PROTOCOL FOR SMALL-SCALE FISHERY DATA COLLECTION AND PROPOSAL FOR MANAGEMENT

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Table of contents

CHAPTER 1: INTRODUCTION 3
CHAPTER 2: The ARGOS "Protocol for small-scale fishery data collection and proposal for management" 3
  2.1. Background 3
  2.2. Goals of the Pilot Action 4
  2.3. The Pilot Action Target Groups 4
  2.4. Fishermen involvement and pilot area 4
  2.5. Pilot action Description and structure 5
    2.5.1. Protocol for data collection 5
      SYSTEM ARCHITECTURE 5
      ONBOARD INSTALLATIONS 9
      DATA COLLECTION AND ANALYSIS 10
    2.5.2. Replicability and proposal for management 16
CHAPTER 3: Final considerations and future perspectives 16
CHAPTER 4: References 17

CHAPTER 1: INTRODUCTION

The ARGOS Working Package 5 - “Sectorial know-how development and pilot project implementation”, intends to improve the sectorial capacities and know-how to change the behaviours of fishery and aquaculture operators towards shared environmental sustainability and responsible actions. To this goal, the WP foresees the implementation of pilot actions at the local and cross-border levels with the crucial involvement of fisheries and aquaculture operators. The collaboration aimed to (i) exchange experiences and knowledge, (ii) test protocols for a common approach to the management of shared fish stocks and (iii) ensure best practices for improving sustainable behaviours in fisheries and aquaculture sectors.

In particular, project Action 5.2 is dedicated to the improvement of fishers’ behaviours by the definition and testing of sustainable protocols for the management and protection of shared fish stocks.

Within this framework, the National Research Council (PP12) and the Vision Robotics Artificial Intelligence Department of the Polytechnic University of Marche (UNIVPM) defined and tested - with an interactive engagement of local fishermen from the Marche Region pilot area - a pilot action for the development of a transferable “Protocol for small-scale fishery data collection and proposal for management”.

CHAPTER 2: The ARGOS “Protocol for small-scale fishery data collection and proposal for management”

2.1. Background

"Small-scale coastal fishing" has been formally defined by the CE Regulation Nº 508/2014 as fishing carried out by fishing vessels of an overall length <12 metres and not using towed gear. SSFs (Small-Scale Fisheries) are thus typically “artisanal” and coastal, using small boats, and targeting multiple resource species using traditional gears.

Up to now, professional small-scale fishing remains untracked and largely unregulated, even though it accounts for 83% of all fishing activity in the Mediterranean Sea. Indeed, only some national initiatives have been implemented to obtain spatiotemporal data from tracking systems (not in Italy, nor the Mediterranean Sea). SSFs’ spatial fishing effort indicators nowadays available have been developed based on local approaches that include interviews, participatory mapping or modelling using generalised behaviour rules, such as distance from the shore and fishing depths.

Nevertheless, at the EU level current negotiations between the EU Commission, Parliament and Council are underway for tracking small-scale fishing vessels by all Member States (EC, P9 TA(2021)0076).

2.2. Goals of the Pilot Action

This pilot action is based on the need to produce standardised protocols in order to (i) securely gather and share data across the inshore fleet, (ii) identify fishing trips and (iii) infer fishing activities of SSFs. The final aim is to obtain a decisive objective framework for future and common policies regarding this fishery sector in the case study area (Marche Region, Figure 1).

2.3. The Pilot Action Target Groups

The pilot action targets fishers, marine planners and fisheries managers (e.g., referents of the small-scale fishery organizations - OP) as the main regional stakeholders.

2.4. Fishermen involvement and pilot area

The local fishing community was an active part of the pilot action as referents of the small-scale fishery organizations and the fishermen belonging to them have been involved in different phases of the activity itself, especially during the procedure of the GPSs installation onboard. Fishers belong to 2 different Marche OPs: Fano (*Consorzio Ittico Fanese*) and Ancona (*Associazione Produttori Piccola Pesca* - with Ancona and Numana harbours).

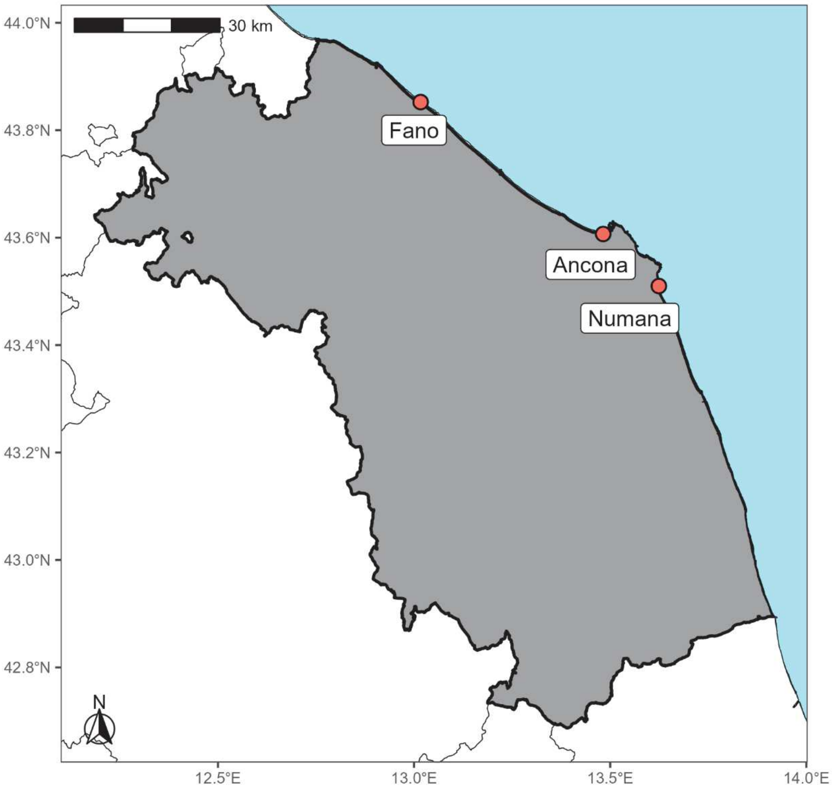


Figure 1. Map of the case study area (Marche region coast), with the three main involved harbours: Fano (Fano OP), Ancona and Numana (both belonging to the Ancona OP).

2.5. Pilot action Description and structure

2.5.1. Protocol for data collection

SYSTEM ARCHITECTURE

In this context, a low-cost architecture was drafted by Tassetti et al. (2022) to collect real-time positional data sent over LoRaWAN or 2G/3G/4G connections by small-scale vessels.

The architecture relies on Traccar, while the high-tech and cost-efficient Teltonika worldwide tracker (e.g., FMM640, FMC130, FMC230) is proposed as Fleet Management System (FMS) hardware.
Instead of just enforcing small vessels to use other cheaper (e.g., raspberry-based) AIS systems, the choice of this FMS was due to the need to easily share positions and enable monitoring, purchasing inexpensive but robust, well-documented, accessible, and license-free transmitters. This is in line with other ongoing projects, which chose similar FMSs.
Moreover, it is noteworthy that using HTTPS and LoRaWAN technology allows the implementation of an encrypted communication channel thanks to the TLS/SSL and LoRaWAN protocols, respectively. Both protocols, unlike AIS, enable authentication and encryption of sent data.

The first compact prototype was installed on a small fishing vessel in the Ancona harbour (Marche, Italy). It records its accurate location, speed, and other features; and sends this data to a dedicated back-end. A sensor attached to the hauler is used in tandem to record when and where it is activated, indicating that the setting/retrieving of the gear is occurring. This information can be assessed in near real-time using a secure-access web platform and is recorded allowing future machine-learning analysis and algorithm development in case of vessels that could not be equipped with the hauler sensor.

Employed services:
- Elastic Search/Kibana
- Amazon Lambda
- Node JS
- AWS Dynamo DB
- LoRaWAN links
- 2G/3G/4G links
- GPS
- HTTPS REST endpoint
- MQTTS broker
- MongoDB
- Traccar

In particular, the architecture has been adapted to collect and ingest data sent by under-12-meter inshore fishing vessels over two different interfaces. One interface is based on a secure REST API over HTTPS, while another is based on a secure Message Queuing Telemetry Transport Secure (MQTTS) broker. The first interface is dedicated to managing data from 2G/3G/4G devices, while MQTTS is suitable for LoRaWAN broadcasts.

Long Range (LoRa) is an expanded spectrum frequency modulation technique derived from Chirp Spread Spectrum (CSS) technology and is used to implement many Internet of Things (IoT) device networks. The LoRaWAN specification is a Low-Power Wide-Area (LPWA) networking protocol designed to connect IoT devices to the Internet, meeting several requirements such as bi-directional communication, end-to-end security, mobility, and localization services. The communication between the LoRa Gateway and the network server is achieved using the MQTT protocol and the MQTT broker as servers to collect messages and clients that can read and write to the broker. Different services are used in the LoraWAN infrastructure to manage the requests of several IoT devices. The LoRa Geo Server is used to geolocate LoRaWAN devices, while the Lora App Server provides a web interface where clients, applications, and devices can be managed (Figure 4). In addition, the LoRa App Server is responsible for managing to join requests and managing/encrypting application payloads and allows integration with external services thanks to gRPC and RESTful API. Messages collected by the LoRa App server are sent to Amazon Web Services, which in turn forwards the requests to the Amazon Lambda service.

The developed architecture also accepts data from asset trackers such as Teltonika devices (e.g., FMM640, FMC130, FMC230) that rely on a mobile network (Figure 2). These trackers send data to the Traccar server through TCP or UDP protocols over secure channels (using TLS/SSL). An interface on a Traccar server is also developed to receive data over a dedicated HTTPS REST interface, which extends the methods available to ingest data. The Traccar server is hosted on the Amazon Elastic Compute Cloud (Amazon EC2) and is managed through Docker. The Traccar system includes a web application - based on the Sencha ExtJS framework and OpenLayers - for managing users, devices, and the map view.

The set of measured variables is augmented with a proximity inductive sensor (i.e., Omron E2B-M12KN08-WP-B1) that is attached to the hauler (Figure 3).

The processing of this signal enables the detection of fishing activity. A dedicated microcontroller filters the signal of the inductive sensor avoiding anomalous behaviours (e.g., start/stop of hauler) and bouncing (input is debounced). The microcontroller drives a hard line that is acquired by the tracker and then ingested through the above-described architecture. When the hauler is active and rotation is detected by the microcontroller, the output signal is kept high for at least 1 min to ensure that the state is properly sent.

Data are stored in the Amazon DynamoDB database. By using a custom lambda function and basing on events from Traccar, sets of consecutive vessel broadcasts are partitioned into individual fishing trips, which could be retrieved through the dedicated REST API.

We rely, where possible, on serverless services to ensure proper scaling when the number of monitor vessels will increase.

Elastic Search and Kibana services are used to retrieve fishing trips efficiently while also providing a graphical dashboard for the end-users that can have a quick overview of performed operations over space and time. Finally, a MongoDB NoSQL database with Node.js and Angular provides the web application to show fishing trips.

Recorded and real-time vessels' movements could be observed on and downloaded from the Traccar Demo server.

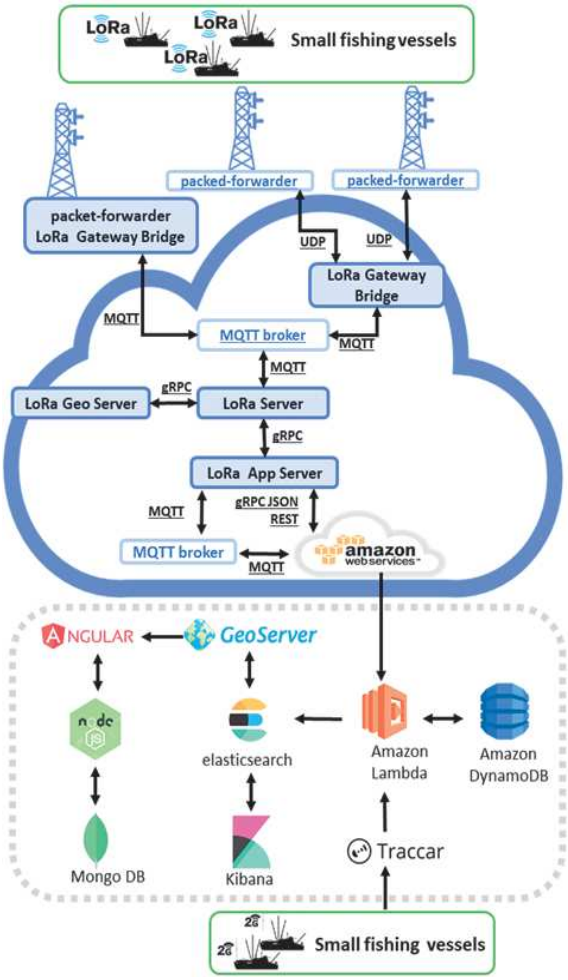


Figure 2. Architecture that manages real-time data sent over LoRaWAN and 2G/3G/4G connections. A GPS tracker collects SSF positional data. The architecture was designed in order to minimise costs and effort by using open-source software and off-the-shelf technologies.

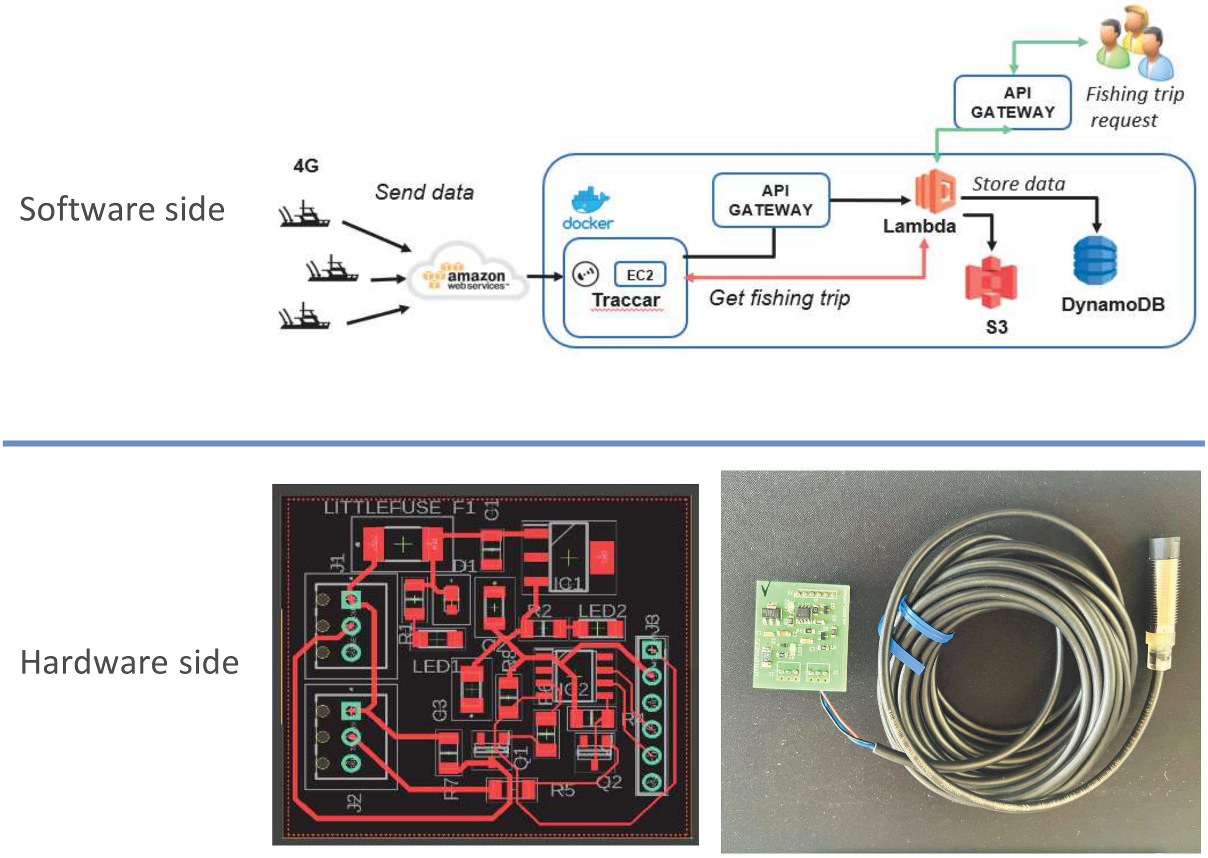


Figure 3. Software and hardware sides of the hall-speed effect sensor prototype.

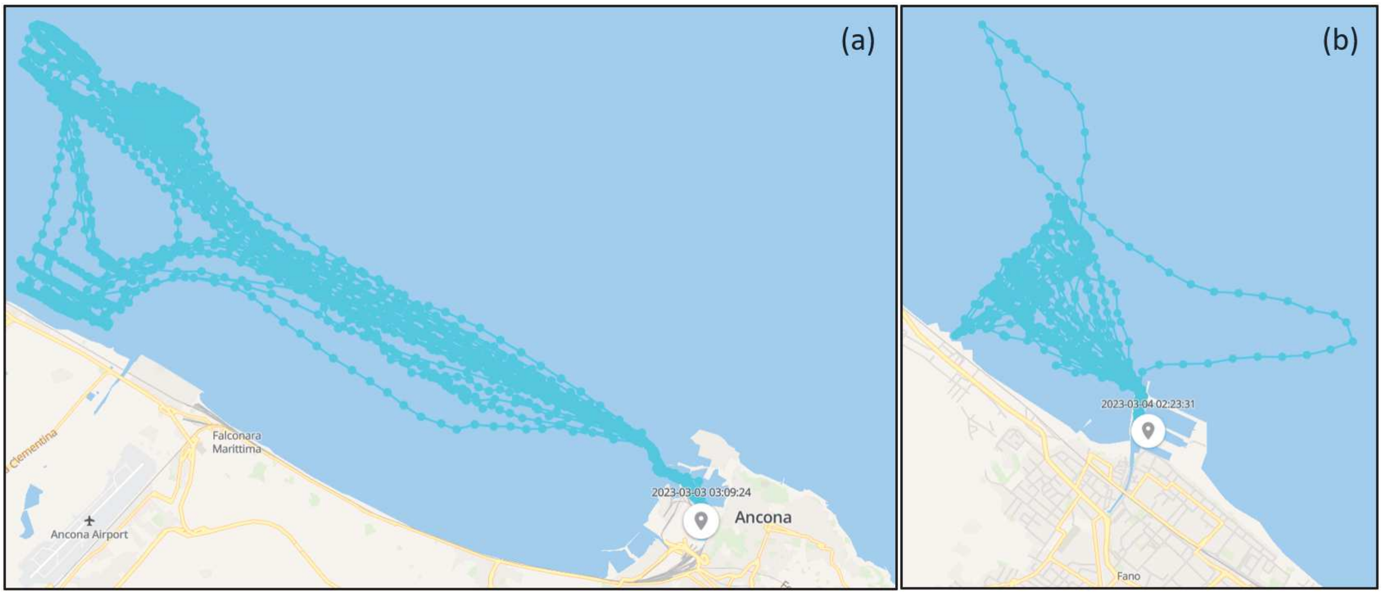


Figure 4. Web interface of the Traccar Demo server—based on the Sencha ExtJS framework—that shows recorded positions of two small fishing vessels in the Ancona (a) and Fano (b) harbours.

ONBOARD INSTALLATIONS

The first low-cost prototype was implemented in 2020 (Figure 5). Currently, the aforementioned tracking system is installed on 20 artisanal fishing vessels (below 15 m in length), operating in the ports of Ancona and Fano (Marche, Italy). The vessels are licensed to use passive gears (gillnets, trammel nets, longlines, pots and traps) and adopt them according to the target species, the market demand, and/or the fishing season. The combination of the above factors inevitably influences the spatiotemporal behaviour of the vessels. The use of passive gears includes two distinct operations: the setting and the hauling of the gears, after a certain time period (i.e., soaking time) and based on the above-mentioned factors and sea weather conditions. In addition, specific regulations related to the use of fishing gears are in force, imposing technical/numerical restrictions and regulating the fishing effort exerted at sea (Tassetti et al., 2022).

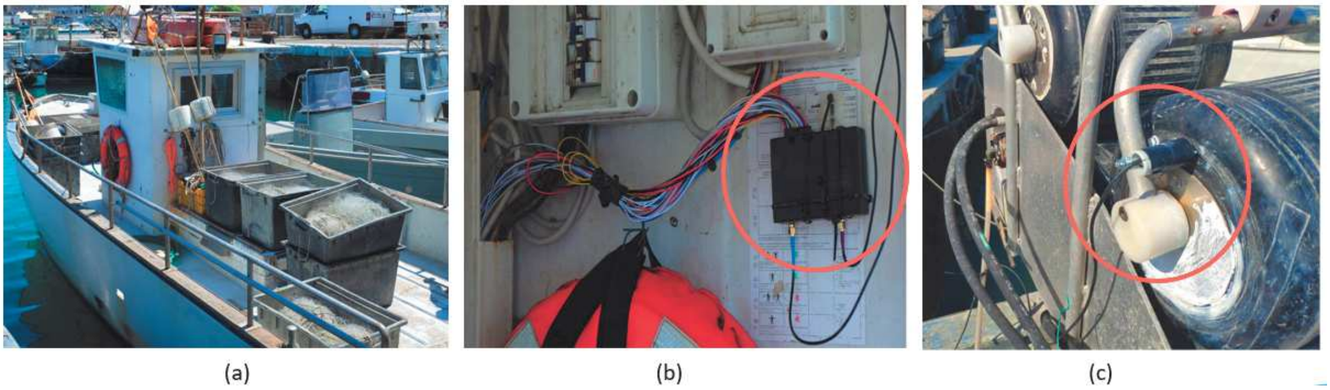

(a) (b) (c)

Figure 5. The first small-scale fishing vessel (a) on board of which the Teltonika FMM640 is installed (b) and the hall-effect speed sensor attached to hauler (c).

The installation of the GPS device and the hall-effect speed sensor attached to the hauler changes according to the vessel's features.

For instance, concerning the sensor, its installation depends upon the type of hauler on which it should be installed, representing a worthy time-consuming work for the operator. Furthermore, sometimes even the same boat was equipped with different haulers, whose use is related to the employed gear (Figure 6).

Moreover, the connection of the GPS to the electrical system (e.g., to the battery switch, directly to the engine, etc.) could affect values of certain parameters (e.g., ignition) and this should be taken into consideration at the time of analysing the fishing trips.

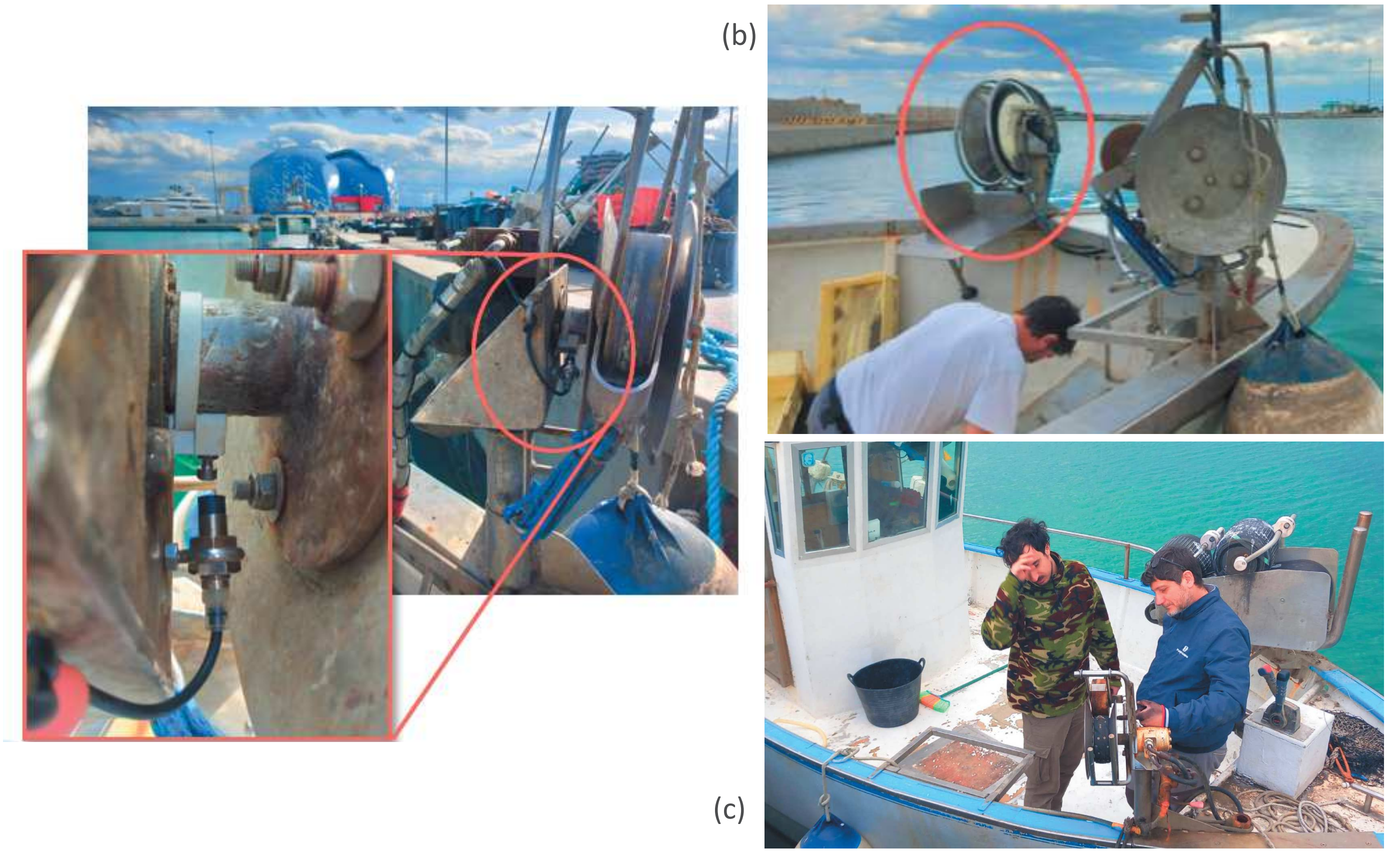


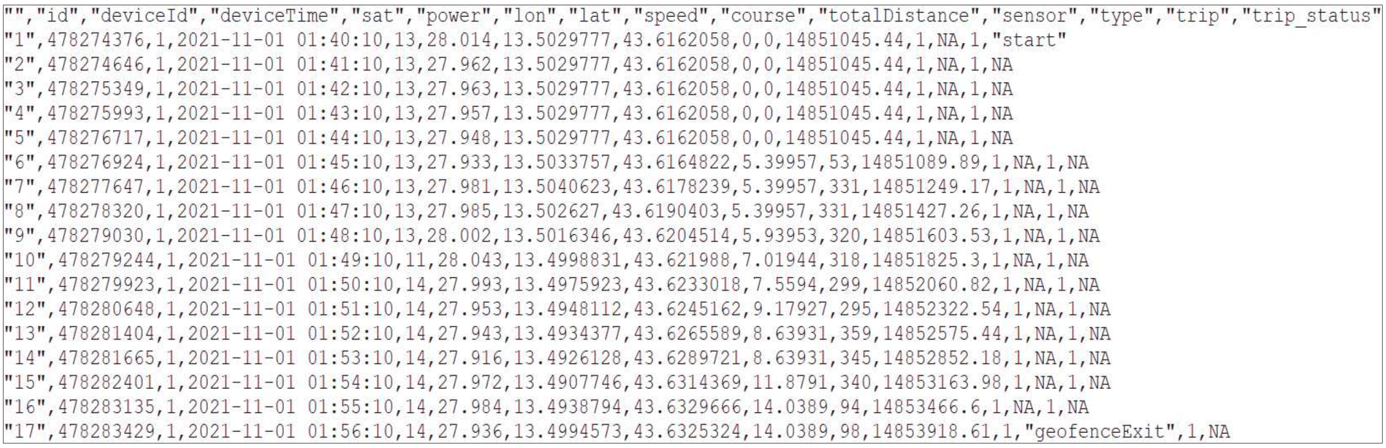
Figure 6. A sensor installed on a hauler used mainly for pots and traps (a); different types of hauler on the same boat: the one on the left is used mainly for nets, while the other is employed for pots and traps (b); technicians onboard during an installation (c).

DATA COLLECTION AND ANALYSIS

For vessels with reasonable power supply, the unit is fitted directly to the vessel ignition system in order to avoid gaps in transmission.

The high acquisition ping rate of ~1 min makes interpolation not required, as opposed to what happens for instance with VMS data.

Data for each vessel have been downloaded from the Traccar Demo Server as CSV files and the structure has been modified as shown in the example dataset available at the following GitHub repository: https://github.com/irbimMAPS/ssf/blob/main/data/gps_data.csv (Figure 7).



```
"","id","deviceId","deviceTime","sat","power","lon","lat","speed","course","totalDistance","sensor","type","trip","trip_status"
"1",478274376,1,2021-11-01 01:40:10,13,28.014,13.5029777,43.6162058,0,0,14851045.44,1,NA,1,"start"
"2",478274646,1,2021-11-01 01:41:10,13,27.962,13.5029777,43.6162058,0,0,14851045.44,1,NA,1,NA
"3",478275349,1,2021-11-01 01:42:10,13,27.963,13.5029777,43.6162058,0,0,14851045.44,1,NA,1,NA
"4",478275993,1,2021-11-01 01:43:10,13,27.957,13.5029777,43.6162058,0,0,14851045.44,1,NA,1,NA
"5",478276717,1,2021-11-01 01:44:10,13,27.948,13.5029777,43.6162058,0,0,14851045.44,1,NA,1,NA
"6",478276924,1,2021-11-01 01:45:10,13,27.933,13.5033757,43.6164822,5.39957,53,14851089.89,1,NA,1,NA
"7",478277647,1,2021-11-01 01:46:10,13,27.981,13.5040623,43.6178239,5.39957,331,14851249.17,1,NA,1,NA
"8",478278320,1,2021-11-01 01:47:10,13,27.985,13.502627,43.6190403,5.39957,331,14851427.26,1,NA,1,NA
"9",478279030,1,2021-11-01 01:48:10,13,28.002,13.5016346,43.6204514,5.93953,320,14851603.53,1,NA,1,NA
"10",478279244,1,2021-11-01 01:49:10,11,28.043,13.4998831,43.621988,7.01944,318,14851825.3,1,NA,1,NA
"11",478279923,1,2021-11-01 01:50:10,14,27.993,13.4975923,43.6233018,7.5594,299,14852060.82,1,NA,1,NA
"12",478280648,1,2021-11-01 01:51:10,14,27.953,13.4948112,43.6245162,9.17927,295,14852322.54,1,NA,1,NA
"13",478281404,1,2021-11-01 01:52:10,14,27.943,13.4934377,43.6265589,8.63931,359,14852575.44,1,NA,1,NA
"14",478281665,1,2021-11-01 01:53:10,14,27.916,13.4926128,43.6289721,8.63931,345,14852852.18,1,NA,1,NA
"15",478282401,1,2021-11-01 01:54:10,14,27.972,13.4907746,43.6314369,11.8791,340,14853163.98,1,NA,1,NA
"16",478283135,1,2021-11-01 01:55:10,14,27.984,13.4938794,43.6329666,14.0389,94,14853466.6,1,NA,1,NA
"17",478283429,1,2021-11-01 01:56:10,14,27.936,13.4994573,43.6325324,14.0389,98,14853918.61,1,"geofenceExit",1,NA
```

Figure 7. GPS data structure

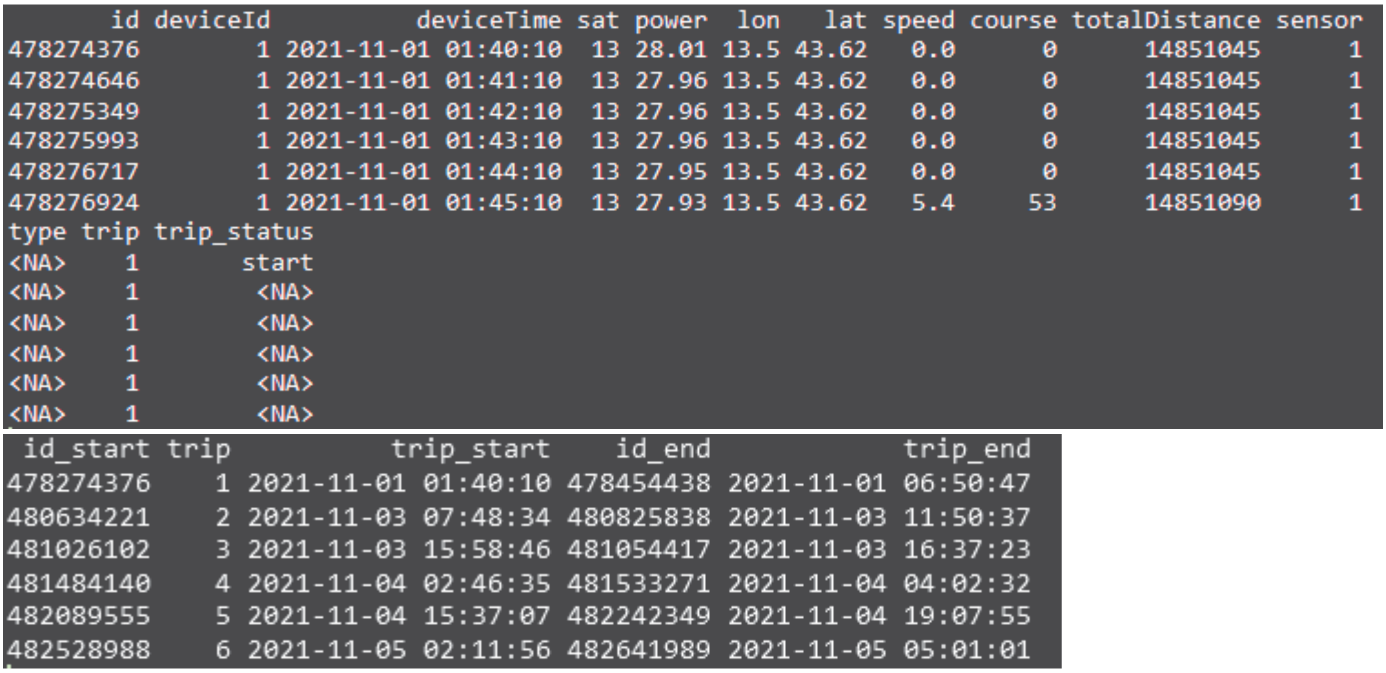
System parameters (such as *sat* and *power*) and other movement variables (*speed, timestamp*) can be used to calculate fishing trips (Figure 8).

The sensor attached to hauler can be used to estimate vessel behaviour (navigation, fishing activity) through the IO device parameter identified as *sensor*.

The geofence parameter (*type)* registers when the vessel leaves the harbour and when it enters.

The algorithm used to define the fishing trips is available at the following GitHub repository: https://github.com/irbimMAPS/ssf/tree/main/R.

The rationale is to detect trips' start and end points, by using the over-mentioned zero *sat* and zero *power* - that occurs during device initialization/booting - pings and setting a minimum interval between a shutdown and the subsequent startup of the system. When the boat is stopped for more than a certain amount of time (here 45 min, but it will vary with the fishery), a new trip would start (Figure 9).



```
        id deviceId          deviceTime sat power  lon   lat speed course totalDistance sensor
478274376        1 2021-11-01 01:40:10  13 28.01 13.5 43.62   0.0      0      14851045      1
478274646        1 2021-11-01 01:41:10  13 27.96 13.5 43.62   0.0      0      14851045      1
478275349        1 2021-11-01 01:42:10  13 27.96 13.5 43.62   0.0      0      14851045      1
478275993        1 2021-11-01 01:43:10  13 27.96 13.5 43.62   0.0      0      14851045      1
478276717        1 2021-11-01 01:44:10  13 27.95 13.5 43.62   0.0      0      14851045      1
478276924        1 2021-11-01 01:45:10  13 27.93 13.5 43.62   5.4     53      14851090      1
type trip trip_status
<NA>    1       start
<NA>    1        <NA>
<NA>    1        <NA>
<NA>    1        <NA>
<NA>    1        <NA>
<NA>    1        <NA>
```

```
 id_start trip          trip_start    id_end            trip_end
478274376    1 2021-11-01 01:40:10 478454438 2021-11-01 06:50:47
480634221    2 2021-11-03 07:48:34 480825838 2021-11-03 11:50:37
481026102    3 2021-11-03 15:58:46 481054417 2021-11-03 16:37:23
481484140    4 2021-11-04 02:46:35 481533271 2021-11-04 04:02:32
482089555    5 2021-11-04 15:37:07 482242349 2021-11-04 19:07:55
482528988    6 2021-11-05 02:11:56 482641989 2021-11-05 05:01:01
```

Figure 8.Some of the outputs obtained through the analysis of the dataset with the aforementioned algorithm.

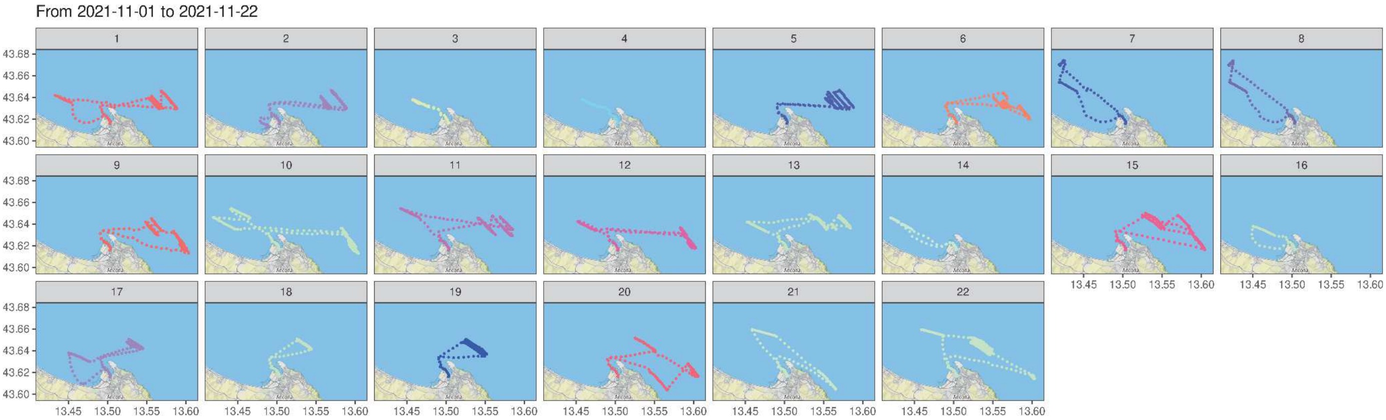


Figure 9. Using the device's system parameters (sat, power) and other movement variables (speed, timestamp) to identify the sequence of positions belonging to the same fishing trips.

Using the signal of the sensor (*sensor*) it is possible to recognise and infer vessel-specific fishing events (set/haul of the fishing net, Figure 10).

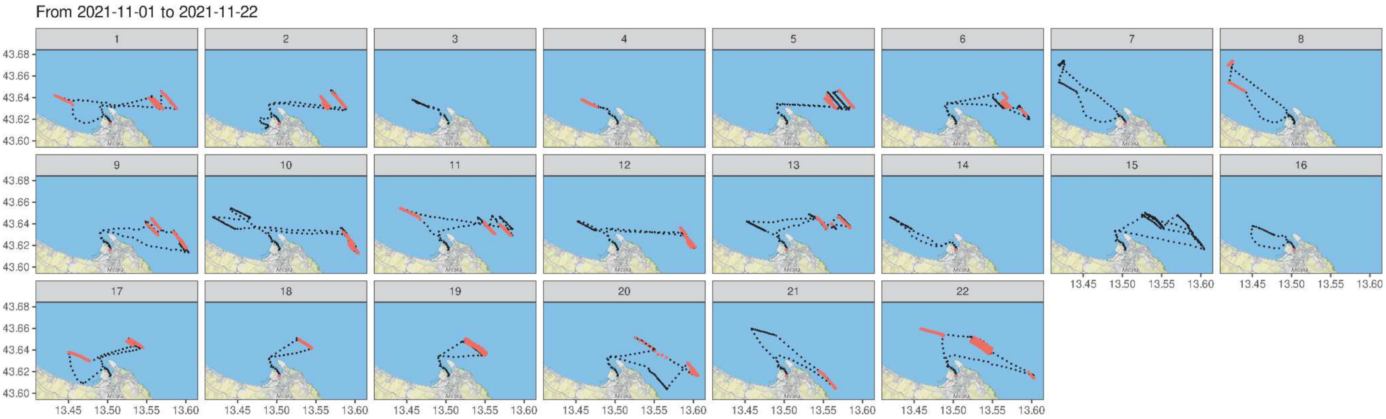
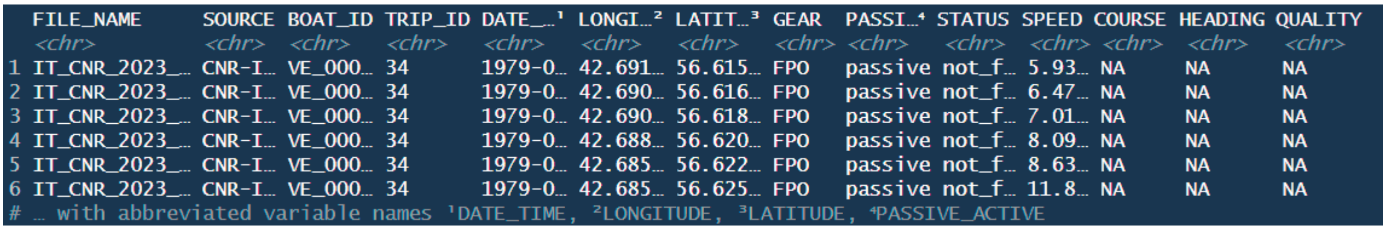


Figure 10. Analysed trips predicting when hauling activity occurred (red pings)

An initial attempt to elaborate the gathered GPS data has been carried out through the aggregation of the fishing events recorded from 14 vessels during January and February 2023 (Figure 12a) on the occasion of the ICES Workshop on Small Scale Fisheries and Geo-Spatial Data 2 (WKSSFGEO2, https://doi.org/10.17895/ices.pub.22789475.v1), held in Faro (Portugal) between the 13th and the 16th of March 2023. This workshop aimed to build up from WKSSFGEO on the development of methods to identify fishing activity in small-scale fisheries, including passive gears and provide an overview of the extent of small-scale fisheries in EU waters using FDI database. The labelled dataset, validated through an expert opinion approach (face-to-face interviews with fishermen), has been shared within the working group (Figure 12b, Figure 13).

Furthermore, during the event, a template for the data field structure has been developed to achieve a common and standardised output (Figure 11).



```
  FILE_NAME     SOURCE BOAT_ID TRIP_ID DATE_…¹ LONGI…² LATIT…³ GEAR  PASSI…⁴ STATUS SPEED COURSE HEADING QUALITY
  <chr>         <chr>  <chr>   <chr>   <chr>   <chr>   <chr>   <chr> <chr>   <chr>  <chr> <chr>  <chr>   <chr>
1 IT_CNR_2023_… CNR-I… VE_000… 34      1979-0… 42.691… 56.615… FPO   passive not_f… 5.93… NA     NA      NA
2 IT_CNR_2023_… CNR-I… VE_000… 34      1979-0… 42.690… 56.616… FPO   passive not_f… 6.47… NA     NA      NA
3 IT_CNR_2023_… CNR-I… VE_000… 34      1979-0… 42.690… 56.618… FPO   passive not_f… 7.01… NA     NA      NA
4 IT_CNR_2023_… CNR-I… VE_000… 34      1979-0… 42.688… 56.620… FPO   passive not_f… 8.09… NA     NA      NA
5 IT_CNR_2023_… CNR-I… VE_000… 34      1979-0… 42.685… 56.622… FPO   passive not_f… 8.63… NA     NA      NA
6 IT_CNR_2023_… CNR-I… VE_000… 34      1979-0… 42.685… 56.625… FPO   passive not_f… 11.8… NA     NA      NA
# … with abbreviated variable names ¹DATE_TIME, ²LONGITUDE, ³LATITUDE, ⁴PASSIVE_ACTIVE
```

Figure 11. The labelled data subset arranged following the data field structure template developed during the WKSSFGEO2.

Moreover, an R-script was produced during the workshop, to open the datasets and run a series of checks and plots prior to inserting them within the created case studies database. The output for the Italian case study labelled dataset can be observed in Figure 13.

All the cited material is shared and available on the WKSSFGEO2 GitHub repository (https://github.com/ices-eg/WKSSFGEO).

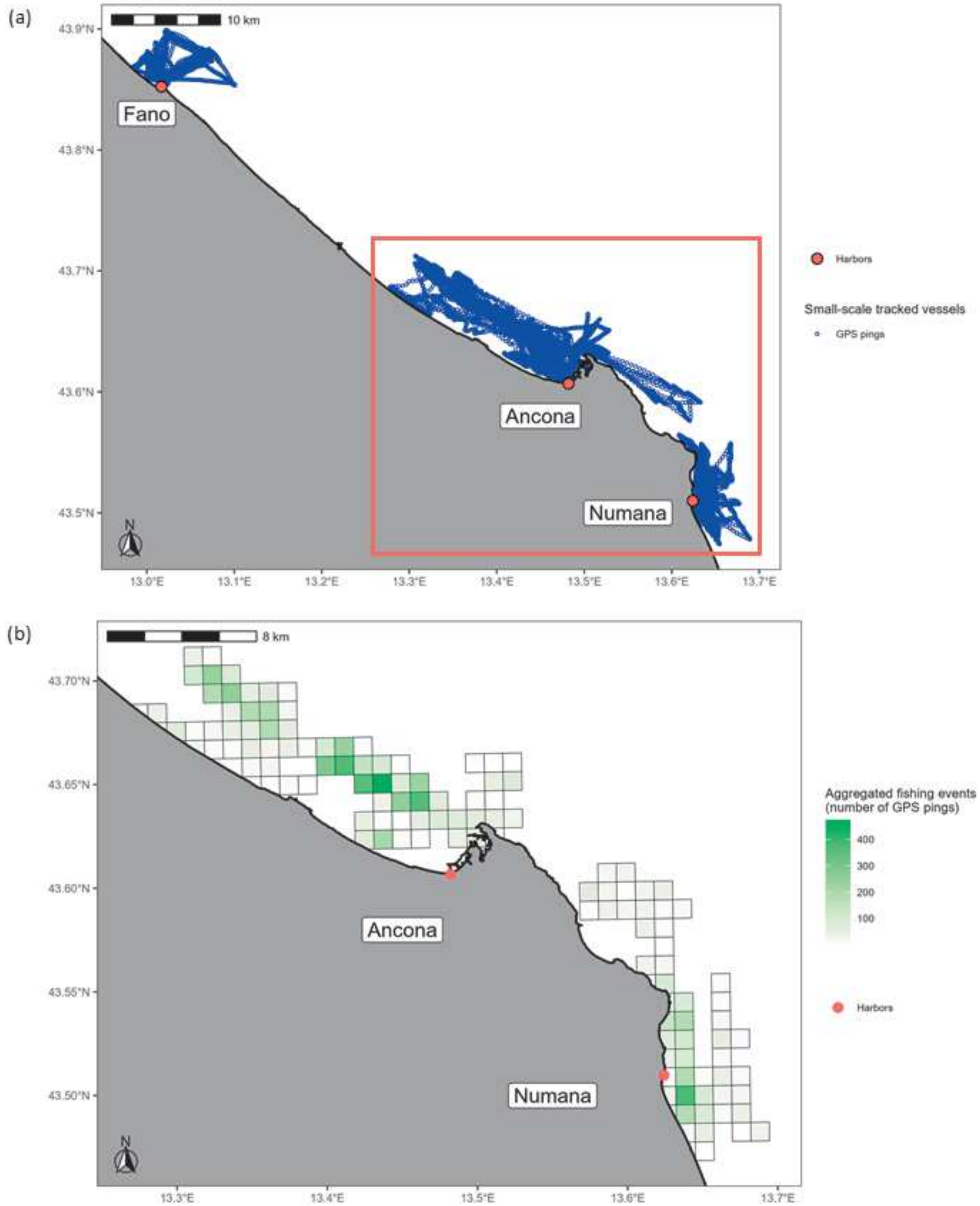
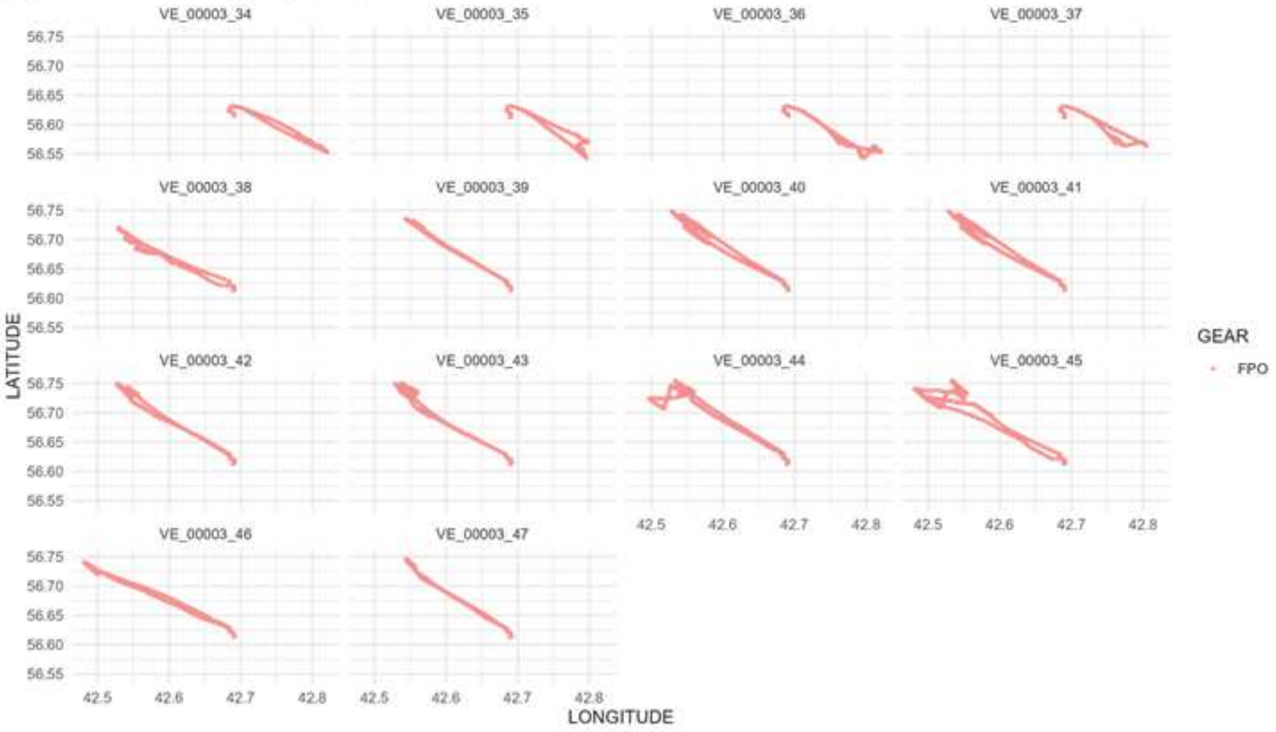


Figure 12. Recorded positions during January and February 2023 from the 14 vessels analysed on the occasion of the ICES WKSSFGEO2 (a). The red square highlights the maritime compartment of Ancona, for which the aggregation of the fishing events has been carried out (b).

(a) Italian case study geographic plots



(b) Italian case study speed plots

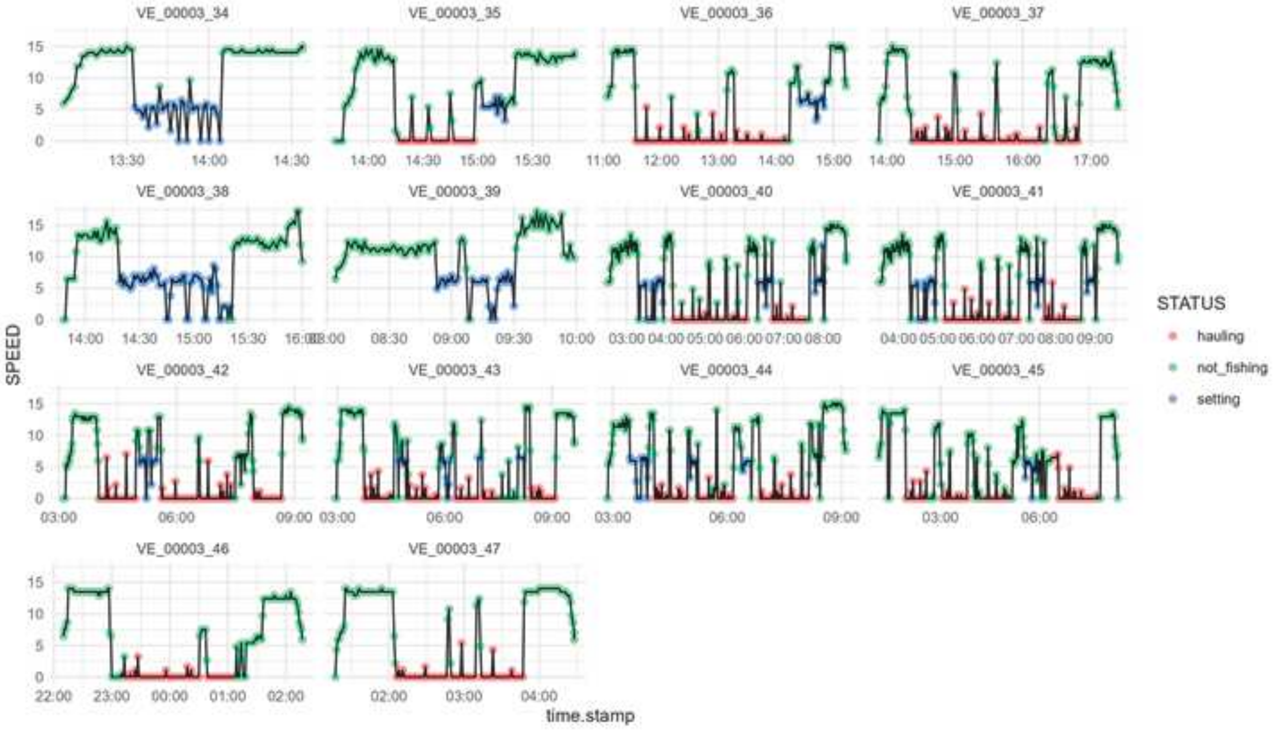


Figure 13. Preliminary graphs and plots obtained through the R-script developed during the WKSSFGEO2. It was tested on a validated data subset of 14 trips from a vessel whose data have been anonymised in space and time.

2.5.2. Replicability and proposal for management

Nowadays, the necessity of producing standardised protocols to securely gather and share data across the inshore fleet, identify fishing trips and infer fishing activities in SSF is no longer negligible. Indeed, standardisation of collected data is necessary in order to achieve comparable results between different case studies.

The availability and the analysis of SSF positional data will help:

- improve fishing effort estimation;
- better assess impacts on ecosystems;
- enhance seafood products traceability;
- assess compliance monitoring in MPAs;
- outline spatial conflicts and competitive exploitation of marine resources (e.g., identifying the main fishing grounds), especially as happen with other fishing fleets (LSFs, Large Scale Fisheries).

SSF vessels are numerically dominant in most EU states and often target high-value low-volume species, using methods which are generally more sustainable if compared with trawling, for instance. Therefore, small-scale fishers should be protected by laws taking appropriate management measures as the small-scale fishing sector plays an important role both economically and culturally. Nevertheless, whenever possible, the information provided by logbooks about catches and targeting the gear type should be integrated to accomplish a more complete overview of the exerted fishing effort at sea.

CHAPTER 3: Final considerations and future perspectives

In this report we present results obtained within the project action 5.2 framework, through the development of a low-cost architecture to collect real-time positioning data sent over LoRaWAN or 2G/3G/4G connections by small-scale vessels. The use of HTTPs and LoRaWAN technology allows to implement an encrypted communication channel thanks to TLS/SSL and LoRaWAN protocols, respectively.

We have monitored the movements of a sample of about 20 boats, trying to analyze the different types of gear used (e.g., trammel nets, longlines, gillnets, pots and traps).

The small unit has proved to:

- be reliable and inexpensive to use (as it has a low-power requirement, operating on 12-24v DC) and easy/quick to fit (as it can be programmed remotely);
- transmit vessel locations securely using protocols endowed with security mechanism (MQTTS in the case of the LoRaWAN-based solution, and HTTPS in the case of the 2G/3G/4G-based solution);

- be coupled with a serverless and cost-effective architecture to ingest positioning data and identify and store individual fishing trips.

The use of additional sensors, such as the proximity inductive sensor attached to the hauler implemented by Tassetti et al. (2022), could help recognise and infer fishing events during a fishing trip. Features related to the movement of the hauler (e.g., rotation frequency) could support the identification of different employed gears. It is noteworthy that, in the SSFs, during the same trip, different gears could be used.
The coupled use of such low-cost technologies and machine-learning automated analyses opens up the potential for more integrated platforms to inform coastal resource and fisheries management, support the design and development of new policies, and understand impacts on marine ecosystems.

In the near future, the team is going to:

- expand the study area and the time range of the data collection (additional 24 vessels are foreseen to be equipped within the National Project PO FEAMP 2014/2020, Mis. 1.39);
- develop/test machine learning and deep learning models to predict when and how (which gear) fishing activity occurs when no sensors can be attached to the hauler;
- attempt to estimate fishing effort exerted along the case study area (Marche region coast);
- develop a solar-powered version of the tracking device and, if needed, a waterproof protective case for boats with little or no power;
- install other electronic monitoring systems onboard for additional information collection (e.g., cameras for counting and identifying by-catch and target species) as a promising alternative to expensive, limited and time-consuming work of observers.

CHAPTER 4: References

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