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

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Abstract. This document describes the dataset of depth (pressure)/temperature profiles collected by means of the 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.

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 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), 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; 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). 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 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 conformations installed on various kinds of fishing vessels, targeting different resources, allowed a spatial extension of the monitored areas in the Mediterranean Sea (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 (Martinelli et al., 2016; Möller et al., 2019). Besides, CNR IRBIM implemented the AdriFOOS (Adriatic Fishery & Oceanography Observing System) observational infrastructure composed by a multifunctional dedicated in 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 server receives daily data sets of environmental parameters collected 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. Puillat et al., 2014; Gaughan et al., 2015; Sparnocchia et al., 2017).

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The acquisition of oceanographic data during the fishing operations can be divided into 3 phases (see paragraph 3.1): 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 profiles has been made accessible (Penna et al., 2020); 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 model 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 collection, storage, quality assurance and control procedures applied to the above mentioned depth (pressure)/temperature profiles dataset. 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 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 Northern, a Central and a Southern sub-basin (Artegiani et al., 1997). The Northern Adriatic is the shallower of the three basins (maximum depth around 100 m). The Central and Southern Adriatic (maximum depth respectively 270 m and 1200 m) are separated by the Pelagosa sill (160 m); another sill (800 m) separates the Southern 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 (Bora 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 Northern 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 Northern 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).

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Therefore, the Adriatic Sea is characterised by an extended continental shelf and eutrophic shallow waters in its Northern-Central 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).

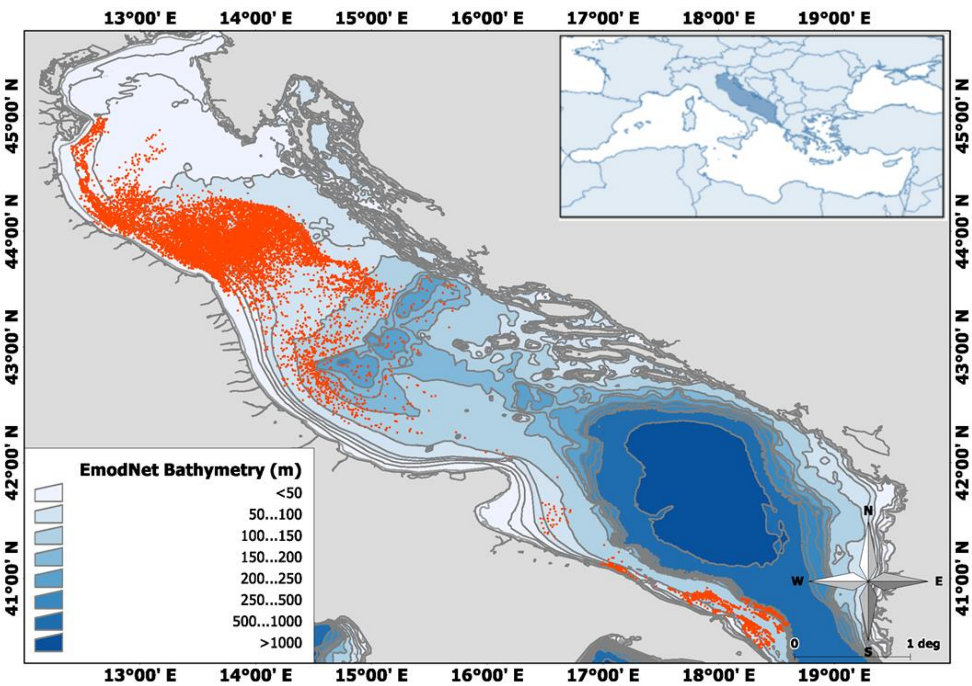

Figure 1. Study area mapped by means of Manifold® GIS (bathymetry source: EMODnet, 2016); in the up-right rectangle the position of the study area within the Mediterranean basin is highlighted; red dots indicate the spatial distribution of the AdriFOOS depth (pressure)/temperature profiles dataset 2012-2020.

3 Methodology

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

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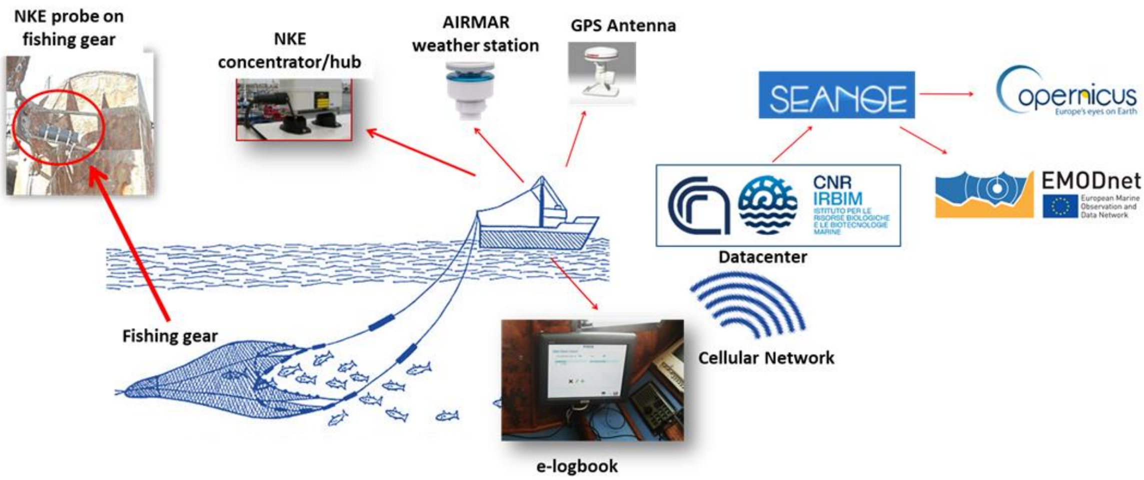

Figure 2. General schema of the AdriFOOS infrastructure.

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 accurate (temperature ± 0.05 ° C; pressure 0.3% of full scale; salinity ± 0.1 psu) and reliable oceanographic data (Martinelli et al., 2016). Their response time (0.5 s) allows the collection of temperature and salinity profiles during the fishing operations (Penna et al., 2020). NKE probes, protected by a silicone layer, are robust enough and reliable for use on fishing gears, however additional Polytetrafluoroethylene (PTFE) cases are used to protect the sensors and allow them to be directly mounted on the gears 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 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 (see paragraph 3.2). Therefore, as already described above, this methodology allows to acquire temperature and salinity profiles along the water column at an aquisition rate comparable to the most commonly used oceanographic profilers, measurements at the depth in which the fishing operation takes place and some data point during the fishing gear recovery.

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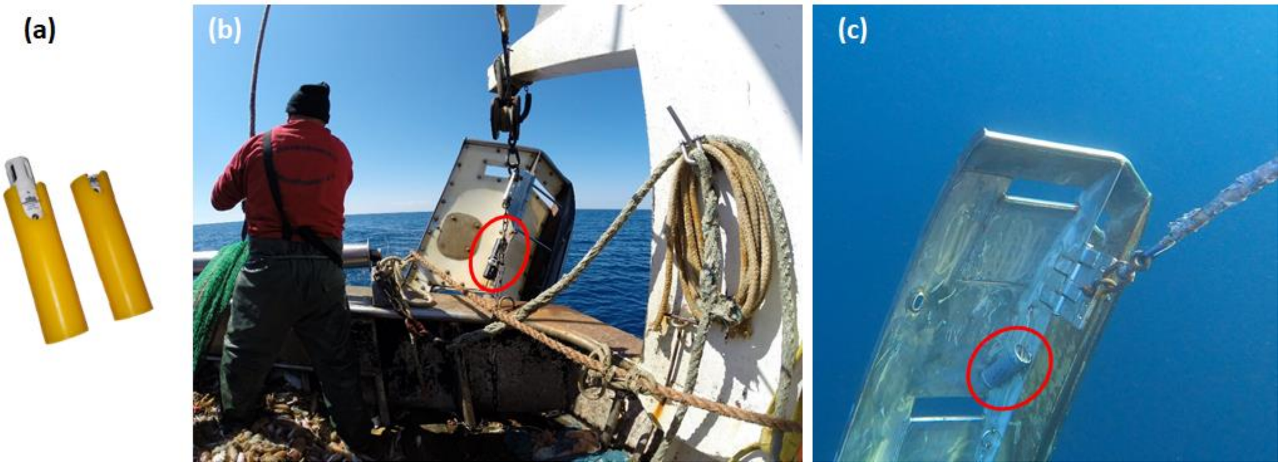

Figure 3. NKE sensors (a) installed on the otter door of a commercial bottom trawler (b); otter door and sensor during the fishing operation (c).

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 inland server.

Figure 4. AdriFOOS GUI used onboard by fisherman: screenshot examples from the catch module (a, b) and the oceanographic real time data visualisation module (c).

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), 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 Inland server

The AdriFOOS server hosts a series of services among which are the waves forecasting module, AdriFOOS data centre web platform and relational databases and they are described in the next subsections.

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. Fig. 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 HTTP protocol and support Transport Layer Security (TLS) encryption, are used. TLS standard allows keeping a private Internet connection and checking that the data

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exchanges by the fishing vessel and the server ashore are encrypted and unmodified.

The table "foos.Settings" is specular to the one included in the DB embedded in the e- logbook and allows to store 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 GSP data (stored in the "foos.PositionSet" table) and the start/end of the oceanographic measurements made by the sensors on the fishing gears (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 fishermen 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 specular 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 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).

3.3.3 AdriFOOS data centre web interface

A visualisation service (hereafter referred to as FOOSweb) is directly connected to the raw data DB. It consists of a web interface 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). 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.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. catch validation tool described in paragraph 4; Fig. 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. 8 and Fig. 12).

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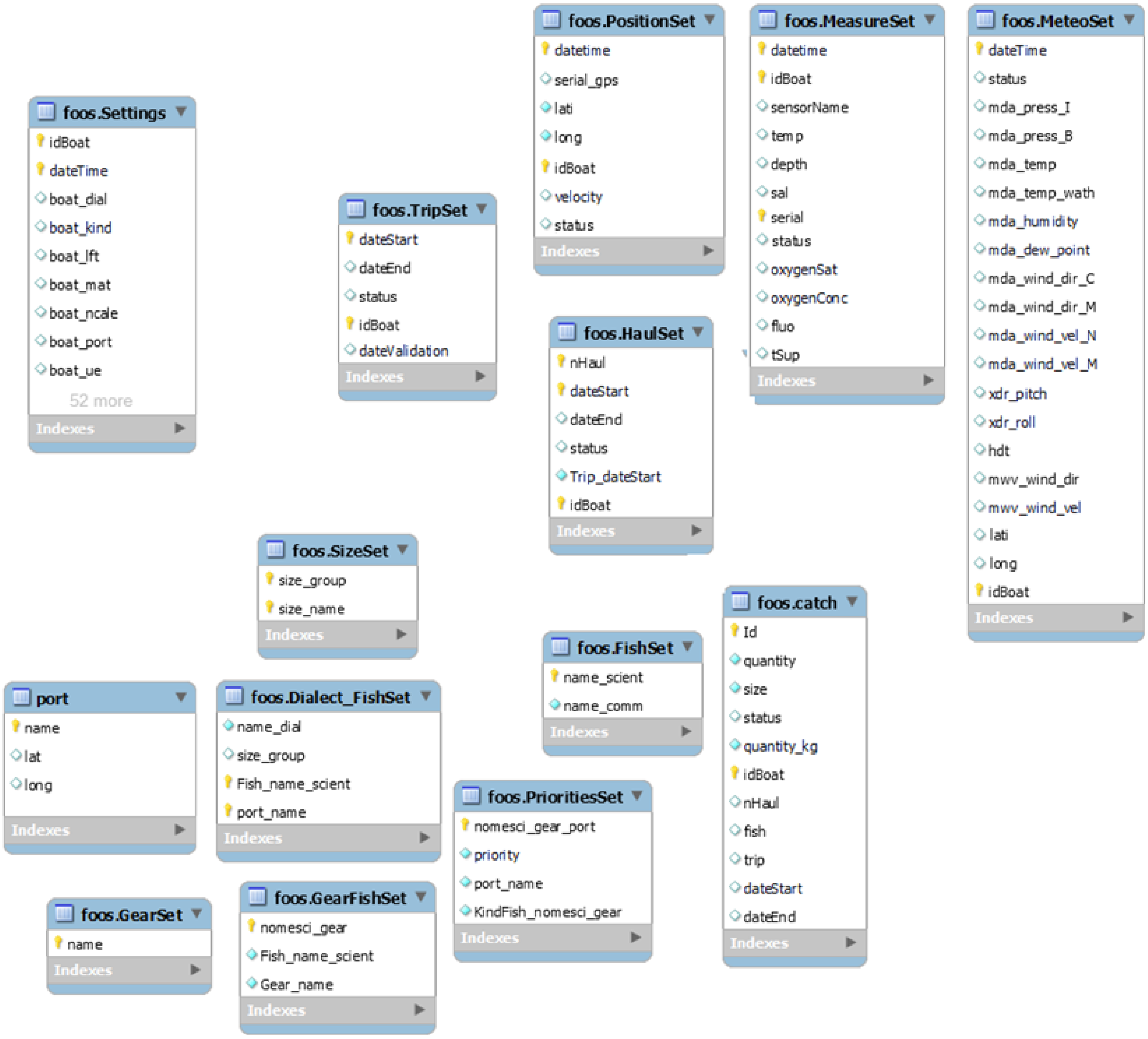

Figure 5. Schema of the relational database embedded in the AdriFOOS server (diagram made by means of MySQL Workbench 8.0).

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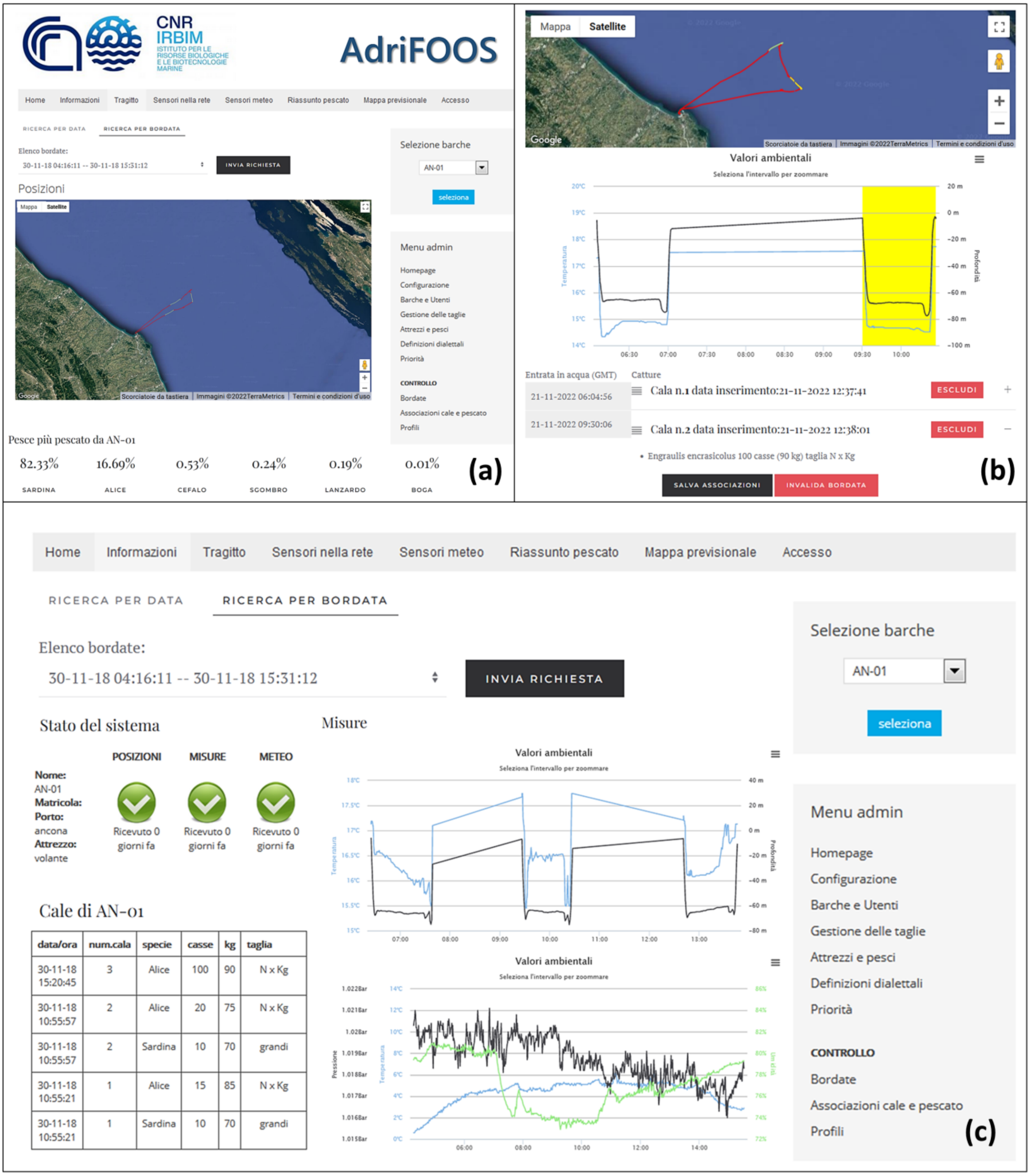

Figure 6. FOOSweb interface: (a) GPS route tracks (in red, with fishing hauls highlighted in green) generated by means of Google Maps APIs (Application Programming Interface; base layer source: Copyright TerraMetrics, LLC – www.terrametrics.com); (b) single haul GPS track highlighted in yellow and corresponding oceanographic and catch data; (c) control dashboard with summary of weather, oceanographic and fishing data.

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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. 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 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 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.

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;
- 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:

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

- 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.

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.

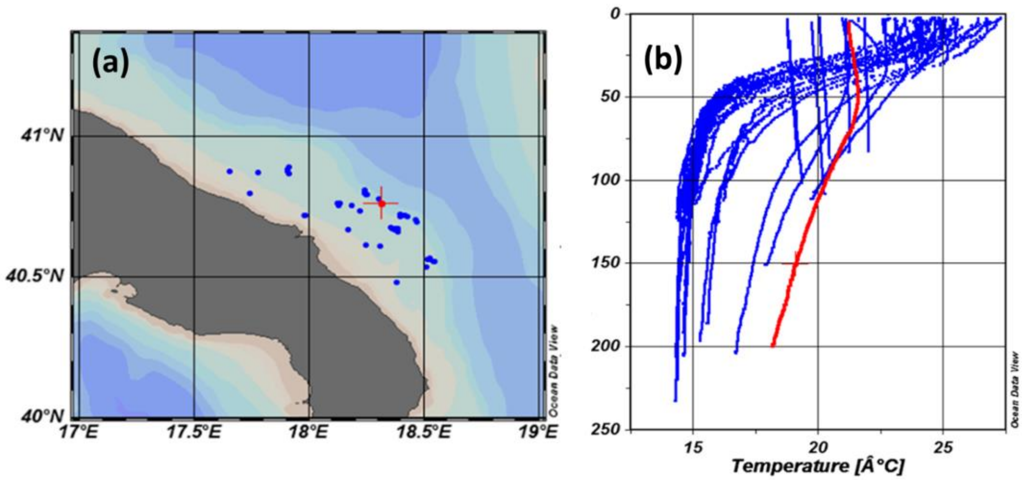

Figure 7. Map of georeferenced profiles obtained by AdriFOOS in the Southern Adriatic Sea for the day July 24, 2013, with one highlighted location (red cross; a) and respective depth (pressure)/temperature profiles plotted in group (b) by means of Ocean Data View (Schlitzer, 2021).

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 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 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. 6b) and based on his knowledge and experience, a fishery biologist can check the automatically defined

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fishing trip and hauls definitions provided by the DB (see 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 profiles and the header with metadata is shown in the Supplement. 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 and can be easily imported in generic database management systems (DBMS) or GIS software. The same dataset can also be exported in Network Common Data Form (NetCDF, 2022) standard format.

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 (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 1 summarises the statistics calculated for each vessel, while Fig. 8 describes the quantitative spatial distribution of these depth (pressure)/temperature profiles.

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. 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.

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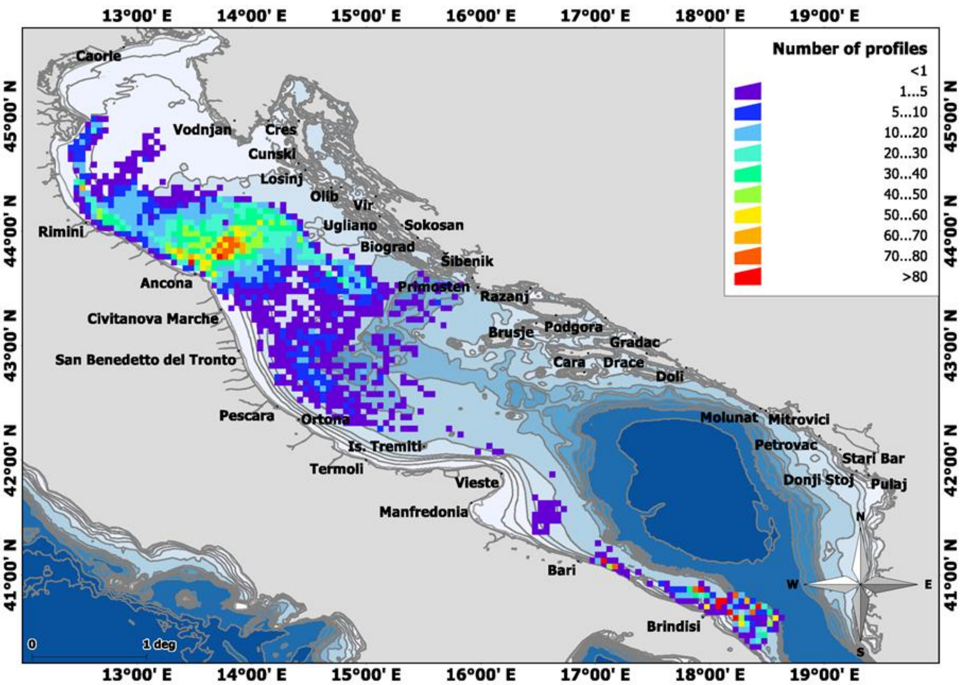

Figure 8. Quantitative spatial distribution of the AdriFOOS depth (pressure)/temperature profiles dataset 2012-2020 mapped by means of Manifold® GIS; bathymetry source: EMODnet, 2016.

Figure 9a 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. 9b). It is evident in Figure 9b 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).

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.

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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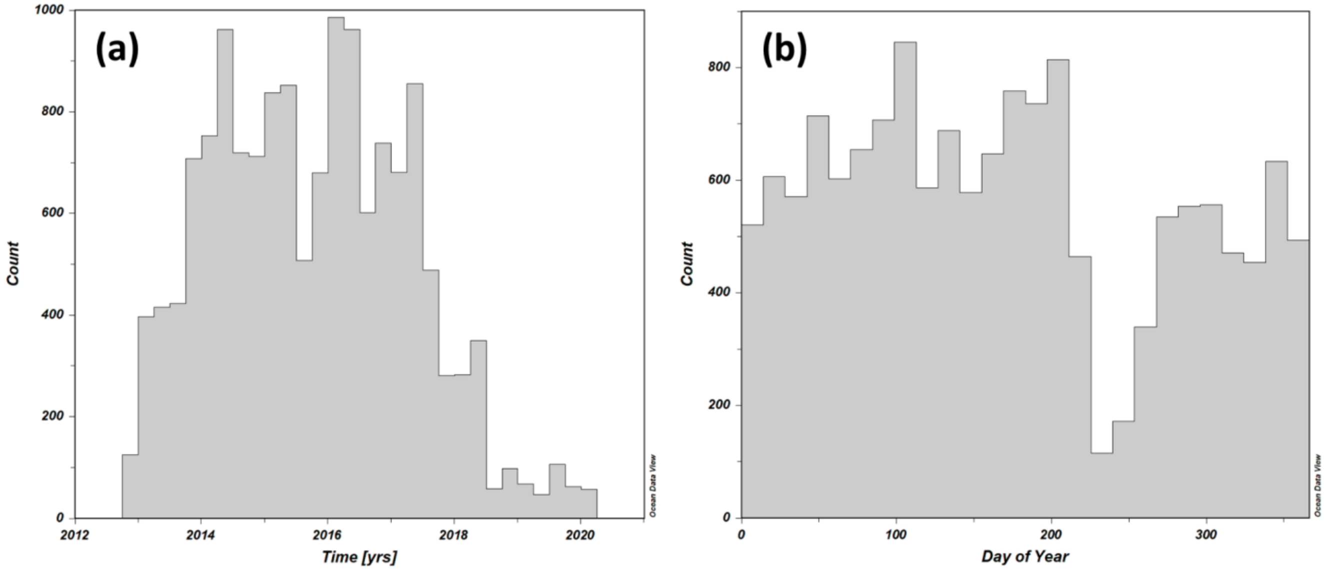

Figure 9. Count of depth (pressure)/temperature profiles over years (a) and day of the year (b); graphs generated by means of Ocean Data View (Schlitzer, 2021).

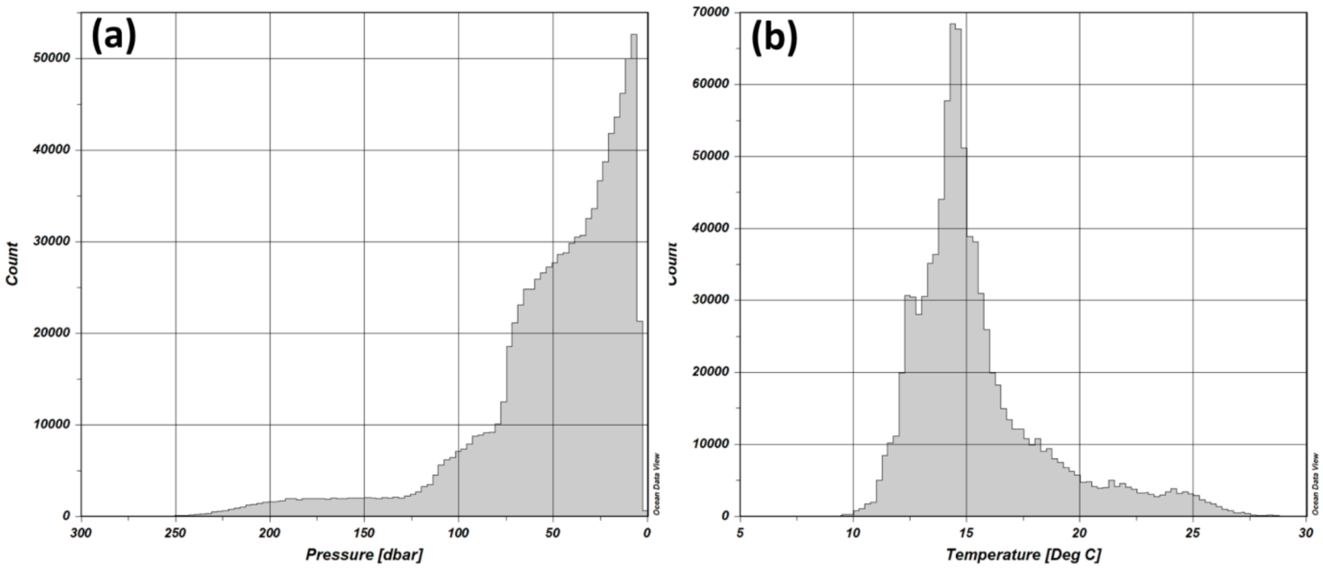

Figure 10. Data distribution over the reference period 2012-2020 in relation to pressure (depth) (a) and temperature (b); graphs generated by means of Ocean Data View (Schlitzer, 2021).

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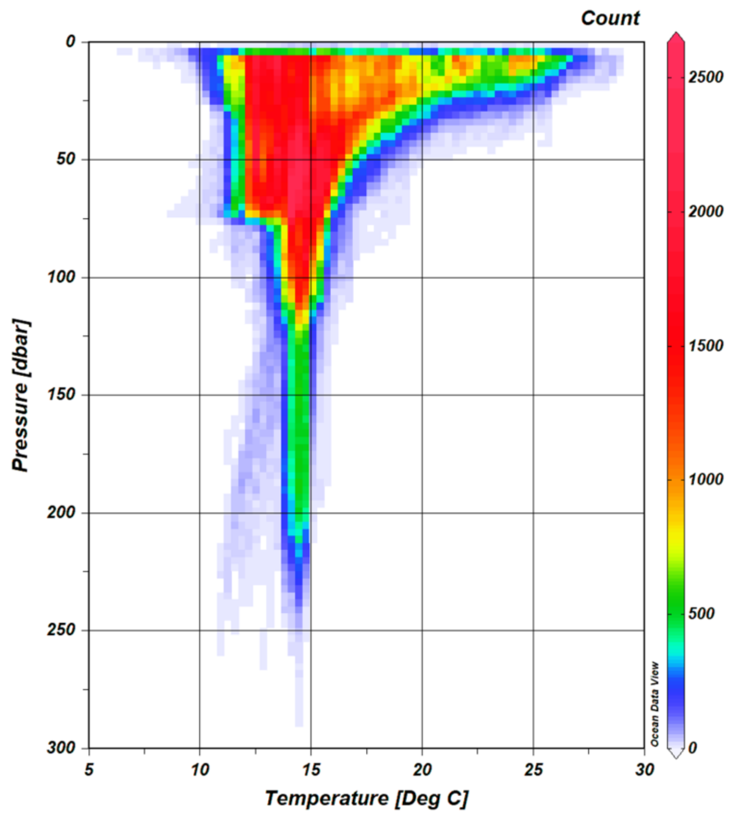

Figure 11. Distribution of pressure (depth)/temperature pair data collected by AdriFOOS from 2012 to 2020; plot generated by means of Ocean Data View (Schlitzer, 2021).

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 profiles 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.

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Figures 12 and 13, 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 12, 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 13 shows seasonal vertical temperature sea sections of the Central Adriatic Sea obtained by AdriFOOS in 2014 and was obtained using the ODV section window, upon defining and selecting a sea section of about 4.7x80 km, ranging from the coast to open sea (Fig. 13a, red rectangle). The profiles 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, Fig. 13b), March 2014-May 2014 (spring, Fig.e 13c), June 2014-August 2014 (summer, Fig. 13d) and September 2014-November 2014 (autumn, Fig. 13e). The temperature difference between the winter and spring seasons (December 2013-May 2014, Fig.e 13b,c) is likely due to the river runoff into the Northern Adriatic, which leads to a strong surface current generating a floating coastal water layer that flows toward South 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 13d, 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 13e.

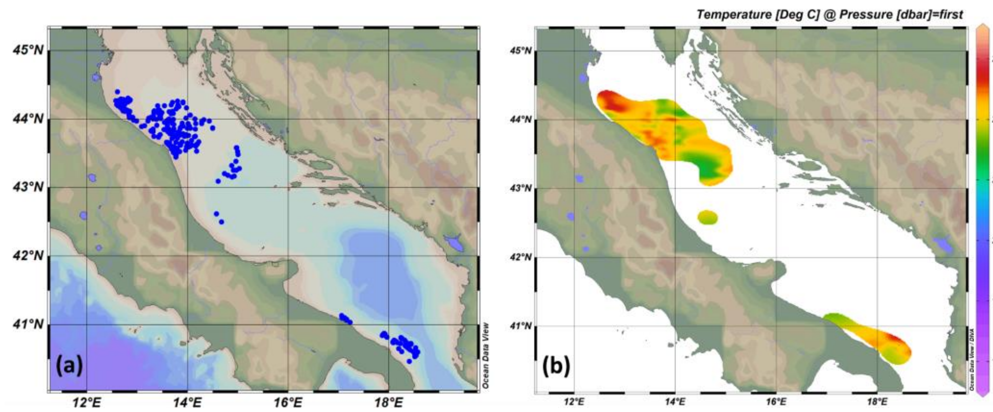

Figure 12. Map of georeferenced profiles in the Adriatic Sea (a) and derived Sea Surface Temperature (SST) horizontal map (b) obtained by AdriFOOS for July 2014 (up is referred to the north); maps generated using Ocean Data View (Schlitzer, 2021).

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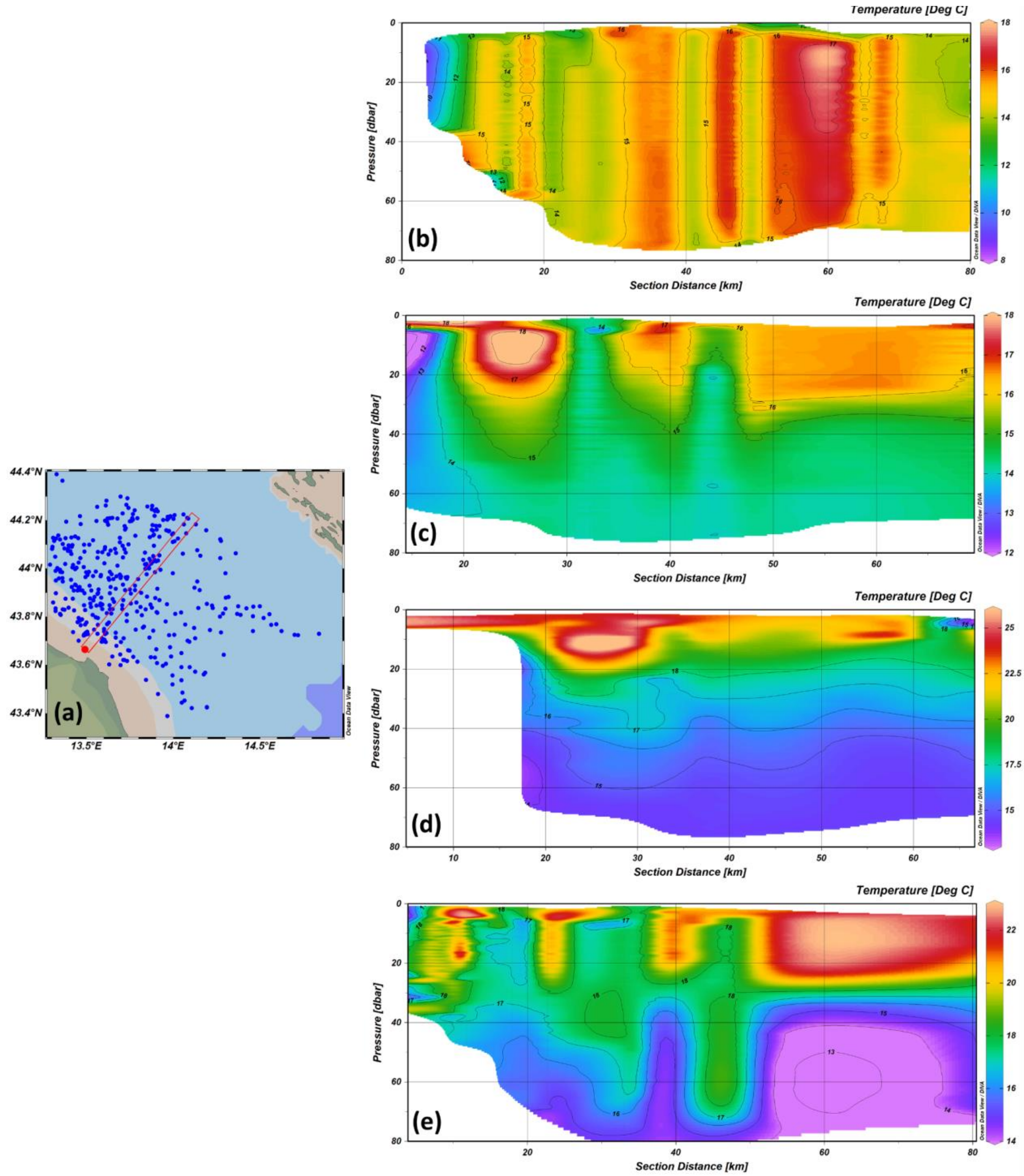

Figure 13: Map of georeferenced profiles with an evidenced sea section in the Central Adriatic Sea (red rectangle) obtained by AdriFOOS in 2014 (a) and derived seasonal temperature vertical section for winter (b), spring (c), summer (d) and autumn (e); map and plots generated by means of Ocean Data View (Schlitzer, 2021).

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Figure 14 shows a comparison between the AdriFOOS profiles 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. 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. Therefore, using the ODV template station, as an example, some adjacent AdriFOOS profiles (in red) and CMEMS stations (in blue) corresponding to the same day were selected in the three Adriatic sub basins (Fig. 14). Despite the formal difference in the considered variables, the plots for the Northern (Fig.14a), Central (Fig. 14b) and Southern (Fig. 14C) sub-basins showed a good correspondence between in-situ and modelled data.

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.

The AdriFOOS validated datasets, have indeed the potential to feed in NRT oceanographic models and, as previously highlighted 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).

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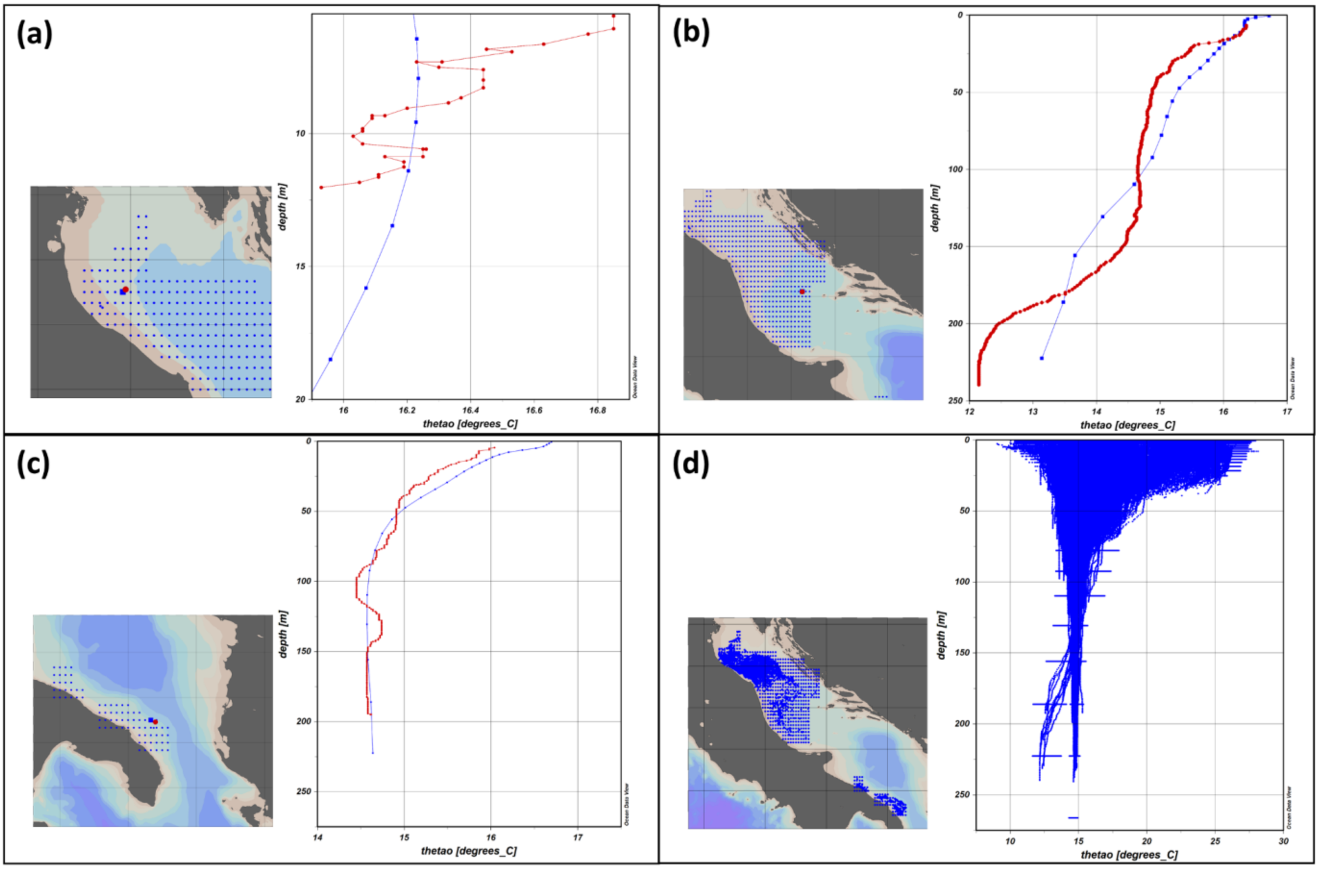

Figure 14: Maps and plots of georeferenced AdriFOOS profiles (red profile) compared to CMES dataset (blue profiles) in the Northern (a; May 2, 2014), Central (b, May 2, 2014) and Southern (c, April 28, 2014) Adriatic sea sub basins; scatterplot (d) of all the 2014 data.

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 Northern part of the Adriatic Sea, mainly fished by the monitored pelagic trawlers (Russo et al., 2015), and those in the Central part, fished by the monitored purse seiners (Lucchetti et al., 2018). Furthermore, 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

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and space, with subsequent influence on fishery sustainability and economy. The catch data 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.

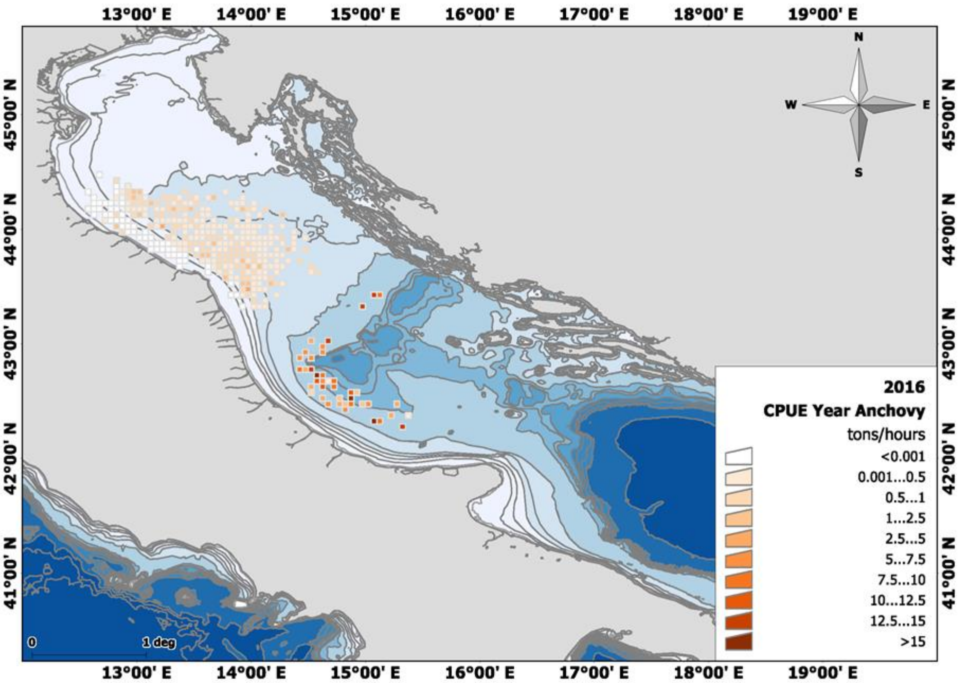

Figure 15. Map of the average Catch Per Unit Effort (tons/ hours) for anchovies in the Adriatic Sea obtained for the year 2016 (coloured cells refer to a 0.05 deg grid); mapped by means of Manifold® GIS; bathymetry source: EMODnet, 2016.

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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