operating in the Adriatic Sea. This information is of the utmost importance to provide data to feed oceanographic models and advance knowledge on climate change, as well as to improve the ecosystem approach to fisheries management.In the last decade, an enormous amount of georeferenced oceanographic data, co-located with catch information, have been collected through the use of commercial fishing vessels operating in the Adriatic Sea and belonging to the fleet monitored by the AdriFOOS infrastructure. This document describes the dataset of depth (pressure)/temperature profiles collected by means of AdriFOOS in the period 2012-2020 and briefly illustrates the structure of this facility, the oceanographic dataset validation procedures, some of the results achieved, and also lists some possible operational applications. This information is of the utmost importance to provide data to feed oceanographic models and advance knowledge on climate change, as well as to improve the ecosystem approach to fisheries management.

Keywords — AdriFOOS, Adriatic Sea, operational oceanography, fishing vessels, Vessels Of Opportunity (VOOs)

1 Introduction

The valuable contribution of Ships of Opportunity (SOOPs) or Vessels Of Opportunity (VOOs) in operational oceanography is already well established (e.g. Ferry box systems); this approach generally allows taking advantage of already existing commercial routes by equipping vessels with scientific instruments to collect data in areas that could not reasonably be covered (in space and time) with traditional research vessel efforts (Petersen et al., 2003; Sloyan et al., 2018; Jiang et al., 2019; Rosa et al., 2021). A recent development uses specifically designed sensors deployed from commercial fishing vessels to collect great amounts of data, useful both for operational oceanography purposes and ecosystem approach to fisheries (Van Vranken et al., 2020).

The Ancona branch~~section~~ of the Institute of Marine Biological Resources and Biotechnologies of the Italian National Research Council (CNR IRBIM; formerly part of the Institute of Marine Science of CNR) carried out from 2003 to 2013 the Fishery Observing System (FOS) program aimed at using Italian fishing vessels for the collection of scientifically useful datasets (Falco et al., 2007, Martinelli et al., 2012). A sample of commercial fishing vessels, targeting small pelagic species in the northern and central Adriatic Sea (see ~~below~~ description of the study area in section 2), were equipped with a system for the collection of information on catches, position of the fishing operation, depth and water temperature during the haul, producing a huge amount of data ~~that demonstrated to be~~ useful both for oceanographic and fishery biology purposes (Carpi et al., 2015; Russo et al., 2015; Aydoğdu et al., 2016; Sparnocchia et al., 2016; Lucchetti et al., 2018). In 2012, in the framework of some national and international projects (e.g. CNR project SSD-Pesca "*Sistema di Supporto alle decisioni per la gestione sostenibile della Pesca nelle regioni del Mezzogiorno d'Italia*", Seventh Framework Programme of the European Union - EU FP7- JERICO project "*Towards a Joint European Research Infrastructure network for Coastal Observatories*", etc.), CNR started the development of a new modular Fishery & Oceanography Observing System (FOOS; Patti et al., 2016). This new~~An updated~~ assemblage of sensors for oceanographic and meteorological data allow nowadays the FOOS to collect more parameters, with higher accuracy and precision, and to send them in Near Real-Time (NRT) to an on land datacenter installed on a dedicated~~inland~~ server (Martinelli et al., 2016; Sparnocchia et al., 2017). Furthermore, the FOOS is a multifunction system able to collect different types of data from the fishing operations and to send back information to the fishermen (e.g. weather and sea forecasts, etc.) through an electronic logbook with an *ad hoc* software embedded (Patti et al., 2016). The adoption of different FOOS modular setups ~~conformations~~ installed on various kinds of fishing vessels, targeting different resources, allowed a spatial extension of the monitored areas in the Mediterranean Sea (see some setup examples in Patti et al., 2016).

CNR IRBIM of Ancona staff also carried out demonstrations on the FOOS use within European funded projects (e.g. Sparnocchia et al., 2017) and contributed to the definition of best practice procedures to be used while approaching this matter (e.g. define optimal operational conditions for each type of sensor to be used, test each sensor for offsets under traditional oceanographic operational conditions before field use on fishing gear, etc; Martinelli et al., 2016; Möller et al., 2019). In addiction ~~Besides~~, CNR IRBIM implemented the AdriFOOS (Adriatic Fishery & Oceanography Observing System) observational infrastructure composed of~~by~~ a multifunctional dedicated o~~i~~n land datacenter based in Ancona and a series of

FOOS installed on board commercial fishing vessels operating in the Adriatic Sea. Since then the AdriFOOS on land datacenter~~server~~ receives daily data sets of environmental parameters collected through~~along~~ the water column and near the seabed (eg. temperature, salinity, etc.), together with GPS (Global Positioning System) haul tracks, catch amounts per haul, target species sizes and meteorological information (e.g. Penna et al., 2020). AdriFOOS infrastructure has 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” and NAUTILOS “New Approach to Underwater Technologies for Innovative, Low-cost Ocean obServation” projects) and some collected datasets were already shared ~~on public repositories~~ and showcased on the projects’ institutional websites (e.g. http://www.jerico-ri.eu/previous-project/service-access/targeted-operation-phase/top-2-data-and-maps-from-sensors-on-board-fishing-vessels/adriatic-sea-fishery-and-oceanography-observing-system/; https://www.nautilos-h2020.eu/data-portal/; Puillat et al., 2014; Gaughan et al., 2015; Sparnocchia et al., 2017).

The acquisition of oceanographic data during ~~the~~ fishing operations can be divided into 3 phases (see also paragraph 3.1): down cast, horizontal profile either on the bottom (or at the depth at which the fishing gear operates) and up cast. ~~profile, permanence on the bottom (or at the depth at which the fishing gear operates) and ascent.~~ Therefore, this methodology allows to acquire data profiles along the water column and measurements at the depth at which the fishing operation takes place, which often occurs close to the sea bottom. Recently, a dataset containing 14810 depth (pressure)/temperature down casts~~profiles~~ has been made accessible in ~~(~~Penna et al.~~,~~ ~~(~~2020) in ASCII and NetCDF formats; this was generated in the period 2012-2020 by 10 vessels belonging to the AdriFOOS fleet and 1 FOOS installed on board the CNR R/V Dallaporta (while carrying out experimental trawl surveys in the central Adriatic Sea; Chiarini et al., 2022). This huge amount of data could be very useful to improve the knowledge about Adriatic Sea mesoscale oceanographic processes and detect possible shifts due to climate change; in addition this could be used to feed operational models though data assimilation and reanalysis as already trialled in the framework of the JERICO – NEXT Project (Mourre et al., 2019).

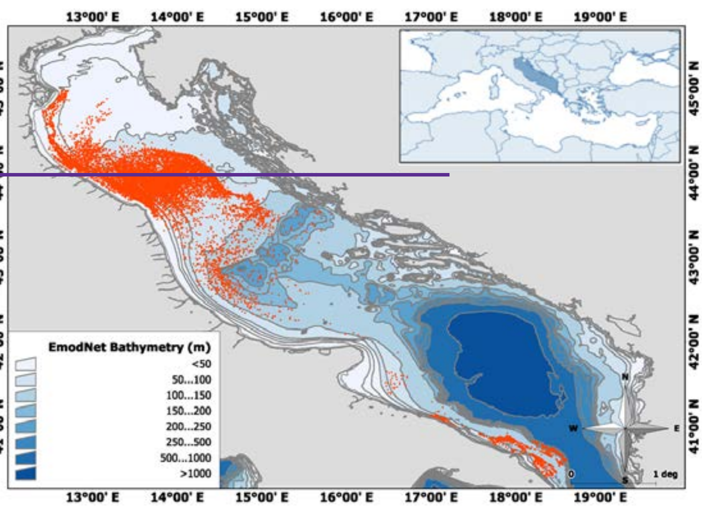
Therefore, the main aim of this paper is to ~~is to~~ specifically describe the sensor data collection, storage, quality assurance and control procedures applied to the ~~above mentioned~~ depth (pressure)/temperature profiles dataset available through Penna et al., 2020. A general description of the AdriFOOS infrastructure is also provided, as well as some details on the validation and quality control applied to some of the other relevant information collected.

2 Study area

The Adriatic Sea is a semi-enclosed basin within the Mediterranean Sea, it is located between the Italian peninsula and the Slovenian–Croatian–Montenegro–Albanian coasts with its major axis in a northwest-southeast direction and it is approximately 800 km long and 200 km wide~~large~~ (Fig. 1). The morphological differences along both directions (longitudinal and transversal) of the basin, the bathymetry and several oceanographic properties conventionally divides it into a nNorthern, a cCentral and a sSouthern sub-basin (Artegiani et al., 1997). The nNorthern Adriatic is the shallowest shallower of the three basins (maximum depth around 100 m). The cCentral and sSouthern Adriatic (maximum depth respectively 270 m and 1200 m) are separated by the Pelagosa sill (160 m); another sill (800 m) separates the sSouthern Adriatic from the Ionian Sea and is located in the Strait of Otranto (Marini et al., 2016). Circulation and water masses are strongly influenced by atmospheric conditions and mainly driven by dominant winds (NE-ENE Bora and the SE SiroccoBora and Scirocco; Orlić et al., 1994, Gačić, 1980). The general circulation is cyclonic: northward along the east coast, southward along the west coast (Poulain, 2001). Furthermore, basin-scale cyclonic eddies, called gyres, dominate the circulation of the three sub-basins and vary in intensity depending on the season (Artegiani et al., 1997).

The Po River, which flows in the nNorthern sub-basin, represents the main buoyancy input accounting for about one third of the total river freshwater input in the Adriatic: river runoff is particularly strong and affects circulation and ecosystem by introducing large flows of nutrients (Marini et al., 2008). The nutrient-rich river water discharged into the nNorthern Adriatic forms a strong surface current and a floating coastal layer that flows south along the Italian coast (Cozzi and Giani, 2011; Grilli et al., 2020).

Therefore, the Adriatic Sea is characterised by an extended continental shelf and eutrophic shallow waters in its nNorthern-Ccentral part, that makes it a very productive area (Campanelli et al., 2011). Indeed the Adriatic Sea is one of the most intensively fished areas of the Mediterranean (Eigaard et al., 2017), in which about 12.5% of the entire Mediterranean fishing fleet operate (FAO, 2020). The Adriatic contributes indeed for around 22.7% of the total Mediterranean catches (ranging between 170000 to 180000 tonnes; average 2016–2018), of which 56.8% and 39.1% are due respectively to the Italian and Croatian fleets (FAO, 2020).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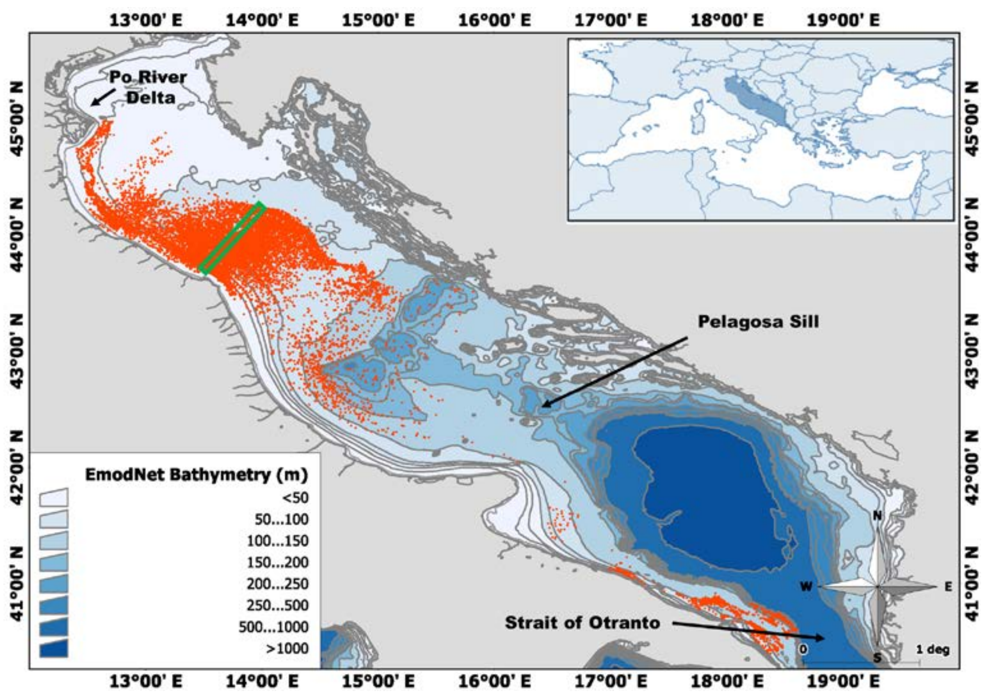


Figure 1. Study area mapped by means of Manifold® GIS (bathymetry source: EMODnet, 2016); in the top right inset~~up-right rectangle~~ the position of the study area within the Mediterranean basin is highlighted; red dots indicate~~-~~ the geolocation, and thus the spatial distribution, of the AdriFOOS down casts belonging to the 2012-2020 dataset; the green rectangle corresponds to the section highlighted in Fig. 10.~~the spatial distribution of the AdriFOOS depth (pressure)/temperature profiles dataset 2012-2020.~~

3 Methodology

In its current configuration, AdriFOOS is composed of 3 functional parts: underwater sensors, on board instruments and an on ~~in~~land datacenter~~server~~ (Fig. 2).

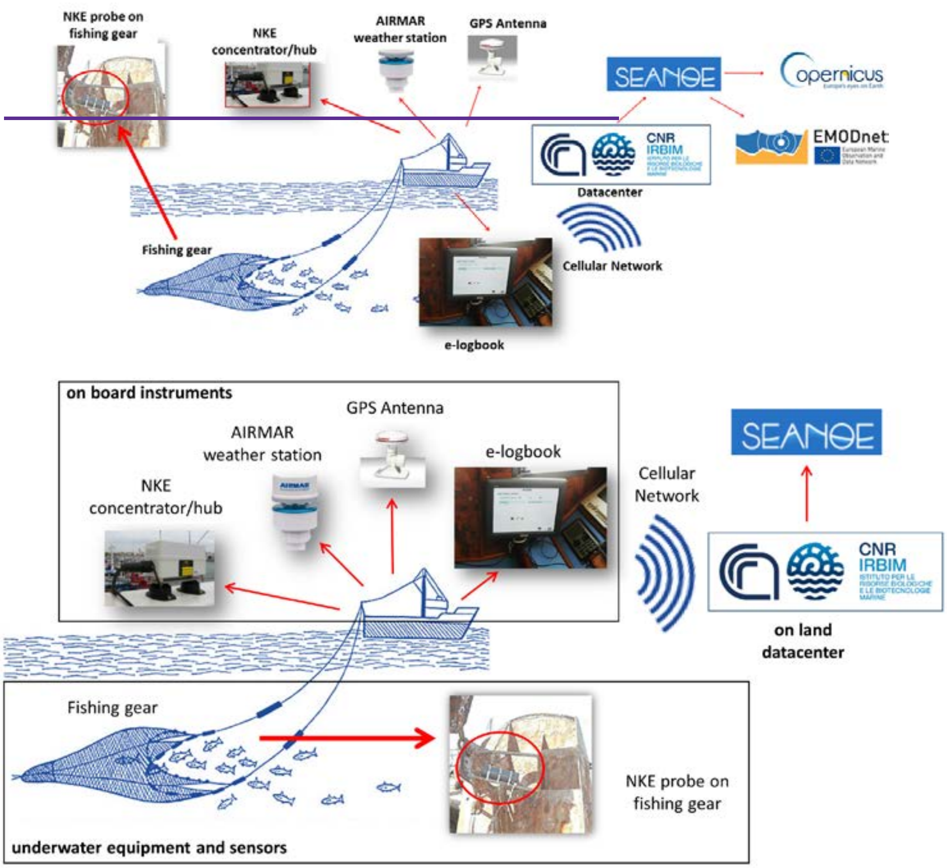


Figure 2. General schema of the AdriFOOS infrastructure.

3.1 Underwater sensors

Since 2012, NKE (https://nke-instrumentation.com) SP2T (depth/pressure and temperature) and STPS (depth/pressure, temperature and salinity) sensors, installed on fishing gears, ensure the acquisition of reliable data~~accurate~~ (pressure: range 0-300 dbar, accuracy 0.3% of full scale; temperature: range -5 to 35 °C, accuracy ± 0.05 ° C;~~ pressure 0.3% of full scale;~~ salinity: range 2-42 psu, accuracy ± 0.1 psu)~~ and reliable oceanographic~~ data (Martinelli et al., 2016). Their response time

ha formattato: Tipo di carattere: (Predefinito) Calibri, 11 pt, Grassetto

(0.5 s) allows the collection of temperature and salinity profiles during the fishing operations (Penna et al., 2020). However, as reported in Martinelli et al. (2016), especially during the profile phase, the salinity measurement obtained by the NKE sensors are probably strongly influenced by the operating conditions (i.e. the water flow inside the sensor) causing noisy readings that could be reduced by post-processing; the latter procedure, as well as those applied to bottom datasets are not described in this paper as salinity datasets, horizontal profiles and up casts, as well as the weather and catch information, are not included in the discussed dataset and are not yet published.

NKE probes, protected by a silicone layer, are robust enough and reliable for use on fishing gears, however additional plastic ~~Polytetrafluoroethylene (PTFE)~~ cases are used to protect the sensors and allow them to be directly mounted on the gear~~s~~ in different positions, according to the fishery type (see example of sensor mounted on an otter door used by a bottom trawler in Fig. 3).

Since the battery consumption depends on the sampling and radio link communication frequencies and on depth and number of the fishing hauls, after a preliminary testing phase it was decided to adopt the following settings to maintain the charge of the internal battery for relatively long periods: when the sensor enters the water and exceeds a depth of 1.5~~3~~ meters, it starts recording with a frequency of 1Hz for 10 minutes (high acquisition rate corresponding to launching of the gear and starting of the fishing operation) after which the sensor records every 1 minutes (continuation of the fishing operation). The recording ends when the fishing gear comes out of the water and subsequently transmits the collected data via radio link to a Concentrator/hub, namely a dedicated data receiver (see section ~~paragraph~~ 3.2). Therefore, as already described above, this methodology allows to acquire temperature and salinity down casts ~~profiles along the water column~~ at an acquisition~~aquisition~~ rate comparable to the most commonly used oceanographic profilers, horizontal profiles~~measurements~~ at the depth at~~in~~ which the fishing operation takes place and some data point during the fishing gear recovery (i.e. the up cast).

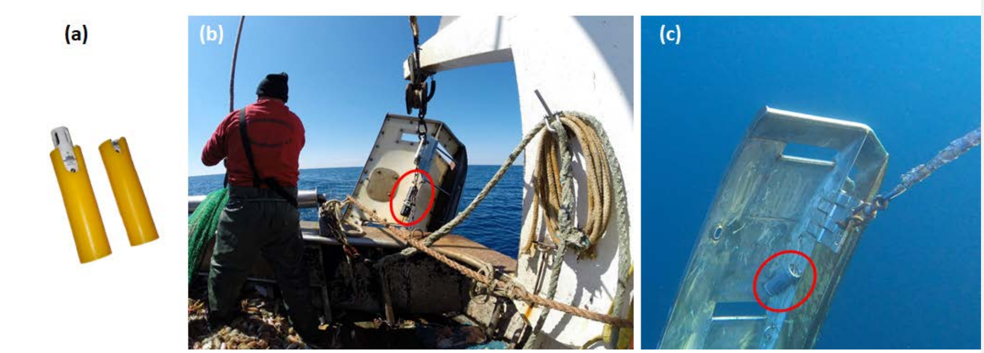


Figure 3. NKE SP2T and STPS sensors inserted into yellow rubber protections supplied by the company (a) installed on the otter door of a commercial bottom trawler (b); otter door and sensor during the fishing operation (c).

3.2 On board equipment

An electronic logbook (e-logbook), namely an Afolux Embedded x86 fanless industrial computer incorporating a touch screen, is installed on board each fishing vessel. This is equipped with adequate hardware and software for managing communication among all devices included in the AdriFOOS architecture (Fig. 2). A Microsoft SQL Server Compact Edition database is installed on the e-logbook allowing to store GPS track, metocean data, specific settings referred to each boat (e.g. fishing gear, harbour etc.) and to acquire catch data (i.e. species by common or dialectal names, quantity and sizes) directly entered by the fishermen through a suitable Graphical Users Interface (GUI; Fig. 4); the latter also gives access to other functionalities such as weather forecast reports and visualisation of collected environmental parameters as described below. The database also allows the storage of the GPS track and metocean data when there is no coverage of the cellular network. As soon as the cellular signal is available, a special procedure allows the data to be sent to the on land datacenterinland server.

Figure 4. AdriFOOS GUI used onboard by fisherman: screenshot examples from the catch module (a) allowing to enter the start/end of the trip (in Italian Inizio/Fine bordata) and caught species quantity (casse) and size (taglia) by haul (Cala) (a, b) and the oceanographic real time data visualisation module (bc) showing fished depth (purple line) and relative temperature (blu line) by haul.

A Teltonika 3G router ensuring bidirectional communication between the e-logbook and the CNR IRBIM servers via cellular network is as well installed on board and connected to the e-logbook. GPRS was chosen due to low operational costs, good coverage along the Italian Adriatic coast (up to 10-nautical miles) and usually short range (up to 60 miles from the coast) and duration of the fishing trips in the monitored area (max 24-48h), which allow the ground station to receive data in NRT.

A customised NKE Concentrator/hub, mounted on the higher vessel deck, records GPS positions every minute and receives data via radio link from the NKE sensors as soon as they are out of the water; this is connected through an RS232 cable to the e-logbook and using an IP connection over Point-to-Point Protocol (PPP) enables an internal File Transfer Protocol (FTP) server (every 60 s the Concentrator/hub communicates its life status to the e-logbook and sends a ping when not receiving data from the sensors). The GUI gives the opportunity to the fishermen to directly view the hydrographic conditions linked to the performed hauls.

A compact Airmar Weather Station is as well mounted on the deck and provides acquisition of GPS data, in situ wind speed and direction (real and apparent, automatically calculated in real time by the device), pitch and roll, air temperature, relative humidity and barometric pressure every 60 s; this communicates as well via RS232 serial link with the e-logbook where the GUI can give access to the collected data.

A Marconi GPS antenna is as well installed on the vessels deck and connected to the e-logbook via RS232 serial link using a standard NMEA 0183 protocol; indeed, even if redundant, this serves to avoid loss of crucial information such as GPS tracking in case of other instruments failure.

3.3 On land datacenter~~Inland server~~

The AdriFOOS server hosts a series of services among which are the waves forecasting module, the AdriFOOS ~~data centre~~ web platform and the relational databases ~~and they are~~ described in detail in the Supplement Section I. ~~the next subsections.~~ The wave forecasting module directly communicates with the e-logbook GUI to provide sea forecasts information to the fishermen. Two databases (hereafter referred to as DBs), built by means of the ORACLE MySQL Database Service, are installed on the AdriFOOS server and contain respectively raw and validated data (see section 4). The raw data relational DB is directly populated by data sent in NRT from the e-logbooks on board the vessels through a Representational State Transfer, Application Program Interface (REST API) based on Hypertext Transfer Protocol (HTTP) and support Transport Layer Security (TLS) encryption. This DB, whose structure is briefly described in the Supplement Section I~~Supplement~~, allows catch and oceanographic data to be associated and georeferenced. Furthermore, a web interface (hereafter referred to as FOOSweb) is directly connected to this. Depending on the access rights, FOOSweb allows users to check the status of each FOOS and enables system administrators to carry out some validation procedures or extract data. The functionalities of FOOSweb are better described in the Supplement, which also provides access information to view a sample of data.

The following paragraphs 3.1-3.3 will be moved to Supplementary materials Section I: On land datacenter detailed description

~~3.3.1~~ Waves forecasting module

The wave forecasting module directly communicates with the e-logbook GUI: a routine installed on the CNR IRBIM server creates daily animated gif files derived from the forecast maps generated by the KASSANDRA storm surge operational forecast system for the Mediterranean and Black seas (Ferrarin et al., 2013); when covered by GPRS signal, the GUI software automatically checks for new available maps and downloads from the AdriFOOS server forecasts related to Adriatic Sea waves height and direction for the next four days (3 hours level detail).

~~3.3.2~~ AdriFOOS databases

Installed on the AdriFOOS server there are also 2 databases (hereafter referred to as DBs) built by means of the ORACLE MySQL Database Service, containing respectively raw and validated data (see section 4). Fig. S1~~5~~ shows the tables componing the relational DB directly populated with data sent in NRT by the e-logbooks on board the vessels. In order to secure communications, REST APIs (Representational State Transfer, Application Program Interface), based on Hypertext Transfer Protocol (HTTP)~~HTTP protocol~~ and support Transport Layer Security (TLS) encryption, are used. TLS standard allows keeping a private Internet connection and checking that the data exchanges by the fishing vessel and the server ashore are encrypted and unmodified.

The table “foos.Settings” is mirrored ~~specular to the one included~~ in the DB embedded in the e- logbook and allows to store encrypted ~~crypted~~ information about the vessels (e.g. landing harbour, fishing gear etc.) and settings or (changes in settings) of the systems installed on board each of them (e.g. sensors serial numbers and types etc.). All tables are linked by means of primary or secondary keys (i.e. idBoat, dateStart, port_name etc.; links not shown in the figure to simplify visualization). In some cases, links among tables are defined by specific algorithms or tools, also able to *a posteriori* fulfil some of the fields (e.g quality flags). For example, the temporal definition of fishing hauls (by means of the field “dateStart” and dateEnd”) is automatically based on the crossing between GPS ~~GSP~~ data (stored in the “foos.PositionSet” table) and the start/end of the oceanographic measurements made by the sensors on the fishing gear~~s~~ (stored in the “foos.MeasureSet” table). Information on the start/end of each fishing trip can be as well derived by data input of the fishers~~men~~ but also automatically corrected on the base of the GPS route and the position of the harbour associated with each vessel (see also validation procedures described in paragraph 4). A series of tables is dedicated to catch data and is again mirrored ~~specular~~ in~~to~~ the e-logbook DB, allowing to reconstruct catch definitions linked to each specific harbour and directly set on board (e.g. name of fish in dialect, etc.) and fishing gear type (e.g. way to refer to species sizes, etc.). All the stored information is then validated (see section ~~paragraph~~ 4) and transferred to a backup DB in which each table contains a validation flag column (the column may contain different codes depending on the data quality assignment; see section 4 of the paper).

3.3.3 AdriFOOS data centre web interface

A visualisation service (hereafter referred to as FOOSweb; http://foosweb.irbim.cnr.it/) is directly connected to the raw data DB. It consists of a web interface, compiled to date only in Italian, from which, once logged in, it is possible to view the status of the system for each vessel. According to the different access levels (depending on user definition) various tools are available; for example fishermen are allowed to check their dataset in a summary screen or visualise single GPS positions' tracks, graphs related to the environmental parameters collected by the sensors on the fishing gear and a summary of the obtained biological data (~~Fig. 6~~a sample of data collected by AdriFOOS in the last period can be accessed in this mode using username: foosample and pwd: fsA@23.mp). Researchers are also allowed to carry out some validation procedures or extract data. Through the links available under the "Menu Admin" section of FOOSweb,~~-~~ it is possible to remotely connect to the FOOS installed on board the fishing vessels and change some settings as: vessel-gear combination, vessel-harbour combination, species priority and species size category (Fig. S2~~6a-c~~). This feature is useful to carry out remote maintenance in case of malfunctions. Under the "Admin Menu" section, some validation procedures are also available to minimise errors and perform a quality control process (e.g. visual inspection of depth/temperature profiles with possibility to manually flag values and catch validation tool both described in paragraph 4; Fig. S2A-B~~6b~~). Both raw and validated data can also be accessed by researchers via Domain Name System (DNS) and for example connected to Geographic Information Systems (GIS; see for example Fig. 6~~8 and Fig. 12~~ in the main text of the paper).

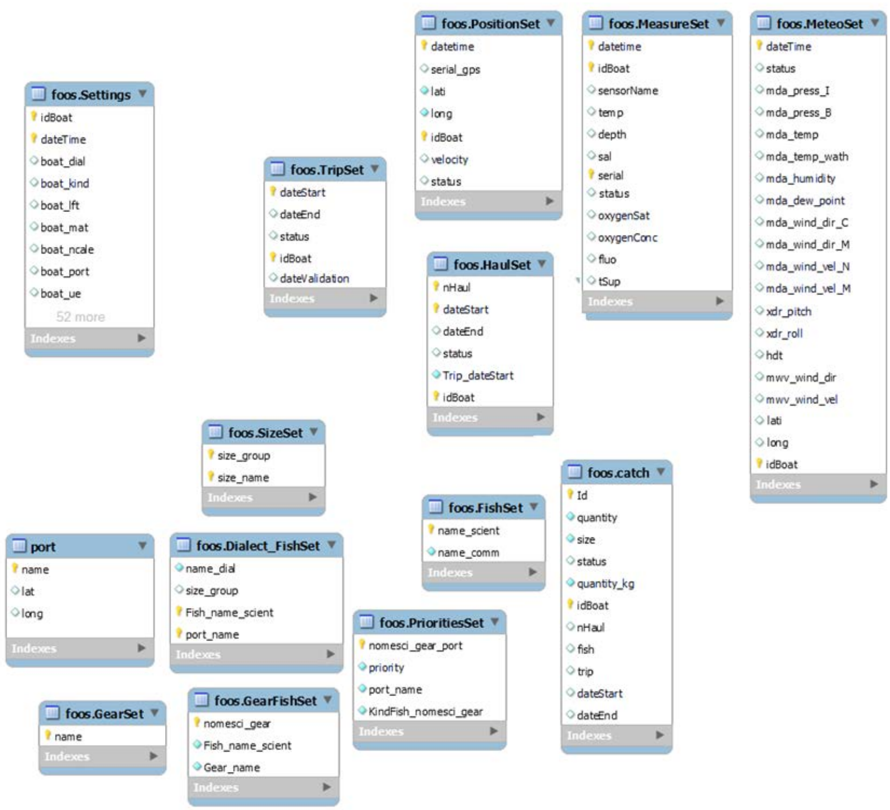
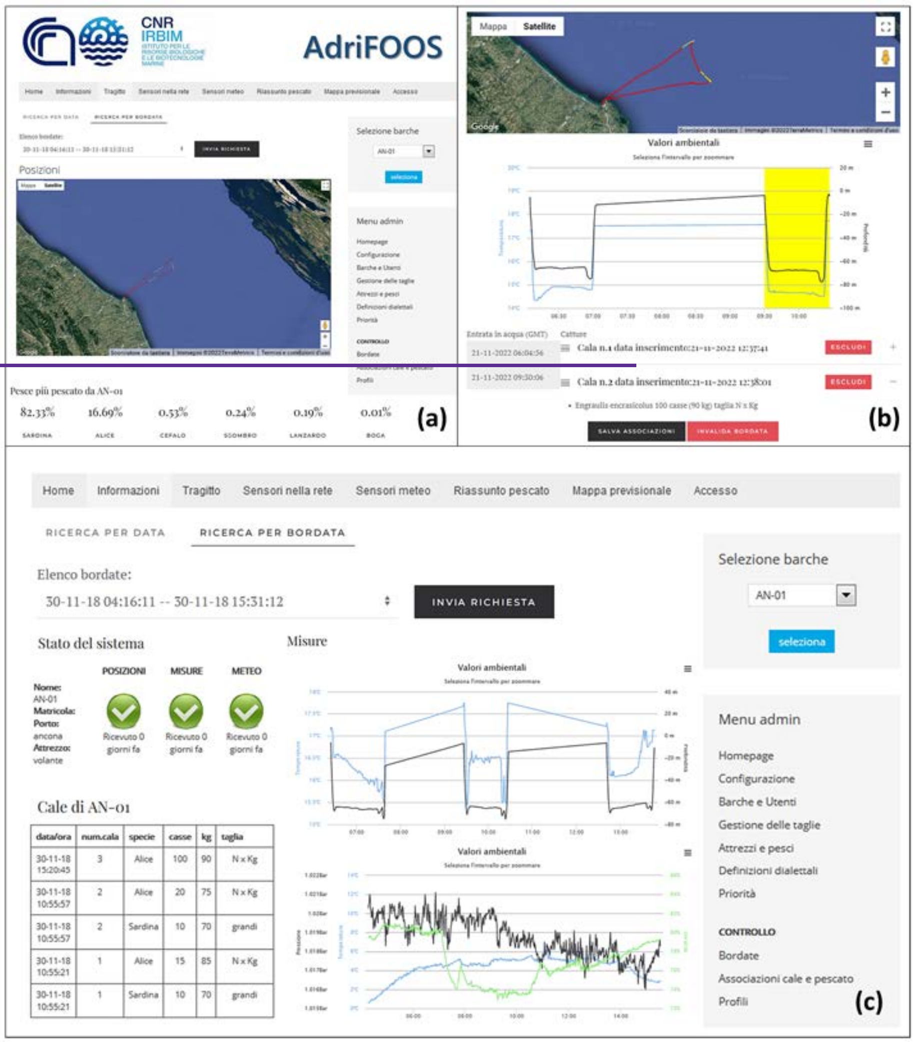


Figure S15. Schema of the relational database embedded in the AdriFOOS on land datacenterserver (diagram made by means of MySQL Workbench 8.0).



CNR
IRBIM
AdriFOOS
Posizioni
Selezione barche
Menu admin
Pesce più pescato da AN-01
82.33%
16.69%
0.53%
0.24%
0.19%
0.01%
SARDINA
ALICE
CEFALO
SGOMBRO
LANZARDO
BOGA
(a)
Mappa
Satellite
Valori ambientali
Entrata in acqua (GMT)
Catture
21-11-2022 06:04:56
21-11-2022 09:30:06
Cala n.1 data inserimento:21-11-2022 12:37:41
Cala n.2 data inserimento:21-11-2022 12:38:01
ESCLUDI
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INVALIDA BORDATA
(b)
Home
Informazioni
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POSIZIONI
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Barche e Utenti
Gestione delle taglie
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data/ora | num.cala | specie | casse | kg | taglia
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30-11-18 10:55:57 | 2 | Sardina | 10 | 70 | grandi
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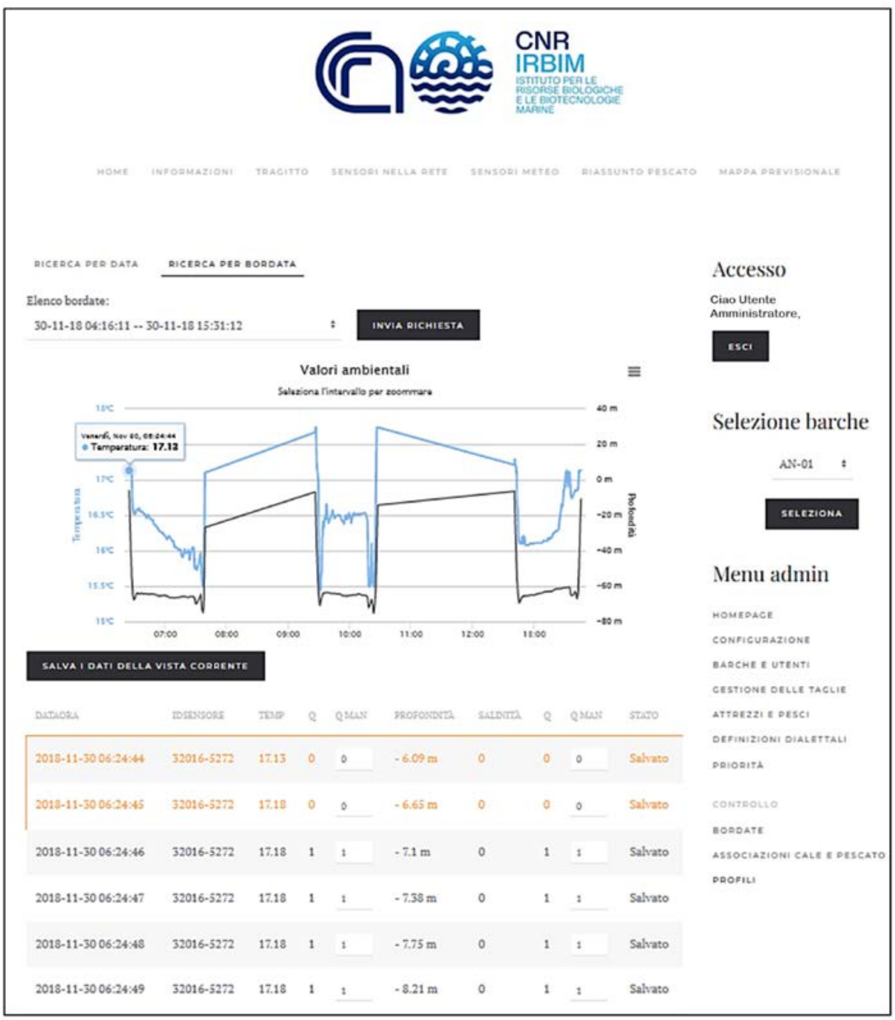

Figure S2A. FOOSweb interface: on top depth profile (in Italian Profondità) in black and temperature profile (in Italian Temperatura) in light blue relating to the entire fishing trip, on the bottom a list of depth/temperature pairs with indication of

quality flag derived from automated procedures (Q) and possibility to modify it manually in the column Qman (this feature is available also for salinity profiles, in Italian Salinità).

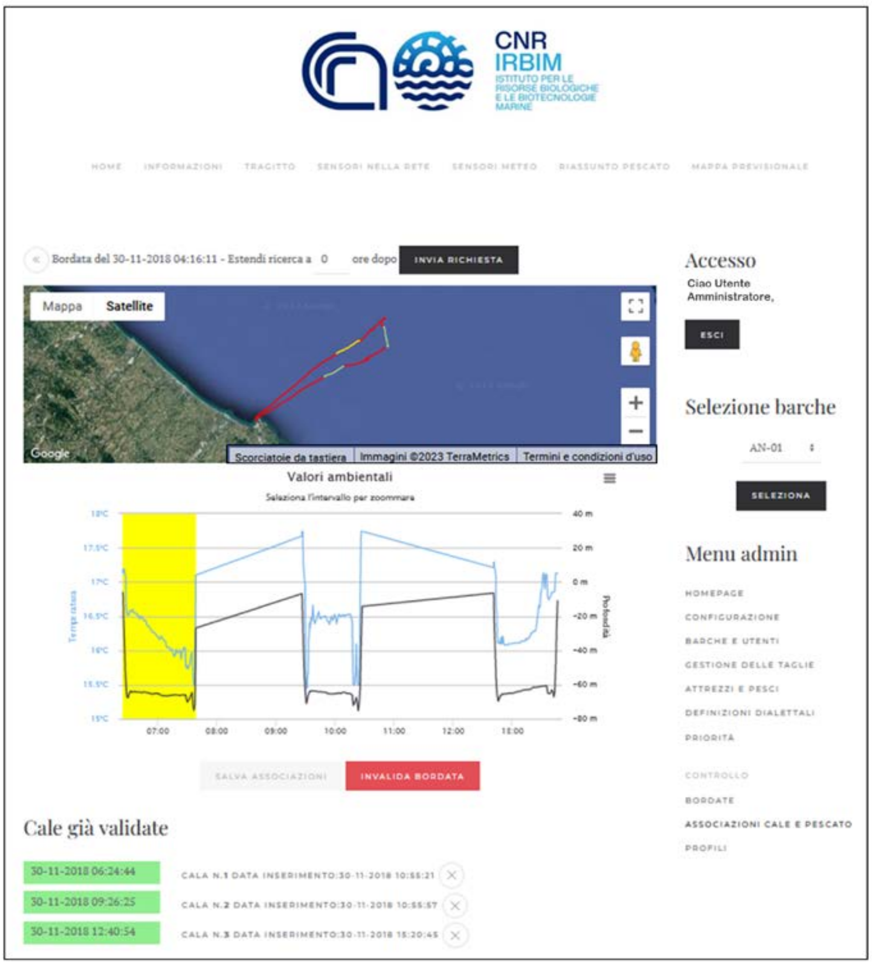

Figure S2B. FOOSweb interface: on top in red, GPS route tracks generated by means of Google Maps APIs (Application Programming Interface; base layer source: Copyright TerraMetrics, LLC – www.terrametrics.com) with fishing hauls highlighted in green and a single haul GPS track highlighted in yellow and corresponding to oceanographic and catch data below.

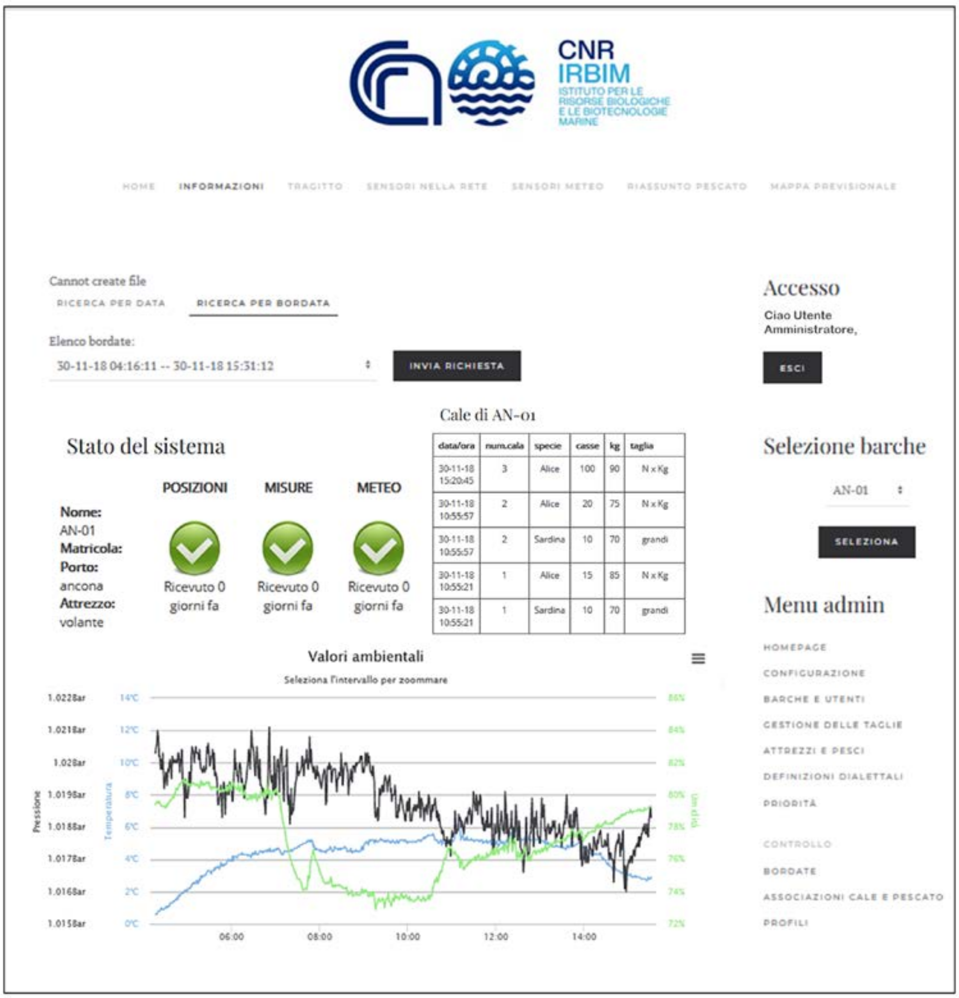

Figure S2C6. FOOSweb interface: (a) GPS route tracks (in red, with fishing hauls highlighted in green) generated by means of Google Maps APIs (Application Programming Interface; base layer source: Copyright TerraMetrics, LLC – www.terrametrics.com); (b) single haul GPS track highlighted in yellow and corresponding oceanographic and catch data; (c) control dashboard with summary of weather, oceanographic and fishing data.

4 Validation and quality control

As mentioned above, the different types of information collected through AdriFOOS are subject to validation and a series of quality assurance (QA) and quality control (QC) procedures are applied by researchers both automatically and manually. All the oceanographic sensors used in AdriFOOS are prior and periodically tested for offsets following Martinelli et al. 2016. 220 The obtained offset values are used to correct the raw data in the DB: the values of the oceanographic parameters are modified for each single sensor identified by its serial number. As part of the applied QA procedure, sensors that developed offsets greater than the accuracy range declared by the producer are discarded and/or sent back to the producers' facilities for recalibration. The information collected by means of FOOS and stored in the raw data DB are processed following the SeaDataNet QC procedures and protocols (SeaDataNet, 2010). Some QC steps are automatically performed by a specific 225 software on the raw data and then further checks are manually carried out, based on the expertise of an oceanographer, through the Ocean Data View (ODV) software (Schlitzer, 2021). QC process is carried out on the oceanographic data according to the different acquisition phases (i.e. profile, permanence of the sensor at the fishing depth and ascent). Normally the profiling phase is very fast as the fishing gears reach very quickly the fishing depth, thus adopting the first recorded GPS position (start of the haul), the acquired profile can be assimilated to a classic CTD (Conductivity, Temperature and Depth) haul. Being 230 georeferenced (position recorded at 1 minute rate), the rest of the oceanographic data could potentially be assimilated and treated as drifter trajectories.

The AdriFOOS dataset 2012-2020 refers to temperature data acquired along the water column during the profile phase (Penna et. Al., 2020). A specific software checks the increase in pressure in the descending phase (i.e. the profile) and marks the 3 different acquisition phases with a specific tag. 235

A range of automatic checks are carried out on the data to ensure that they have been imported into the raw data DB with the correct format and without any loss of information; these include:

- header details check (vessel, cruise number, station numbers, date/time, latitude/longitude (start and end), instrument serial number and type, number of data points);
- pressure increasing check; 240
- automatic range checking and flagging of each parameter;
- automatic flagging of spikes in the data.

A dedicated tool was also developed to allow export of profile datasets in the ODV standard format (Schlitzer, 2021) and thus allowing a visual inspection of data. In particular, the QC on the profile dataset 2012-2022 was carried out according to the following steps: 245

- plotting profiles collected in the same area and period to check for evident discrepancies (Fig. 7);

12

- ~~visual inspection on the profiles to identify spurious or wrong values;~~
- ~~flagging of spikes in the dataset (or interpolating when there is only one incorrect data);~~
- ~~flagging of suspicious data;~~
- ~~flagging of wrong profiles. 250~~

~~In fact, one of the most delicate and fundamental phases of the whole quality control process is the visual inspection of the profiles. Figure 7 shows temperature profiles which, while passing the automatic checks, are evidently still invalid and consequently flagged as incorrect. All flags used follow the standard L20 vocabulary (Seadatanet measurand qualifier flags, 2022). After the QC, data are re-imported in the backup DB containing validated data.~~

As mentioned above, the different types of information collected through AdriFOOS are subject to validation through~~and~~ a series of quality assurance (QA) and quality control (QC) procedures~~ are~~ applied by researchers both automatically and manually. Data received in NRT are stored in the raw data DB in which some automatic or manual procedures described below are applied (columns are available in the DB tables for specific quality flags), and once definitively validated they are transferred in a validated data DB (see DB structure in Supplement Section I). Data are stored in physical units following the standard metric of the International System of Units; time and position are recorded following respectively the Coordinated Universal Time (UTC) and the World Geodetic System 1984 (WGS84) formats. Validated datasets include flags for each record to indicate the estimated quality of the measurement (see section 4.2). Metadata are available for each dataset. QC process is carried out on the oceanographic data according to the different acquisition phases (i.e. down cast, horizontal profile and up cast). The AdriFOOS dataset 2012-2020 refers ~~only~~ to temperature and pressure data acquired along the water column during the down cast phase (Penna et. al., 2020), therefore the procedures applied to these data will mainly be described below.

4.1 Field test of sensors and evaluation of the offset

All the oceanographic sensors used in AdriFOOS (see characteristics in section 3.1) are prior and periodically tested in the field for offsets and their performance is compared to oceanographic class CTD (Conductivity, Temperature and Depth) probes through simultaneous casting, following Martinelli et al. (2016). Where needed, the obtained offset values can be used to correct datasets in the validated data DB (see Supplement Section I); in this case the values of the oceanographic parameters are modified for each single sensor identified by its serial number. As part of the applied QA procedure, sensors that developed offsets greater than the accuracy range declared by the producer are discarded and/or sent back to the producers' facilities for recalibration.

4.2 Quality flags in use

All flags used follow the standard L20 vocabulary (SeaDataNet measurand qualifier flags, 2022) and are reported in Table 1. QC process is carried out on the oceanographic data according to the different acquisition phases (i.e. down cast, horizontal profile and up cast). Normally the profiling phase is fast as the fishing gears reach very quickly the fishing depth, thus adopting the first recorded GPS position (start of the haul), the acquired profile can be assimilated to a classic CTD haul. Instead, for example, the horizontal profile data collected during the fishing phase could potentially be assimilated and treated as drifter trajectories as the GPS position is recorded at 1 minute rate.

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Quality code	meaning
0	no quality control
1	good value
2	probably good value
3	probably bad value
4	bad value
5	changed value
6	value below detection
7	value in excess
8	interpolated value
9	missing value
A	value phenomenon uncertain
B	nominal value

Q	value below limit of quantification

Table 1. **SeaDataNet** quality codes (and their meaning) used to flag records in the dataset Penna et. al., 2020.

4.3 Automatic validation procedures

The information collected by means of FOOS and stored in the raw data DB are processed following the SeaDataNet QC procedures and protocols (SeaDataNet, 2010). The QC phases described below are performed automatically on the raw data by a specific ad hoc software compiled in PHP (Hypertext Preprocessor), which directly assigns the appropriate flag codes. Some general assumptions are applied to the dataset:

- the QC flag value assigned by a test cannot override a higher value from a previous test;
- only measurements with QC flag = 1 can be used safely without further check;
- if the measurement has QC flag = 4 should be rejected;
- if any of the general information (e.g. time and location) are inconsistent, the whole profile is marked as “bad”, which means that all pressure/temperature data pairs are flagged using code 4(=bad value).

The sequential automatic QC steps carried out on the data set include:

1. header details consistency check (vessel code, cruise number, station number, instrument serial number and type, adequate number of data points): all the used codes must be included among those stored in the corresponding tables included in the DB (see section Supplement 1); if any of this information is inconsistent, the whole profile is marked as “bad”;
2. impossible date-time test: date must be between 26/11/2012 and the date of data transfer to the inland server; if the date-time data are inconsistent, the whole profile is marked as “bad”; none of the records included in the Penna et. al., 2020 data set failed the test;
3. impossible location test: due to some random GPS malfunctions, unfortunately some profiles cannot be associated with any position and in this case the data are directly deleted; furthermore considering that the monitored vessels work in the Adriatic Sea, latitude within the datasets must be between 40.4°N and 45°N and longitude between 12.4°E and 18.6°E, if any of the positions in a dataset is inconsistent then the whole profile is marked as “bad”; none of the positions recorded in the Penna et. al., 2020 dataset failed the test;
4. global temperature range test: a filter taking into account the temperature range of the sensors in use is applied on the observed values; if any of the temperature records fails the test this is marked as “bad”; none of the temperature records in the Penna et. al., 2020 data set failed the test;

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5. regional temperature range test: a filter taking into account the expected extreme temperatures encountered in the Adriatic Sea (5-32 °C) is applied on the observed values; if any of the temperature records fails the test this is marked as “bad”; none of the temperature records in the Penna et. al., 2020 data set failed the test;
6. pressure range test: the control range goes from -5 to 300 dbar to include any measurement in air and to take into account the maximum operating depth indicated by the manufacturer for the sensors in use; preliminarily fishermen who normally operate at depths within the range of the sensors were selected in order to avoid measurements out of range; if any of the pressure records fails the test this is marked as “bad”; none of the pressure values in the Penna et. al., 2020 dataset failed the test;
7. pressure increase/decrease test: the 3 different acquisition phases (i.e. the down cast, horizontal profile and up cast) are marked with a specific internal tag within the DB; to mark a downcast the test requires a monotonically increasing pressure; Penna et. al., 2020 dataset includes only data marked as downcast by this procedure;
8. spike test: assuming that a spike is defined by a large difference between adjacent values (SeaDataNet, 2010), the algorithm used to identify it is: test value = | V2 – (V3 + V1)/2 | – | (V3 – V1) / 2 | , where V2 is the measurement being tested as a spike, and V1 and V3 are the previous and next; the test fails when the test value exceeds 1.0°C and data are flagged using code 2 (=probably good value).

4.4 Visual inspections

- Further controls can be manually carried out, based on the expertise of an oceanographer, directly through a web interface connected to the raw data DB (FOOSweb; see Figure S2A in Supplement Section I). A specific panel under the “Menu Admin” section (Figure S2A) allows users to visualize all acquired casts. This feature was developed in order to be able to quickly verify possible sensor failures or anomalies and thus provide technical assistance as soon as possible. Furthermore this allows to check and modify the quality flags derived from the automated procedures described in the previous section for every depth/temperature data pair and keep track of this process (this feature is available also for salinity profiles). Flags automatically set at code 0 (=no quality control) can thus be changed semi-automatically to code 1 (=good data). For the Penna et. al., 2020. dataset, this feature was also used to check for highlighted spikes and adjacent values to be used for interpolation; in this case the record flag was consequently changed to code 8 (= interpolated value).

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A dedicated tool was also developed to allow export of profile datasets in the ODV standard format (Schlitzer, 2021) and thus allow a further global visual inspection of data. In particular, the QC on the down casts dataset 2012-2022 was carried out according to the following steps:

- plotting profiles collected in the same area and period to check for evident discrepancies (Fig. 5);
- visual inspection on the profiles to identify any remaining spurious or wrong values;
- flagging of wrong profiles.

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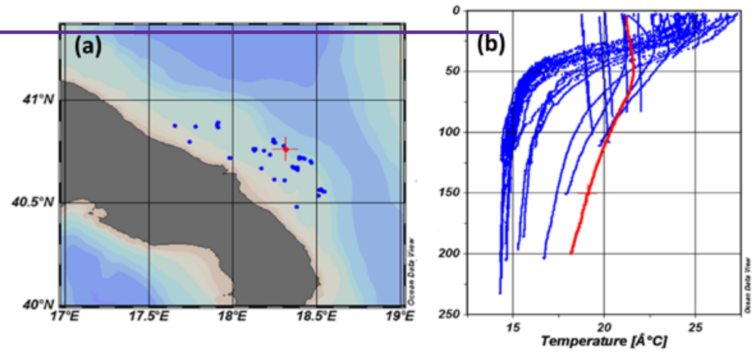
Using this procedure a further check on pressure records was done on the Penna et. al., 2020 dataset: values between -5 and 1.5 meters were detected globally and marked with flag code 4 (=bad value) as the sensor is normally set to activate the acquisition after exceeding the 1.5 dbar threshold.

Figure 5 shows temperature down casts which, while passing the automatic checks, are evidently still invalid and consequently flagged as "bad" (i.e. the red profile and those indicated by red arrows in panel b). At this point, if necessary data are also corrected with the offsets calculated in the field tests and, after the QC, are re-imported in the DB containing validated data.

Data that underwent the procedures described above are then ready to be exported in ODV, NETCDF or any other type of interoperable format.



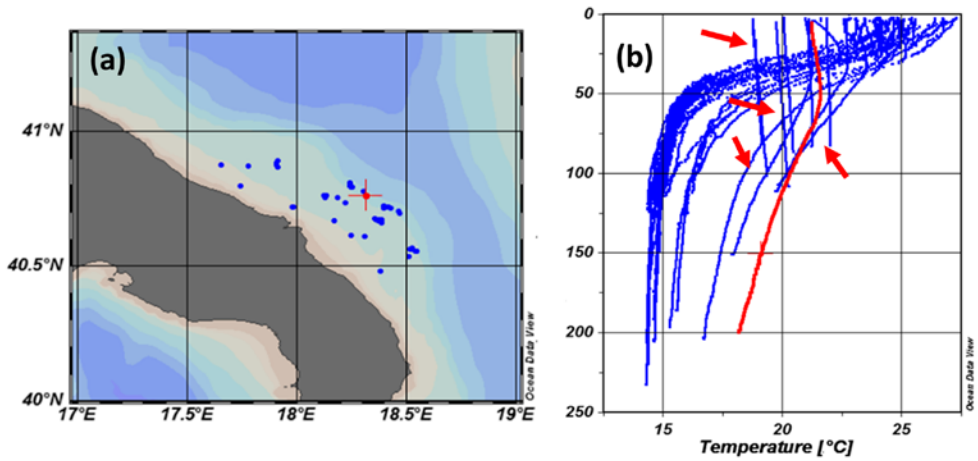


Figure 5~~7~~. Map of georeferenced profiles obtained by AdriFOOS in the s~~S~~outhern Adriatic Sea for the day July 24, 2013, with one highlighted location (red cross; a) and respective depth (pressure)/temperature profile~~s plotted in group~~ (red profile; b) by means of Ocean Data View (Schlitzer, 2021); the highlighted profile and those indicated by red arrows are flagged as "bad".

4.5 Other quality check procedures featured in AdriFOOS

~~-~~As reported above, the procedures and post processing applied to ~~in Martinelli et al. (2016), especially during the profile phase, the salinity measurement obtained by the NKE sensors are probably strongly influenced by the operating conditions (i.e. the water flow inside the sensor) causing noisy readings that could be reduced by post-processing; the latter procedure, as well as those applied to bottom datasets are not described in this paper as~~the salinity datasets, horizontal profiles and up casts collected through AdriFOOS are not broadly discussed in this paper. ~~and in general oceanographic data acquired during the permanence of the fishing gears close to the bottom and the ascent phase, as well as the weather and catch information, are not yet published.~~

However it is worth~~woth~~ to mention that the FOOSweb interface also embeds a "Catch validation tool", whose purpose is to correctly associate by haul the data on the caught fish species to the oceanographic georeferenced information. Indeed, sometimes may happen that this two sets of data do not correspond due to the fact that fishermen were not able to enter the catch data in NRT before the start of the following hauls; in the haste of the work on board, catch can be also wrongly inserted (e.g. clearly unreliable in reference to the fishing gear or the fishing area, species reported in unsuitable quantities etc.). In this case, through the FOOSweb (Fig. S2B~~6b~~) and based on his knowledge and experience, a fishery biologist can check the automatically defined fishing trip and hauls definitions provided by the DB (see Supplement Section I~~paragraph 3.3.2~~), correct the wrong associations, QC and label (i.e. assign validation flags) each catch/haul combination.

5 Data record

The dataset in Penna et al., 2020 is supplied in tab-delimited text ASCII format, according to Ocean Data View-Seadatanet standards (Lowry, 2019). An example of 2 depth (pressure)/temperature down cast~~profile~~s and the header with metadata is shown in the Supplement Section III. Therefore, the data files produced by AdriFOOS can be directly uploaded in the ODV software (version >4, Schlitzer, 2021) for visualisation and analysis. ~~This software is freely available for non-commercial, non-military research and teaching purposes.~~ Furthermore, the ODV standard tab-delimited ASCII text format (Lowry, 2019) contains self described metadata (e.g. measurement ranges, producer and type of sensors, precision and accuracy) and can be easily imported in generic database management systems (DBMS) or GIS software. The same dataset can also be ~~exported~~ downloaded in Network Common Data Form (NetCDF, 2022) standard format; for the latter, compliance with version 1.7 of the Climate and Forecast (CF) Metadata Conventions was verified through the Integrated Ocean Observing System (IOOS) Compliance Checker Tool (https://compliance.ioos.us/index.html).

The profiles generated by the AdriFOOS fleet during the period from November 26, 2012 to February 26, 2020 were 14810, consisting of 942672 depth (pressure)/temperature data pairs (Penna et al., 2020). After being subjected to QA and QC, the dataset can be considered accurate in temperature at 0.05°C and +- 0.3% full scale (i.e. 300 dbars) ~~(for most of the used sensors corresponding to 300 dbars, while for few of them, used in the deepest areas of the basin, it corresponded to 600 dbars)~~ in pressure. Table 2~~1~~ summarises the statistics calculated for each vessel, while Fig. 6~~8~~ describes the quantitative spatial distribution of these depth (pressure)/temperature down cast~~profile~~s.

Anonymised vessel code	***Station Count***	***Sample Count***	***Longitude Range***	***Latitude Range***	***Time Period***
1 AN-01	**1543**	**46657**	**12.7°E - 14.6°E**	**43.3°N - 44.4°N**	**14 Apr 2014 - 26 Feb 2020**
2 AN-02	**1358**	**25025**	**12.9°E - 14.6°E**	**43.3°N - 44.4°N**	**16 Sep 2013 - 04 Jan 2018**
3 AN-03	**6897**	**429985**	**12.9°E - 15.2°E**	**43.1°N - 44.3°N**	**26 Nov 2012 - 28 Jun 2018**
4 BA-01	**234**	**22485**	**17°E - 17.4°E**	**41°N - 41.2°N**	**05 Dec 2013 - 21 Oct 2014**
5 BR-01	**1964**	**310332**	**17.5°E - 18.6°E**	**40.4°N - 40.9°N**	**05 Jul 2013 - 20 Jun 2017**
6 Dallaporta	**135**	**24174**	**14.1°E - 15.8°E**	**42.4°N - 43.9°N**	**13 Apr 2013 - 20 Oct 2019**
7 ML-01	**491**	**27703**	**14.2°E - 17.1°E**	**41.2°N - 43.8°N**	**20 Mar 2013 - 25 Sep 2017**
8 RN-01	**554**	**5493**	**12.5°E - 13.4°E**	**43.8°N - 44.6°N**	**14 Apr 2014 - 30 Jun 2017**
9 RN-02	**1261**	**39841**	**12.4°E - 13.5°E**	**43.8°N - 45°N**	**16 Sep 2013 - 08 Nov 2016**
10 SB-01	**338**	**8783**	**14°E - 15.4°E**	**42.5°N - 43.9°N**	**14 Apr 2014 - 10 Aug 2016**
11 TR-01	**35**	**2194**	**16.5°E - 16.7°E**	**41.4°N - 41.7°N**	**13 Mar 2013 - 09 Apr 2013**
All vessels	**14810**	**942672**	**12.4°E - 18.6°E**	**40.4°N - 45°N**	**26 Nov 2012 - 26 Feb 2020**

Table ~~1~~2. Number of profiles (Station count), number of records (depth (pressure)/temperature data pairs count), space and time span of the data collection indicated for each vessel.

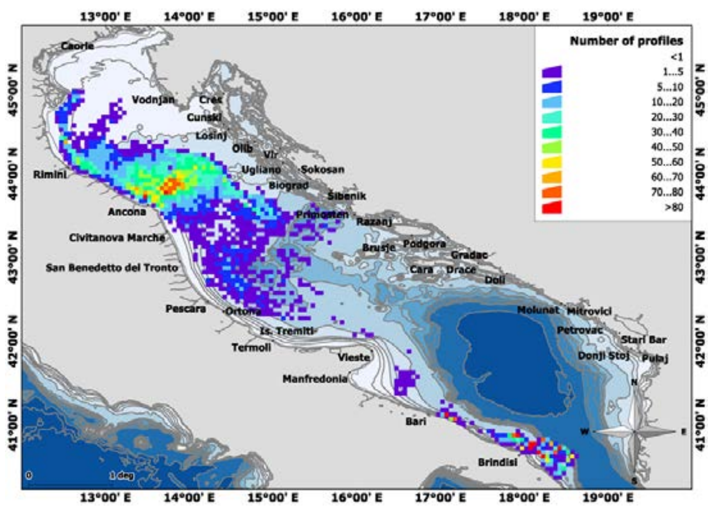


Figure 6~~8~~. Quantitative spatial distribution of the AdriFOOS depth (pressure)/temperature profiles dataset 2012-2020 mapped by means of Manifold® GIS; bathymetry source: EMODnet, 2016.

Figure 7~~9~~a highlights that the highest number of profiles was recorded in 2014, 2016 and 2017, when 11 fishing boats were operational. From 2018 to 2020, unfortunately the number of monitored vessels temporarily decreased due to a series of operational limitations (e.g. decommissioning of some of the long term monitored vessels, difficulty in recruiting new collaborative captains, bureaucratic or funding limitations, etc.). Taking into account the days of the year, an average of about 600 depth (pressure)/temperature profiles were recorded every 2 weeks (Fig. 7~~9~~b). It is evident in Figure 7~~9~~b a reduction in the number of recorded profiles (hauls) during the summer season (spanning between day of the year number 230 and 264), which could be related to the national annual temporal closure of fisheries implemented in the Adriatic Sea (30 days in a variable period every summer; FAO, 2022).

The number of pressure data points (counts) collected by AdriFOOS over the reference period 2012-2020 is shown in Figure 8a~~Figure 10 shows the distribution of pressure (a) and temperature (b) data over the reference period 2012-2020~~; a higher density of records corresponds to pressure lower than 120 dbar~~ and a temperature of about 15 °C~~.

The quantity (counts) of pressure (depth)/temperature data pairs is shown instead in Figure 8b;~~Figure 11 further highlights that most of the depth (pressure)/temperature~~ data pairs are aggregated in a pressure range between 0 and 80 dbar and a temperature range between 13 and 20 °C.

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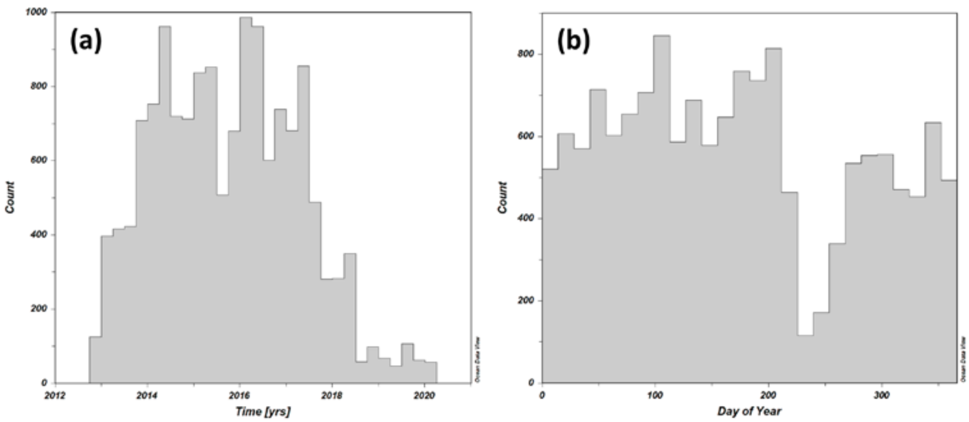
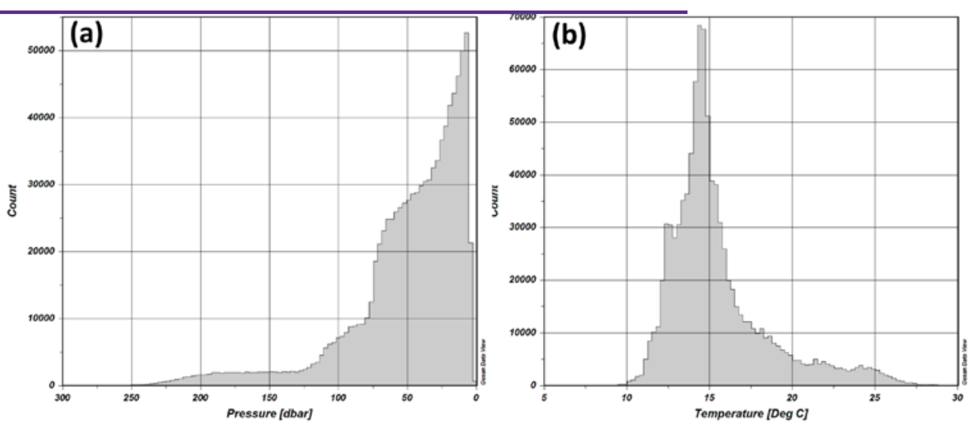


Figure 79. Count of depth (pressure)/temperature profiles over years (a) and day of the year (b); graphs generated by means of Ocean Data View (Schlitzer, 2021).



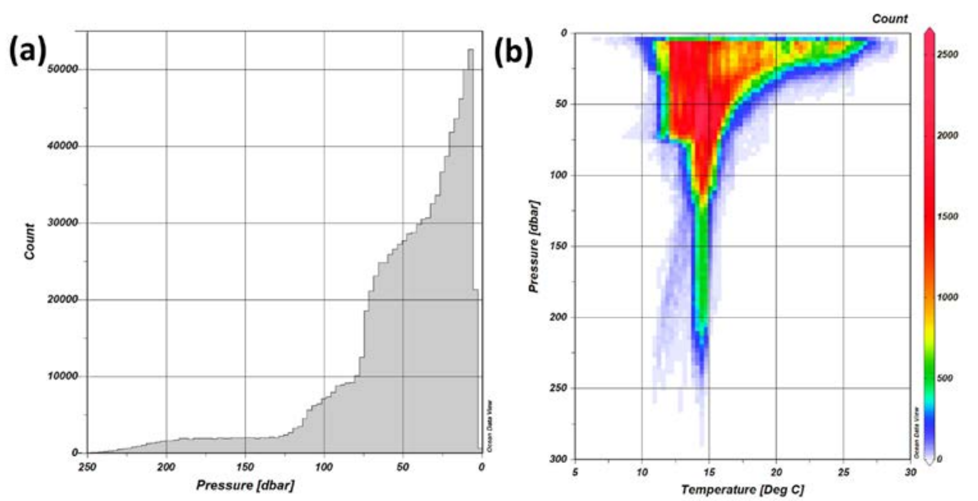
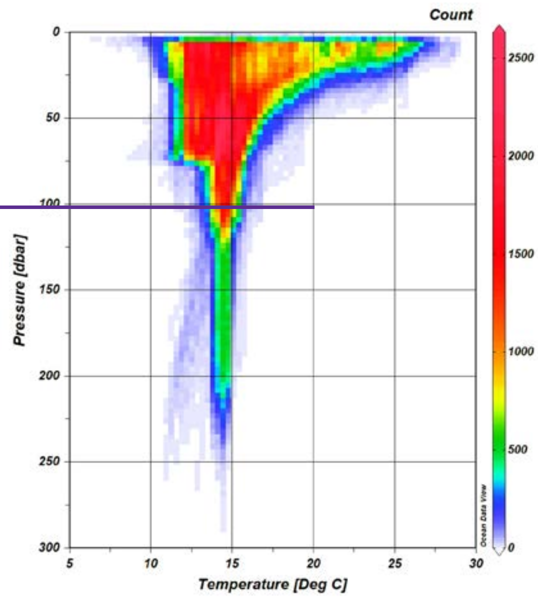


Figure 810. Data distribution of data collected by AdriFOOS over the reference period 2012-2020 in relation to pressure (depth) (a) and distribution of pressure (depth)/temperature pairstemperature (b); graphs generated by means of Ocean Data View (Schlitzer, 2021).



~~**Figure 11. Distribution of pressure (depth)/temperature pair data collected by AdriFOOS from 2012 to 2020; plot generated by means of Ocean Data View (Schlitzer, 2021).**~~

6 Data availability

The sea water column oceanographic data (i.e. depth and temperature acquired during the profiling phase) described in this paper are available in the SEA scieNtific Open data Edition (SEANOE) repository at https://doi.org/10.17882/73008 (Penna et al., 2020). The dataset consists of 14810 depth (pressure)/temperature water column down cast~~profile~~s recorded by the AdriFOOS infrastructure in the Adriatic Sea during commercial fishing operations. The dataset underwent QA and QC processes and is supplied in tab-delimited text ASCII format.

7 Results and discussion

The first trials on the AdriFOOS infrastructure were carried out in June 2012 by means of a commercial bottom trawler belonging to the Ancona fleet. In 2014, nine vessels (five pelagic pair trawlers, two purse seiners and two bottom trawlers) were operational in the Adriatic Sea, increasing not only the spatial extension toward the southern part of the basin but also the possibility to monitor various kind of fisheries, if compared to systems previous in use.

Figures 912 and 103, produced through specific ODV functions (Schlitzer, 2021), show examples of oceanographic data products that may be obtained by means of AdriFOOS. The ODV embedded Data-Interpolating Variational Analysis interpolation algorithm (Troupin et al., 2019), set to automatic scale length, was used.

Figure 912, shows the sea surface temperature map obtained for the month of July 2014; it was generated first creating an isosurface variable "temperature at first available georeferenced pressure value" and then plotting it using the surfer window template.

Figure 103 shows seasonal vertical temperature sea sections of the cCentral Adriatic Sea obtained by AdriFOOS in 2014 and was obtained using the ODV section window, upon defining and selecting a sea section of about 4.7x10080 km, ranging from the coast to open sea (Fig. 103a, red rectangle). The down castprofiles falling within the defined section were used to create seasonal vertical temperature sections, showing the natural seasonal variability over the periods December 2013-February 2014 (winter, 4942 data pairs, Fig. 103b), March 2014-May 2014 (spring, 3279 data pairs, Fig.e 103c), June 2014-August 2014 (summer, 2003 data pairs, Fig. 103d) and September 2014-November 2014 (autumn, 4481 data pairs,Fig. 103e). The temperature difference between the winter and spring seasons (December 2013-May 2014, Fig.e 103b,c) is likely due to the river runoff into the nNorthern Adriatic, which leads to a strong surface current generating a floating coastal water layer that flows toward sSouth along the Italian coast (Cozzi and Giani, 2011; Grilli et al., 2020). A well pronounced thermocline occurring in the summer season is instead evident in Figure 103d, highlighting the stratification of the water column: a temperature of about 25°C in the first 20 meters gradually decreases to 14-15°C near the sea bottom. In autumn, this stratification slowly disappears and a mixing of the water column is evident at least up to 50 km from the coast, as shown in Figure 103e.

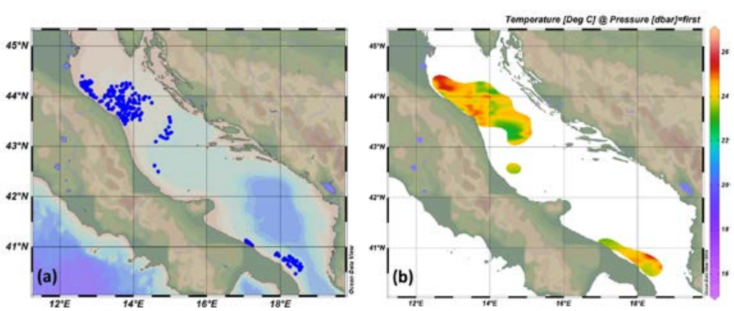
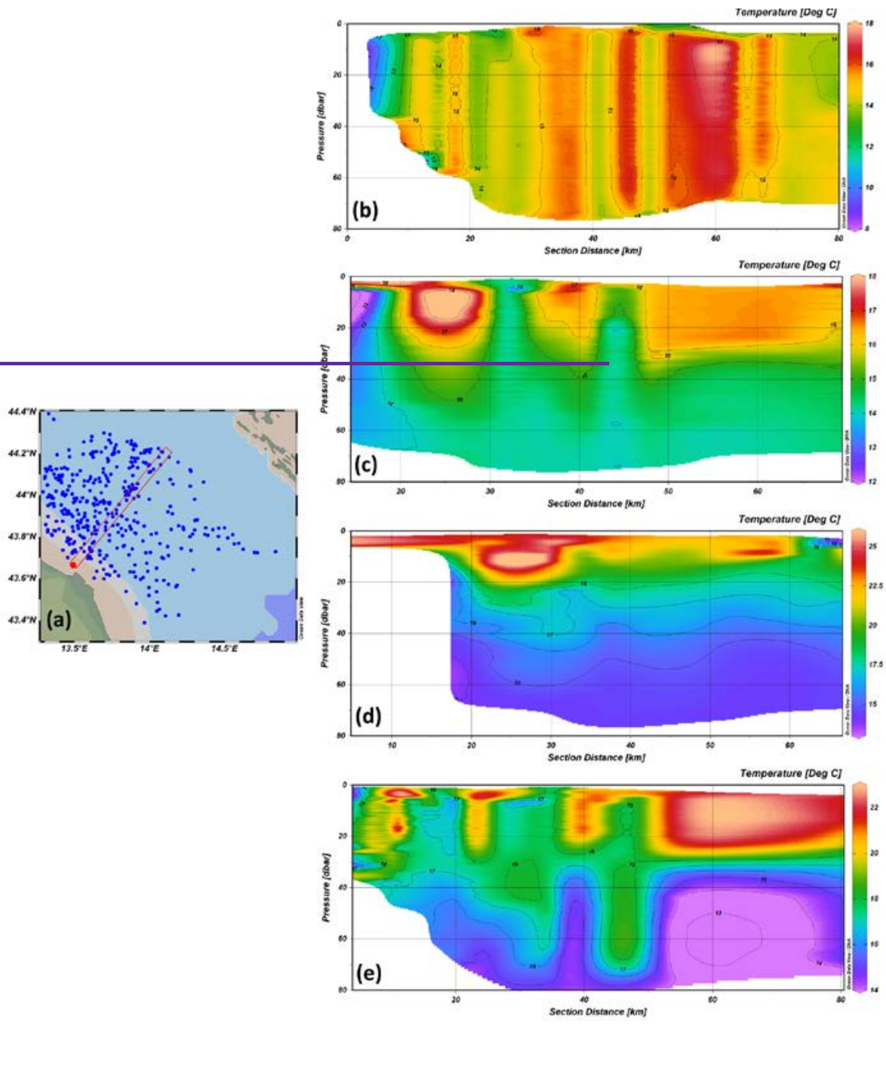


Figure 912. Map of georeferenced castprofiles in the Adriatic Sea (a) and derived Sea Surface Temperature (SST) horizontal map (b) obtained by AdriFOOS for July 2014 (up is referred to the north); maps generated using Ocean Data View (Schlitzer, 2021).



(a)
44.4°N
44.2°N
44°N
43.8°N
43.6°N
43.4°N
13.5°E
14°E
14.5°E
(b)
(c)
(d)
(e)
Temperature [Deg C]
Pressure [dbar]
Section Distance [km]

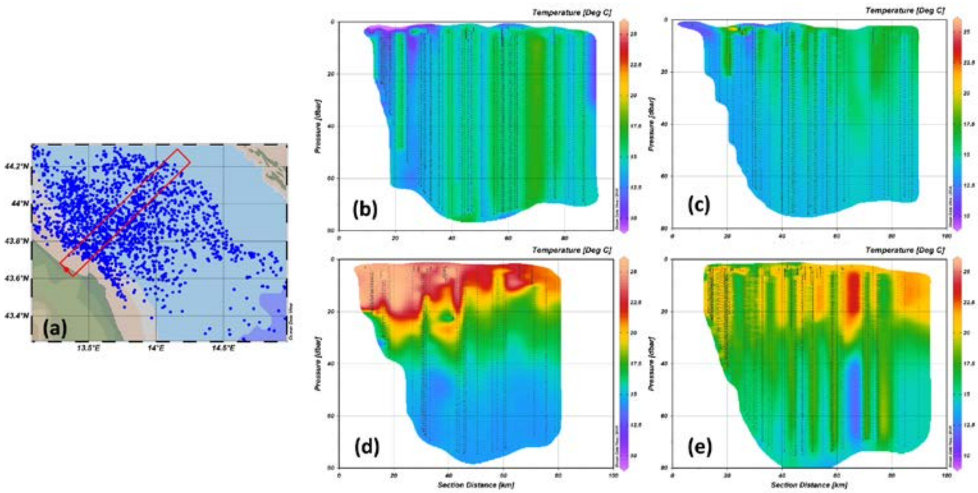


Figure 103: Map of georeferenced castprofiles obtained by AdriFOOS in 2014 in the Northern Adriatic Sea with an evidenced sea section highlighted in the NortherncCentral Adriatic Sea (red rectangle; a) obtained by AdriFOOS in 2014 (a) and derived seasonal vertical temperature vertical section for winter (b), spring (c), summer (d) and autumn (e); map and plots generated by means of Ocean Data View (Schlitzer, 2021).

Figure 14 shows a A use case generated using the ODV scatter template function is displayed in Figure 11, which shows aA comparison- between the AdriFOOS down castprofiles of the year 2014 and those provided by Copernicus Marine Service (CMEMS, 2022) for the same area and period (day) in the Global Ocean Physics Reanalysis dataset (GLORYS12V1, 2022) in which daily averaged data are calculated. An ODV merged data collection was specifically created to carry out this comparison (find more details on adopted assumptions and procedures in Section II of Supplementary material).

The following paragraph will be moved to Supplementary materials Section II: Assumptions and procedures used to create a new ODV merged data collection

To create a new ODV merged data collection, the following steps were followed:

1) by using the CMEMS Ocean data visualisation tools (MYOCEANPRO, 2022), the Adriatic Sea data in the CMEMS GLORYS12V1 products were selected and and downloaded in NETCDF format;

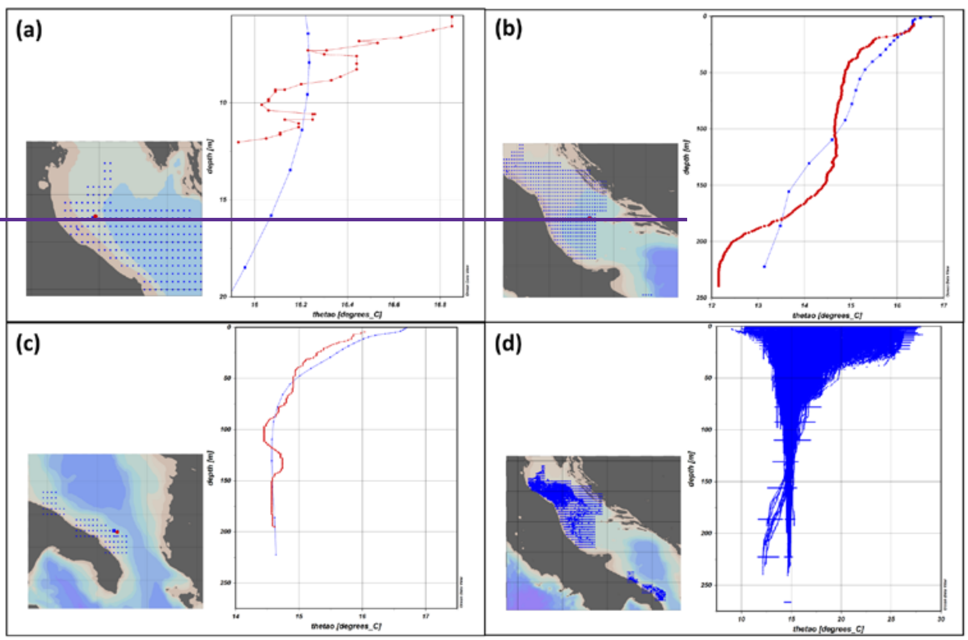
2) the dataset was imported and opened by using ODV open file function;

3) the dataset was exported in text format (export/data/ODV spreadsheet file function);

4) the file created in step 3 was imported into the AdriFOOS ODV collection (import/ODV spreadsheet file function).

During the input phase, date, location and depth of the CMEMS GLORYS12V1 data were associated with date, location and pressure of the AdriFOOS dataset and the corresponding potential temperature in the CMEMS GLORYS12V1 dataset was associated with the AdriFOOS measured temperature data. This comparison could be improved in future and be made more stringent by converting pressure to depth and using salinity profiles to calculate potential temperature in the AdriFOOS dataset. However considering that at the latitudes of the Adriatic Sea, the difference between pressure and depth is empirically in the order of 0.1% and that the potential temperature, at a salinity of 35 PSU (Practical Salinity Unit), has a minimum difference (in order of cents), this methodology can be considered suitable for the purpose of visually comparing the AdriFOOS dataset and the CMEMS data product GLORYS12V1.

AdriFOOS data fall in general within the temperature range resulting from the model (Fig. 11a). Therefore, using the ODV template station, aAs an example, some adjacent AdriFOOS down casts profiles (in red) and CMEMS stations (in blue) corresponding to the same day were selected in the three Adriatic sub basins (Fig. 11 b-d4). Despite the formal difference in the considered variables, the plots for the nNorthern (Fig.11b134a), cCentral (Fig. 114cb) and sSouthern (Fig. 11dc4C) sub-basins are useful to check the correspondence betweenshowed a good correspondence between in-situ and modellled data. Probably due to the presence of rivers with large flows, such as the Po river, discrepancies are particularly evident in the northern basin (Fig. 11b), while they tend to decrease in the central basin (Fig. 11c). The vertical structure of the water column seems to be more correctly represented by the data calculated by the model only in the southern basin (Fig. 11d)..
Figure 14d was generated using the ODV scatter template function and shows a plot including all the AdriFOOS profiles and the CMEMS dataset; this plot indicated a general correspondence between the datasets.
This represents an interesting exercise capable of highlighting the potential of the validated dataset produced by the AdriFOOS infrastructure, that certainly could be of help also to improve the accuracy of the CMEMS product under reanalysis.
Although it is beyond the main scope of this data description paper, the comparison between in situ observed and modeled data, represents an interesting exercise highlighting the potential of the validated dataset produced by the AdriFOOS infrastructure. The AdriFOOS validated datasets, have indeed the potential to feed in NRT oceanographic models and, as previously highlighted also by assimilation experiments (e.g. Aydoğdu et al., 2016; Mourre et al., 2019), can substantially contribute to improve their outputs as well as be useful for reanalysis of historical data.
Furthermore, thanks to the collaboration with other European institutions and small and medium-sized enterprises (SMEs) and to the participation to various European funded projects (i.e. JERICO, NeXOS and JERICO NEXT), AdriFOOS is nowadays also an internationally recognised test platform for new oceanographic sensors designed for fishing gear use.; AdriFOOS infrastructure is indeed currently involved in the EU H2020 NAUTILOS project as validation and demonstration platform for sensors able to collect various parameters (i.e. dissolved oxygen and fluorescence sensors) and to transmit NRT data using various methods (Pieri et al., 2021).



(a)
(b)
(c)
(d)
depth [m]
thetao [degrees_C]

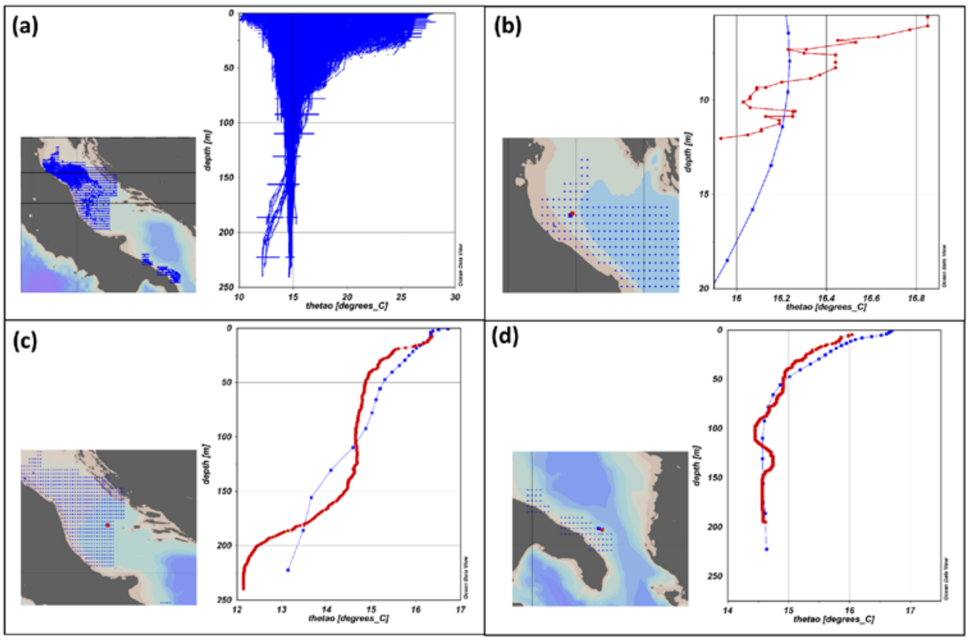


Figure 114: Maps and plots of georeferenced AdriFOOS down castprofiles (red profile) compared to CMES dataset (blue profiles): scatterplot of all the 2014 in situ observed and modeled data (a), downcasts selected for comparison in the nNorthern (ba; May 2, 2014), cCentral (cb, May 2, 2014) and sSouthern (dc, April 28, 2014) Adriatic sea sub-–basins; scatterplot (d) of all the 2014 in situ observed and modeled data.

Furthermore, Figure 15 shows an elaboration obtained from validated catch data by means of GIS: coloured cells (belonging to a 0.05 deg grid) represent the area in which all monitored vessels targeting small pelagic fish operated in the year 2016, the colour palette refers to annual average values of the obtained Catch Per Unit Effort (CPUE, expressed in tons per hour of fishing) for anchovy (*Engraulis encrasicolus*). FOOS systems may indeed also help to study fishing patterns related to different fishing gears targeting the same resource; in fact, in Figure 15 it is evident the difference in CPUE values between cells in the nNorthern part of the Adriatic Sea, mainly fished by the monitored pelagic trawlers (Russo et al., 2015), and those in the cCentral part, fished by the monitored purse seiners (Lucchetti et al., 2018). Furthermore Besides, it is well known that fish distributions and stock sizes are linked to environmental variables (e.g. temperature, salinity, oxygen and chlorophyll) and their changes in time and space, with subsequent influence on fishery sustainability and economy. Therefore,- catch data also obtained by AdriFOOS can also directly be put in relation with the values of environmental parameters collected at the same place, depth and time of the fishing event. In the near future, the refinement of the AdriFOOS catch and bottom parameters datasets and their inclusion in species abundance and distribution models (e.g. Carpi et al., 2015; Chiarini et al., 2022) will allow increasing the knowledge of fish spatial movements, influence of environmental drivers and climate change on their distribution and abundance and status of exploitation of a resource; this is of utmost relevance in the framework of an ecosystem approach to fisheries management.

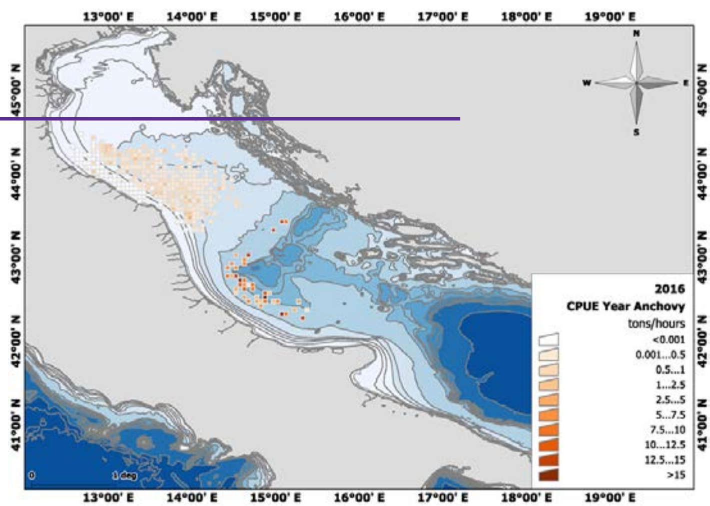


Figure 15. Map of the average Catch Per Unit Effort (tons/ hours) for anchovies in the Adriatic Sea obtained for the year 2016 (coloured cells refer to a 0.05 deg grid); mapped by means of Manifold® GIS; bathymetry source: EMODnet, 2016.

Author contributions

Conceptualization, M.M. and P.P.; Data curation, M.M. and P.P.; Formal analysis, M.M. and P.P.; Funding acquisition, A.B and M.M.; Investigation, A.B., F.D., M.M. and P.P.; Methodology, A.B., M.M. and P.P.; Project administration, M.M.; Software, M.M. and P.P.; Supervision, A.B., M.M. and P.P.; Validation, M.M. and P.P.; Visualization, M.M. and P.P.; Writing – original draft preparation, F.D., M.M. and P.P.

Competing interests

The authors declare no competing financial interests.

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References

Artegiani, A., Bregant, D., Paschini, E., Pinardi, N., Raicich, F., Russo, A., The Adriatic Sea General Circulation. Part I: Air–Sea Interactions and Water Mass Structure, J. Phys. Oceanogr, J. Phys. Oceanogr., 27, 1492– 1514, 1997.

Aydoğdu, A., Pinardi, N., Pistoia, J., Martinelli, M., Belardinelli, A., Sparnocchia, S., Assimilation Experiments for the Fishery Observing System in the Adriatic Sea, J. Mar. Syst., 162, 126-136, doi:10.1016/j.jmarsys.2016.03.002, 2016.

Campanelli, A., Grilli, F., Paschini, E., Marini, M., The influence of an exceptional Po River flood on the physical and chemical oceanographic properties of the Adriatic Sea, Dynam. Atmos. Oceans, 52, 284e297, do:10.1016/j.dynatmoce.2011.05.004, 2011.

Carpi, P., Martinelli, M., Belardinelli, A., Russo, A., Arneri, E., Coluccelli, A., Santojanni, A., Coupling an oceanographic model to a Fishery Observing System through mixed models: the importance of fronts for anchovy in the Adriatic Sea, Fish. Oceanogr., 24(6), 521–532, doi:10.1111/fog.12126, 2015.

Cozzi, S., Giani, M., River water and nutrient discharges in the Northern Adriatic Sea: Current importance and long term changes. Cont. Shelf Res. 31, 1881–1893, 2011.

Chiarini, M., Guicciardi, S., Angelini, S., Tuck, I.D., Grilli, F., Penna, P., Domenichetti, F., Canduci, G., Belardinelli, A., Santojanni, A., Arneri, E., Milone, N., Medvešek, D., Isajlović, I., Vrgoč, N., Martinelli, M., Accounting for environmental and fishery management factors when standardising CPUE data from a scientific survey: A case study for *Nephrops norvegicus* in the Pomo Pits area (Central Adriatic Sea), PLoS ONE 17(7), e0270703, doi:10.1371/journal.pone.0270703, 2022.

CMEMS, Copernicus Marine Service (or Copernicus Marine Environment Monitoring Service), https://marine.copernicus.eu/, last access 23 december, 2022).

Troupin, C., Watelet, S., Ouberdous, M., Sirjacobs, D., Alvera-Azcárate, A., Barth, A., Toussaint, M.E., Beckers, J.M., Data Interpolating Variational Analysis User Guide, doi:10.5281/zenodo.836723, 2019.

Eigaard, O.R., Bastardie, F., Hintzen, N.T., Buhl-Mortensen, L., Buhl-Mortensen, P., Catarino, R., Dinesen, G.E., Egekvist, J., Fock, H.O., Geitner, K., Gerritsen, H.D, González, M.M., Jonsson, P., Kavadas, S., Laffargue, P., Lundy, M., Gonzalez-Mirelis, G., Nielsen, J.R., Papadopoulou, N., Posen, P.E., Pulcinella, J., Russo, T., Sala, A., Silva, C., Smith, C.J., Vanelslander, B., Rijnsdorp, A.D., The footprint of bottom trawling in European waters: distribution, intensity, and seabed integrity, ICES J. Mar. Sci., 74(3), 847–865, doi:10.1093/icesjms/fsw194, 2017.

EMODnet, EMODnet Bathymetry Consortium. EMODnet Digital Bathymetry (DTM 2016), doi:10.12770/c7b53704-999d-4721-b1a3-04ec60c87238, 2016.

Falco, P., Belardinelli, A., Santojanni, A., Cingolani, N., Russo, A., and Arneri, E., An observing system for the collection of fishery and oceanographic data, Ocean Sci., 3, 189–203, doi:10.5194/os-3-189-2007, 2007.

FAO, The State of Mediterranean and Black Sea Fisheries 2020, General Fisheries Commission for the Mediterranean, Rome, doi:10.4060/cb2429en, 2020.

FAO, National fisheries closures, https://www.fao.org/gfcm/data/maps/nfclosures/en/, last access: 19 December, 2022.

Ferrarin C., Roland A., Bajo M., Umgiesser G., Cucco A., Davolio S., Buzzi A., Malguzzi P., Drofa O.,Tide-surge-wave modelling and forecasting in the Mediterranean Sea with focus on the Italian coast, Ocean Model., 61, 38-48, doi: 10.5194/asr-6-227-2011, 2013; (updated link: http://kassandra.ve.ismar.cnr.it:8080/kassandra, last access: 4 October 2022).

Gaughan, P., Nolan, G., Puillat, I, Farcy, P., Mowlem, M., Seppala, J., Seppo, K., Martinelli, M., Coppola, L., Delauney, L., Guicciardi, S., Penna, P., Belardinelli, A., Croci, C., Domenichetti, F., Santojanni, A., Paschini, E., Sparnocchia, S., WP10 Deliverable 10.4 - Report on Potential New Sensors (Fishing Vessels and Voluntary Opportunity Ships), JERICO (Towards a Joint European Research Infrastructure network for Coastal Observatories) EU FP7 project, https://www.jerico-ri.eu/download/filebase/jerico_fp7/deliverables/D10.4-Report-on-Potential-New-Sensors-Fishing-Vessels-and-Voluntary-Opportunity.pdf, 2015.

Gačić M., Some characteristics of the response of the Adriatic Sea coastal region to the atmospheric forcing, Acta Adriat., 21, 239-254, 1980.

GLORYS12V1, CMEMS Global Ocean Physics Reanalysis, 10.48670/moi-00021, last access: 23 December, 2022.

Grilli, F., Accoroni, S., Acri, F., Bernardi Aubry, F., Bergami, C., Cabrini, M., Campanelli, A., Giani, M., Guicciardi, S., Marini, M., Neri, F., Penna, A., Penna, P., Pugnetti, A., Ravaioli, M., Riminucci, F., Ricci, F., Totti, C., Viaroli, P., Cozzi, S. Seasonal and Interannual Trends of Oceanographic Parameters over 40 Years in the Northern Adriatic Sea in Relation to Nutrient Loadings Using the EMODnet Chemistry Data Portal, Water, 12, 2280. doi:10.3390/w12082280, 2020.

Jiang, ZP., Yuan, J., Hartman, S.E., Fan, W., Enhancing the observing capacity for the surface ocean by the use of Volunteer Observing Ship, Acta Oceanol. Sin., 38**,** 114–120, doi:10.1007/s13131-019-1463-3, 2019.

Lowry, R., Fichaut, M., Schlitzer, R., Maudire, G., Bregent, S., SeaDataNet. Datafile formats. ODV, MEDATLAS, NETCDF. DELIVERABLE D8.5, doi:10.13155/56547, 2019.

Lucchetti, A., Belardinelli, A., D'Andrea, L., Marčeta, B., Martinelli, M., Russo, T., Keč, V.Č., Zorica, B., Virgili, M., Small pelagic purse seines in the Adriatic Sea: A spatial analysis and technical overview in relation to Mediterranean Regulation provisions, Mar. Policy, 98, 104-114, doi:10.1016/j.marpol.2018.09.031, 2018.

Manifold® Geographic Information System System Release 8, https://manifold.net/doc/mfd8/index.htm, last access: 13 December 2022.

Marini, M., Jones, B. H., Campanelli, A., Grilli, F., Lee, C. M., Seasonal variability and Po River plume influence on biochemical properties along western Adriatic coast, J. Geophys. Res., vol. 113, C05S90, doi:10.1029/2007JC004370, 2008

Marini, M, Maselli, V., Campanelli, A., Foglini, F., Grilli, F. Role of the Mid-Adriatic deep in dense water interception and modification, Mar. Geol., 375, 5-14, doi:10.1016/j.margeo.2015.08.015, 2016.

Martinelli, M., Falco, P., Belardinelli, A., Cingolani, N., Arneri, E., Russo, A., Santojanni, A., Fishery observing system (FOS): a tool for collecting oceanographic data and data on fish in the Adriatic, Oper. Oceanogr. Italy Towar. a Sustain. Manag. Sea, 277-284, 2012.

Martinelli, M., Guicciardi, S., Penna, P., Belardinelli, A., Croci, C., Domenichetti, F., Santojanni, A., Sparnocchia, S., Evaluation of the oceanographic measurement accuracy of different commercial sensors to be used on fishing gears, *Ocean* Eng., 111, 22–33, doi:10.1016/j.oceaneng.2015.10.037, 2016.

Möller, K.O., Petersen, W., Nair, R., Greenwood, N., Read, C., Laes-Huon, A., Daniel, A., Bakker, K., Blandfort, D., Gehrung, M., Ylöstalo, P., Haraguchi, L., Ruohola, J., Karlson, B., Artigas, F., Lizon, F., Thyssen, M., Wacquet, G., Ntoumas, M., Créach, V., Jaccard, P., Delauney, L., Seppälä, J., King, A.L., Sørensen, K., Marty, S., Willstrand ,A.W., Laakso, L., Cantoni, C., Petersen, W., Voynova, Y., Martinelli, M., D2.5 Report on Best Practice in the utilization of sensors used for measuring nutrients, biology related optical properties, variables of the marine carbonate system, and for coastal profiling, H2020 JERICO – NEXT Project "Joint European Research Infrastructure network for Coastal Observatory – Novel European eXpertise for coastal observaTories", doi:10.25607/OBP-898, 2019.

Mourre, B., Hernández-Lasheras, J., Juza, M., Reyes, E., Aguiar, E., Heslop, E., Orfila, A., Tintoré, J., Vitorino, J., Korres, G., Perivoliotis, L. , Mpouma, E., Doumas, M., Ferrer, L., Rubio, A., Mader, J., Ciliberti, S., Jansen, E., Coppini, G., Griffa, A., Berta, M., Martinelli, M., Penna, P., Sparnocchia, S., Laakso, L., Björkqvist, JV., Wedhe, H., Karlson, B., Axell, L., Aneborg, L. Chapter 8, Operational oceanography and coastal forecasting, in: Gremare, A., Puillat, I., Karlson, B., Artigas, F., Nizzetto, L., Rubio, A., Laakso, L., Mourre, B., JERICO-NEXT JRAP Synthesis and contribution to the strategy for the future, JERICO-NEXT-WP4-D4.5-220919-V5.0 doi:10.13155/68871, 2019.

MyOceanPro, Copernicus Marine Service, https://data.marine.copernicus.eu/viewer/expert, last access: 13 December, 2022.

NetCDF, Network Common Data Form, https://www.unidata.ucar.edu/software/netcdf/, last access: 13 December, 2022.

Orlić M., Kuzmi M., Pasari Z., Response of the Adriatic Sea to the Bora and Scirocco forcing, C 14-1, 91-116, 1994.

Patti, B., Martinelli, M., Aronica, S., Belardinelli, A., Penna, P., Bonanno, A., Basilone, G., Fontana, I., Giacalone, G., Gallì, N. G., Sorgente, R., Angileri, I.V.M., Croci, C., Domenichetti, F., Bonura, D., Santojanni, A., Sparnocchia, S., D'Adamo, R., Marini, M., Fiorentino, F., Mazzola, S., The Fishery and Oceanography Observing System (FOOS): a tool for oceanography and fisheries science, J. Oper. Oceanogr., 9(1), s99-s118, doi:10.1080/1755876X.2015.1120961, 2016.

Penna, P., Belardinelli, A., Croci C. S., Domenichetti, F., Martinelli, M., AdriFOOS Depth/Temperature profiles dataset 2012-2020, SEANOE, doi:10.17882/73008, 2020.

Petersen, W., Petschatnikov, M., Schroeder, F., Colijn, F., FerryBox systems for monitoring coastal waters, Elsevier Oceanogr. Ser., 69,325-333, doi:10.1016/S0422-9894(03)80052-1, 2003.

Pieri, G., Ntoumas, M., Martinelli, M., Chatzinikolaou, E., Martins, F., Novellino, A., Dimitrova, N., Keller, K., Raimund, S., King, A., Smerdon, A., Mazza, M., Malarde, D., Cocco, M., Torres, A., Triantafyllou, G., Sá, S., Bebianno, M., Sparnocchia, S., Trond, K., Lusher, A., New technology improves our understanding of changes in the marine environment. In Proceedings of the 9th EuroGOOS International Conference. EuroGOOS, Online Streaming Virtual Conference, 3–5 May, 500-508, doi:10.13155/83160, 2021.

Poulain P.M., Adriatic Sea surface circulation as derived from drifter data between 1990 and 1999. J. Mar. Syst., 29, 3-32, 2001.

Puillat, I., Farcy, P., Beaume, N., Second periodic report – Month 18 to 36, Document ID JERICO-WP11-PERIODIC-M36-300614-V2, JERICO (Towards a Joint European Research Infrastructure network for Coastal Observatories) EU FP7 project, https://www.jerico-ri.eu/download/filebase/jerico_fp7/reports/Jerico-period2-interim-activity-report-M36_V2.pdf, 2014.

Rosa, T.L., Piecho-Santos, A.M., Vettor, R., Guedes Soares, C., Review and Prospects for Autonomous Observing Systems in Vessels of Opportunity, J. Mar. Sci. Eng., 9, 366, doi:10.3390/jmse9040366, 2021.

Russo, T., Pulcinella, J., Parisi, A., Martinelli, M., Belardinelli, A., Santojanni, A., Cataudella, S., Colella, S., Anderlini, L., Modelling the strategy of mid-water trawlers targeting small pelagic fish in the Adriatic Sea and its drivers, Ecol. Modell., 300, 102- 113, doi:10.1016/j.ecolmodel.2014.12.001, 2015.

Schlitzer, Reiner, Ocean Data View, https://odv.awi.de, 2021, last access: 13 December 2022.

Seadatanet, Pan-European infrastructure for ocean & marine data management, Seadatanet qc manual, 2010, (https://www.seadatanet.org/content/download/596/file/SeaDataNet_QC_procedures_V2_%28May_2010%29.pdf, last access: 13 December, 2022).

~~Seadatanet, Pan-European infrastructure for ocean & marine data management, Seadatanet Measurand Qualifier Flags (L20 vocabulary http://vocab.nerc.ac.uk/collection/L20/current/accepted/ last access: 13 December, 2022).~~

Sloyan, B.M., Roughan, M., and Hill, K., The global ocean observing system, in "New Frontiers in Operational Oceanography", E. Chassignet, A. Pascual, J. Tintoré, and J. Verron, Eds., GODAE OceanView, 75-90, doi:10.17125/gov2018.ch0, 2018.

Sparnocchia, S., Nair, R., Petihakis, G., Aydoğdu, A., Dobricic, S., Farcy, P., Martinelli, M., Petersen, W., Petit de la Villeon, L., An interlinked coastal observatory network for Europe, J. Oper. Oceanogr., 9(1), s193-s201, doi: 10.1080/1755876X.2015.1114808, 2016.

Sparnocchia, S., Martinelli, M., Del Rio, J., Belardinelli, A., Penna, P., Domenichetti, F., Campanelli, A., Toma, D.M., Martinez, E., Nogueras, M., D9.3– Mediterranean Sea Demonstration Report: Report on demonstration of sensor systems in the Mediterranean, FP7 Ocean 2013 NeXOS project "Next generation Low-Cost Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management", https://www.nexosproject.eu/sites/default/files/170831-NXS-WPX_D.9.3-v.1.4_29082017_Final.pdf, 2017.

Van Vranken, C.H., Vastenhoud, B.M., Manning, J.P., Plet-Hansen, K.S., Jakoboski, J., Gorringe, P., Martinelli, M., Fishing Gear as a Data Collection Platform: Opportunities to Fill Spatial and Temporal Gaps in Operational Sub-Surface Observation, Front. Mar. Sci., 7: Article 485512, doi:10.3389/fmars.2020.485512, 2020.