WORKSHOP ON SMALL SCALE FISHERIES AND GEO-SPATIAL DATA 2 (WKSSFGEO2)

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i Executive summary

The aim of the Workshop on Small Scale Fisheries and Geo-Spatial Data 2 (WKSSFGEO2) was to continue the work developed during WKSSFGEO, namely on analysis of the high-resolution geo-spatial data in small-scale fisheries (SSF), as well as large-scale fisheries (LSF) taking into consideration low duration fishing events. During this workshop, an open database of examples of SSF across the EU, including a script to anonymize the data, was produced. The data set currently available has 9 full case studies from different countries, gears, geo-position recordings and temporal intervals, is fully functional and openly available on ICES github. Various methods to infer fishing activities were compared, and the main issues and recommendations were discussed.

Testing of the effect of temporal resolution in the data using the example data base was initiated but further work is required on this aspect. Based on preliminary analysis, it was concluded that a conservative approach of a 'ping rate' of 30 secs (to obtain a 1 min temporal interval) is recommended if a generalisation is to be made that is applicable in all Metiers and that can be used to estimate all EU Multiannual Programme for data collection variables.

Based on available data sources (EU FDI, ICES VMS/Logbook Data Call, Global Fishing Watch AIS) an overview of small-scale fisheries (SSF) in EU Waters, visualized in figures, maps and tables was created. It was clear that it is difficult to directly compare data from the three available sources as each have different issues, e.g., different vessel length groups, covering fisheries from different countries and different legislation behind the data sources. Based on FDI data we can see that the passive gears are responsible for most fishing effort and that around ⅓ fishing effort from EU vessels in area 27 (North Atlantic) is from mobile bottom-contacting gears. In area 37 (Mediterranean and Black Sea) the proportion of fishing effort from mobile bottom-contacting gears is smaller. With regards to position data from the SSF, the VMS data can provide good coverage for vessels larger than 12 m, and the AIS could supplement for the smaller vessels, but the analysis comparing the fishing days by vessel length classes for the three data sources show that it is not a complete picture. The Global Fishing Watch data has shown another useful additional source which could be useful in future analysis. The resulting maps indicate significant gaps in data or data availability and a complete profile of SSF in EU cannot yet be produced with these data.

WKSSFGEO2 discussed the opportunities, challenges and benefits for an EU-wide tracking system for small-scale fisheries vessels and this report provides a guidance document with various recommendations on ways forward.

ii Expert group information

Expert group name	Workshop on Small Scale Fisheries and Geo-Spatial Data 2 (WKSSFGEO2)
Expert group cycle	workshop
Chairs	Marta Rufino, Portugal
	Tania Mendo, Scotland, UK
Meeting venue and dates	13–16 March 2023, Faro, Portugal; hybrid meeting (38 participants)

1 Introduction to the workshop

Presentation abstracts

ARGOS project: A glimpse of small-scale fishing effort along the Marche Region coast

Anna Nora Tassetti, Alessandro Galdelli, Pamela Lattanzi, Adriano Mancini, Luca Bolognini (Italy)

In the Mediterranean Sea, professional small-scale fishing still remains untracked and largely unregulated, even though it accounts for 83% of all fishing activity. Up to now, only some national initiatives have been implemented to obtain spatio-temporal data from tracking systems (not in Italy, nor in Mediterranean Sea). However, at the EU level, current negotiations between the EU Commission, Parliament and Council are underway for the tracking on small-scale fishing vessels by all Member States (EC, P9 TA(2021)0076). Therefore, it is necessary to produce standardised protocols to securely gather and share data across the inshore fleet, identify fishing trips and infer fishing activities in SSF.

In this workshop we present some initial results obtained within the ARGOS project (Interreg V-A Italy-Croatia CBC Programme 2014–2020, Strategic calls for proposal) 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.

Furthermore, the use of additional sensors, such as the proximity inductive sensor attached to the hauler implemented by Tassetti *et al.* 2022, could help 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.

An initial visualization/identification of the main fishing grounds has been carried out through the aggregation of the fishing events recorded from 20 vessels. The labelled dataset, validated through an expert opinion approach (face-to-face interviews with fishermen), has been shared within the working group.

In the near future, the team is going to: (i) develop/test machine learning and deep learning models to predict when fishing activity occurs if no sensors can be attached to the hauler, recognizing the employed gear too; (ii) attempt to estimate the fishing effort exerted on the case study area (Marche region coast); (iii) expand the study area and the time range of the data collection.

A framework to select a machine learning algorithm to estimate fishing effort using high-resolution spatio-temporal data

João Samarão, André N. Carvalho, Miguel B. Gaspar, Marta Rufino (Portugal)

The small-scale fisheries in Portugal have been tracked since 2016, using grey boxes powered by the vessels battery, implemented by the Portuguese Institute for the Sea and Atmosphere (IPMA). Initially, this system was implemented mostly for research, management and to monitor the fishing activity in real time, with the future perspectives of using it further in control, inspection, and safety at sea.

Currently, there are 150 boxes in the Portuguese SSF fleet. IPMA installed the first devices in 2016 in the entire bivalve dredge fleet (80 vessels) under the MONTEREAL project, and the use of this equipment is already mandatory for these fleet. On a voluntary and experimental basis, the use of these boxes is being extended to other SSF métiers, namely 10 trammel net vessels (PPCentro project) have been monitored since 2020 and 60 octopus pots and traps vessels since 2021 (PARTICIPESCA project). The Grey Boxes used were developed by the company ROBOT, and each one has a GPS (Global Positioning System) module, and a GSM/GPRS module that transmit the data through the GPRS to the Reception Center (RC). The data collected every 30 seconds is vessel name, vessel status (e.g. engine off, engine on) record date (dd/mm/aaaa), record time (hh:mm:ss), latitude, longitude, bearing (°) speed (knots) and zones (legally established zones for the production of bivalve molluscs).

It is estimated that global fishing production reaches 200 Mt by 2029. Therefore, to evaluate the impact on the ecosystem and maintain sustainability, IPMA started a program in Europe by equipping SSF fleet with a monitoring system using GPRS devices. In this study, through the available data of 170 boat tracks of all the bivalve dredge fleet and some vessels of pots and traps targeting octopus from three Portuguese fishing grounds and validated by expert validation, we propose a framework to select a machine learning approach to estimate fishing effort by predicting fishing and non-fishing activities.

The framework starts by evaluating how the variables that come directly through the GPS, namely, Latitude, Longitude, Speed, Time, and Month would affect the model's performance. The results demonstrated that Gradient Boosting Classifier (GrBo), Random Forest Classifier (RaFo), and Extreme Gradient Boost Classifier (XGBo) with all the variables included would be the best options, achieving accuracies above 95%. Further, it was concluded that Speed was the variable that most contributed to the right decision on the activity.

Secondly, we tested how the percentage of data that was used for train would influence the algorithms. This analysis helped to understand how the variables were explanatory enough to detect the fishing and non-fishing activities, as even with the lowest amount of data used to train the models (10% – 17 trips) the accuracies would be between 80% and 96%.

The third point addresses the problem of having different temporal resolutions. There are several distinct tracking devices over the fleets around the world, thus it is essential to find a model that can lead with such an abundance of resolutions and still has a good performance. Through the intervals established (30s, 1min, 1.5min, 2min, 4min, 5min, 6min, 8min, and 10min) we averaged the variables and tested the performance of the models, where it was concluded that it would vary depending on the model used. However, the best performance was obtained with the raw interval of 30 seconds using RaFo.

For a final pre-processing analysis, it was tested how a speed moving average would contribute to the models' performance. It was concluded that by increasing the points used to average the speed, the accuracy would increase too. Despite a positive slope relationship between the moving average and the accuracy, the performance did not improve so much after averaging using 10 points. Therefore, we proceeded with a speed moving average using 10 points.

These pre-processing procedures improved the performance of the models. However, the models were not perfect. Although the accuracies were around 99%, there were isolated points, which means that in a sequence of points classified as fishing, in the middle of them there was one classified as non-fishing. Also, occasionally there are sequences with more than one misclassified point. To solve these problems, post-processing procedures were implemented. (i) an Algorithm that analyzes the K-neighbors of a point and changes it based on the class of the neighbors; (ii) a threshold that restricts fishing activities with speeds higher than 6 knots.

Hence, applying all those procedures, the model that achieved the highest accuracy (99.07%) was Random Forest. Although machine learning algorithms demonstrated to perform really well in predicting fishing and non-fishing activities, other algorithms should be taked into account as these ones consider the observations independently and identically distributed, which means that there is no consideration for timeline structure and sequences. Therefore, for future work, we are expecting to start implementing deep learning algorithms to predict fishing activity through images, detecting which gear is being used, distinguish hauling, setting, and non-fishing activities, how many fishing events happen in a single boat trip and identifying port without using polygons manually defined.

Spatio-temporal changes in fishing effort by the artisanal fleet in the Alboran Sea using geo-spatial data

Cristina García-Fernández, Jose Miguel Serna-Quintero, Jorge Baro (Spain)

Green boxes (GB) were implemented by the regional government of Andalucía in the smallscale fishery (SSF) fleet in both the Atlantic and Mediterranean coasts. The implementation of this technology was driven primarily by its ability to provide real-time visualization of fishing activity, study fishery resources, enable control and inspection, and facilitate maritime rescue. Andalucía is the first region testing this technology in small scale fisheries and the first test was in 2004. In fact, the device was one of the measures implemented in the recuperation plan (between 2003 and 2005) of an important commercial species (*Pagellus bogaraveo*) which had been overexploited in the strait of Gibraltar with a locally designed hook line known as "Voracera". Each Green Box has a GPS Global Positioning System and a GSM/GPRS wireless communications module. In its normal operation, the Green Box connects to the Reception Center (RC) through the GPRS and system and periodically sends the position of the fishing vessel, normally every three minutes. The information collected is boat ID, date (day and hour), position, speed and course.

This system nowadays is implemented in almost all SSF vessels, generally classified as multigear and multi-species. The target area of the study is the geographical subarea 1 (GSA1) in the western part of Mediterranean Sea, located in the South of Spain, specifically the Northern Alboran Sea. The data for the earlier years is less accurate and of lower quality, due to the limited number of vessels equipped with the technology during that time, and the experimental nature of the device itself. With this geospatial data, we achieve some objectives: to determine the main fishing grounds of the small scale fisheries fleet of the area and the fishing strategies. In addition, we would also identify the target species and analyse trends in terms of biomass and economic benefit.

Exploratory analysis based on the 2021 data shows that around 100 fishing vessels with GB are operating along the year with almost 9000 recognised fishing trips (trips lasts one day). The fleet deploys different gears, both passive and active: boat dredges, hand-lines and pole-lines, trammel nets, gillnets, longlines and pots. Gear data was obtained by linking GB data with the official sale notes dataset and main target species are mainly bivalves, octopus, sparids, *Mullus* sp. and cuttlefish. Furthermore, the classification of the status of the vessel (fishing or not fishing) was established based on the speed of fishing operations and trajectory of the track for each gear, which was validated by fishermen and onboard observers. However, some difficulties are arising. There are cases in which there is no uniformity of pings, with time gaps between pings exceeding 3 minutes and significant variability in the frequency of ping emissions during a trip.

Moreover, the match rate between GB data and sales notes is not really high - for 2021 only 55% of trips- so the rest of trips may be removed from the analysis (we have no information about the gear used) and based on the multi gear behaviour of the SSF in the area, we cannot associate a permanent gear for a specific boat for the whole year. For future work, we are going to work with the protocol implemented in this workshop and try to reach the objective of analyzing the spatio-temporal dynamic of this important sector in the target region.

Computation of net fishing effort by combining machine-learning and geocomputing methods available in the R-package iapesca

Julien Rodriguez, Mathurin Sans, Sébastien Demaneche (France, Ifremer-HISSEO)

The Delmoges program is based on a multidisciplinary scientific approach aimed at better understanding the mechanisms of cetacean by-catch in the Bay of Biscay. In this context, developments regarding the estimation of nets fishing efforts are carried out. Two databases are used to describe netters activity, the qualification of operations being carried out from sensors or video observations. They concern 38 fishing vessels for 3577 fishing trips.

By analyzing the possibility of describing fishing effort for different temporal resolutions, it appears that a ping resolution of 15 minutes may offer the possibility of recovering degraded but consistent measures of fishing vessel effort for SSF (small scale fisheries), described by their number of fishing hours. However, in order to distinguish complete hauling and setting operations, and thus compute more appropriate metrics for passive gears (soak time and net lengths), 1 minute would be required for SSFs, and 2 minutes for vessels over 15 meters.

A 15 min resampled dataset was used as a proof of concept to develop the methods and algorithms made available through the R-package iapesca (https://archimer.ifremer.fr/doc/00819/93094/). A comprehensive workflow was developed to process fishing vessels positions and retrieve gear-based effort metrics more suitable for describing passive gears activity. Machine-learning models are used to recover the fishing vessel effort. Random-forest or XGBoost models demonstrate better ability than conventional speed/turning angle filter approaches to describe vessel behaviours, provided the positions are linearly resampled and features selection is relevant. To translate this information into gear-based effort, geocomputation algorithms including consolidation process have been developed. For vessels longer than 15 meters, this approach demonstrated good results for retrieving realistic soak times and net lengths.

This workflow will be calibrated and tested for other temporal resolutions and the results will be validated with fishermen. A spatio-temporal analysis aiming at describing the possible evolutions in fishing practices in the Bay of Biscay regarding the fishing areas, the length or heights of the nets, the soaking times will be possible thanks to this approach.

Possible application of vessel detections from satellite imagery

Luca Marsaglia, Global Fishing Watch - Fisheries Analyst Europe; University of Tor Vergata - PhD candidate

Global Fishing Watch processes imagery from Sentinel - 1 (Synthetic Aperture Radar) and sentinel 2 (Optical) imagery are publicly available from the European Space Agency. Global Fishing Watch applies an algorithm to detect vessels and likely fishing vessels.

The detections can be matched with the position of vessel transmitting AIS thus revealing detections of vessels that are not broadcasting AIS. This dataset could potentially be useful in understanding the fishing footprint in areas where tracking devices are not present. Some preliminary results were shared in this presentation and a public dataset of vessel detection is already present in Global Fishing Watch Map.

Estimating passive gear fishing effort from highly resolved geospatial data

Mendo, T.; Glemarec, G., Mendo, J.; Hjorleifsson, E.; Smout, S.; Northridge, S.; James, M.

Opportunities to map the activities of fishing vessels at an unprecedented level of detail have arisen with the availability of highly-resolved vessel tracking data. However, most effort mapping methods to date have focused on large scale fisheries, primarily active gears such as trawls or dredges, where hours spent fishing at sea are typically used as an indicator of fishing effort to map the most important fishing grounds. Conversely, we have discovered that for passive gears used in small-scale fisheries, spatial indicators of effort (i.e., length of vessel track) are more effective than time-at-sea in measuring fishing effort. We have also developed and validated a method to estimate gear soak time from vessel tracking data, and we have demonstrated that maps of effort that consider soak time may differ from those based solely on time spent fishing at sea. The availability of precise, fine-scale effort maps will enhance spatial planning tools that can support sustainable fishing practices.

An approach to mapping and quantifying the fishing effort of passive fishing gears using geospatial data

Nuno Sales Henriques

Here we describe a new methodology to classify vessel tracking data using passive gears within a polyvalent fishery context, i.e., when more than one type of gear is used. The presented approach is able to classify tracking data into the four main fishing behaviours within a fishing trip using passive gears: Steaming, Deployment of gears, Hauling of gears and Slow navigation/Drift. Since this methodology is able to identify the beginning (Deployment) and the end (Hauling) of fishing events, it is then possible to calculate the soak time of the fishing events. The combination of the soak time with the spatial distribution of the fishing events allows us to map the areas that have been mostly fished, in terms of soak time, by polyvalent fishing vessels using these types of fishing gears.

Identification of longline fishing grounds using machine learning for benthic habitat impact assessment

Daniel Cano and Jose Rodriguez

At IEO we are developing a project for identification of longline fishing grounds using machine learning for benthic habitat impact assessment. Within this project our goal is to use some on board observers in order to train an AI so it can later predict using AIS data as input, whether the vessel is fishing or not. Using this output, fishing grounds are identified, and later impact assessment studies can be taken. First results are promising, and random forest algorithm does quite well, but more observer data is needed as a simple review of fishing tracks shows that there are many varieties among fishing styles. This fishing gear is highly dependent on geographical location, so good spatial coverage with validated data is needed to be able to assimilate regional differences for the same gear.

A workflow for standardizing the analysis of highly resolved vessel tracking data

Mendo, T.; Mujal-Colilles, A.; Jonathan Stounberg, Gildas Glemarec, Josefine Egekvist, Estanis Mugerza, Rene Swift, James, M.

Highly-resolved vessel tracking data has become an important source of data to improve fishing effort estimators. There are several sources that can provide highly-resolved temporal and spatial tracking data such as Automatic Identification System (AIS), GNSS and Electronic Monitoring (EM), which incorporate the need to standardize the analysis of the data. We propose a workflow to analyse highly-resolved tracking data and obtain location of fishing activity. The workflow has been tested on AIS and GNSS data from gillnets and pots and traps respectively and aims to be used regardless of the source of data and the metier. It also includes the option to automatically detect mooring sites in cases where the fishing fleet does not use traditional docking infrastructure such as ports or piers or the user does not have the list of ports in advance.

Merging FSN and AIS for Small-Scale Fishery in the Basque Country

Maria Mateo, Estanis Muguerza, Eneko Bachiller, Maria Korta, Lucía Zarauz (Basque Country, Spain)

To estimate the fishing activity of the small-scale fleet in the Basque Country, the First Sales Notes (FSN) and the Automatic Identification System (AIS) data have been merged. For this study, the Basque SSF fleet is defined as those vessels smaller than 15 meters, with home port in the Basque Country, and for the period from 2017 to 2021. This fleet represents on average 37% of the entire Basque fleet, and it is multis-specific, with six main fishing gears: handlines, longlines, netters (gillnets and trammelnets), pots and/or traps, and trolling. In terms of landings, this fleet lands about 5% of the total Basque fleet, and the handlines are by far the most important fishing activity. Although this fleet lands more than 100 species, only ten species generate 90% of the fleet's total income (mackerel, white tuna, European hake, etc.). To link FSN and AIS data, both are first processed and cleaned. In the case of the AIS data, we used the standardized methods defined during the WKSSFGEO. The link between FSN and AIS is made by trips, which are defined in both data sources as a day. Therefore, all FSNs matching the AIS pings are linked through the vessel identifier and the trip or date.

Once the data is linked, the fishing gears and the catches of the FSN can be associated with the AIS data, allowing the identification of the fishing activity. Through the information obtained by the fishermen we define the speed ranges in which they are fishing. For the passive gears, it is estimated that between greater than zero and one, the vessel carries out the setting and hauling operations. In the case of trolling, the gear is hauled between 6 and 7 knots. For example, in 2018 the 55% of FSN are linked to AIS fishing trips, but the percentage is higher regarding the link to the whole AIS trip (pings where the vessel is steaming are also linked to the FSN but they are discarded as these pings are not considered as fishing events). Once the speed profile and fishing trips are validated, fine scale effort and landing patterns can be displayed. A more accurate validation will be carried out for some vessels that have GPS trackers and devices where fishermen indicate the start and end of the trip and the species caught. Finally, this data is used by other

AZTI teams to estimate from the carbon footprint to the habitat suitability, among other applications.

Geospatial data at NOAA Fisheries

Talya ten Brink

For the United States, AIS is directly downloadable at AccessAIS. A data dictionary shows the collected data definitions in this dataset and their resolutions. VMS requirements depend on the region, and data is processed and contained in databases and servers throughout different branches in each region. For the Northeast and MidAtlantic of the US, the VMS datasets are available via a rest endpoint and commercial fishing data by fishery or gear type is also available. The Pacific Coast, Islands, and Alaska region also have a cloud-based VMS/AIS platform. It will also have environmental variables being linked to AIS, such as sea surface temperature, chlorophyll, by integrating remote sensing data. In the US, classes of AIS can be transmitters in Class A or B. Class A transmitters are more expensive and have a greater transmission power to send and receive AIS data over longer distances. For the US Pacific Islands and Alaska, many boats use Class B and for boats far from shore, they can only be picked up via satellite.

Mapping bio-economic layers of fishing activity to define protection strategies: the ABIOMMED project

Tommaso Russo & the ABIOMMED Team

The ABIOMMED project (callDGENV/MSFD2020;GA110661/2020/839620/SUB/ENV.C2) aims to support a coherent and coordinated assessment of biodiversity and measures across the Mediterranean for the next 6-year cycle of the MSFD implementation. One of the main goals of ABIOMMED is to contribute to a coordinated approach towards EU-MSFD and Barcelona Convention-EcAp implementation for Descriptor/Ecological objective 6 (seafloor integrity). ABIOMMED Activities 3 and 6, focus on the assessment of physical pressures on seabed and the exploration of measures for reducing their impact. In particular, we present the outcomes of the preliminary work carried out in the framework of Task 3.3, related to exploring alternative measures or reducing the fishing impact on the seafloor with spatially explicit models. In this context, a modelling approach was applied to reconstruct the activity of the bottom otter trawlers and the corresponding landings (as well as some key bioeconomic parameters) in four case studies (Adriatic Sea, WMS, Sicily Channel and Ionian Sea) encompassing the EEZ of Italy, Croatia, Albania, Malta & international waters. Landings-per-unit-of-effort (LPUEs) were estimated for the most relevant target species in the given fleets/areas. Fishing costs per exploited cell were estimated using fuel prices, distance to coast and effort. Revenues were estimated using the market value of all the selected landed species. Profitability was estimated as the difference between revenues and costs. A series of spatial scenarios are being tested. In particular, we focus on the estimated effect of reducing maximum trawlable depth from 1000m to 800m. The simulation shows, in the given conditions and in the context of the WMS case-study, relatively little effect in terms of landings and revenues, as deep-sea trawling is mainly concentrated in the higher depth stratum (e.g., 600–800m). Such result must be confirmed by introducing the modeling of the effects of displacement as well as testing the implications of these spatial scenarios in the other investigated case-studies. Simulations, also testing other spatial management scenarios, will be concluded in the incoming months.

2 Open data set of case studies of high-resolution boat tracks examples

ToR a.i) Create an open data set of case studies (anonymized) to test the methods, with different gear types and locations

An example data set was developed during the workshop, with the objective of creating a database with different case studies around the EU, and a diversity of metiers. The intention is that this data will be open access and widely available, so that anyone can use it to test the methods or procedures in their works. Thus, in the future, if testing fishing activity prediction methods, effects of changing ping rates, or data processing protocols, besides using their own dataset researchers can apply their approaches to this example data, so that the results will be comparable among works. If required, the data can be anonymized, including the geographic positions, times or boat identifiers, and a script was provided for this purpose.

The structure of this dataset was defined in detail, with agreement of all participants in plenary, including the naming convention of the columns and respective format.

To make this data set, three documents were produced during the workshop:

1. A meta data form where the general details of the specific example data set are submitted.
2. A template of the data specification, with the detailed definitions of each column required.
3. A script to open the data, make preliminary plots, check and correct any common data issues, add required variables such as speed if not provided (with a function developed for it) and export the standardised data. This code can then be used to open the datasets by any user for any analysis purpose.

Position data analysed in the ToR were acquired from different tracking systems.

- VMS (Vessel Monitoring System) is a system that uses satellite positioning technology to track and record the location of a ship in real-time and transmit this information to a receiving center. The device usually consists of a GPS receiver onboard the ship and a transmitter that sends position information and some additional data to a land station, where it is processed and stored. The information can be transmitted via satellite communications or high-speed wireless networks. VMS systems transmit positions at established intervals, and some systems allow for an increase in the transmission frequency when necessary. The system must be able to automatically transmit messages or position reports (on request or periodically) that include the following information: boat ID, Date (year, month, and day), and UTC time (hours and minutes) at which the position of the vessel was determined, latitude, longitude, current heading, current speed and activity (fishing/non-fishing).
- iVMS (Inshore Vessel Monitoring Systems) is a vessel monitoring system designed specifically to monitor and track fishing activities on small-scale vessels operating in coastal waters or nearshore offshore areas. iVMS records the precise location, speed, and heading of vessels through a secure and rugged device that transmits this data to a national operations centre via the GPRS mobile phone signal.
- AIS (Automatic Identification System) was designed as a collision avoidance system, not as a global ship tracking system. The data from the AIS system is open, sent via VHF

radio waves, and can, therefore, be received by anyone with an AIS receiver, potentially revealing a vessel's primary fishing sites to its competitors. VMS is a more suitable tool for fisheries management for three main reasons: i) It allows for a greater volume of data transfer, thus opening the doors to other supplementary services, such as Logbooks, ii) VMS is a secure system that guarantees the delivery of data, iii) VMS should not be able to be disconnected, which can be done with AIS.

- Green Boxes (GB) are special devices installed on small scale fleet boats in the Spanish region of Andalucía. Each Green Box has a Global Positioning System (GPS) and a wireless communication module GSM/GPRS. During normal operation, the Green Box connects to the Reception Center (RC) through the GPRS system and periodically sends the location of the vessel (3 minutes/ping). In case of loss of communication coverage, the Green Box records the positions in a queue that is uploaded to the RC once coverage is recovered. If communication cannot be established through the GPRS channel, the Green Box communicates through the backup GSM channel (SMS). GSM is a voice and text communication technology that uses circuit-switched, i.e., it establishes a direct connection between two communication devices to transfer information. On the other hand, GPRS is a packet communication technology that uses a packet-switched network connection which is more efficient and allows faster data transfer speeds (focused on data transmission) than GSM (focused on voice and text transmission). Similar system has been implemented in Portuguese SSF (see details above in Samarão *et al.* summary), developed by another company (grey boxes), but giving 30 seconds ping rate.

2.1 Form

A google form was developed to record the meta data of each data set provided (Figure 1). Each data provider was invited/required to populate the form (it takes no longer than 2 minutes). The form then transfers the important details of the case studies entered into the form into a table. The form has a common/shared field with the data template and the data file, which is the FILE_NAME, to connect all sources of the information. The following link provides access to the form: https://docs.google.com/forms/d/e/1FAIpQLSc1pIZMBh8H_Ofod7FAYuSyb7OFfsQ3qpIJIgZKx5MBwHF2rg/viewform

Figure 1. Google form header for recording a metadata summary associated with the geo-spatial data of small-scale fisheries submitted.

The metadata summary/form has the following fields:

1. E-mail: the email of the data provider;
2. File name: the name of the uploaded file. The naming of the file should follow the following format: country code (2 digits)_institution/source (3 digits)_year (YYYY format)_device code 3 digits (GRB for green boxes; GPS, VMS, IVM for iVMS, AIS, etc). Example: PT_IPM_2022_AIS. This is a required field;
3. Data owner (institution): acronym of the institution that provides the data. This is a required field;
4. Project funding: Research project name and funding institution responsible for the data (if applicable);
5. Data anonymisation: identify which fields have been anonymised (select fields if applicable) or state if no anonymization was done. This is a required field;
6. Gears in the data set: field to indicate which fishing gear(s) are used by the vessels. This is a required field;
7. ICES geographic sub-regions (location of the geo-spatial data): ICES sub-region from where the tracking data was generated. This is a required field;
8. Start month (numeric value as: MM): field to indicate the month corresponding to the beginning of the tracking data. This is a required field;
9. Start year (numeric value as: YYYY): field to indicate the year corresponding to the beginning of the tracking data. This is a required field;
10. End month (numeric value as: MM): field to indicate the month corresponding to the end of the tracking data. This is a required field;
11. End year (numeric value as: YYYY): field to indicate the year corresponding to the end of the tracking data. This is a required field;
12. Temporal resolution (time interval between pings/geographic coordinates (mode), numeric value in seconds): field to indicate the mode of the temporal frequency of the datapoints, e.g. 60. This is a required field;
13. Number of points (numeric value, e.g. 3455): The total number of datapoints. This is a required field;

14. Number of complete tracks/trips (numeric value, e.g. 34): The total number of tracks/trips. This is a required field;
15. Number of complete tracks validated (numeric value, e.g. 34): The total number of tracks/ trips for which the fishing activity status is validated/classified. This is a required field;
16. Type of validation: How was the data validated, e.g. onboard observers, expert judgment, etc;
17. Number of vessels (numeric value, e.g. 34): Total number of unique vessels within the data. This is a required field;
18. Angle If a directional variable is included in the data set, indicate what the angle corresponds to e.g. bearing, heading, etc;
19. Type of tracking system: type of device that generated the tracking data. This is a required field;
20. Geographic Reference System: field to specify the geographic reference system of the uploaded data (if possible, give proj6 CRS code, e.g. 4326);
21. Has the data been published (in a paper, report, etc)? Which reference? (if available, provide the DOI only): field to provide a link (DOI) to the published work that used/generated the uploaded data.

2.2 Data template

The data field structure of the example data sets was developed, and discussed in plenary, to achieve a common and standardised output. This task was necessary, since different 7institutes use different methodologies, codes, and data sources. The required data structure/format is composed of 14 fields (columns). A description of each field in the data set, including whether or not it is mandatory and examples for each field such as units, numerical or text, etc are provided to guide data providers. The template can be found in DATA SET.

Bellow each field of the example data is described:

1. FILE_NAME: Name of the file uploaded. The format of the file name should be: (country code (2 digits)_institution/source (3 digits)_year (YYYY format)_device code 3 digits: (GRB for green boxes; GPS, VMS, IVM for iVMS, AIS, etc)); Example: PT_IPM_2022_AIS. This is a required field;
2. SOURCE: the dataset provider (institute acronym). This is a required field;
3. BOAT_ID: unique identifier of the fishing vessel (alphanumeric code). This is a required field;
4. TRIP_ID: unique identifier of the fishing trip (numeric value). This is a required field;
5. DATE_TIME: date and time in UTC of the point in ISO STANDARDS 8601 (YYYY-MM-DD HH:MM:SS). This is a required field;
6. LATITUDE: (decimal format in EPSG:4326 CRS). This is a required field;
7. LONGITUDE: (decimal format in EPSG:4326 CRS). This is a required field;
8. GEAR: gear identification using ICES codes (https://vocab.ices.dk/?ref=1498). This is a required field;
9. PASSIVE_ACTIVE: Type of gear (passive or active permitted). This is a required field;
10. STATUS: for passive gears; setting/hauling/not_fishing; for active gears: fishing /not_fishing This is a required field;

11. SPEED: current speed of the vessel. Values that are provided by the device (if available, should be in knots). This is an optional field;
12. COURSE: Course over ground, defined as the angle with respect to north and clockwise of the vessel direction provided by the device (if given, should be in degrees). This an optional field;
13. HEADING: Heading: defined as the angle with respect to north and clockwise of the direction of the line joining bow and stern of a vessel (where the bow is pointing at) provided by the device (if given, should be in degrees). This an optional field;
14. QUALITY: A field to flag some possible quality issues on the classified/validated data, such as possible wrong classification, uncertainties, etc, regarding the STATUS field. This an optional field;

2.3 Script to correct and test the example data-set

An R-script was produced during the workshop, to open the datasets received prior to the workshop, and run a series of checks and plots about the case studies. Once the data is uniformized, it is then exported to the database. This script is available for all users. The script name is 'WKSSFGEO2_examples_data_base.Rmd' and can be found in the ICES SharePoint (for workshop members) and on the WKSSFGEO2 GitHub repository (for anyone).

2.4 Example data-set description

The example dataset included case studies from Portugal (2 cases), Spain, Italy, France, Ireland and Denmark. Table 1 shows a summary of the meta data collected for each case study. The case studies include a good representation of gears types, ping frequencies and devices used within the EU to collect SSF and static gears high resolution data. The summarising plots of each case study (i.e. the outputs of the script), can be found in this report's supplementary material.

Table 1. Summary of the example data sets provided.

File Name	DK_DTU_1897_EM	ES_AZT_2018_AIS	ES_IEO_2021_GRB	FR_IFR_2021_GP	IE_MII_2019_IVMS	IR_MII_2020_IVMS	IT_CNR_2023_GP	PT_CCM_2021_GP	PT_IPM_2017_GP	UK_USA_2018_GP
Data owner (institution)	DTU Aqua	AZTI	IEO	IFREMER	Marine Institute	Marine Institute Ireland	CNR-IRBIM	Center of Marine Science (CCMAR)	IPMA	University of St. Andrews
Project funding	DCF (Data Collection Framework)				DCF (Data Collection Framework)		Interreg Italy-Croatia - ARGOS	Participesca	MONTE-REAL	
Data anonymisation	Boat names, Coordinates, Time/dates	Boat names, Coordinates, Time/dates	Boat names	Boat names, Coordinates	Boat names, Coordinates, Time/dates	Boat names, Coordinates, Time/dates	Boat names, Coordinates, Time/dates	Boat names	Boat names, Time/dates	Boat names, Coordinates, Time/dates

Gears in the data set	Gillnets (GNS)	Longline (LLS), Trolling lines (LTL), Handlines (LHM), and tram-melnets-gillnets (GXX)	Dredge (DRB), Gillnets (GNS), Longline (LLS), Pots and traps (FPO), Tram-mel nets (GTR)	NT	Hydraulic Mechanized dredges (HMD)	Pots and traps (FPO)	Pots and traps (FPO)	Pots and traps (FPO)	Dredge (DRB), Pots and traps (FPO)	Pots and traps (FPO)
Ices sub-regions	Greater North Sea, Baltic Sea, Black Sea	Bay of Bis-cay	Western Medi-terranean	Greater North Sea	Celtic Seas	Celtic Seas	Adriatic Sea	Iberian Coast	Iberian Coast	Celtic Seas, Greater North Sea
Start month (numeric; M)	12	1	1	12	1	na	1	9	3	3
Start year (numeric YYYY)	1897	anony-mized as 1974 (2018)	2021	2021	2019	2020	2023	2021	2017	2018

End month (numeric M)	3	12	2	1	1	na	2	2	3	5
End year (numeric YYYY)	1898	anony-mized as 1975 (2018)	2021	2022	2019	2020	2023	2022	2017	2018
Temporal resolu-tion (secs)	10	60 seconds	180	900	300	60	60	20	30	60
Number of points (numeric only, e.g. 3455)	879053	163882	192612	1937	2094	322	3699	10667	9115	2226
Number of com-plete tracks (numeric only, e.g. 34)	284	605	2326	8	8	6	14	5	8	5

Number of complete tracks validated (numeric only, e.g. 34)	284	605	3326	8	None	0	14	5	8	5
Type of validation	Electronic monitoring	Expert based (visual), qualitative validation, errors can occur	Expert based (visual)	fisherman information (nets positions and times)	Expert based (visual), Validation only done visually. Could be wrong	no validation	Expert based (visual)	Expert based (visual), On-board observers	Expert based (visual)	On-board observers
Number of vessels (numeric only, e.g. 34)	5	7	73	1	6	1	1	3	8	5
Angle. If given, the angle corresponds to:	Course		Course		Heading	Heading			Bearing	

Type of tracking system	green box/black box/robot (GPRS or GSM communication (mobile phones - data and image))	AIS satellite (sentinel), linked to sales notes	green box/black box/robot (GPRS or GSM communication (mobile phones - data and image))	?	iVMS	iVMS	GPS (Teltonika)	portable GPS (download the tracks after the trip)	green box/black box/robot (GPRS or GSM communication (mobile phones - data and image))	portable GPS (download the tracks after the trip)
Has the data been published (paper, report, etc)?		NO	NO	10.13155/93094	NO	NO	NO	NO	submitted	

3 Test methods to classify positions into fishing activities

ToR a.ii) Test and compare methods to classify positions into fishing activities (i.e. random forest, machine learning, geocomputing) on different types of vessel tracking data and gear types to infer relevant effort parameters

The subgroup discussed examples on different methods used to infer positions for different fisheries using different gears (Table 2). The main issues encountered when using each method were discussed as well as recommendations to deal with these issues.

Table 2. Examples of methods used by workshop participants to infer fishing activities.

Fishery/Gear **Type of device and ping rate**	**Methods and explanatory variables used** **Method of validation (on-board observers, expert validation)**	**Issues**	**Recommendations**	**References**
Pots and traps fishery - passive gears Scotland. vessels < 12 metres Teltonika trackers (GPRS) ping rate 60 seconds	Overall speed rule (speed) Per trip speed rule (speed) Expectation maximisation algorithm (speed) Hidden Markov models (speed and angle) packages: HMM Random forest - randomForest package (variables: speed, angle, proportion of time elapsed since start of trip On-board observers	The overall speed rule gave bad predictions because the vessels behave very differently in different regions of Scotland and also because the different vessel size classes operate with different speeds.	For this fishery, the accuracy and precision of detecting fishing or non-fishing events was not very different between the other different methods, but trip-based Gaussian mixture model (from expectation maximisation algorithm) provides the best overall performance and highest computational efficiency for our case study Random forests performed better because you can add more variables to inform model.	Mendo *et al*. 2019. https://royalsocietypublishing.org/doi/10.1098/rsos.191161
Pots and Hydraulic Mechanized dredges in Ireland	Hidden Markov Models	Generalization of initial parameter values for HMM models.		

FPO HMD iVMS - 1,5,10 min ping rates	(step, angle and reclassification based on calculated speeds) Still not validated. Planned observer trips in 2023.	Ping rates above 10min		
Italian small-scale fishing vessels (below 15 m) Passive fishing gears: GNS GTR FPO LLS IT_CNR_2023_GP.csv → only FPO	System parameters (*sat, power*) and other movement variables (*speed, timestamp*) are used to calculate fishing trips. The sensor attached to the hauler can be used to estimate vessel behaviour (navigation, fishing activity) through the *sensor* parameter. 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	The installation of the GPS device and the proximity inductive sensor attached to the hauler depends on the vessel features. Fishing gears and setting/hauling of the gears are still difficult to recognise, especially between GNS and GTR. Up to now, just one fisherman employs LLS.	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 when you run the algorithm to analyse the fishing trips.	Algorithm used to identify fishing trips: https://github.com/irbimMAPS/ssf Tassetti *et al*. 2022 https://www.mdpi.com/1424-8220/22/3/839

GPS tracker (Teltonika) 1 min ping rate	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. Expert validation (interviews to fishermen)			
Crayfish Fishery (Southwest coast Ireland) Vessels < 12m Tangle nets iVMS - 10 min ping rates	Speed filter to classify fishing activity HMM (ping rate over 5 min - Need to use interpolation, model excludes trips with ping rate > 5 min) On-board observers	Ping rate 10 min		
Basque SSF fleet < 15 m GXX	Speed intervals depending on the gear.	Depending on the vessel's behaviour, the interval is not always well defined. The speed interval must be	You need to know the fishing gear used on each trip.	

LTL LLS LHM FPO AIS - 1 minute ping rate	Expert validation	reviewed using mixed models. The number of AIS pings received each year differs due to external factors (coverage problem, system shutdown…). We'll validate for some		
Octopus Traps, south Portugal Traps - Passive Gear GPS tracker, 20 seconds interval.	Speed Threshold. Track interpolation. R package momentuHMM. Definition of daily trip On-board observers	It is very difficult to determine setting events and get fishing effort by soaking time (hours)		
OTB & PS Greece (mainly 18m< vessels) VMS <2 hours (artificial increase in VMS ping temporal	OTB considered fishing at speed intervals lower/equal to 4kn. PS considered fishing at speeds lower/equal to 1kn. Fishing effort expressed in			Kavadas *et al.* 2014. PERSEUS Project. only OTB: 1) Maina *et al.* 2016 http://dx.doi.org/10.1016/j.fishres.2016.06.021

frequency via interpolation as suggested by Russo *et al.* 2011)	days multiplied by GT at a 5*5 km grid. VMSbase R package (ref Miana *et al.* 2018) no validation			2) Maina *et al.* 2018 https://doi.org/10.1016/j.seares.2018.06.001
mainly OTB, PS and LLD (Greece) VMS ping rate 15min (position, time, speed) AIS ping rate 2sec-3min (position, time, speed)	Distributed Subtrajectory Join to fuse VMS and AIS data (Tampakis *et al.* 2020). Future predictions based on AIS data via Long Short-Term Memory (LSTM) neural networks (NN)			i4sea platform (Big Data in Monitoring and Analyzing Sea Area Traffic: innovative ICT and analysis models) Tampakis *et al.* 2022 https://doi.org/10.1080/10095020.2021.1971055
Longlines Cantabrian sea. Aviles canyon. LLS AIS data ~3 minutes ping rate.	Random forest. Speed is the most important as usual. Calculated variables as turning angles, rates of heading change, acceleration. Trajectories created from data using TRAJR package which is useful for	Need more validated data in order to properly train the model. Some "validated" data needs review since may lack accuracy because some observers did not annotate	Set some clear protocol/workflow/guide for on board observers	

GPS to train data at various ping rates (5 secs to 3 min)	calculating the previously stated variables. Random forest with RANGER package and TIDYMODELS. On board observers	set and haul times with enough precision.		
Bivalve Dredges, and Octopus Pots and Traps. Northwest, Southwest, and South of Portugal < 15m GPS devices, 30 seconds intervals	Supervised machine learning algorithms: The algorithms that produced better results were Random Forest, Gradient Boosting, and XGBoost. Others were tested, such as LogisticRegression, Support Vector Machines, Ridge Classifer, and K-nearest neighbour. The variables used, were the ones that come directly from the GPRS devices, namely, Latitude, Longitude, Speed, Month, and Time. Other variables were considered such as Depth, Distance to the Coast, among others.	We had some problems identifying the different gears in the South of Portugal using the methodologies described, we think that other methods should be used, and test different variables. Also, for certain gears classifying the setting and hauling events. (need more data to test). Find ports without using polygons.	We recommend before applying machine learning algorithms to do pre-processing procedures on the data, such as moving average, testing different temporal resolutions. Future implementation of neural networks using gps observation and images.	

	All of this was resorting to python libraries -> sklearn, numpy. Expert Validation			
French netters sensor-based: 15 min ping frequency video-observation: 1 s	Combination of machine-learning and geocomputing. R-package iapesca R & few Python scripts for training machine-learning models Sensor-based database for 2254 fishing trips Video observation for 1323 fishing trips. Total of 38 vessels. Validation of some results with fishermen	Post-qualification of the sensor-based database due to the decorrelation between vessel and gear lifes. The sensor being linked to the gear, identifying the setting events is difficult. Algorithms were developed to handle these problems	Machine-learning clearly out-performs classical methods. The geo-computation process is necessary to retrieve fishing gears metrics	Rodriguez 2023 https://gitlab.ifremer.fr/iapesca https://archimer.ifremer.fr/doc/00819/93094/

In the current workshop, machine learning and statistical methodologies, such as Random Forest, Hidden Markov Models, and Speed thresholds were applied to identify fishing activities in fisheries with different gears (Netters, Bivalve dredges, Octopus Pots and Traps, Longlines, Bottom outer trawlers, Tangle nets, Gillnets). For the available validated data, the most common approach to evaluate fishing and non-fishing activities were expert validation, video observation, fishermen validation, and onboard observers. These observations were obtained with distinct devices, namely, GPRS / GSM (1-minute to 3-minute ping frequency), sensor-based (15-minute ping frequency), video-observation (1-second ping frequency), GPS (5-second to 3-minute ping frequency), AIS (2-second to 3-minute ping frequency), VMS (15-minute to 2-hour ping frequency), iVMS (1-minute to 10-minute).

Machine learning algorithms demonstrated to be very efficient so far. Several case studies in different countries used this kind of approach, where Random Forest was the most common algorithm to identify fishing and non-fishing events (France, Portugal, Scotland, and Spain). Machine-learning models and the different methods tested aim at assessing the fishing vessel behaviour. From this information, only metrics regarding fishing vessel effort could be potentially retrieved. When dealing with passive gears, fishing gears-related metrics will be more relevant to describe the effective fishing effort. In the case of nets, for example, we will be interested in retrieving the length hauled and the soaking time. In the case study presented for the French netters, using a combination of random forest with geo-computation algorithms demonstrated the possibility to produce consistent fishing gear metrics and soak time. A similar approach developed for the Scottish pots and traps fishery is also yielding promising results for the estimation of soak time.

As for Portugal, in the project involving Bivalve Dredges and Octopus Pots & Traps a framework to select a machine learning algorithm to estimate fishing effort showed that Random Forest would be one of the best algorithms to distinguish between fishing and non-fishing activities, achieving accuracies between 98.88% and 99.07%. For Scottish potters, random forests showed great promise, achieving an accuracy of 94% to distinguish between fishing activities and non-fishing activities. Despite their good performance, machine learning algorithms don't consider the sequences or timelines structures as the observations are always considered independent and identically distributed, which is not the ideal way to analyze boat trips.

Contrary to the machine learning models stated above, Hidden Markov Models do not assume independence between subsequent observations, in this case, datapoints. HMM rely on the Markov process where the probability of each event depends, among other things, on the state obtained on the previous observation. The accuracy performance of this model proved to be quite accurate and it has been widely used on other tracking classification exercises, such as for animal and vessel tracking data. There are two major issues with the application of HMM, first, it is a complex model which is not easily understood by inexperienced users of the type of model. The second concern is that it is very demanding, computationally speaking. This becomes challenging when trying to analyze big datasets, as the time processing the data can be too long.

Besides the methodologies that were regularly mentioned during the workshop, there were some projects that started mentioning neural networks. In addition to the models already mentioned, neural networks can also be applied to identify fishing activities in fisheries with different gears. Neural networks are particularly effective for processing high-dimensional data, such as satellite imagery or sonar data, which can be used to estimate fishing effort and identify specific types of fishing gear.

Neural networks can also be used for a variety of other applications beyond estimating fishing effort and gear. For example, they can be used to identify specific fishing behaviours, such as discarding or targeting specific species, and to predict the impact of climate change on small-scale fisheries. Additionally, neural networks can be trained on large datasets to develop predictive models for other variables relevant to fisheries management, such as stock assessments or fish migration patterns.

Overall, while machine learning algorithms and Hidden Markov Models have demonstrated promising results in identifying fishing activities, neural networks offer additional capabilities in processing high-dimensional data and identifying specific fishing behaviours. Additionally, neural networks have a broader range of potential applications beyond estimating fishing effort and gear, which can be valuable for fisheries management and conservation efforts.

Comparing methods: Case studies

3.1 Pots and traps fishery in Portugal

Two different methods available in the Rmarkdown “Methods to compare effort” provided during WKSSFGEO2 were applied to the CCMAR dataset (PT_CCM_2021_GP.csv). This dataset has data from 7 daily trips of a pots and traps fishery and belongs to three different boats. Data comes from GPS onboard with 20 seconds interval and were classified as “not_fishing”, “setting” and “hauling” but for the purpose of this exercise were reclassified has “not_fishing” and “hauling”. Both methods gave similar results, the first method, based on the “Overall” speed threshold and using Expectation Maximisation (EM) algorithm, aims to identify distributions related to hauling and not_fishing. The second method uses the same algorithm but applied in each individual trip. Results indicate an accuracy of 74%, for both methods, with a slight increase if using trip discrimination, precision were also higher if using individual trips (64%) against 63%. Overall, both methods were able to identify hauling activity but failed mainly in classifying not_fishing behaviour.

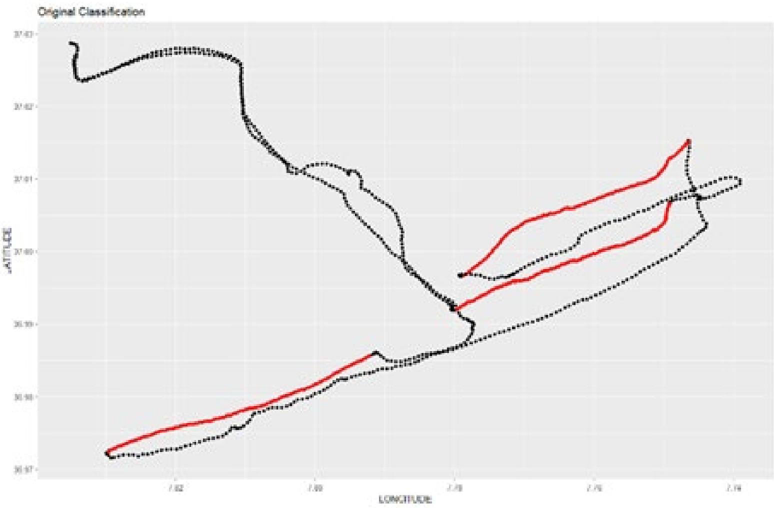


Figure A. Example trip showing fishing (in red) and not fishing (in black).

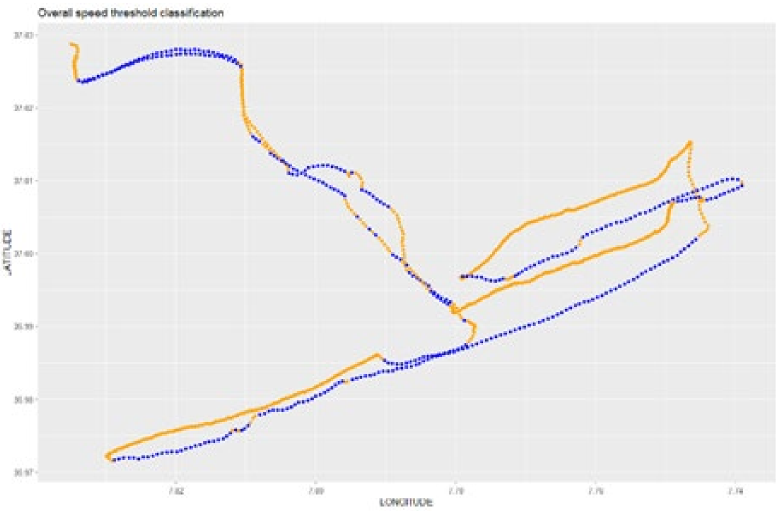


Figure B. Example trip showing fishing (in yellow) and not fishing (in blue), when using an overall speed threshold.

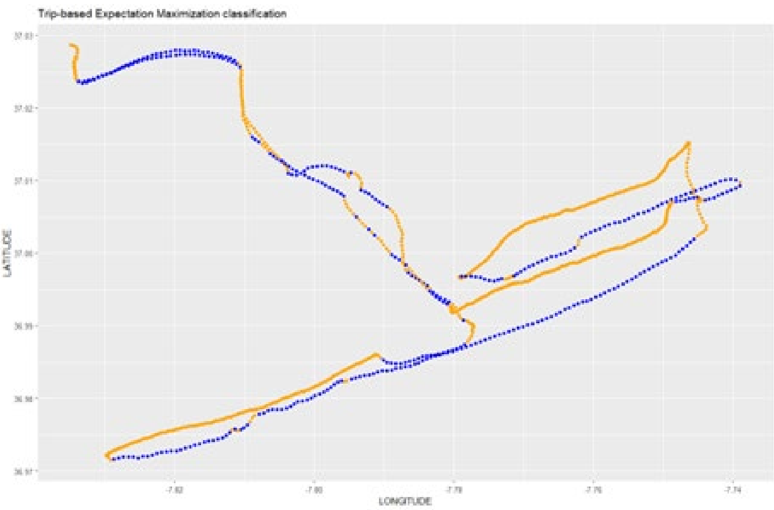


Figure C. Example trip showing fishing (in yellow) and not fishing (in blue), when using a trip-based Expectation maximisation classification.

3.2 Irish potting case study

HMM models developed for the Irish potting case study were modified and tested in several of the databases presented during WKSSFGEO2. Modifications included, the generalization of starting parameter definition using EM algorithms (to accommodate other gear behaviours) and the extension to analyze 10 min pings. Code is wrapped within a function and available in the WKSSFGEO2 github.

The outputs of the HMM model classify movement states as “Fishing”, “Transit” and “Mix_Transit” using step changes and turning angles. Initial parameters for each of these states are defined at boat level, rather than by trip level. This might result in non-satisfactory results, if movement behaviours vary substantially for different trips within the same boat (e.g. trips using different gears for the same boat). Additionally, classification states in this HMM model might not be appropriate for some of the datasets presented during the WK which distinguish between setting and hauling operations.

Results were assessed by visualization of the HMM classified states, against the validated data. Agreement between HMM outputs and the validated examples varied substantially across the datasets analyzed. Fishing behaviours tended to be identified as, either “Fishing” or “Mix_Transit” levels. In certain trips however, results showed a large proportion of wrongly identified pings. Further investigation is required to assess this mis-classification. Results could be further improved by including model covariates such as vessel speeds, refining the classification states, and better tuning the initial parameter definition on which HMM models rely. Three examples are provided below, from well-identified fishing activity, to large misclassification of pings.

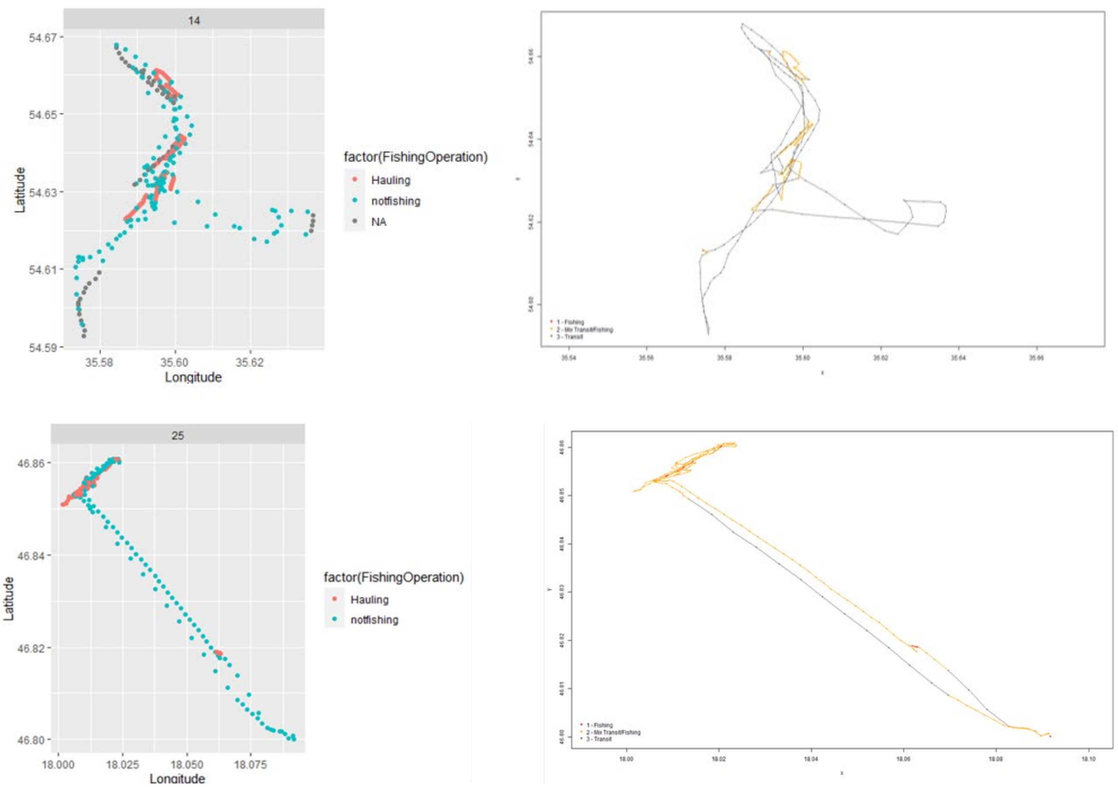


Figure 2.1 Visual comparison of HMM model outputs against validated classification by workshop participants. Track examples displayed belong to different countries and gears. Order of figures displayed go from well classified fishing activity to poor classification results.

3.3 French netters

Different methods were applied to a dataset for nets including 8 fully qualified fishing trips. The qualification was made using the fisherman's information on nets geolocation and times. The data used in the code has been provided (FR_IFR_2021_GP.csv) and is loaded directly from the iapesca package in r-script. Package source may be downloaded from https://gitlab.ifremer.fr/iapesca.

The code is available on https://github.com/ices-eg/WKSSFGEO2/blob/main/EffortMethodComparison_IFR_iapesca_Dataset.Rmd

The HTML document is available on the WKSSFEO2 SharePoint in the personal folders.

The best result was obtained using the binary clustering method with an accuracy of 65%. These results are not satisfying and may be explained by a confusion between hauling operations and the vessel waiting on the fishing grounds. This behaviour leads to a large number of false positives identified as hauling events. Classical methods based on speed/turning angle may have difficulties distinguishing these waiting behaviours. Machine-learning models were optimized and calibrated on this dataset using a 3-folds cross-validation on the fishing trips. The features are calculated using the iapesca::CalcFeatures function.

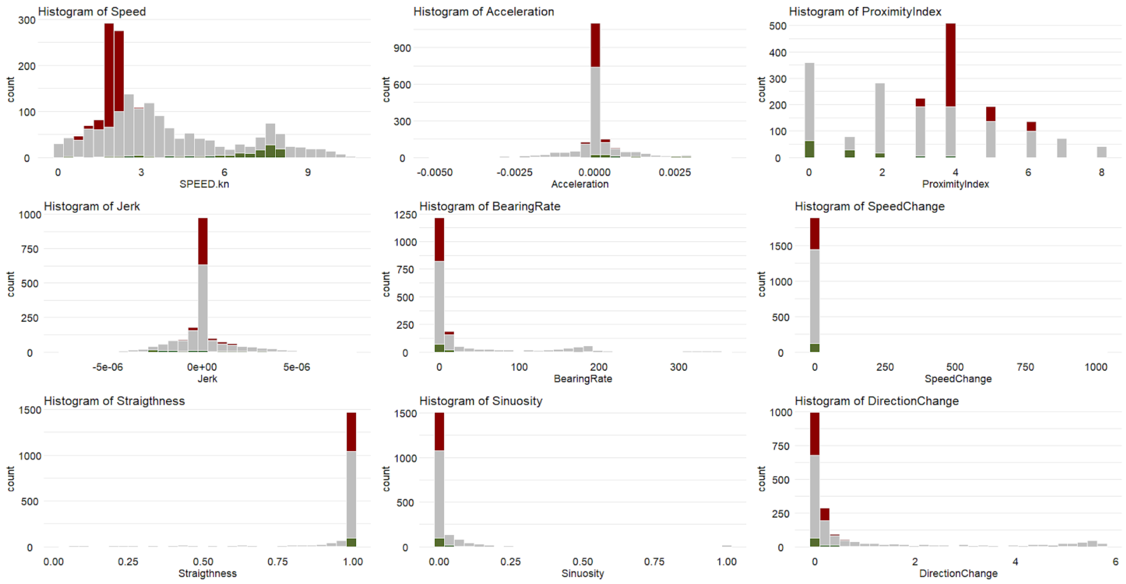
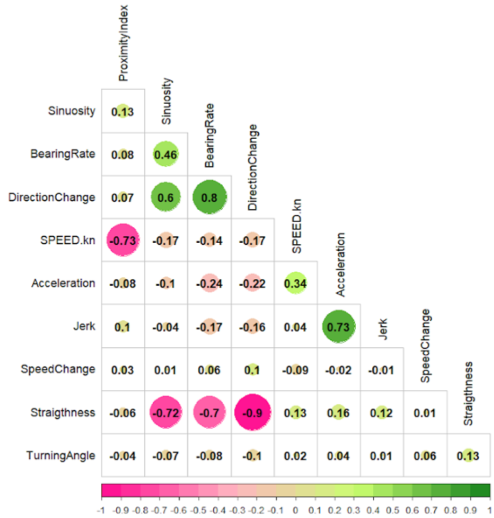


Figure 2.2. Features distribution and their relation to fishing operations (hauling in red and setting in green).



Features correlations

Two models were trained: a CART simple decision tree and a random-forest model. Both of them demonstrate a much better accuracy regarding their capacity at identifying hauling, but also setting events, with results over 90%. The final random-forest model selected was tested using a 3-folds cross-validation on fishing-trips and provided an overall accuracy of 91.5%. The prediction being good for hauling events compared to other methods, but the accuracy remains really bad regarding setting events.

	Model predictions		
	Hauling	NotFishing	Setting
Hauling	**402**	49	0
NotFishing	24	**1304**	5
Setting	0	83	**35**

The table below shows the different results obtained on assessing the fishing operations with the different methods tested.

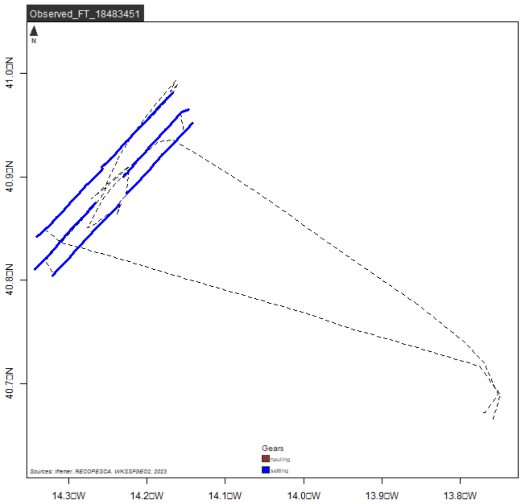
Method	Accuracy
Overall speed thresholds	49.12%
Trip-based Expectation Maximization	49.12%
Binary Clustering for behavioural annotation using Gaussian mixture models on a trip-by-trip basis	64.94%
Hidden Markov model with speed only	42.60%
Hidden Markov Model with speed and turning angle	50.00%
ML models (CART & RF)	91.5%
RF + Geocomputation	94.3%

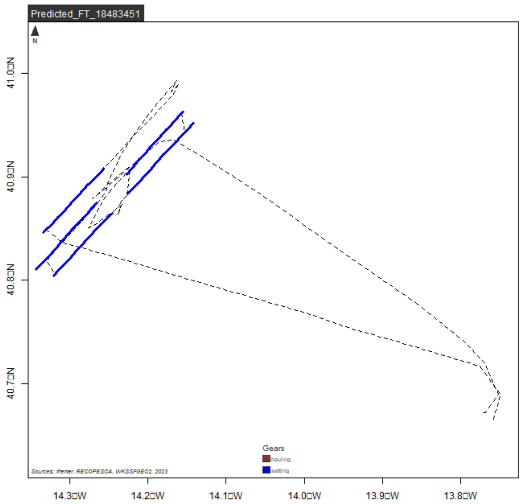
Machine-learning models and the different methods tested aim at assessing the fishing vessel behaviour. From this information, only metrics regarding fishing vessel effort can be retrieved. When dealing with passive-gears, fishing gears related metrics are more relevant to describe the fishing effort (Mendo *et al.*, submitted). For nets we will be interested in retrieving the length hauled and the soaking time. These variables will be summarized by fishing trips (sum and median respectively).

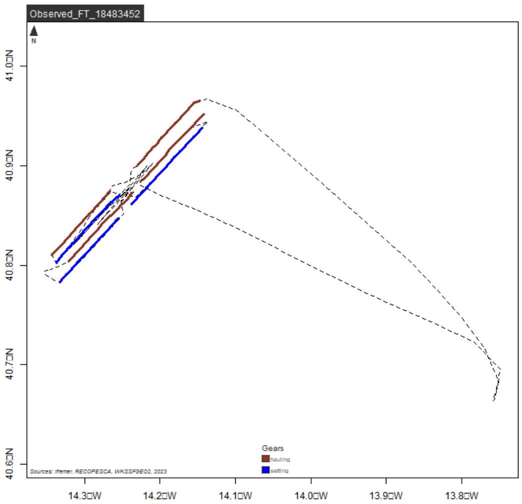
To be able to compute and evaluate fishing gear effort, hauling events must be assessed efficiently and be linked to their related setting events. To do this, the geo-computation algorithms provided in the "iapesca" package were used. The nets are created based on the hauling events, more easily detected than settings, using the iapesca::Create_NetsByBoat function. The "Use.BehaviourChanges" argument was activated, this method being more suited when working with degraded temporal resolutions (15 mins in this case). The option for "Auto.ThreshHolds.Detection" was also used to retrieve statistics on nets and clean them, this method being developed to handle false positives detections based on expected values on hauling speeds, net length and direction. The iapesca::Retrieve_SettingOperations function is then applied to the positions and nets to retrieve the setting events based on the use of buffers and a scoring of candidate sequences from their position in time, sequence length and the presence of detected setting events.

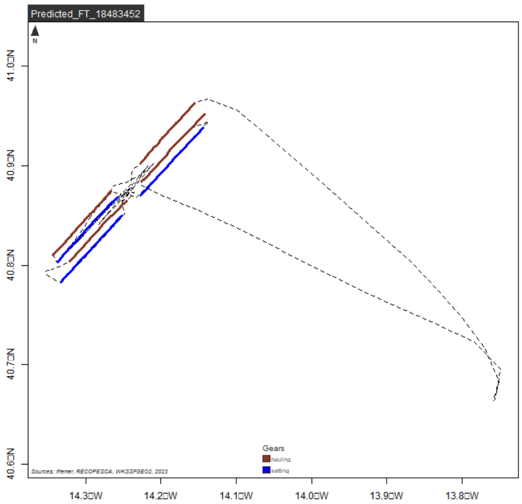
For these 8 fishing trips, 39 nets are identified from the observations with a total length of 398816.9 m. From the predictions, 37 nets for a total length of 362263.5 m were finally retrieved using the cross-validation prediction results.

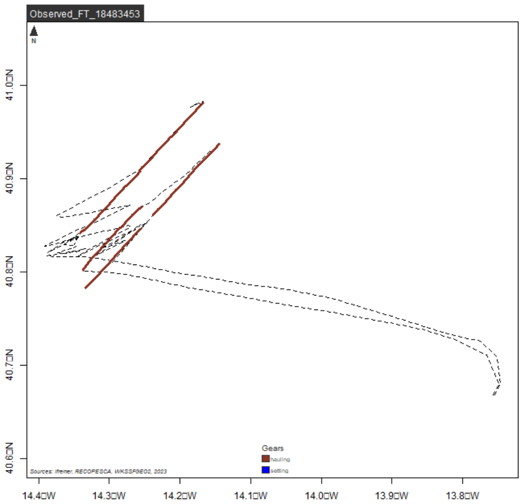
The maps below present the nets hauled and set for each fishing trip from the observation and the prediction.

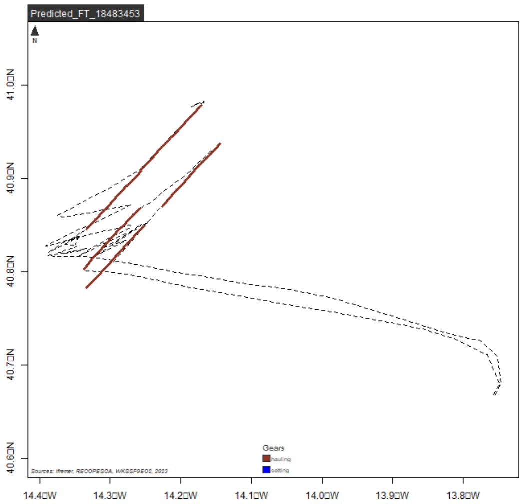


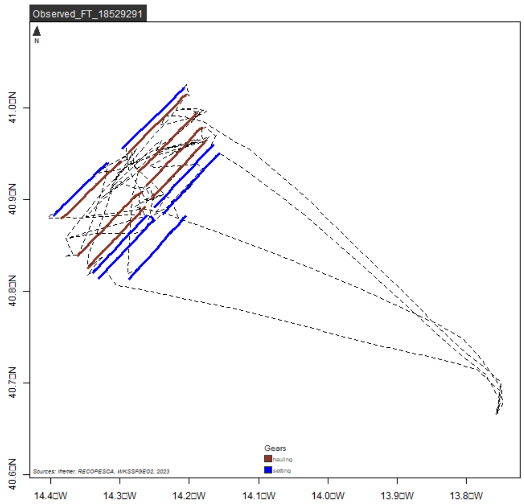


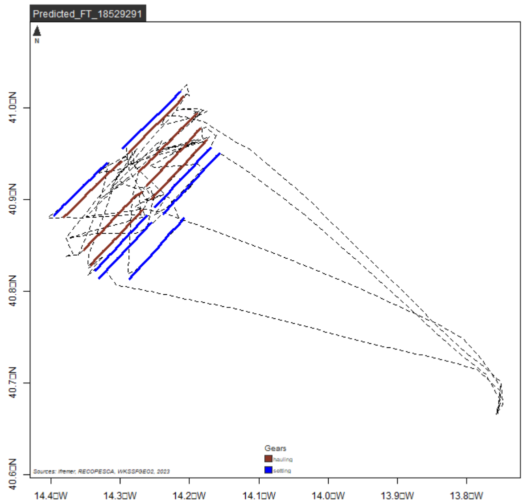


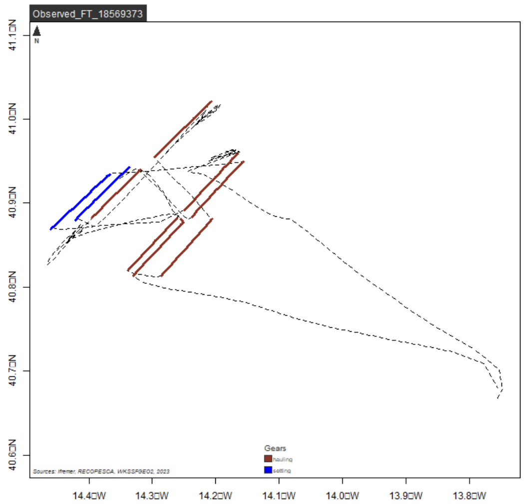


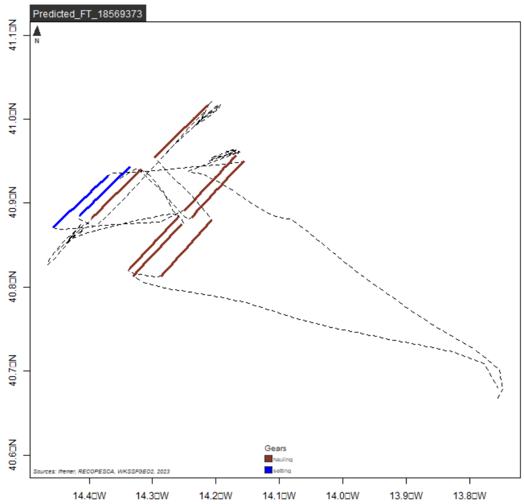





Observed_FT_18529291
Gears
Sources: Ifremer, RECOPESCA, WKSSFGEO2, 2023


Predicted_FT_18529291
Gears
Sources: Ifremer, RECOPESCA, WKSSFGEO2, 2023


Observed_FT_18569373
Gears
Sources: Ifremer, RECOPESCA, WKSSFGEO2, 2023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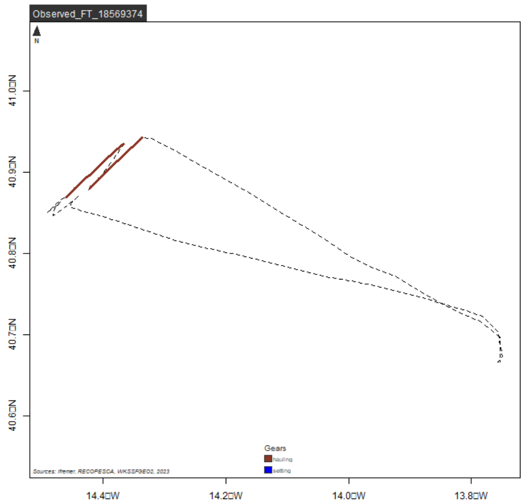
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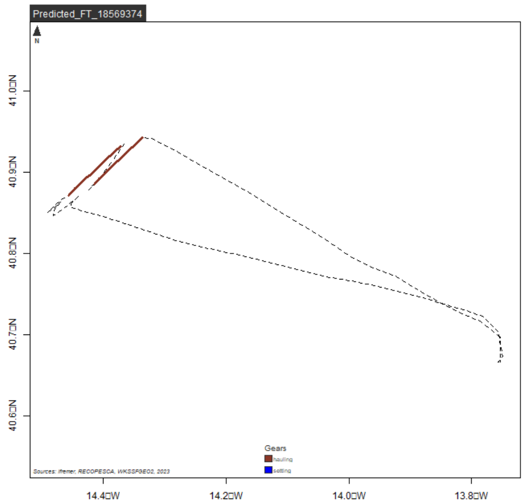
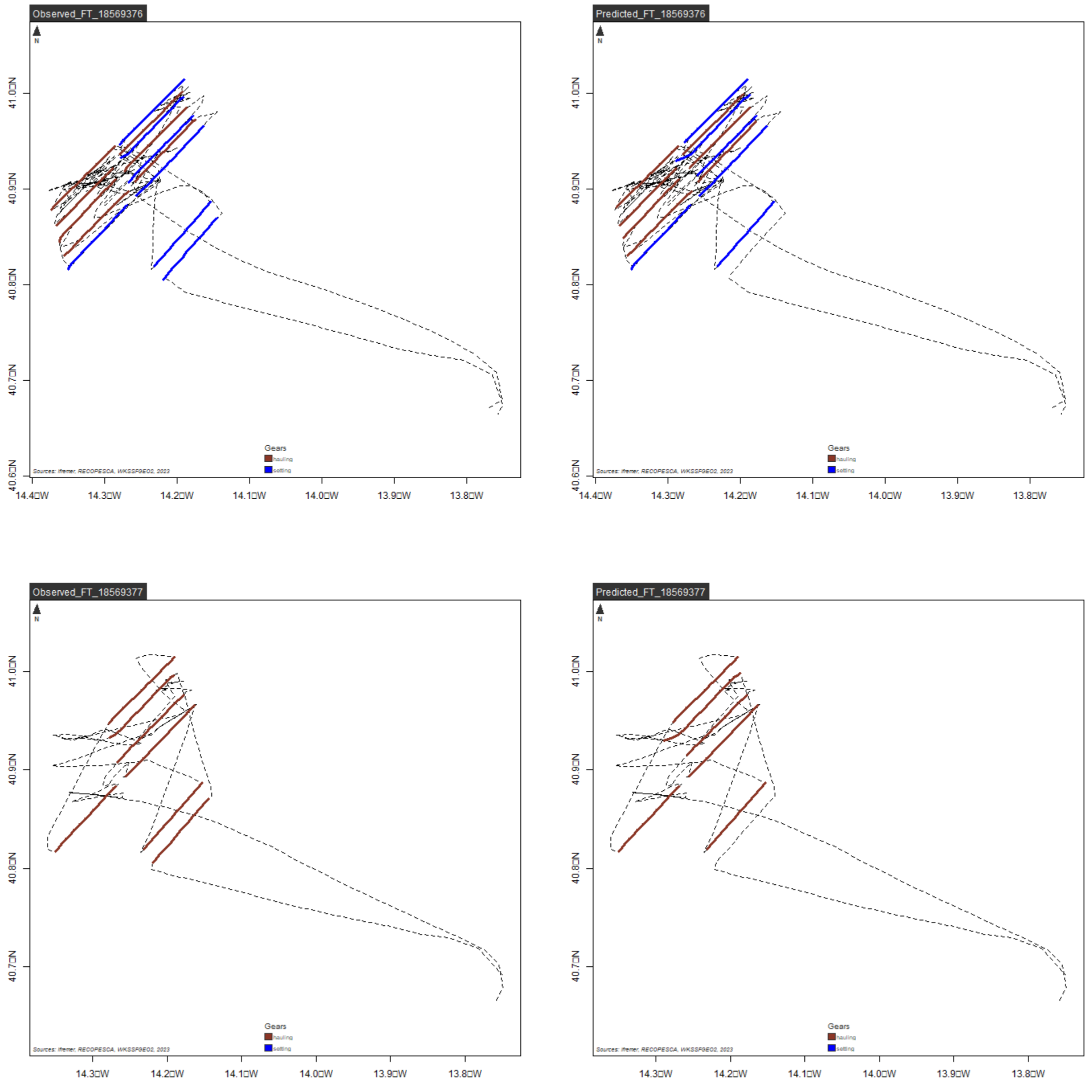
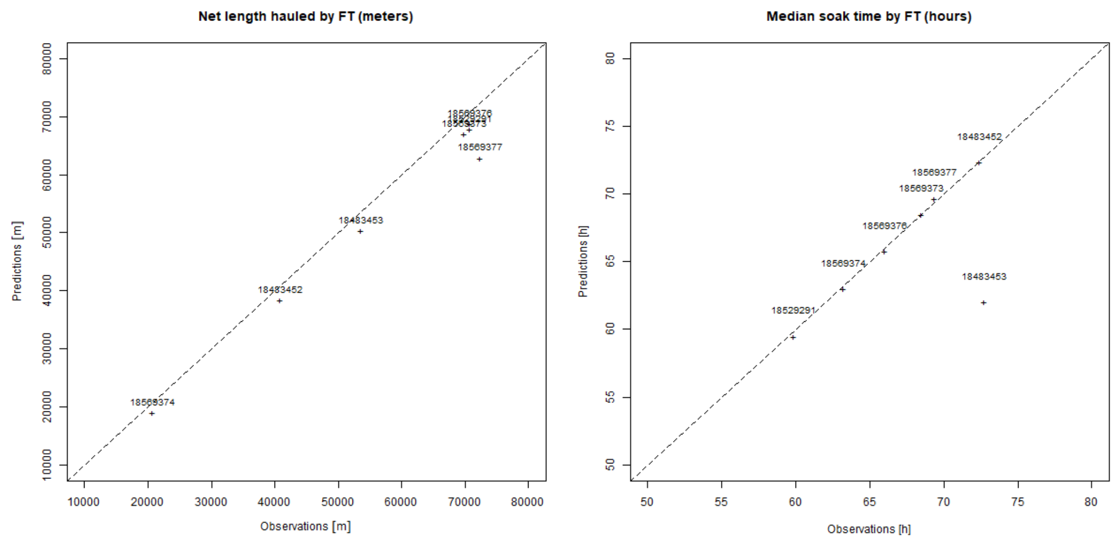
Sources: Ifremer, RECOPESCA, WKSSFGEO2, 2023


Predicted_FT_18569374
Gears
Sources: Ifremer, RECOPESCA, WKSSFGEO2, 2023



The fishing effort metrics can now be computed and aggregated to the fishing trip level showing consistent results for 7 fishing trips on 8. 1 net on 7 being actually not detected, the net length hauled is under-estimated for the last fishing trip “18569377”.

The soaking time is underestimated for the fishing trip “18483453” but its value remains consistent related to the fishing vessel practices.



Applying this geo-computation process also allows a significant increase in estimations regarding the fishing vessel effort, from 91.5% to 94.3%. The consolidation process applied when creating the nets removes most of the false hauling events (but also a few true hauling events) and the retrieval of setting events by the geo-computation algorithm allowing a better detection of fishing operations.

4 Optimal frequency of acquisition of geopositional data (temporal resolution, ping rate)

ToR a.iii) Recommend the optimal/maximum frequency of acquisition of geopositional data (time between pings) by gear types to infer relevant fishing activities

4.1 Evaluation framework to test temporal resolution

A script was adapted from a manuscript (in prep) to evaluate the effect of varying the ping rate on performance metrics of methods to classify positions into fishing activities (script 'Rufino_2023_ping_rate.Rmd'), using:

1. Preliminary plots
2. Error measures estimated with the confusion matrix;
3. Fishing effort indicators.

Once the example data sets are properly functional, these can be directly interrogated using the adapted script. The framework was built and computed, but it still requires further work to apply it to full datasets for statistical analyses, and thus the results are not presented in the current report. Figure 3 shows an example of the preliminary plots produced for one of the fishing trips, where we can clearly observe the effects of varying ping rate on visual interpretation of tracks and speed profiles. The results obtained by the functions, are shown in Table 3, whereas an example plot of some error measures and fishing effort indicators, is shown in Figure 4.

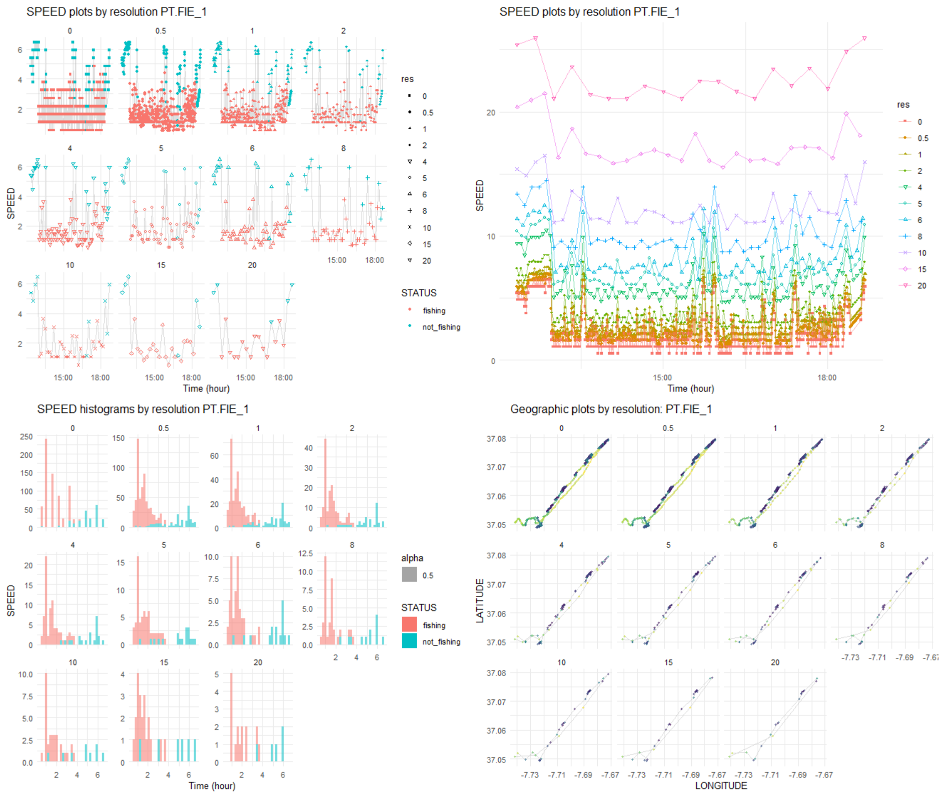


Figure 3. Effect in vessels tracks when changing temporal resolution (30 secs up to 20 min considered), using one example boat trip. Upper left panel: speed versus time plots for different temporal resolution; upper right panel: speed versus time, where a constant was added to speed for each temporal resolution level to improve visualization; lower left panel: speed histograms; lower right panel: geographic plot of the boat track.

Table 3. Example of the performance metrics, error measures, and fishing indicators obtained for some of the boat trips studied.

Example of the error table output, for different boat trips

country	boat.trip	res	GEAR	TP	FP	FN	TN	N	per.pos	class.error	Accuracy	Precision	Sensitivity.recall	Specificity	F1.score	AUC	fishing.valid.s	fishing.fix.th.s
DK	ID_1_759	0	GNS	193	446	0	118	757	25.495	58.917	41.083	30.203	100.000	20.922	46.394	60.461	0 secs	6418 secs
DK	ID_3_3229	2	GNS	167	66	0	158	391	42.711	16.880	83.120	71.674	100.000	70.536	83.500	85.268	20040 secs	27960 secs
DK	ID_9_7377	6	GNS	32	31	0	54	117	27.350	26.496	73.504	50.794	100.000	63.529	67.368	81.765	11520 secs	22680 secs
FR	NAVIRE_0075_18529291	1	NT	1244	3402	16	1548	6210	20.290	55.040	44.960	26.776	98.730	31.273	42.127	65.001	75600 secs	278760 secs
FR	NAVIRE_0075_18569377	20	NT	56	119	1	19	195	29.231	61.538	38.462	32.000	98.246	13.768	48.276	56.007	68400 secs	210000 secs
IT	VE_00003_40	8	FPO	19	7	0	20	46	41.304	15.217	84.783	73.077	100.000	74.074	84.444	87.037	9120 secs	12480 secs
IT	VE_00003_45	10	FPO	22	7	0	15	44	50.000	15.909	84.091	75.862	100.000	68.182	86.275	84.091	13200 secs	17400 secs
PT	CAR_6	4	DRB	53	3	0	3	59	89.831	5.085	94.915	94.643	100.000	50.000	97.248	75.000	12720 secs	13440 secs
PT	PER_5	0	DRB	677	120	0	41	838	80.788	14.320	85.680	84.944	100.000	25.466	91.859	62.733	18077 secs	20862 secs
PT	VE_00002_5	15	FPO	11	0	0	13	24	45.833	0.000	100.000	100.000	100.000	100.000	100.000	100.000	9900 secs	9900 secs
PT	VE_00003_4	5	FPO	46	2	22	62	132	51.515	18.182	81.818	95.833	67.647	96.875	79.310	82.261	20400 secs	14400 secs

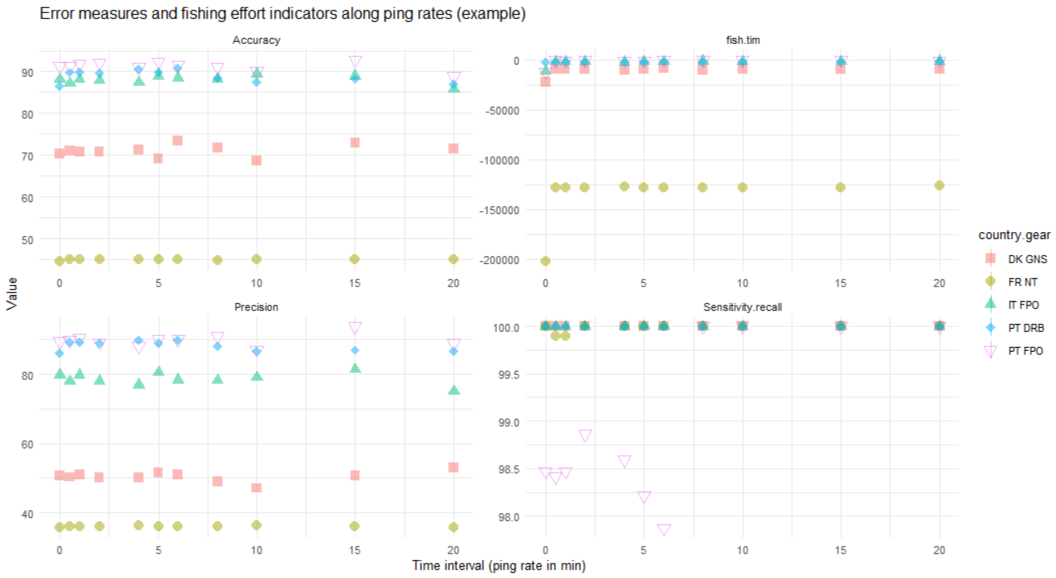


Figure 4. Change in three error measures and one fishing effort indicator as an effect of temporal resolution, for some of the example case studies.

4.2 Temporal resolution and EU variables

To recommend the optimal temporal resolution (ping rate) to estimate the EU map variables, several aspects should be considered (listed below), and these are of varying significance depending on the metier of interest. If a generalisation is to be made, a conservative recommendation of a 30 secs ping interval for all fisheries would enable estimation of EU MAP variables (as to obtain a 1 min interval the ping rate should be 30 sec).

Technologies that permit system administrators to easily change the ping rate or provide a lower/higher time interval if required, are always preferable and allow for greater flexibility and future proofing. If a dataset has a higher resolution, it is easy to aggregate/downsample it to a lower one, but the opposite (interpolation between points) is less reliable.

To define the required ping frequency:

1. It is essential to know the variety of fishing trips and fishing events duration, to get enough data points per fishing trip/event to adequately model fisher's behaviour.
2. How many successive trips fishers may do per day. If the turn-around time between consecutive trips can be short the ping rate needs to be short enough to capture one trip ending and another starting.
3. The complexity of the fishing trips tracks. For example, if the fishing track is complex (not straight) and the ping interval is high, we may not identify all the different phases of a fishing trip and therefore not properly quantify the entirety of the fishing effort.
4. How many fishing events there are within one trip. If the ping interval is high, fishing events may be missed if the time interval between fishing events is small, i.e. the result would be two fishing events merged into one fishing event.
5. To calculate soaking time for passive gears, more data points are required to ensure there is a good number of data points generating spatial overlap between setting and hauling tracks.

The effectiveness of interpolating lower ping rates to a higher temporal resolution will depend on the complexity of the fisheries tracks (i.e. gear, metier), and the duration of the fishing events. For example, if the gear operates over a straight line, this should be not too problematic, but if it operates doing circles, much of the effort might be lost and underestimated.

In terms of the analysis and application of models to data points, it is possible to easily calculate a suitable ping rate, for example, if the minimum trip duration is 2h and the analysis/model would require at least 50 datapoints (pings) to apply any robust statistical or ML analysis, then, it would be necessary to have a ping rate of 1 ping for every 3.6 minutes : 2 * 60 min = 120 min / 50 pings = 3.6 minutes as the minimum ping rate.

Thus, it is concluded that the quality of most EU map variables estimated, will depend on the frequency of ping rate used and characteristics of each metier.

5 An overview of data available for describing the SSF using ICES VMS/Logbook, EU FDI and Global Fishing Watch data

ToR b) Using data already available:

i) Analyze the availability of VMS and logbook data submitted to ICES that corresponds to small-scale fisheries in EU waters

ii) Provide an overview of the extent of small-scale fisheries in EU waters using the FDI database, the corresponding extent of bottom contacting fishing gear and provide recommendations for data collection and determination of fishing effort for the most impacting gear(s) to the seafloor

iii) Combine the previous datasets (ii) and iii) to quantify coverage of small-scale fishing fleet in EU waters

The ToRs are specified to give input to part of an advice request from DG Environment to ICES:

"Provide analyses of the spatial and temporal distribution and intensity of fishing using bottom-contacting fishing gears. This should include using data from VMS and Logbooks to provide a more comprehensive analysis and coverage of vessels lacking VMS (i.e. <12m in length, 'day' vessels >12m), be supplemented with data from other sources (e.g. AIS, Global Fishing Watch, national initiatives, other projects) where possible. The data should cover at least the most recent 6-year period, but could extend further back where data are available, and be analyzed per métier. The gaps in the data used (by area, by vessel type) should be clearly documented to estimate the likely level of under-reporting of fishing effort in the analyses."

ICES provided access to VMS and Logbook data for vessels less than 15 m submitted for the ICES VMS/Logbook data call. From the EU FDI (Fisheries Dependent Information) data call, public data available with vessel length categories were used. In addition, and thanks to participation from Global Fishing Watch to the workshop, AIS data were available to the group as well. To focus the work within the WKSSFGEO2, the advice request was taken into consideration. In part of the analysis, we focused on mobile bottom-contacting gears, knowing that some gears that are considered passive also have a bottom impact, but this is not defined yet. The gear groups are defined as Mobile bottom-contacting gears (MBCG), Passive gears, Pelagic trawls and Unknown.

5.1 Data sources

5.1.1 Description of VMS and logbook data as collated by ICES

Fishing logbooks only have to be filled in by vessels longer than 10 meters, or longer than 8 meters in most parts of the Baltic Sea. In the logbooks, some gear information is specified, including mesh size and selection devices. The implementation is different among EU MS, in some cases the logbook needs to be specified by haul, in others by day and main ICES rectangle. In some MS the information on e.g., length of set nets is mandatory, while it is optional in other MS.

The exact fishing position does not have to be entered in the logbook for the hauls in most EU waters, it is sufficient to indicate the so-called ICES statistical rectangles, which have a size of 1*0.5 degrees, which corresponds to 30x30 nautical miles at 60°N. At the moment, this represents the highest spatial resolution data available of fishing activities by vessels that do not have to be equipped with VMS in EU waters.

For control purposes, all fishing vessels above 12 meters of length (above 15 meters length until 2012 provide geographical position data via satellite to a central receiving station every two hours. The data of the so-called VMS (Vessel Monitoring System) contain, in addition to the position information (longitude and latitude), the direction and speed of the vessel at the time of data transmission. However, the VMS data do not contain any information about the activity (e.g., fishing or steaming) at the time of the report.

Member states collect VMS data at national level with different temporal resolutions (a minimum resolution of two hours is required for EU vessels fishing in EU waters under the remit of the EU Common Fisheries Policy (CFP). The minimum imposed time interval of two hours is however not capable of capturing vessels movements at a fine scale. The coarse temporal resolution of two hours affects the spatial resolution of VMS data (e.g., a vessel moving at 25 knots in straight line can cover up to 90 km in 2 hours, likewise a vessel moving in straight line at 2 knots covers a distance of 7 km in 2 hours). Spatial granularity and confidentiality issues force VMS and logbook data products to be calculated and disseminated at an aggregated level where the aggregated VMS data for the ICES VMS/Logbook data call is requested by c-squares of 0.05*0.05 degrees.

By combining the VMS data with logbook data, the fishing activity of vessels can be displayed with high spatial resolution. Using standardized procedures, the VMS and logbook data can be processed and intersected (Bastardie *et al.*, 2010; Hintzen *et al.*, 2012). This also includes the differentiation on the basis of speed using various methods and algorithms as to whether a fishing vessel is currently steaming or fishing at the respective reported position. The methods for identifying fishing activity from the VMS data varies between countries; therefore, there may be some country-specific biases that ICES cannot evaluate. Additionally, activities other than active towing of gear may have been incorrectly identified as fishing activity. This would have the effect of overestimating the apparent fishing intensity in ports and in areas used for passage.

VMS and logbook data are submitted by member states to ICES on aggregated (monthly) levels. The proportions of total landings (by weight) recorded by logbooks that are represented by VMS data increased in 2012 where the vessel length for which VMS was mandatory changed from larger than15 meters to larger than 12 meters.

The ICES VMS/Logbook data call contains two tables specified here: one with VMS data by 0.05*0.05 degrees c-square and one with ICES rectangle based logbook data. The logbook data contain a 'VMSenabled' field that indicates if the row specified in the logbook is covered in the VMS table and can be used to assess the coverage of VMS data compared to what is reported in logbooks.

5.1.2 Description FDI data (EU Fisheries Dependent Information)

FDI is an EU data call on Fisheries Dependent Information, issued by DG MARE and processed by JRC Fisheries Dependent Information - European Commission (europa.eu). The data call is for landings, discards, effort and fleet capacity, and contains information on vessel length groups and gears which can be used to illustrate the extent of fishing with mobile bottom-contacting gears for vessels below 12 meters by ICES areas, GSA areas and ICES rectangles.

In the FDI data call data are also requested for vessels without logbooks (<10 m), the sources of the information for the SSF are listed in FDI STECF-21-12 tables 3.1.4.1 and 3.1.5.1 and are based on SSF specific declarative forms, logbooks sales notes or surveys. The FDI data are disseminated publicly (Fisheries Dependent Information - European Commission (europa.eu)). In datasets aggregated by country some records are marked as confidential, but in datasets where the country information is not available, all data are available by ICES/GSA area or ICES statistical rectangle.

5.1.3 Description of Global Fishing Watch data (AIS)

AIS broadcasts a ship's position so that other ships are aware of its location, in order to avoid collision. The International Maritime Organization (IMO) started to mandate the use of AIS on vessels larger than 300 gross tonnes that travel internationally under the 2002 International Convention for the Safety of Life at Sea (SOLAS). Since 2014 Class A-AIS has been mandatory onboard EU fishing vessels longer than 15 m. Smaller fishing vessels can have Class B-AIS and operate AIS voluntarily.

The key factors that affect the completeness and accuracy of footprints derived from AIS analysis are its use and reception. AIS must be installed and broadcast in order to be detected. AIS reception is a measure of how likely it is for a vessel's AIS message to be received correctly by the existing network of satellites and terrestrial antennas placed along the world's coastlines. In regions of the world with high maritime traffic, satellite AIS signals can interfere with each other, which reduces the reliability of S-AIS. Terrestrial AIS is more accurate since the messages are VHF band broadcasted but the range is limited to 120 nm maximum and 50 nm as average.

A recent study by FAO and Global Fishing Watch found that in Mediterranean waters, almost 100 percent of EU vessels over 15 meters use AIS. However, AIS captures mostly trawlers and purse seiners and often fails to capture other gears that are commonly used by smaller vessels, such as gillnets or longliners.

Besides the direct use of ICCAT and EU registries the fishing vessels analyzed in this report were also chosen based on the Global Fishing Watch database of fishing vessels. The fishing database is defined in Kroodsma *et al.* (2018) and includes fishing vessels based on registry database information or as defined by a convolutional neural network. The most commonly transmitted fishing vessel identity information such as name and IMO on AIS were used in this analysis, while the vessel flag was identified from a combination of registry and AIS transmission records.

For this report Global Fishing Watch AIS data were filtered to only fishing vessels present in the European Fleet Register. Thus, countries like Norway and Iceland are excluded from this analysis.

5.2 Data issues

To standardize the analysis across the different data sets, the following decisions and grouping were made:

- **Countries**: The analysis only contains data from EU countries. Therefore, data from e.g. Norway and Iceland submitted to the ICES VMS/Logbook data call were excluded. Data submitted by UK was included, as they were member of EU in part of the period (2009–2021). In the ICES Logbook data submitted for the ICES VMS data call, data from Portugal and Lithuania were removed from the analysis due to inconsistencies across years, and potential errors.

- Vessel length groups:

  FDI: The vessel length groups submitted in the data call are for the Mediterranean and Black Sea: VL0006, VL0612, VL1218, VL1824, VL2440, VL40XX. For all other areas the vessel length groups are VL0010, VL1012, VL1218, VL1824, VL2440, VL40XX. In the FDI data call the vessel length categories don't split at 15 m, making direct comparison with ICES VMS logbook data provided for vessels less than 15 m difficult.

  ICES VMS/Logbook data call requests data to be submitted with the following vessel length groups: VL0006, VL0608, VL0810, VL1012, VL1215, VL1518, VL1824, VL2440, VL40XX. These vessel length categories were introduced for the data call in 2022, and for the countries that didn't submit data for that data call, older data are available with the old vessel length codes: <8, 8–10, 10–12, 12–15. There are also data with the category <12. In the Portuguese VMS data from 2010 and 2011 the category <12 is present, which has been transformed to VL1012. This is 76 points in 2010 and 52 points in 2011

- Gear groups:
  - MBCG (mobile bottom-contacting gears) contain following gear codes: DRB, HMD, OTB, OTT, PTB, TBB, SVB, SDN, SV, SB, SSC
  - Pelagic trawl contains following gear codes: OTM, PTM, PS
  - Passive gears contain following gear codes: FPN, FPO, GN, GND, GNS, GTN, GTR, LHM, LHP, LLD, LLS, LTL, LX
  - Unknown contain following gear codes: MIS, NK

Global Fishing Watch data gear groups:

For the Global Fishing Watch AIS data, the gear is not available from the logbooks, but another gear classification method is used, which can be found here. For more details Kroodsma *et al.* 2018 can be consulted. It was not possible to make exactly the same gear classification as was done for the FDI and ICES VMS/Logbook, as the trawlers in the GFW do not split between demersal and pelagic trawlers. It was also investigated if the EU fleet register gears could be used instead, but it did not seem as a better alternative than using the GFW gear classification. For vessels less than 15 m, very few are using pelagic trawls, so they are grouped in the MBCG. The seiners could both be demersal seiners and pelagic purse seiners, and for this purpose they were grouped in the pelagic trawl category. This should be kept in mind when comparing the figures from the data sources. The GFW gear classification algorithm will be updated within the current year to classify OTM and OTB separately which would be relevant for this analysis. For this report, gear was classified as the following for Global Fishing Watch data:

- MBCG (mobile bottom-contacting gears) contain the following code in Global Fishing Watch vessel class: trawlers and dredge_fishing
- Pelagic trawl contains the following code in Global Fishing Watch vessel class: seiners
- Passive gear: drifting_longlines, set_gillnets,fixed_gear, set_longlines, trollers, pole_and_line, pots_and_traps
- Unknown contain the following code in Global Fishing Watch vessel class: fishing

Time-series: For overview figures of development in the time-series in the data available, the full time-series for each data type is displayed in the analysis below. The time-series available was not the same from the different data sources available. For more detailed plots, data are displayed only for the year 2021.

- From ICES VMS/Logbook data call, the time-series 2009–2021 was available
- From the public FDI data time-series 2013–2021 was available
- From Global Fishing Watch AIS data time-series 2016–2021 was available

5.3 Analysis - overview of SSF in EU waters

5.3.1 Effort per vessel length group

Figure 5 and Figure 6 below show the total fishing days reported for the FDI data call for the years 2013–2021 in the FAO area 27 (Northeast Atlantic) and GSA (Mediterranean and Black Sea) per vessel length group. The results show that both regions have a major fraction of the fishing effort (fishing days) coming from the vessels below 12 m.

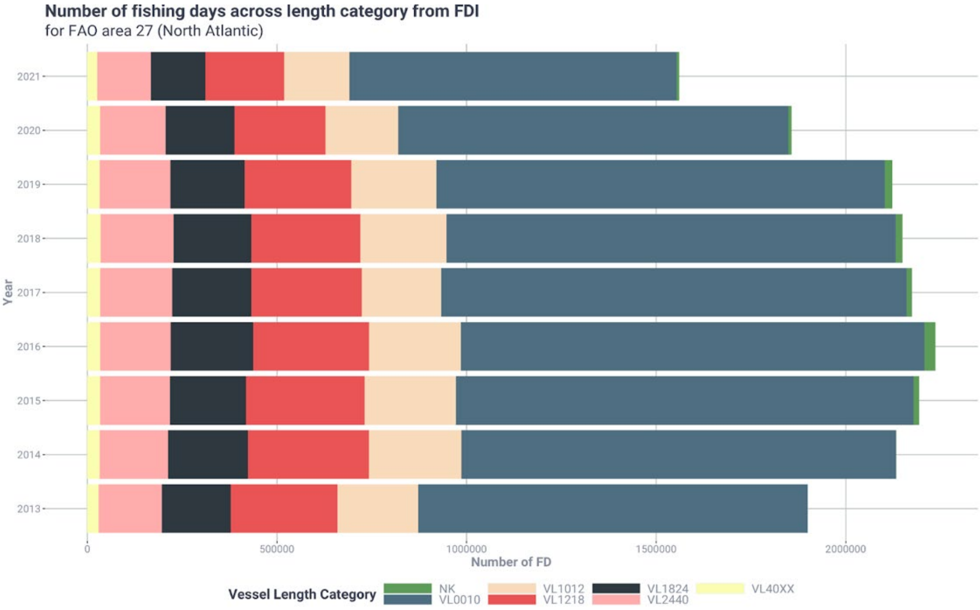


Figure 5. Total fishing days reported in FAO area 27 (Northeast Atlantic) in the FDI data call per year and vessel length group.

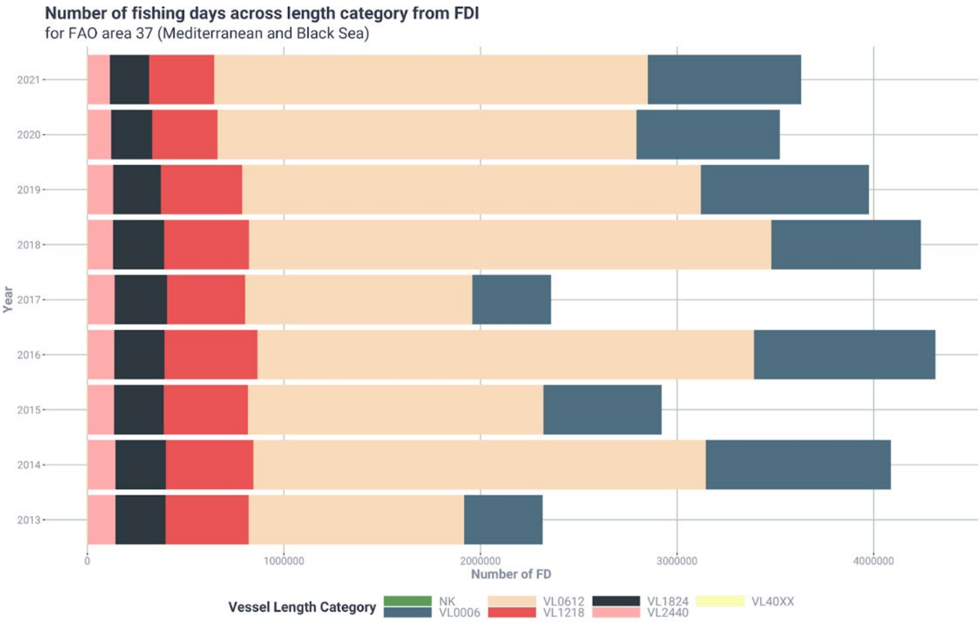


Figure 6. Total fishing days reported in FAO area 37 (Mediterranean and Black Sea) in the FDI data call per year and vessel length group.

Figure 7 and Figure 8 below show data reported for vessels below 15 m for the ICES VMS/Logbook data call in 2009–2021 covering the Northeast Atlantic per vessel length group. The number of fishing days reported in the logbooks look consistent over the years, while there is an increase in the fishing hours reported in VMS data, showing the change of vessel length where VMS was mandatory from 15 m to 12 m in 2012, and which took a few years to be fully implemented.

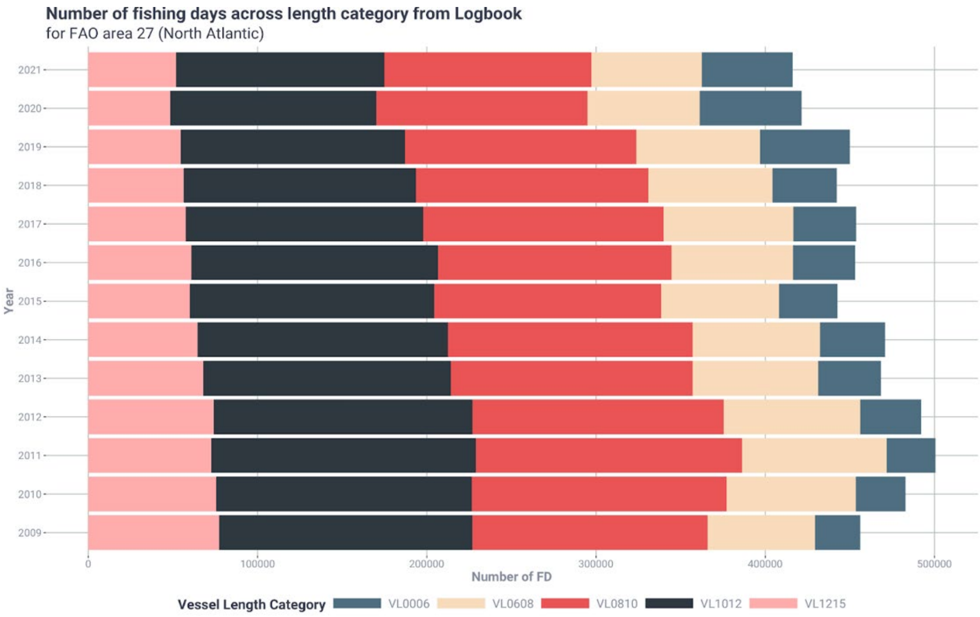


Figure 7. Total fishing days from logbooks reported in ICES VMS/Logbook data call per year and vessel length group, for vessels less than 15 m, for EU countries (including UK) but excluding data from Lithuania and Portugal.

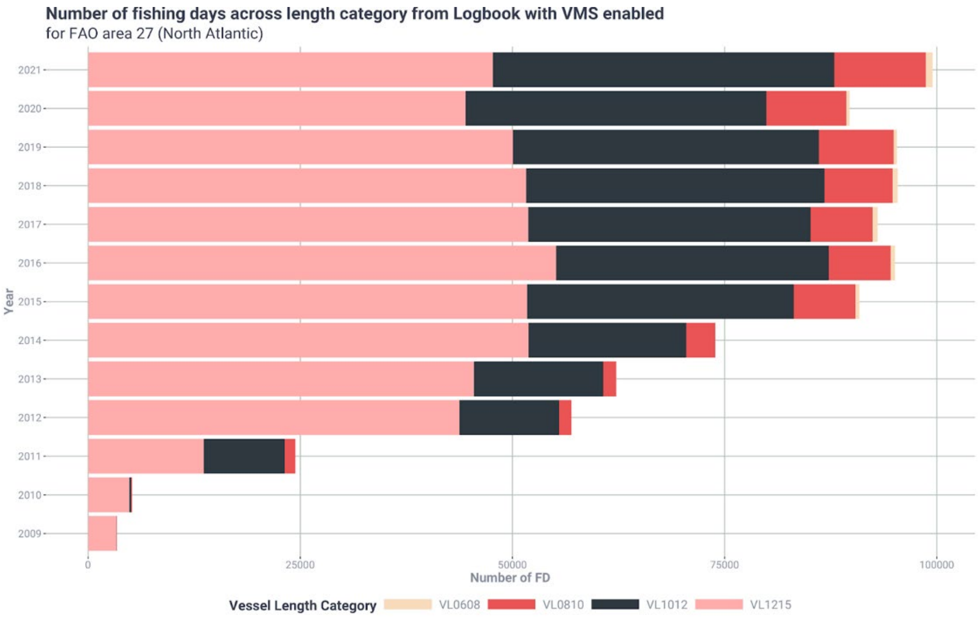


Figure 8. Total fishing hours from VMS reported in ICES VMS/Logbook data call per year and vessel length group, for EU countries (including UK) vessels less than 15 m.

Figure 9 and Figure 10 below show the total fishing days estimated from the Global Fishing Watch AIS data for the years 2016–2021 in the FAO area 27 (Northeast Atlantic) and GSA (Mediterranean and Black Sea) per vessel length group. During the period there is an increase in the available AIS data across all length groups, which is probably a result of more vessels using AIS, and most data are available in the vessel length group 12–15 m.

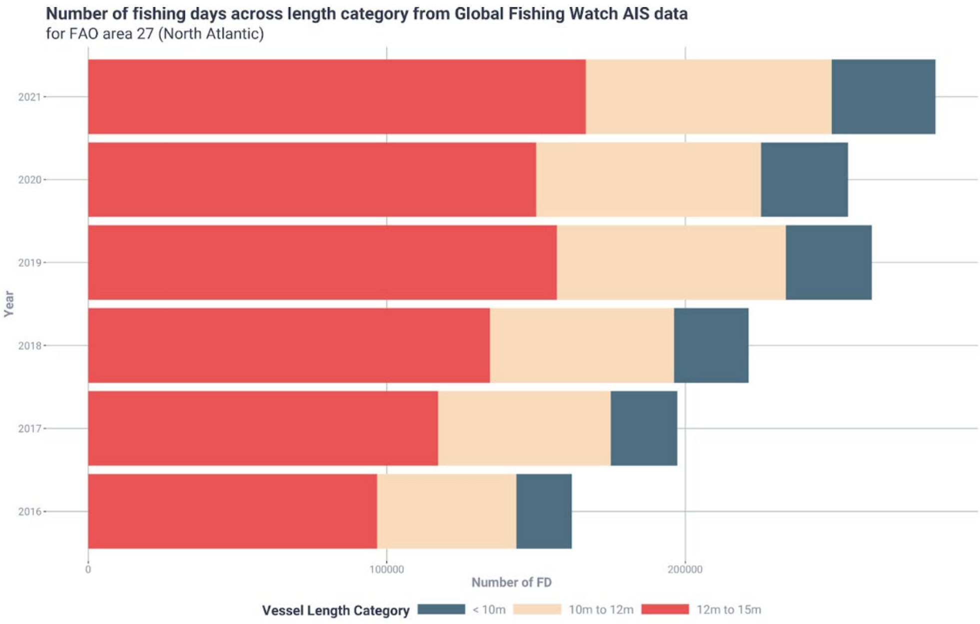


Figure 9. Total fishing days from Global Fishing Watch AIS data in FAO area 27 (Northeast Atlantic) per year and vessel length group, for EU countries (including UK) vessels less than 15 m.

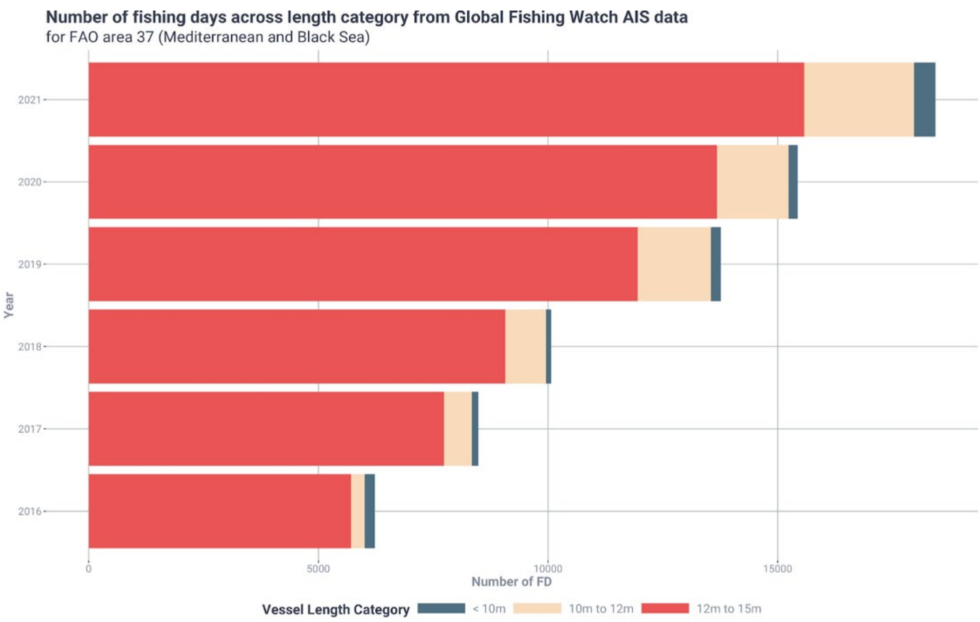


Figure 10. Total fishing days from Global Fishing Watch AIS data in FAO area 37 (Mediterranean and Black Sea) per year and vessel length group, for EU countries (including UK) vessels less than 15 m.

5.3.2 Effort per Gear group

Figure 11 and Figure 12 below show the total fishing days reported for the FDI data call for the years 2013–2021 in the FAO area 27 (Northeast Atlantic) and GSA (Mediterranean and Black Sea) for all vessel length groups per gear group. In both regions, but especially in the Mediterranean and Black Sea the major part of the fishing effort is from passive gears.

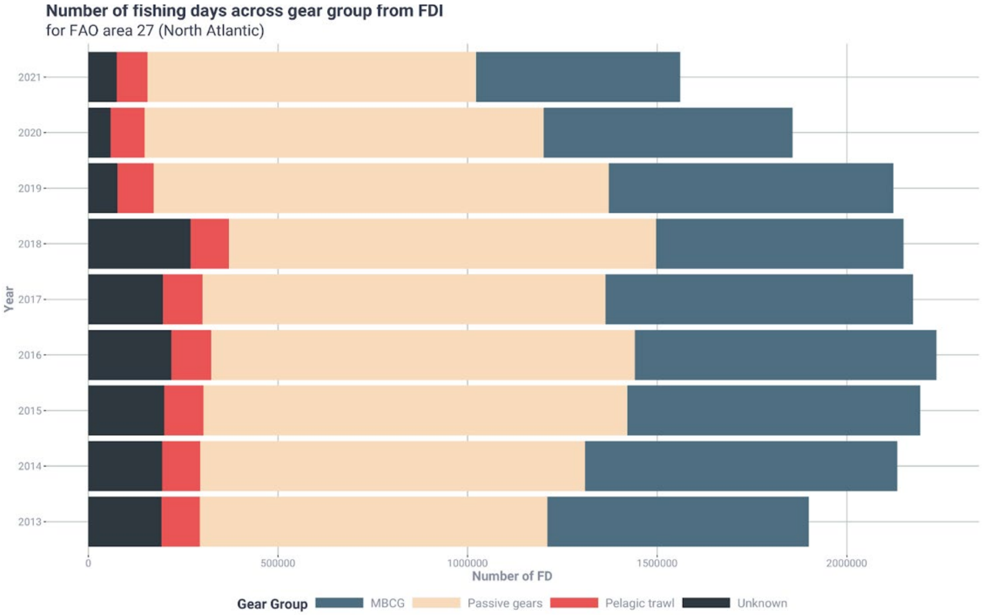


Figure 11. Total fishing days reported in FAO area 27 (Northeast Atlantic) in the FDI data call per year and gear group for all vessel lengths.

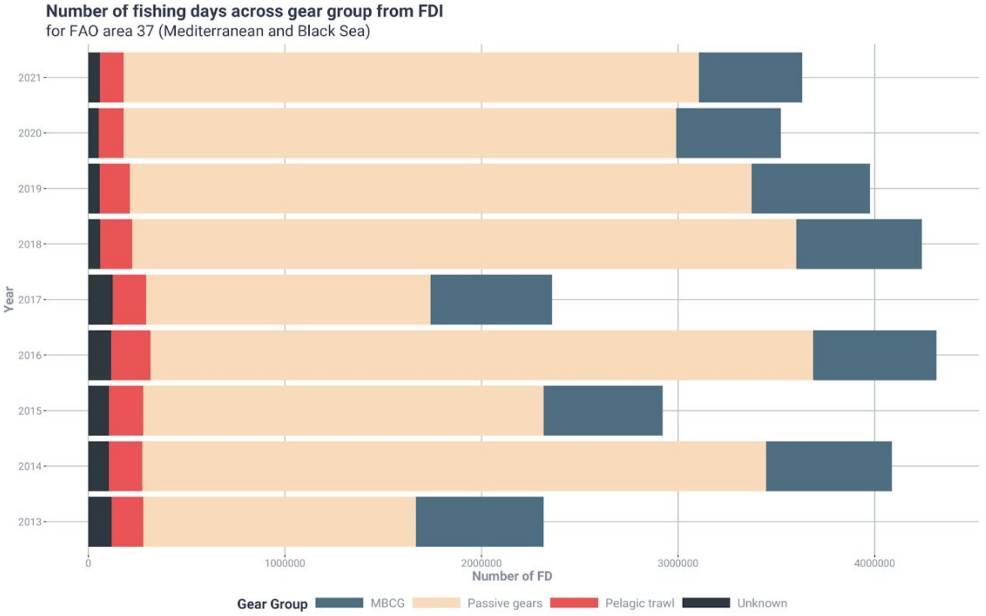


Figure 12. Total fishing days reported in FAO area 37 (Mediterranean and Black Sea) in the FDI data call per year and gear group for all vessel lengths.

The two Figures 13 and 14 below show data reported for vessels below 15 m for the ICES VMS/Logbook data call in 2009–2021 covering the Northeast Atlantic per gear group. In the vessels below 15 m reported in the logbooks, the major part of the effort is from passive gears, while the major part of the effort reported in the VMS is from mobile bottom-contacting gears.

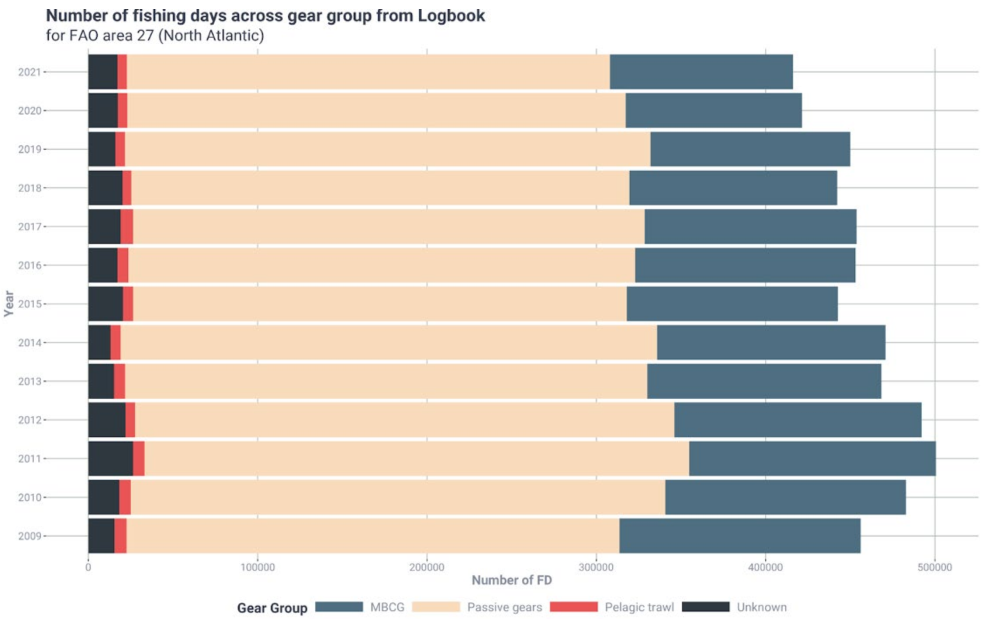


Figure 13. Total fishing days from logbooks reported in ICES VMS/Logbook data call per year and gear group, for vessels less than 15 m, for EU countries (including UK) but excluding data from Lithuania and Portugal.

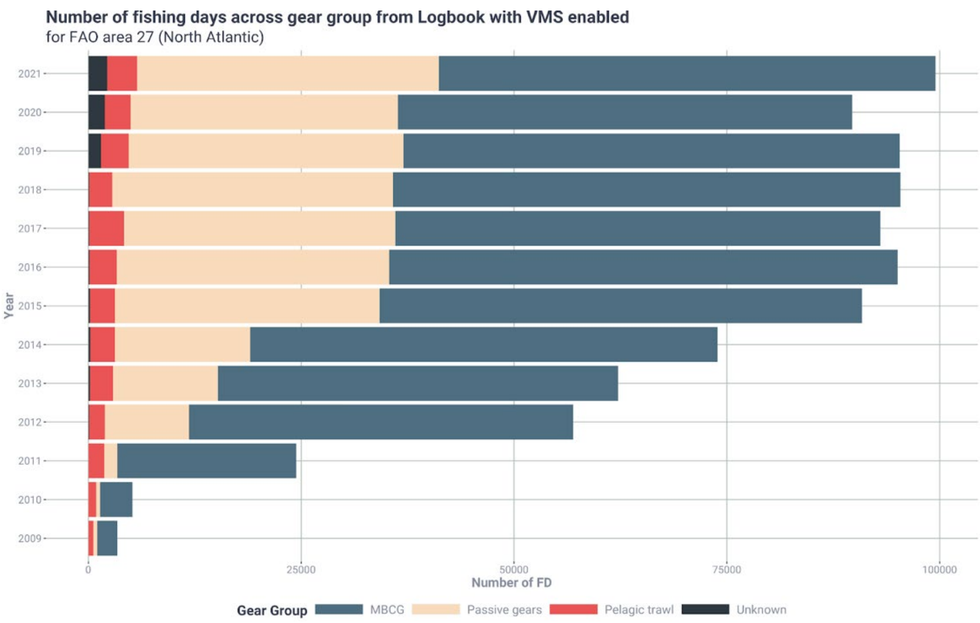


Figure 14. Total fishing hours from VMS reported in ICES VMS/Logbook data call per year and gear group, for EU countries (including UK) vessels less than 15 m.

Figure 15 and Figure 16 below show the total fishing days estimated from the Global Fishing Watch AIS data for the years 2016–2021 in the FAO area 27 (Northeast Atlantic) and GSA (Mediterranean and Black Sea) for vessels less than 15 m per gear group. In both regions, there is effort from both mobile bottom-contacting gears and passive gears.

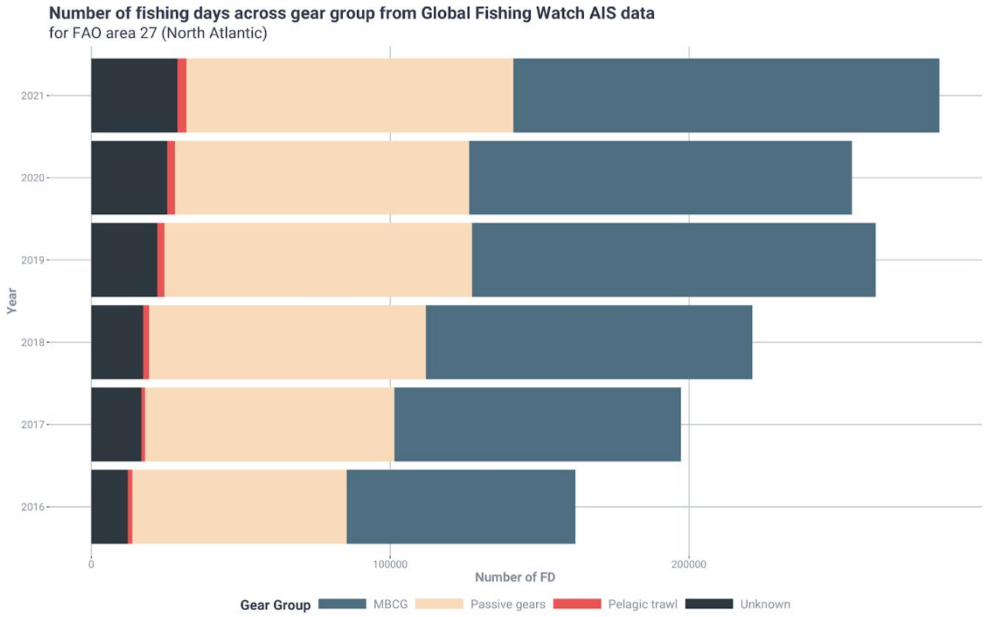


Figure 15. Total fishing days from Global Fishing Watch AIS data in FAO area 27 (Northeast Atlantic) per year and gear group, for EU countries (including UK) vessels less than 15 m.

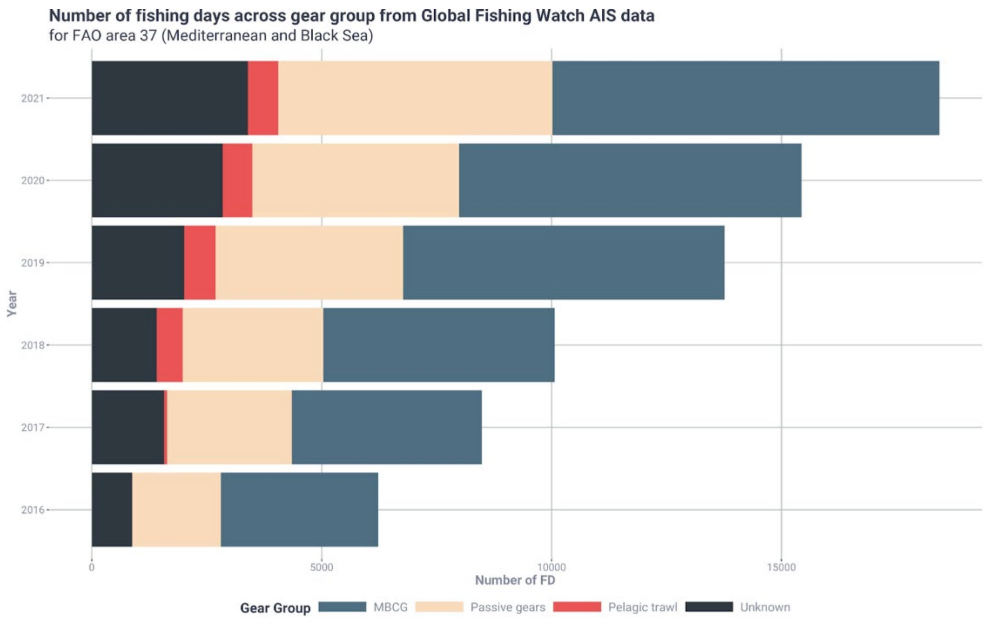


Figure 16. Total fishing days from Global Fishing Watch AIS data in FAO area 37 (Mediterranean and Black Sea) per year and gear group, for EU countries (including UK) vessels less than 15 m.

Based on FDI data from area 27 (Northeast Atlantic), Figure 17 gives an overview of fishing days per gear group, vessel length range and area in the year 2021. To reduce the number of plots in this report, the year 2021 was chosen as the most recent year, present in all available data sources. Note that the x-axis are different for each plot. Especially area 27.9.A have a very high effort from vessels less than 10 m, but also a high effort from passive gears in the Baltic Sea subdivisions is apparent. Figure 18 shows the same for area 37 (Mediterranean and Black Sea) which is in general dominated by passive gears.

Figure 17. Total fishing days from FDI data call area 27 (Northeast Atlantic) for the year 2021, per gear group, vessel length range and area.

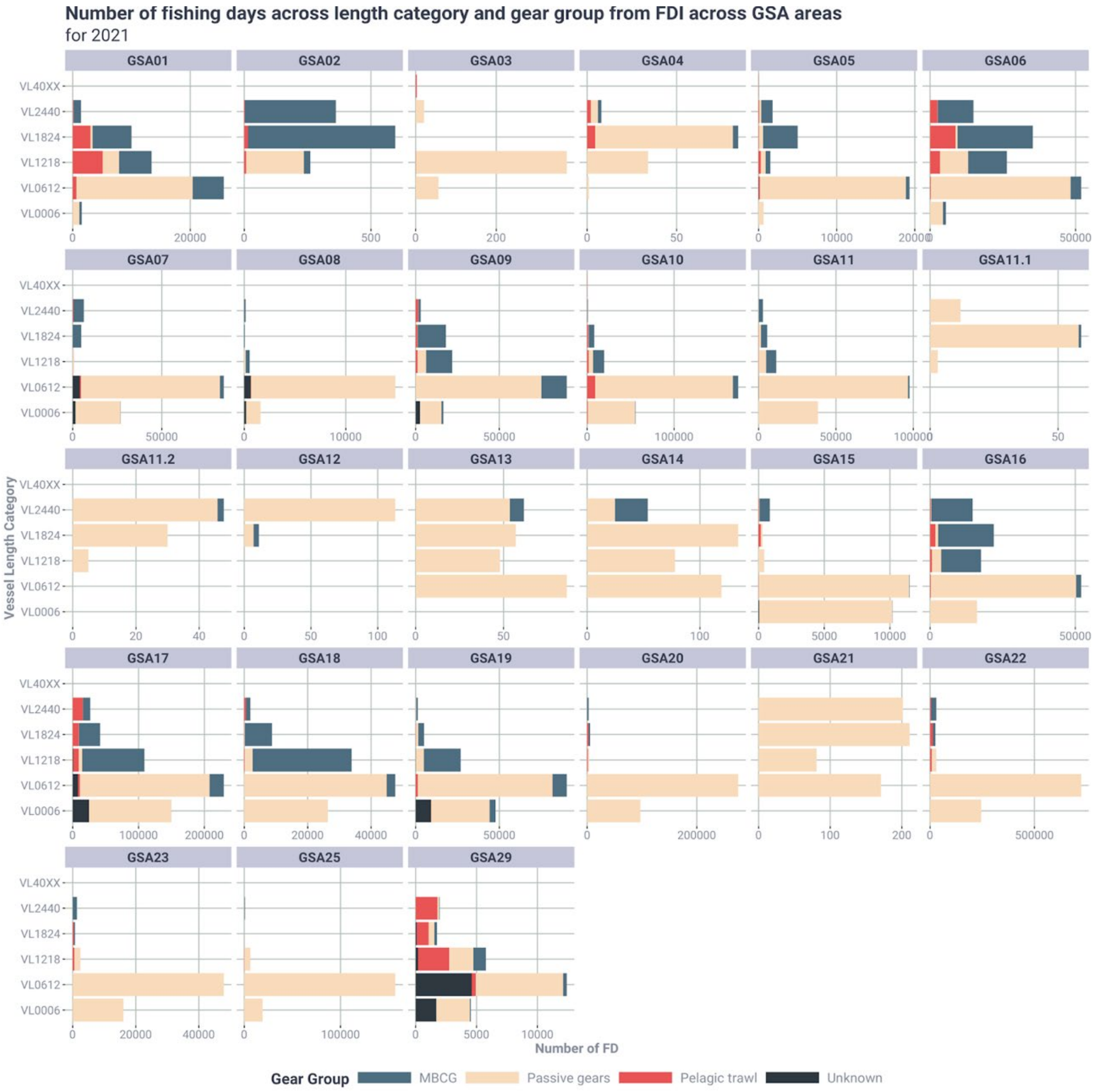


Figure 18. Total fishing days from FDI data call area 37 (Mediterranean and Black Sea) for the year 2021, per gear group, vessel length range and subregion.

Figure 19 and Figure 20 shows the fishing days based on Global Fishing Watch AIS data by ICES area, gear group and vessel length group for area 27 (Northeast Atlantic) and area 37 (Mediterranean and Black Sea).

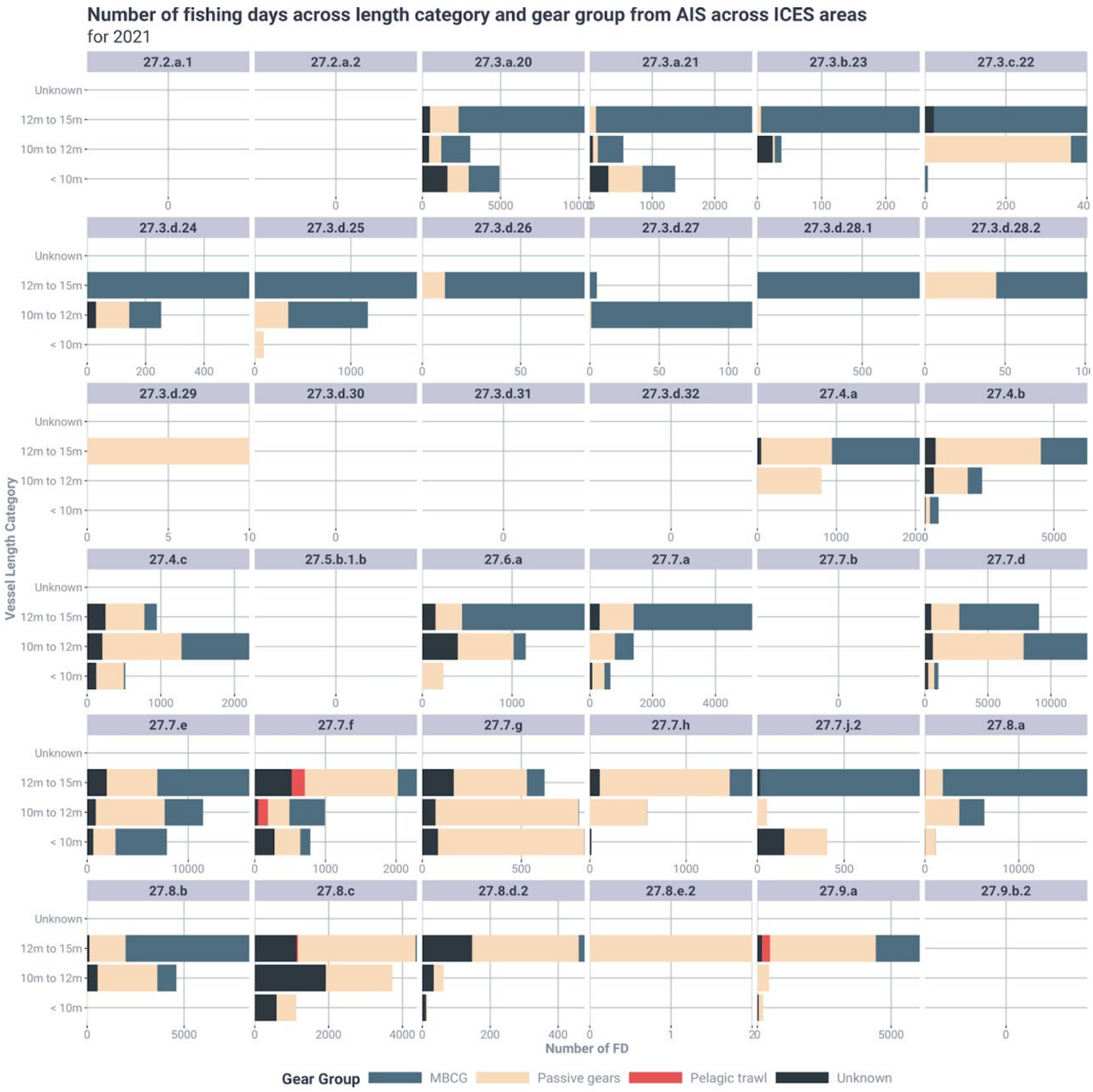


Figure 19. Total fishing days from Global Fishing Watch AIS data call area 27 (Northeast Atlantic) for the year 2021, per sub-region and gear group.

Figure 20. Total fishing days from Global Fishing Watch AIS data call area 37 (Mediterranean and Black Sea) for the year 2021, per sub-region and gear group.

5.4 Comparing Fishing days across different data sources

The logbook data in the ICES VMS/Logbook data call has a field called VMSenabled, indicating if the row of data is covered by VMS data. Figure 21 indicates for 2021 the proportion of fishing days in the logbooks that are VMS enabled by vessel length category and gear group. For the passive gears, a larger proportion of the effort doesn't have VMS, for the mobile bottom-contacting gears, the vessel length group 12–15 m is almost fully covered by VMS, at EU level we expect that the majority of the vessels under 12 m are not VMS enabled but there are some effort in the vessel length groups 8–10 and 10–12 m with mobile bottom-contacting gears with VMS that has been submitted for the ICES VMS/Logbook data call. Figure 22 show the VMS enabled field by year and vessel length group for the years 2009–2021. It is clear that over the years, the vessel length group 12–15 has an increased coverage by VMS.

Figure 21. Total fishing days from logbooks reported in ICES VMS/Logbook data call for 2021 showing the vmsEnabled field per vessel length range and gear group, for vessels less than 15 m, excluding data from Lithuania and Portugal.

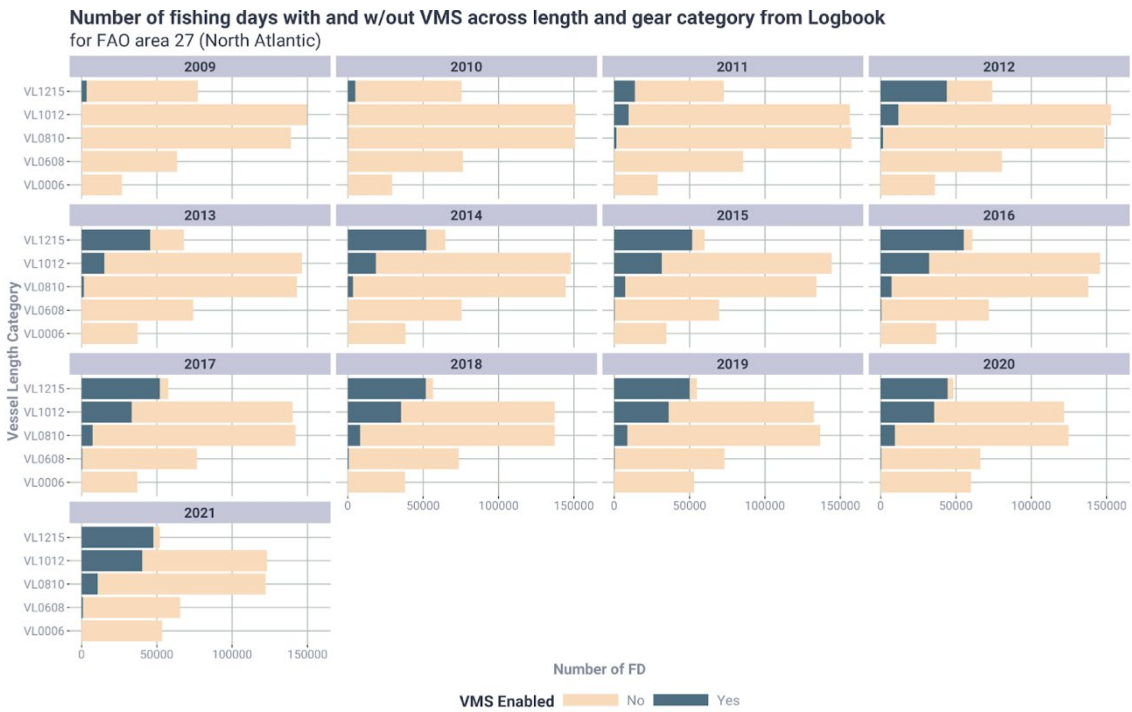


Figure 22. Total fishing days from logbooks reported in ICES VMS/Logbook data call showing the vmsEnabled field per year and vessel length range, for vessels less than 15 m, excluding data from Lithuania and Portugal.

Figure 23 show by area the total fishing days from the different data types AIS (in blue), FDI (in red) and ICES logbooks (in yellow). Note that the fishing days from the different data sources are stacked, so they don't sum up to the total fishing days per area and length category, but indicate the proportion of fishing days indicated in the different data sources for each category. Also note that for the FDI data the vessel length group is 12–18 instead of 12–15 as it is in the ICES logbook and Global Fishing Watch AIS data. In 2021, UK was not part of the EU FDI data call, and therefore the FDI effort is lower/missing in areas where the UK vessels are fishing. If the effort reported in the three data sources were equal, the proportion of each colour in each bar would be equal. It is clear from the figure, that the different data sources have different issues, and are difficult to compare.

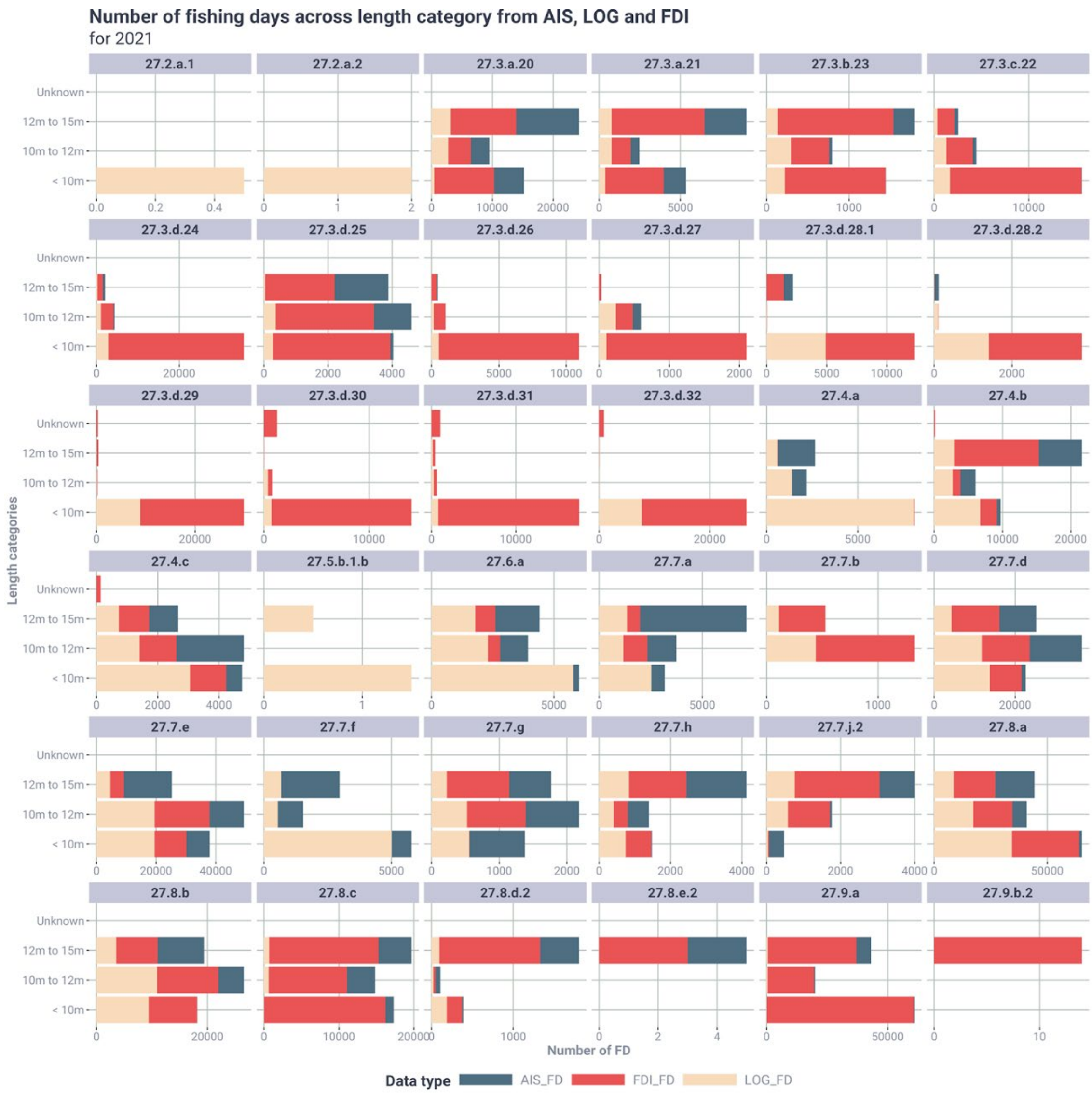


Figure 23. Total fishing days from different data type: AIS), FDI and logbook for different length category by ICES area. Note that for the FDI data the vessel length group is 12–18 instead of 12–15 as it is in the ICES logbook and Global Fishing Watch AIS data. Also note that UK data were not submitted for the EU FDI data call on 2021 data.

The table in Annex 3 compares the total fishing days for mobile bottom-contacting gears from the three data sources: Global Fishing Watch AIS, ICES logbook and FDI by ICES area for the year 2021 by the vessel length groups <10, 10–12 and 12–15 (note that for the FDI data, the vessel length group is 12–18). UK data has not been submitted to the FDI data call for 2021 data. The logbook fishing days from the ICES VMS/Logbook data call will often only have the effort reported in logbooks, meaning that the effort from vessels less than 10 m (8 m in the Baltic) is missing. In the data reported for the EU FDI data call, the effort from vessels without logbooks are reported, based on coastal logbooks, sampling or sales notes, where one sale note is assumed to be one fishing day, see FDI (STECF-21–12) report. As the AIS gear classification is not based directly from logbooks, the classification on the MBCG group is more uncertain, and also include pelagic trawlers, but as the analysis only contains vessels smaller than 15 m, there are few pelagic trawlers. The seiners are grouped in the pelagic trawl category, containing both demersal seiners and pelagic purse seiners, and therefore the demersal seine effort is missing in the MBCG from the AIS data for this analysis.

The tables in Annex 4 shows the percentage of fishing days from vessels below 12 m compared for mobile bottom-contacting gears for the year 2021 in the FAO area 27 (Northeast Atlantic) based on the FDI data. It is clear that in the area 9.a, there is a very high effort from vessels below 12 m with mobile bottom-contacting gears, giving the total of 44% of effort from MBCG coming from vessels below 12 m. The table for the Mediterranean and Black Sea is showing the same for FAO area 37 but giving the total of 14% effort from MBCG coming from vessels below 12 m.

The maps in Figure 24, Figure 25 and Figure 26 show the VMS data available from the ICES VMS/Logbook data call with mobile bottom-contacting gears by the vessel length groups <10 m (Figure 24), 10–12 m (Figure 25) and 12–15 m (Figure 26), summed over the years 2009–2021 in the left maps and only for 2021 in the maps to the right. There might be some classification errors as the map in Figure 25 show fishery with vessels 10–12 m on the continental slope which is not expected from vessels of this size. Figure 27 show maps from Global Fishing Watch AIS data by vessel length categories <10m, 10–12m and 12–15 m vessels using trawl in 2021.

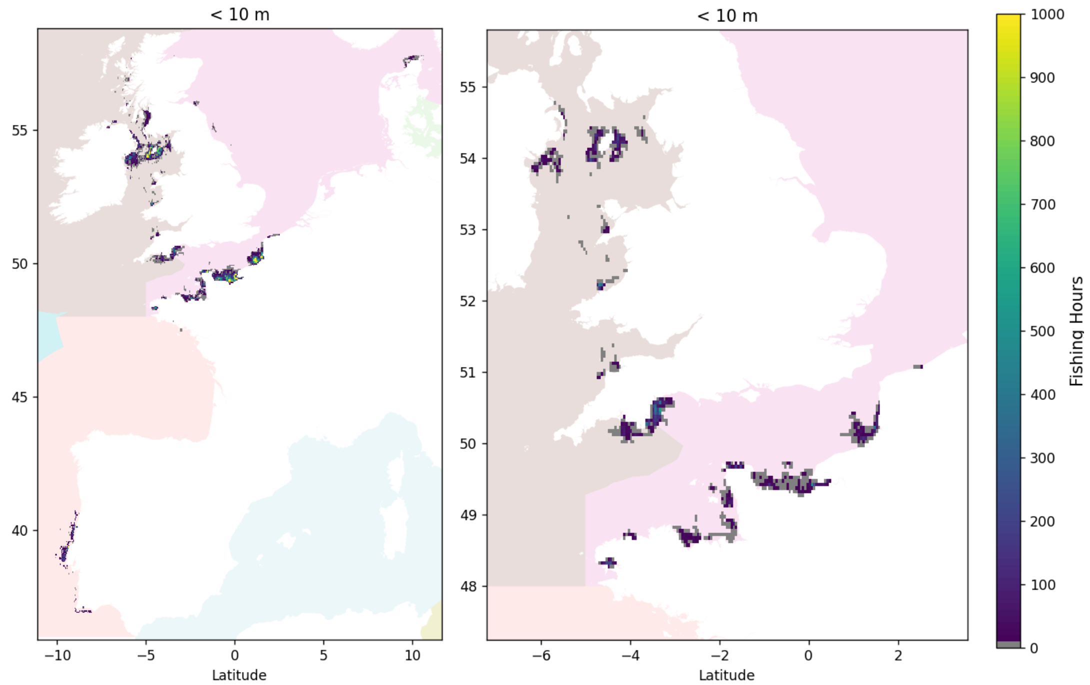


Figure 24. Map showing total fishing hours from VMS reported in ICES VMS/Logbook data call for vessels less than 10 m using mobile bottom-contacting gears, in the left map it is summed over the years 2009–2021, in the right map it is only for 2021.

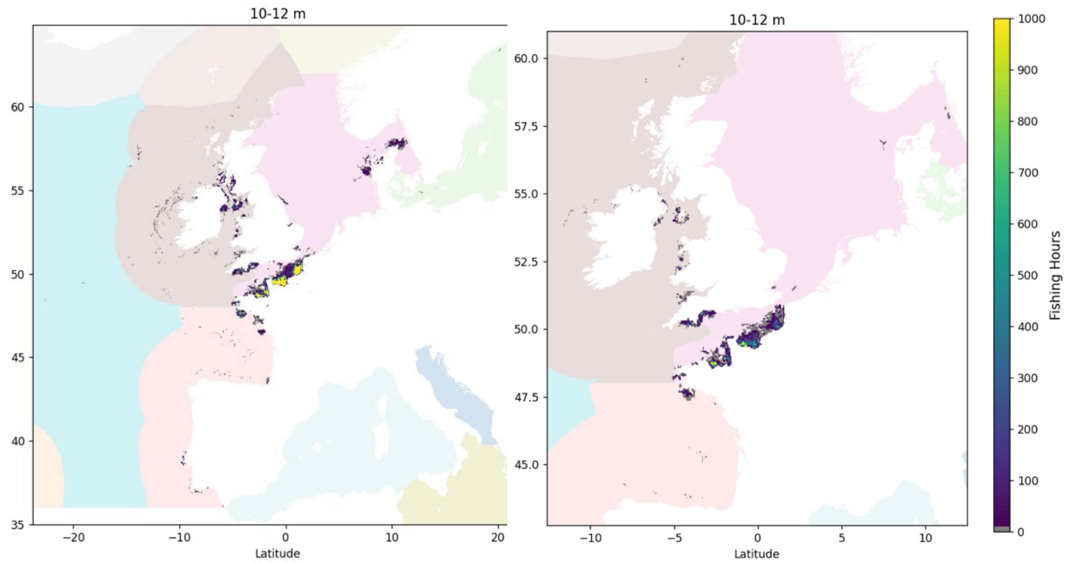


Figure 25. Map showing total fishing hours from VMS reported in ICES VMS/Logbook data call for vessels 10–12 m using mobile bottom-contacting gears, in the left map it is summed over the years 2009–2021, in the right map it is only for 2021.

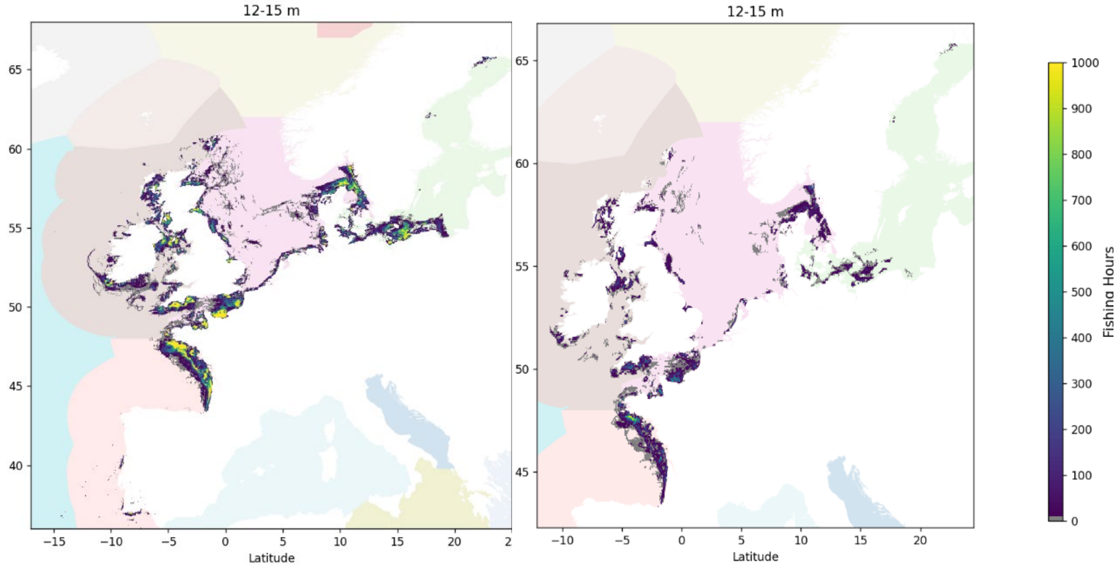


Figure 26. Map showing total fishing hours from VMS reported in ICES VMS/Logbook data call for vessels 12–15 m using mobile bottom-contacting gears, in the left map it is summed over the years 2009–2021, in the right map it is only for 2021.

Figure 27. Map showing total fishing hours from Global Fishing Watch AIS data by vessel length categories <10m, 10–12m and 12–15 m vessels using trawl in 2021.

The maps below in Figure 28 to Figure 31 by ICES ecoregion show a comparison of fishing days by ICES rectangle from the three data sources: Global Fishing Watch AIS, FDI and ICES logbooks. The plots are for all gears and are divided into the vessel length ranges <10, 10–12 and 12–15, but note that for the FDI data the vessel length group is 12–18 m.

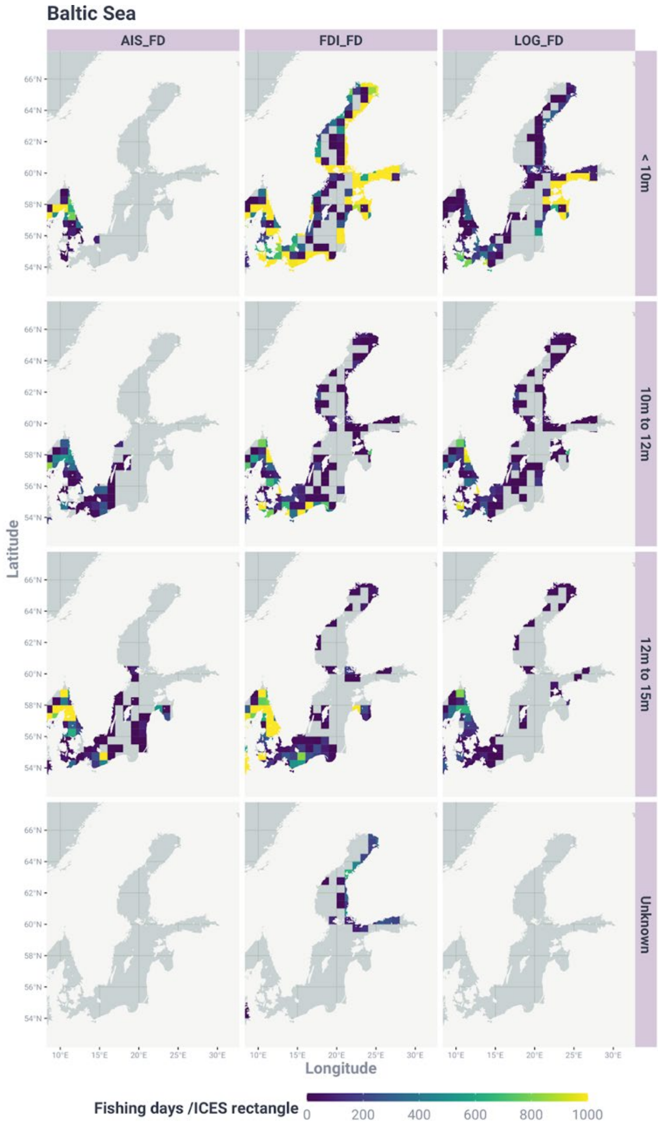


Figure 28. Maps by ICES rectangles showing the effort in fishing days from the three data sources Global Fishing Watch AIS, FDI and ICES VMS/Logbook data call for the ICES ecoregion Baltic Sea for the year 2021, for all gears. Note that for the FDI data, the vessel length group is 12–18 m.

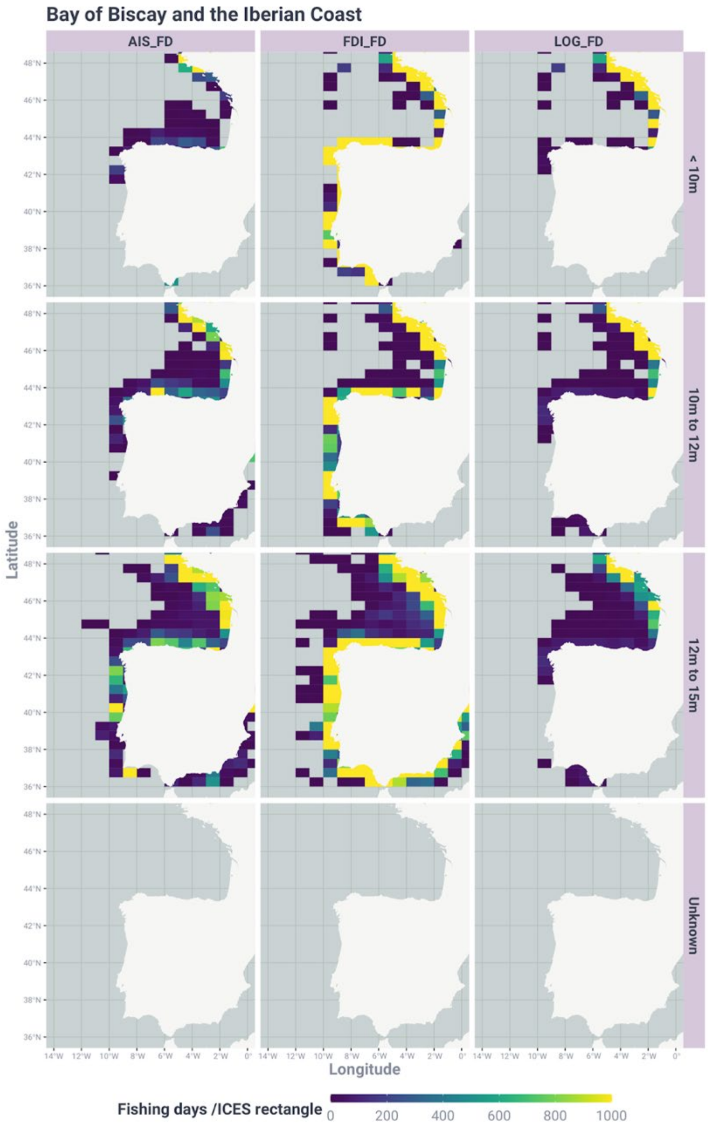


Figure 29. Maps by ICES rectangles showing the effort in fishing days from the three data sources Global Fishing Watch AIS, FDI and ICES VMS/Logbook data call for the ICES ecoregion Bay of Biscay and the Iberian Coast for the year 2021, for all gears. Note that for the FDI data, the vessel length group is 12–18.

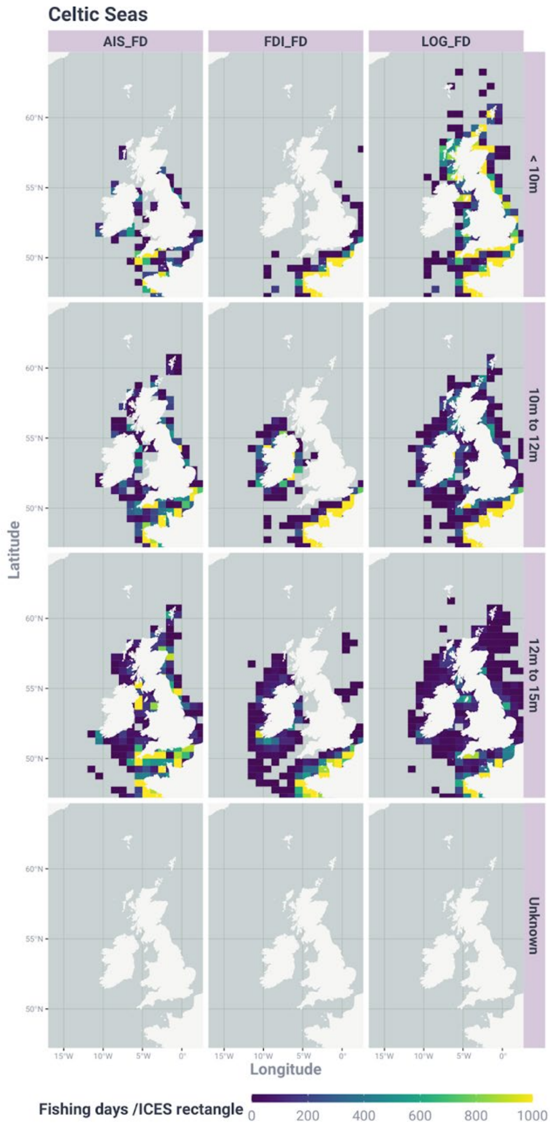


Figure 30. Maps by ICES rectangles showing the effort in fishing days from the three data sources Global Fishing Watch AIS, FDI and ICES VMS/Logbook data call for the ICES ecoregion Celtic Seas for the year 2021, for all gears. Note that for the FDI data, the vessel length group is 12–18 m.

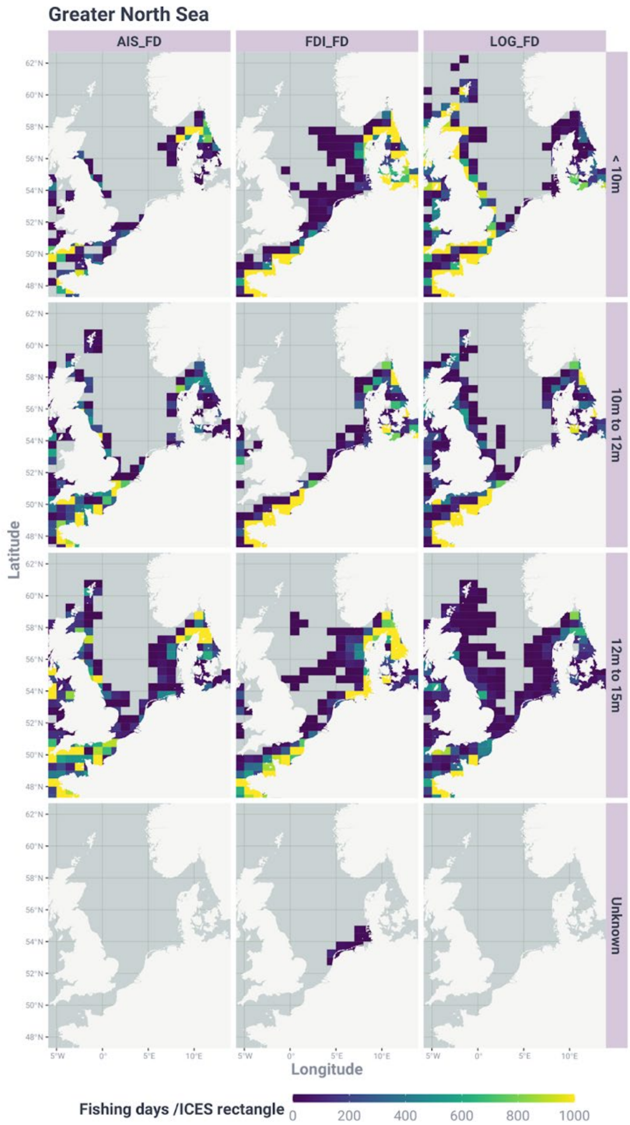


Figure 31. Maps by ICES rectangles showing the effort in fishing days from the three data sources Global Fishing Watch AIS, FDI and ICES VMS/Logbook data call for the ICES ecoregion Greater North Sea for the year 2021, for all gears. Note that for the FDI data, the vessel length group is 12–18 m.

5.5 Conclusions on analysis of available data sources to create an overview of SSF in EU waters

The aim of the above analysis was to create an overview of SSF in EU waters, based on available data sources (FDI, ICES VMS/Logbook, Global Fishing Watch AIS). It is clear that it is difficult to directly compare data from the three data sources, as each have different issues, e.g., different vessel length groups, covering fisheries from different countries and different legislation behind the data sources. Based on FDI data we can see from figures 11 and 12 that the passive gears have the most fishing effort and that around ⅓ fishing effort from EU vessels in area 27 (North Atlantic) is from mobile bottom-contacting gears; in area 37 (Mediterranean and Black Sea) the proportion of fishing effort from mobile bottom-contacting gears is smaller. From the FDI data we can see that a larger amount of the fishing effort from vessels using mobile bottom-contacting gears is from vessels over 12 m (Annex 4) regardless of the variation between areas. The ICES area 27.9.a has a high proportion of MBCG from vessels below 12 m. Overall in the Mediterranean and Black Sea the proportion of fishing days from vessels fishing with mobile bottom contacting gears is 14%.

With regards to position data from the SSF, the VMS data can provide good coverage for vessels larger than 12 m, and the AIS could supplement for the smaller vessels, but the analysis comparing the fishing days by vessel length classes for the three data sources show that it is not a complete picture. The Global Fishing Watch data has shown another useful additional source which could be useful in future analysis.

It is important to acknowledge that in relation to marine spatial planning and other reasons such as compliance monitoring in MPAs, the availability of position data for the SSF is very important. SSF vessels are numerically dominant in most EU states and often target high value low volume species.

5.6 Draft recommendations (ToR b.ii)

To address the **ToR b.ii** "to provide recommendations for data collection and determination of fishing effort for the most impacting gear(s) to the seafloor", WGSSFGEO2 has the following recommendations.

In order to be able to respond to the increasing demand for requests requiring data on high spatial resolution from various governmental institutions at national and EU level, the fisheries data required for this purpose must also be available in sufficiently high temporal and spatial resolution for those institutions (e.g. ICES; national fisheries institutions) that are commissioned to respond to these requests.

A combination of logbook reporting on the gears used and a vessel tracking system with suitable temporal resolution in relation to the métier/vessel length (or a general minimum of 30 seconds as concluded in ToR a.iii) that is linked to the logbook data would be required. These data should be collected on a mandatory basis for all EU vessels and provided by the national control agencies in EU to the fisheries data scientists.

It is important to consider that the coordinates are stored with 4–5 decimals in order to retain the accuracy of the position data.

The following is a list of options for providing this necessary data on actual fishing effort.

1. An obligation for vessels of all sizes to provide logbook information. For the small vessels it is important that the logbook reporting system is kept as simple as possible, and the logbook setup should be targeting the gear type to make it as easy as possible to fill it in. It could be possible to indicate in the logbook the geographical positions for each fishing operation (setting and hauling), and the dimensions of the gear used (e.g. length and height of the net; number of hooks, width of the demersal tow) and for passive gears a reporting on the gear soaking time. A disadvantage could arise for very small, uncovered boats that do not have an easy way to keep electronic or paper logbooks at sea. Here, however, it would also be conceivable to fill in this information later after returning to port, or for example, the possibility of keeping an electronic logbook using robust tablets. A disadvantage of using logbook information alone could be that the information (positions, gear, soaking times) must be entered correctly, and there is a risk of poor compliance and high data entry errors. It is suggested to avoid paper logbooks as additional errors can be introduced when digitizing the data, and therefore a form of electronic reporting is recommended.

2. An automatic tracking device that collect and store position GPS information with a sufficiently high frequency which could be adapted to the fishing gear used. It might be preferable to link such tracking devices with a simple device (e.g. Bluetooth button) to indicate start and end of each fishing operation. A disadvantage here would be the higher costs for the procurement and maintenance of these devices as well as their sufficiently technical robustness and reliability. In addition, these data might have to be analysed more elaborately afterwards to determine the location and time of the actual fishing effort. The devices would have to be used according to the specifications. Another consideration is the power source of the units as SSF and in particular vessels <8 m may have no power. Therefore, solar powered units could be an option, but there is a trade-off between power from solar panels and transmission frequency especially in higher latitudes and in winter.

3. Make VMS mandatory for vessels of all sizes and increase the VMS ping rate, depending on the fishing gear used for each fishing operation with a minimum of what ToR a.iii has recommended. The disadvantage here would be, on the one hand, higher costs for the acquisition and installation of the technically more complex devices. In addition, there would be higher costs for transmitting the data via communication satellites. However, flat rates are increasingly being offered instead of costs per individual transmission. Some VMS can also transmit through the GSM network where most SSF vessel operates within the mobile phone network, reducing the transmission costs. In the case of very small vessels, sufficient space for installation and power supply as mentioned above for the GPS devices could be problematic. The real-time VMS data transmission of position data via satellites has e.g. been used to monitor compliance with areas closed to fishing, but real-time data transmissions are not required in all cases.

4. AIS data: Since AIS was introduced for a completely different purpose (vessel collision avoidance at sea), the data are not always easily and/or freely available to the scientists. Some small scale vessels already have a Class-B AIS antenna. However, they can currently switch the AIS devices on and off. Yet, in the vicinity of some e.g. Natura 2000 areas and other marine protected areas, it is already mandatory to operate only with AIS switched on to monitor even smaller fishing vessels. An advantage would be the relatively high temporal transmission rates (5 s to 3 min in Class B, 2 s to 3 min in Class A). Class A AIS allow to enter the navigational status as 0 (underway using engine) and 7 (engaged in fishing). A disadvantage can be sufficient coverage and recording of all fishing operations, depending on the nature of the respective coast, distance to the coast as well as availability of receiving stations.

As described above, all the different systems have advantages and disadvantages. The logbook data gives valuable information on gear and catches but need to be entered by the fisher. The position data gives information that is not dependent on the fisher, and with new developments on methods to estimate fishing activities from position data, this can provide a good indication of the fishing effort in different metiers. A combination of an electronic logbook system that is made simple and possibly via a mobile app, and a positioning system that can work in the smaller vessels, considering challenges with space and power supply, may be a workable combination of methods. If the logbook and position system have a direct link, the gear information would be known, and the detailed spatial footprint of the small-scale fishery would be available for many purposes including marine spatial planning, monitoring of compliance with MPAs etc, which is important especially in the near-shore areas where the SSF typically operates. The classification of fishing activities based on position data can be considered an indirect method, and has some uncertainties, but on the other hand it is widely used for advice requests to consider areas important for fishing for marine spatial planning. Currently positioning data are collected by different authorities and in scientific projects, and it would be an advantage if the data can be collected by the national control agencies in EU and made available to fisheries data scientists that work with the data. This should be made mandatory for all EU vessels in order to ensure as complete coverage of SSF as possible.

6 Develop a guidance document collecting a group discussion on opportunities, challenges and benefits for tracking of small vessels (ToR c)

6.1 Introduction

Recent amendments to the fisheries control regulation highlight the role of small-scale fisheries in the EU, the need to consider the impacts of small-scale fisheries in the ecosystem and a requirement for Members States to track all fishing vessels below 12 metres of length. Further, the amended text aims to enhance the effectiveness of controls including small scale vessels where Member States should monitor their activities by means of a simplified format for keeping an electronic logbook and for submitting logbook information (e.g. submit the information contained in logbook at least once, before landing operations begin).

At the EU level, there are ongoing negotiations between the EU Commission, EU Parliament and Council for an EU-wide tracking system on small scale fishing vessels by all EU Member States (European Parliament 2023).

In the meantime, several ICES members countries have adopted voluntary tracking systems for their SSF fleets with the aim to ensure safety at sea, to better control fishing activities and to improve the assessment of fisheries resources. For example, in the UK a mandatory system with iVMS that covers England and Wales is being rolled out and will be mandatory in 2023. The regional government of Andalusia, Spain, started to install its own real time monitoring systems on small vessels in 2004 (known as green boxes).

WKSSFGEO2 discussed the opportunities, challenges and benefits for an EU-wide system for tracking small vessels. The results of the plenary discussions are listed in the following section.

6.2 Opportunities and benefits of an EU-wide system for tracking small vessels

- The installation of tracking devices on board to automatically locate and identify small-scale vessels would allow a more **complete analysis** of the fishing activity and impact on the ecosystem and overall **better data for assessments** and for supporting a wider range of legal obligations.
- Knowing the precise location of the fishing location would provide good opportunities for **traceability** and could potentially be used as a compliance/control tool. However, the dual use for control purposes could be overall detrimental (see section 3).
- Importantly, a tracking system for SSF could enable SSF into **marine spatial planning** processes as a proof of activity for MSP management and among other could support trade-off analysis and resolve spatial conflicts between fishing fleets.
- Tracking SSF fleet would help **identify fishing grounds** and take appropriate management measures to ensure a sustainable use.
- Strengthen the visibility of stakeholders
- Allow the quantification of SSF in marine protected areas (MPAs) under Natura 2000
- Potential to include as valuation in bioeconomic models and for ecosystem services considerations
- Improved safety at sea-depending on openness of the data

- The benefits of an EU-wide system for tracking of small-scale vessels can often be interpreted as opportunities (section 7.2) and the group discussion led to similar outcomes.
- A higher quality of the scientific advice and the possibility to contribute to a wider number of assessments was also seen as a benefit.
- The coexistence with the offshore renewable sector for science organization and industry can greatly benefit communication among stakeholders and bring more transparency to the process.
- A benefit for multi-segment data integration to help solve spatial conflicts between fishing fleets.
- It could close knowledge gaps and allow for a more sustainable management of the SSF sector.

6.3 Challenges of an EU-wide system tracking for small vessels

- Increased costs and maintenance required to support the data acquisition and processing.
- Universal application in a single step may be difficult and a phased or pilot scale approach could be implementation.
- Complexity to align with existing data that may have a different format and are incomplete at times.
- Potential duplication of data reporting systems and overestimation of fishing activity.
- Lack of common understanding between the stakeholders, mainly fishermen and management. Objectives and requirements need to be clear to all parties.
- Issues associated with regulating for the first time a diverse, non-regulated segment of the fishing fleet,
- Perception of overcontrol by fishermen- as opposed to unregulated and uncontrolled activity in most cases- that can lead to mistrust.
- Some vessels with the small-scale fleet are very 'basic' and the installation and maintenance of tracking devices can be challenging.

6.4 EU mandatory tracking of fishing vessels - discussion and recommendations

In May 2018, the Commission proposed to update the EU's fisheries control system to ensure compliance with the Common Fisheries Policy (CFP-2013). The Commission proposal amends five regulations, of which Council Regulation (EC) 1224/2009 (the Control Regulation), forms the core of the EU fisheries control system. One of the changes proposed is tracking of all fishing vessels, which was supported by the European Parliament. They amended the proposal to: "it is necessary to obtain position data of those vessels and it should be possible to receive those data at regular intervals, ideally close to real time without prejudice to other requirements included in international agreements. Therefore, Member States should be able to track all fishing vessels, including fishing vessels which are less than 12 metres' length."

The establishment in the EU regulation of a measure requiring all fishing vessels to have a tracking system, thus including all vessels under 12 meters, would provide a relevant source of information to provide scientific advice and improve current marine management. Under this scenario, and assuming information from these vessel tracking systems would be incorporated into ICES data calls as is currently the case with VMS data from larger fishing vessels, workshop participants discussed the implications of such changes in terms of spatial data analysis and the harmonisation of these outputs among member states. Such EU Data call should allow the compilation of all SSF activity in a homogeneous and standardised way. This procedure has a lot of similarities with current ICES VMS Data Call ("VMS/Log book data for fishing activities in the North East Atlantic and Baltic Sea for the provision of ICES advice on the spatial distribution and impact of fisheries 2009 to 2022, ICES 2023).

From the experience gained through the VMS Data Call, participants discussed some of the elements and work that would be needed to respond to a data call. In this scenario, we envision a similar situation to what has occurred in England and Wales, where a nation-wide implementation of a tracking system (iVMS) for all fishing vessels < 12 m is currently being implemented. As explained in this document from Marine management Organisation in the UK (MMO, 2022), using GPRS mobile phone signals, I-VMS devices provide positional information (latitude and longitude, course, speed and date and time of each positional report) which is sent to MMO's UK VMS Hub. When a device is located outside GPRS range, the device will continue to store the positional information and submit the data once GPRS coverage next becomes available. This is different to the VMS devices used by larger vessels, which transmit data via satellite and can become expensive. The MMO listed a series of specifications and invited suppliers to identify/provide devices that met the specification. Four tracking devices provided by four suppliers passed the MMO requirements in England (MMO, 2022). This experience suggests that once the Commission has specified requirements deemed as suitable for tracking, a series of suppliers might be expected from the different member states. While each member state will be required to deal with the specifics of their data, the subsequent data call will require a harmonised framework to meet the data call.

Participants agreed that, in line with VMS Data Call, this call would require anonymized and monthly aggregated data. The activity of the SSF, closer to coastal areas, and the fact of departing from a higher ping rate (seconds to minutes) make that the spatial resolution, to be defined, could be higher and refer to 0.01 x 0.01 degree grid using the approach of C-square reference.

From an operational point of view, a workflow and a quality control system will be needed to process national data in a homogeneous way. For that purpose, ideas for developing an R package were discussed. Experience from the vmstools package (Hintzen *et al.*, 2012), which processes, analyses and visualises VMS data is used by Members States to meet the requirements from the ICES VMS Data Call (effort, landings, etc) is considered a very positive example. The VMS tools package was the results of a 2- year project funded by the Commission of the European Communities fund.

Participants agreed that the development of similar tools for highly resolved geospatial data from SSF is not feasible via piecemeal workshops and a working group, as they are insufficient to allocate the time and effort needed. It would require a project of a similar time scale that the aforementioned VMS project with input from researchers from member states and ICES (Figure 32). It was also discussed that ICES could have a more central role in different tasks as to maintain the database or key issues such as those related to data governance.

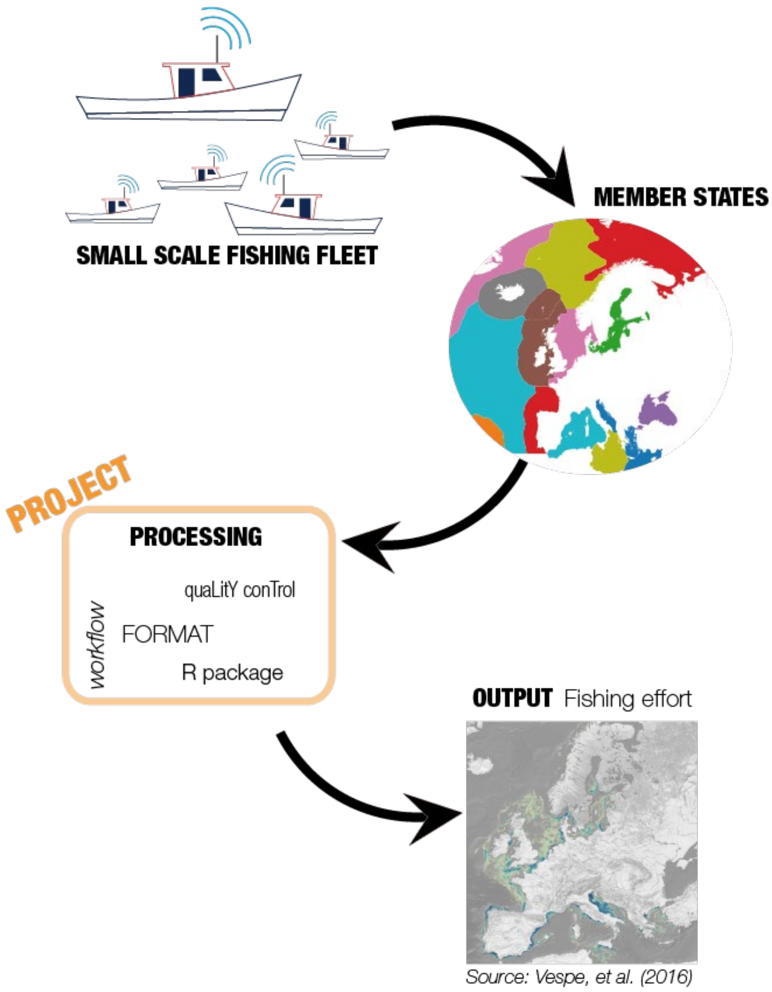


Figure 32. Workflow envisioned to produce a harmonised framework to meet potential data call requirements. Map taken from Vespe *et al.* 2016.

7 General conclusions and way(s) forward

The open example data is a breakthrough for the scientific community working on vessel tracking. This milestone already includes 10 case studies around the EU, dozens of Metiers and Portugal, Spain, Italy, Scotland and Denmark data. The structure to add more data in the future, if other people want to join in, was built during the workshop and is well established, with the agreement of the plenary (i.e. including experts from all EU). This data can be used in the future to test any methodological advances, so that the results will be comparable, but also to develop new protocols that can be generalisable across countries.

Several methods have been trialled to infer fishing activities and fishing operations from highly resolved geopositional data, including speed thresholds, expectation maximisation algorithms, Hidden Markov models, and machine learning approaches (i.e. Random forests). Comparing and testing different methods through case studies demonstrated that there is no "fit for all" method, but that accuracy in detecting fishing activities varied depending on, for example, the gear used. Overall, however, machine learning algorithms and Hidden Markov Models have shown promising results to infer fishing activities. Neural networks might offer another promising avenue to explore in this field.

An interval between coordinates of 1 minute (i.e. acquisition of 30 seconds) is recommended as a conservative approach to be able properly estimate EU effort variables, for any métier.

It is difficult to directly compare data from the three data available data sources (FDI, ICES VMS/Logbook, Global Fishing Watch AIS) as each have different issues, e.g., different vessel length groups, covering fisheries from different countries and different legislation behind the data sources.

Based on FDI data we can see that the passive gears have the most fishing effort and that around ⅓ fishing effort from EU vessels in area 27 (North Atlantic) is from mobile bottom-contacting gears; in area 37 (Mediterranean and Black Sea) the proportion of fishing effort from mobile bottom-contacting gears is smaller. From the FDI data we can see that a larger amount of the fishing effort from vessels using mobile bottom-contacting gears is from vessels over 12 m regardless of the variation between areas. The ICES area 27.9.a has a high proportion of mobile bottom-contacting gears from vessels below 12 m. Overall in the Mediterranean and Black Sea the proportion of fishing days from vessels fishing with mobile bottom contacting gears is 14%.

With regards to position data from the SSF, the VMS data can provide good coverage for vessels larger than 12 m, and the AIS could supplement for the smaller vessels, but the analysis comparing the fishing days by vessel length classes for the three data sources show that it is not a complete picture. The Global Fishing Watch data has shown another useful additional source which could be useful in future analysis.

It is important to acknowledge that in relation to marine spatial planning and other reasons such as compliance monitoring in MPAs as well as calculating bycatch rates of protected, endangered and threatened species, the availability of position data for the SSF is very important, and even if it is a small proportion of the effort/landings compared to the LSF it can be important locally.

A combination of logbook reporting on the gears used and a vessel tracking system with suitable temporal resolution in relation to the metier/vessel length (or a general minimum of 30 seconds as concluded in ToR a.iii) that is linked to the logbook data would be required. These data should be collected on a mandatory basis for all EU vessels and provided by the national control agencies in EU to the fisheries data scientists.

In line with the ongoing negotiations between the EU Commission, EU Parliament and Council for a EU-wide tracking system on small scale fishing vessels by all EU Member States (P9_TA (2023)0019), the group considered that if effort indicators derived from these tracking data were to inform a data call, a project of a similar size as the one used to develop the R package VMSTools to harmonise and standardise the analysis of highly resolved geopositional data should be considered, in order to harmonise member states submissions.

Participants agreed that the development of similar tools for highly resolved geospatial data from SSF is not feasible via piecemeal workshops and a working group, as they are insufficient to allocate the time and effort needed. It would require a project of a similar time scale that the above-mentioned VMS project with input from researchers from member states and IC.

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Annex 2: WKSSFGEO2 resolution

A **Workshop on Small Scale Fisheries and Geo-Spatial Data 2** (WKSSFGEO2), chaired by Tania Mendo, UK; and Marta Rufino, Portugal; will be established and will meet in Faro, Portugal, 13–16 March 2023 to:

a) Build up from WKSSFGEO to progress on the development of methods to classify positions into fishing events in small-scale fisheries, including passive gears, using high resolution geo-spatial data and specifically:

i) Create an open data set of case studies (anonimized) to test the methods, with different gear types and locations.

ii) Test and compare methods to classify positions into fishing activities (i.e. random forest, machine learning, geocomputing) on different types of vessel tracking data and gear types to infer relevant effort parameters.

iii) Recommend the optimal/maximum frequency of acquisition of geopositional data (time between pings) by gear types to infer relevant fishing activities

Data from case-studies shared at WKSSFGEO will be available but participants are encouraged to bring their own data as well to test the different methods.

b) Using data already available:

i) Analyse the availability of VMS and logbook data submitted to ICES that corresponds to small-scale fisheries in EU waters.

ii) Provide an overview of the extent of small scale fisheries in EU waters using the FDI database, the corresponding extent of bottom contacting fishing gear and provide recommendations for data collection and determination of fishing effort for the most impacting gear(s) to the seafloor.

iii) Combine the previous datasets (ii) and iii) to quantify coverage of small scale fishing fleet in EU waters

c) Develop a guidance document collecting a group discussion on opportunities, challenges and benefits for tracking of small vessels.

WKSSFGEO2 will report by 31 March 2023 (via HAPISG) for the attention of the ACOM and SCICOM.

Supporting information

Priority	The activities of this Workshop will feed into ICES advice to EC/DGENV on the spatial extent of fisheries that are not carrying VMS and represent a high percentage of the total fleet . Consequently, these activities are considered to have a very high priority.
Scientific justification	**Term of Reference a)** In the EU, VMS data are available for vessels larger than or equal to 12 m since 2012, with a maximum ping rate of 2 hours, and with a possibility for an excemption for 12-15 m vessels if they operate within the territorial waters of the MS or never spend more than 24 hours at sea per trip. However, information of fisheries from vessels that are not carrying VMS is missing resulting in an underestimation of the fishing pressure, especially in coastal areas. WKSSFGEO discussed and developed standard procedures for identifying trips/hauls in SSF using geo-spatial data (e.g. AIS, GPRS trackers) that can be compatible with VMS derived outputs. WKSSFGEO2 will build up from WKSSFGEO and follow-up on the building blocks required to estimate effort indicators for SSF and harmonize with the EU-MAP variables. The classification of the position of the vessel is key to obtain information on effort indicators and infer fishing activity. Using the methods that provided best results at WKSSFGEO, WKSSFGEO2 will test and compare the different approaches, e.g. Random Forest, Machine

	learning and speed-filter methods, on different types of data and gear types (on open anonymized data set). The optimal frequency between pings depends very much on the gear and type of fishery. WKSSFGEO2 will recommed the best frequency by gear to classify the positions into fishing activites and provide relevant effort indicators. For passive gears, WKSSFGEO2 will improve the workflow at ICES to map fishing activity, work on effort estimates from EU MAP, discuss the potential for estimation of soaking time, the best temporal resolution and alternative data sources to estimate number of hooks, pots or traps. **Term of Reference b)** In response to a special request from DGENV to advise on the impact of small scale fisheries in the seabed, WKSSFGEO2 will: i) Use existing VMS and logbook data submitted to ICES to inform about the current coverage of VMS-tracked small scale fleet, the proportion of 12-15m vessels without VMS from table 2 of the VMS/logbook data call and discuss suitability to be used in ICES advice, ii) Describe the extent of small-scale fisheries by MSFD (sub)region in all EU-waters using STECF FDI database, report on the most predominant gears and focus on the development of metrics and methods to determine fishing activity of the most predominant gears. **Term of Reference c)** Several ICES members, such as the UK, have started a mandatory tracking system for England and Wales with iVMS, and for some countries AIS data or other tracking systems are available. Additionally, at the EU level current negotiations between the EU Commision, Parliament and Council are underway for the tracking on small scale fishing vessels by all Member States (P9_TA(2021)0076) but there is not a general framework to support this decision. WKSSFGEO2 will draft a guidance document exploring the challenges and opportunities of introducing a vessel tracking system for all vessels, the benefits for a common tracking system, provide advice on the temporal resolution needed for different gears, importance of including the small-scale fleet for marine spatial planning considerations and the implications for estimation of by-catch events by small-scale fleet.
Resource requirements	Secretariat support and advice process.
Participants	The group will be attended by members of WGSFD, WGCATCH and other invited experts.
Secretariat facilities	Standard EG support.
Financial	Covered by DGENV special request to ICES.
Linkages to advisory committees	The report from WKSSFGEO2 will be peer-reviewed and enter into the ICES Advisory process to be approved by ACOM.
Linkages to other committees or groups	WGSFD, WGCATCH, WGBYC, WGTIFD, SCICOM, HAPISG
Linkages to other organizations	EU Regional Coordination Groups Intersessional Subgroups on Small-scale fisheries and Metie and transversal variable issues.

Annex 3: Table fishing days from AIS, ICES logbook and FDI MBCG

Total fishing days from AIS, ICES logbook and FDI for mobile bottom-contacting gears by vessel length range for the year 2021. Note that for the FDI data the vessel length range is 12–18 m.

Area_Full	AIS_FD	LOG_FD	FDI_FD
MBCG - < 10m			
27.3.a.20	1974	309	1566
27.3.a.21	524	272	828
27.3.b.23	0	0	6
27.3.c.22	7	26	62
27.3.d.24	0	1	10
27.3.d.25	0	0	7
27.3.d.26	0	2	2
27.3.d.28.1	0	23	29
27.3.d.28.2	0	1	1
27.3.d.29	0	1	2
27.3.d.31	0	0	21
27.4.a	0	872	18
27.4.b	342	963	497
27.4.c	20	462	645
27.5.b.1.b	0	1	0
27.6.a	0	190	0
27.7.a	188	767	0
27.7.d	329	1711	1169
27.7.e	5102	5257	3726
27.7.f	144	294	0

27.7.g	2	1	1
27.7.j.2	0	35	31
27.8.a	24	4678	4790
27.8.b	0	329	371
27.8.c	0	0	737
27.8.d.2	0	2	2
27.9.a	0	3	9703
MBCG - 10m to 12m			
27.3.a.20	1848	1153	1650
27.3.a.21	411	559	913
27.3.b.23	10	147	312
27.3.c.22	40	234	441
27.3.d.24	111	191	347
27.3.d.25	828	38	61
27.3.d.27	116	127	133
27.3.d.28.1	0	6	0
27.3.d.28.2	0	1	1
27.3.d.29	0	0	1
27.3.d.30	0	26	26
27.3.d.31	0	95	131
27.4.a	0	170	0
27.4.b	559	845	739
27.4.c	923	128	153
27.6.a	136	259	0
27.7.a	606	366	138
27.7.b	0	35	69
27.7.d	5049	4878	5214

27.7.e	3801	12093	11469
27.7.f	501	176	0
27.7.g	2	81	153
27.7.h	4	13	12
27.7.j.2	0	98	200
27.8.a	2666	6348	6445
27.8.b	993	2199	2689
27.8.c	0	17	214
27.8.d.2	0	11	10
27.9.a	0	26	3967
MBCG - 12m to 15m (note that for FDI it is 12-18 m)			
27.3.a.20	8035	2830	9717
27.3.a.21	2499	714	5473
27.3.b.23	247	133	1393
27.3.c.22	379	294	1417
27.3.d.24	555	176	1107
27.3.d.25	1689	29	984
27.3.d.26	70	0	12
27.3.d.27	5	0	28
27.3.d.28.1	774	0	0
27.3.d.28.2	56	0	0
27.3.d.30	0	1	2
27.3.d.31	0	80	101
27.4.a	1107	316	14
27.4.b	1801	1447	10964
27.4.c	172	311	741
27.5.b.1.b	0	0	0

27.6.a	1364	989	34
27.7.a	3773	1030	314
27.7.b	0	15	45
27.7.d	6328	3250	10353
27.7.e	9109	3062	2477
27.7.f	273	117	0
27.7.g	90	101	731
27.7.h	232	294	433
27.7.j.2	920	288	1034
27.8.a	15414	7113	14302
27.8.b	6397	2136	3477
27.8.c	36	2	5
27.8.d.2	16	0	5
27.9.a	1642	42	6666
MBCG - Unknown			
27.3.d.29	0	0	5
27.3.d.31	0	0	2
27.4.b	0	0	129
27.4.c	0	0	140

Annex 4: Table fishing days from FDI vessels less than and larger than 12 m

Total fishing days from FDI data call for the year 2021 for the FAO area 27 (Northeast Atlantic), by sub-region for mobile bottom-contacting gears (MBCG) for vessels 0–12 m and vessels larger than 12 m, and the percent fishing days from vessels 0–12 m.

Sub-region	Gear group	Fishing days vessels 0-12 m	Fishing days vessels >12 m	% fishing days from vessels 0-12 m
27.1.A	MBCG	0	1090	0
27.1.B	MBCG	0	607	0
27.10.A	MBCG	0	12	0
27.10.B	MBCG	0	24	0
27.12	MBCG	0	56	0
27.14.A	MBCG	0	28	0
27.14.B	MBCG	0	651	0
27.2.A	MBCG	0	234	0
27.2.B	MBCG	0	840	0
27.3.A.20	MBCG	3976	21654	16
27.3.A.21	MBCG	2804	11655	19
27.3.B.23	MBCG	5	18	22
27.3.C.22	MBCG	937	2380	28
27.3.D.24	MBCG	373	1443	21
27.3.D.25	MBCG	81	1411	5
27.3.D.26	MBCG	2	30	6
27.3.D.27	MBCG	134	36	79
27.3.D.28.1	MBCG	35	0	100
27.3.D.28.2	MBCG	22	76	22
27.3.D.29	MBCG	37	0	100

27.3.D.30	MBCG	56	26	68
27.3.D.31	MBCG	155	101	61
27.4.A	MBCG	17	5853	0
27.4.B	MBCG	1595	52900	3
27.4.C	MBCG	914	29230	3
27.5.A	MBCG	0	21	0
27.5.B	MBCG	0	77	0
27.6.A	MBCG	9	3088	0
27.6.B	MBCG	0	804	0
27.7.A	MBCG	4246	5559	43
27.7.B	MBCG	269	2603	9
27.7.C	MBCG	0	2690	0
27.7.D	MBCG	13679	26990	34
27.7.E	MBCG	20331	13481	60
27.7.F	MBCG	0	2105	0
27.7.G	MBCG	174	16559	1
27.7.H	MBCG	13	9138	0
27.7.J	MBCG	264	9156	3
27.7.K	MBCG	0	3641	0
27.8.A	MBCG	18399	26059	41
27.8.B	MBCG	3113	6844	31
27.8.C	MBCG	8581	9466	48
27.8.D	MBCG	12	211	5
27.8.E	MBCG	1	5	17
27.9.A	MBCG	155297	35109	82
27.9.B	MBCG	0	6	0
Total	**MBCG**	**235531**	**303964**	**44**

Total fishing days from FDI data call for the year 2021 for the FAO area 27 (Northeast Atlantic), by sub-region for mobile bottom-contacting gears (MBCG) for vessels 0–12 m and vessels larger than 12 m, and the percent fishing days from vessels 0–12 m.

GSA area	Gear group	Fishing days vessels 0-12 m	Fishing days vessels >12 m	% fishing days from vessels 0-12 m
GSA01	MBCG	5716	13490	30
GSA02	MBCG	0	966	0
GSA04	MBCG	0	5	0
GSA05	MBCG	499	6480	7
GSA06	MBCG	4649	51421	8
GSA07	MBCG	2355	10526	18
GSA08	MBCG	3	597	0
GSA09	MBCG	16267	33726	33
GSA10	MBCG	6698	19712	25
GSA11	MBCG	1148	13151	8
GSA11.1	MBCG	0	1	0
GSA11.2	MBCG	0	2	0
GSA12	MBCG	0	4	0
GSA13	MBCG	0	8	0
GSA14	MBCG	0	29	0
GSA15	MBCG	78	795	9
GSA16	MBCG	1738	47077	4
GSA17	MBCG	21743	138019	14
GSA18	MBCG	2714	41178	6
GSA19	MBCG	12100	26394	31

GSA20	MBCG	0	5608	0
GSA22	MBCG	0	36754	0
GSA23	MBCG	0	1709	0
GSA25	MBCG	0	537	0
GSA29	MBCG	384	1279	23
Total	**MBCG**	**76091**	**449469**	**14**

Annex 5: WKSSFGEO2 on SSF high resolution tracking

Example dataset uniformization and exaploration

WKSSFGEO2

23 March 2023

Summary

This scripts aims to open and standartise the high resolution tracking example data set, of SSF and static GEARs, assembled during WKSSGEO2 (https://www.ices.dk/community/groups/Pages/wkssfgeo2.aspx). Standartised data sets have the same file name as original submitted datasets, but with a ‘2’ in the end of the file name.

Open datasets

The datasets are found in the WKSSFGEO github (https://github.com/ices-eg/WKSSFGEO/blob/main/data-examples), WKSSFGEO2 github (https://github.com/ices-eg/WKSSFGEO2) and in WKSGEO2 sharepoint (https://community.ices.dk/ExpertGroups/WKSSFGEO2/_layouts/15/start.aspx#/SitePages/HomePage.aspx?RootFolder=%2FExpertGroups%2FWKSSFGEO2%2F2022%20Meeting%20Documents%2F06%2E%20Data&FolderCTID=0x0120004189A4195F850241B1FA78CAACDE8D32

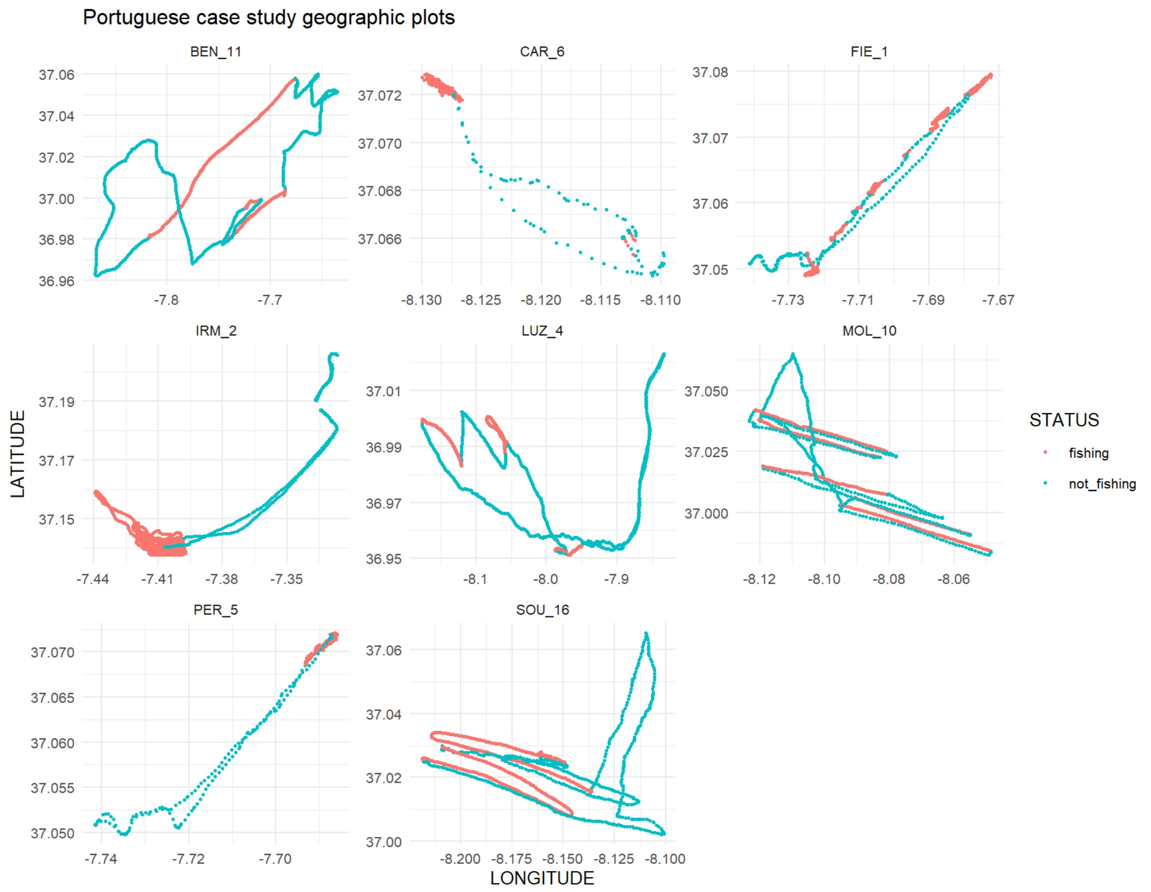
Let’s open and prepare an example dataset, of the portuguese bivalve dredges and octopus fisheries.\

Portuguese dataset (IPMA)

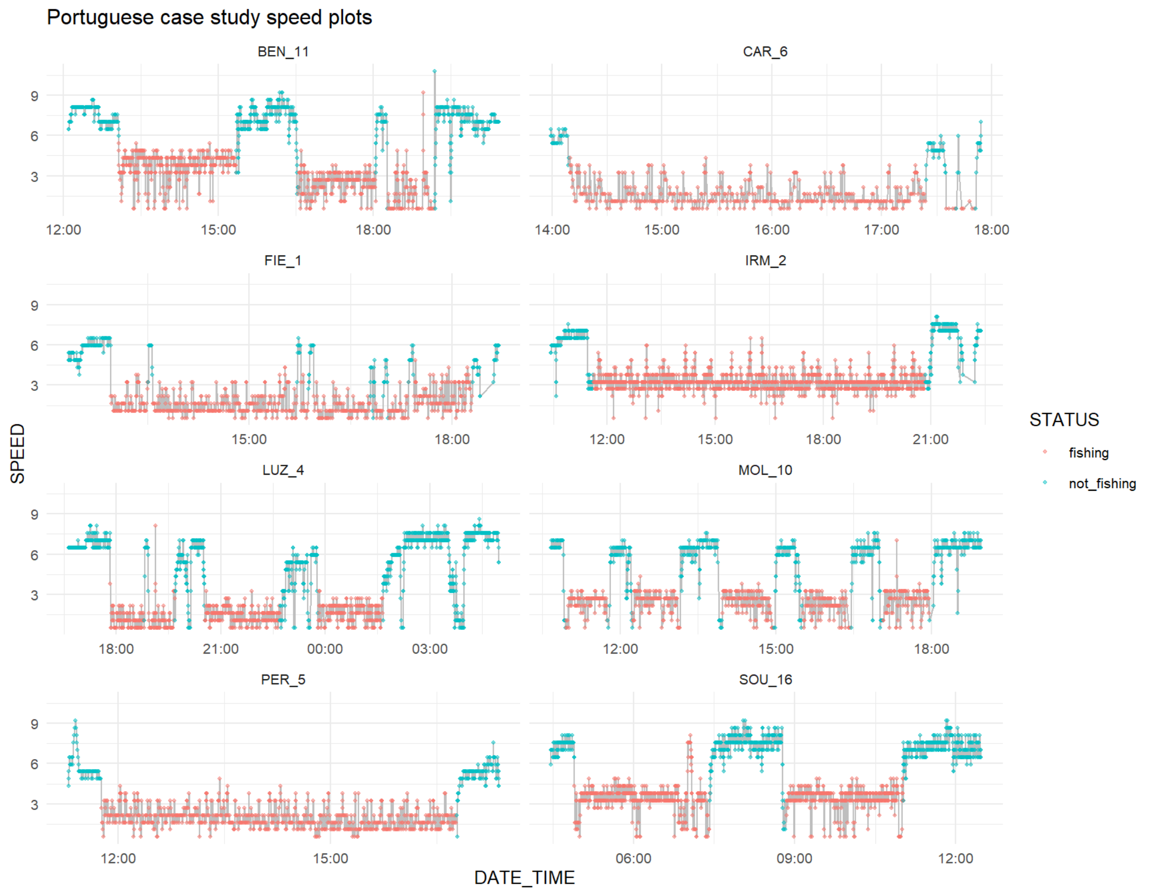
The Portuguese data set has data obtained by GPRS trackers located on a bivalve dredge and octopus pots & traps in the south of Portugal. Resolution is 30 secs. Data has been validated by an expert.\

PT_IPM_2017_GP

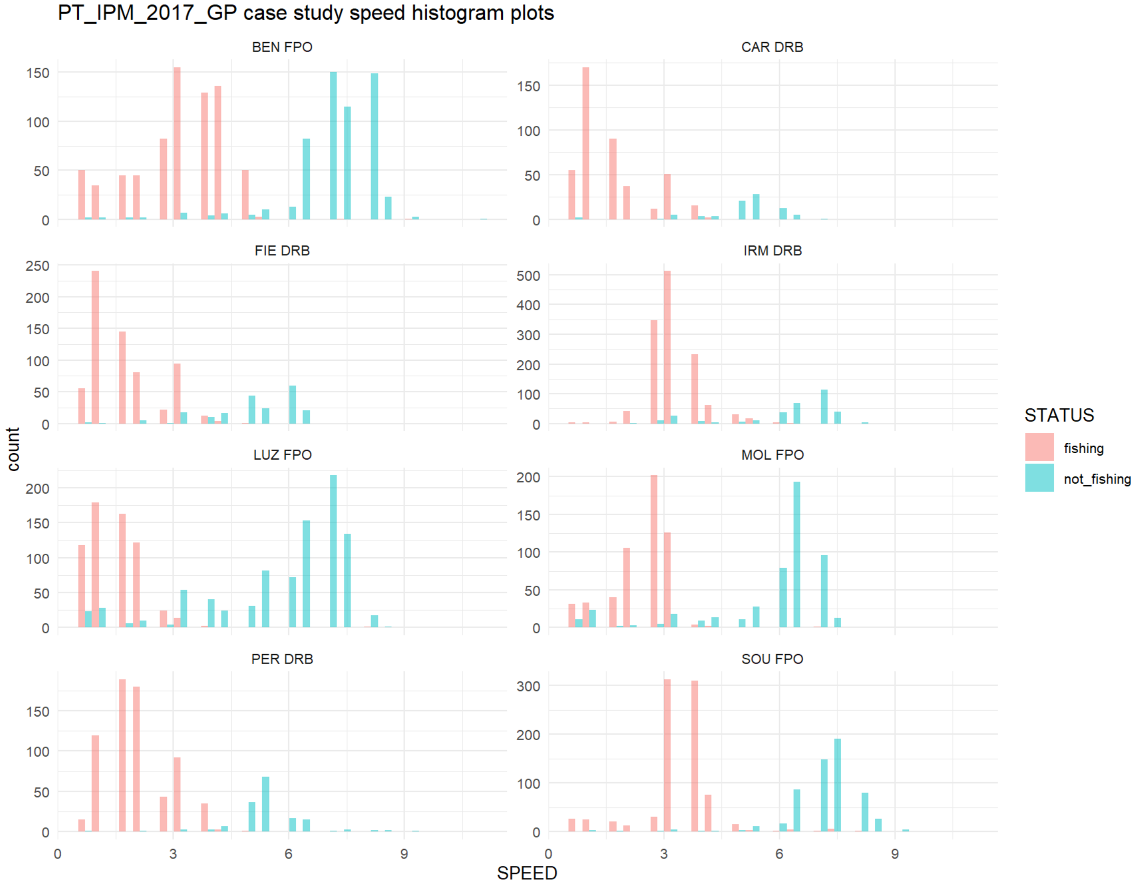
BOAT_ID	TRIP_ID	GEAR	n
BEN	11	FPO	1308
CAR	6	DRB	517
FIE	1	DRB	857
IRM	2	DRB	1597
LUZ	4	FPO	1522
MOL	10	FPO	1050
PER	5	DRB	838
SOU	16	FPO	1426



Portuguese case study geographic plots
BEN_11
CAR_6
FIE_1
IRM_2
LUZ_4
MOL_10
PER_5
SOU_16
LATITUDE
LONGITUDE
STATUS
fishing
not_fishing



Portuguese case study speed plots
BEN_11
CAR_6
FIE_1
IRM_2
LUZ_4
MOL_10
PER_5
SOU_16
SPEED
DATE_TIME
STATUS
fishing
not_fishing

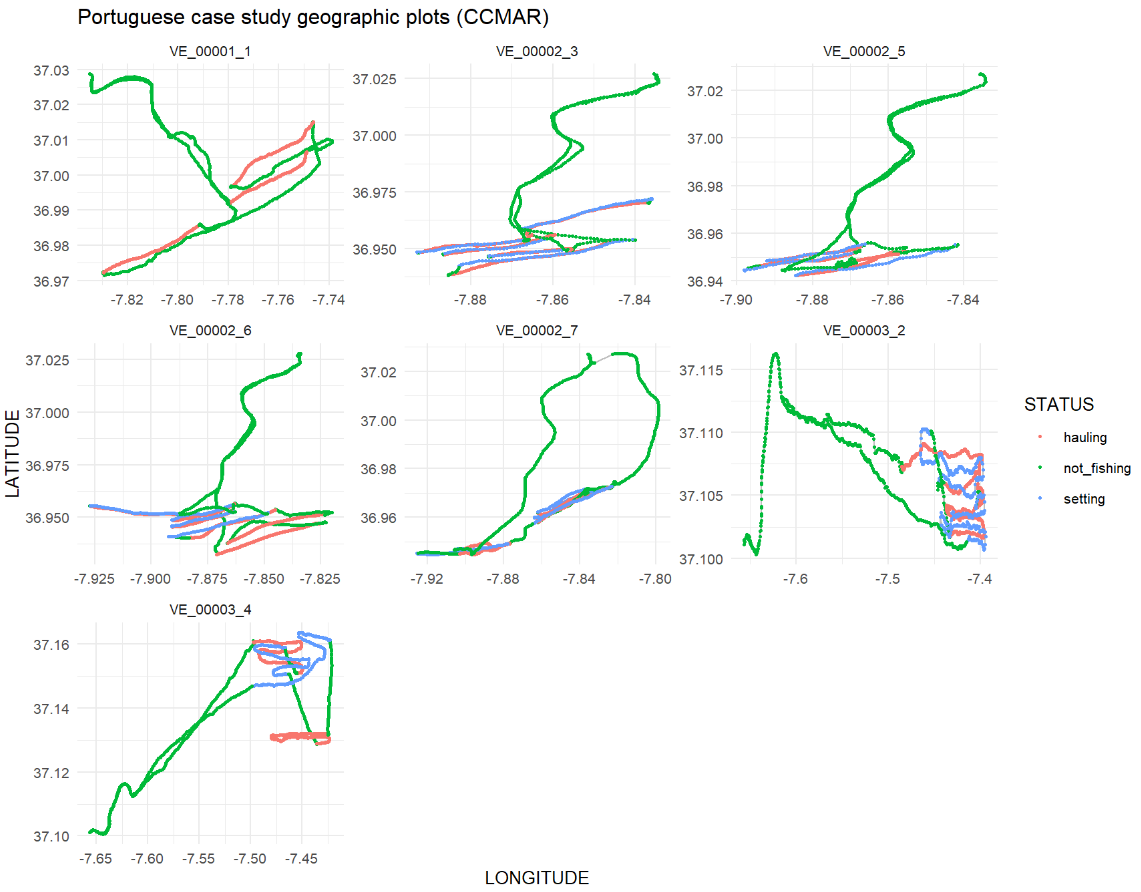


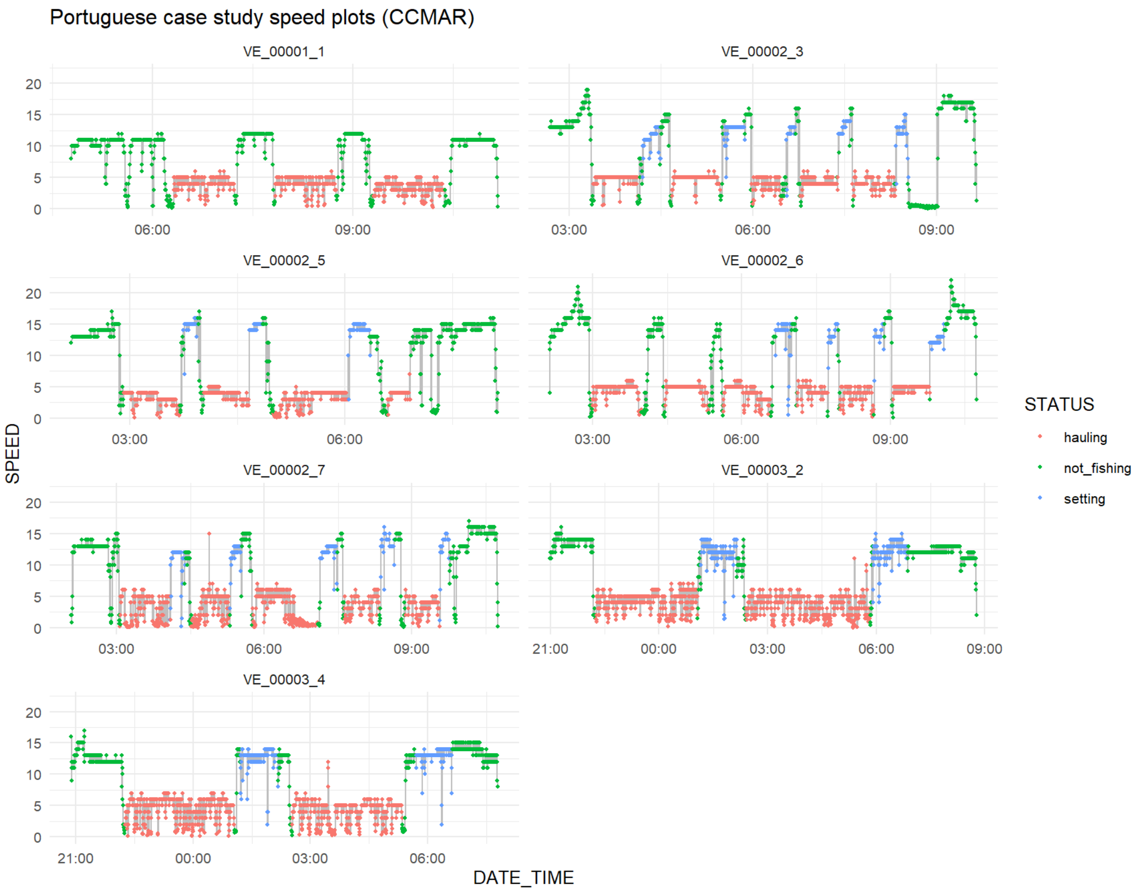

```
## # A tibble: 3 × 3
##   tim.int diff.time.s     n
##     <dbl> <drtn>      <int>
## 1      30 30 secs      5649
## 2      31 31 secs       412
## 3       4  4 secs       162
```

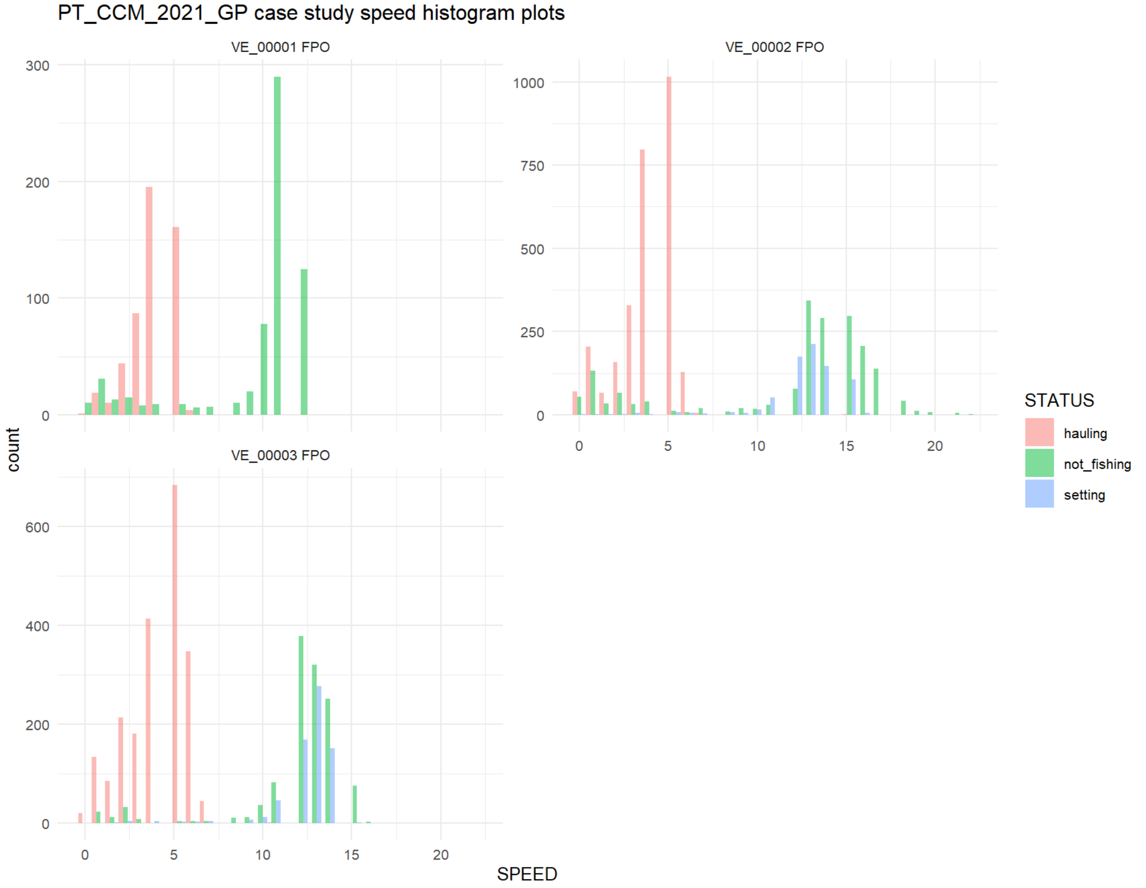
Portuguese dataset (CCMAR)

PT_CCM_2021_GP

BOAT_ID	TRIP_ID	GEAR	n
VE_00001	1	FPO	1152
VE_00002	3	FPO	1255
VE_00002	5	FPO	1071
VE_00002	6	FPO	1550
VE_00002	7	FPO	1549
VE_00003	2	FPO	2122
VE_00003	4	FPO	1968


Portuguese case study geographic plots (CCMAR)
VE_00001_1
VE_00002_3
VE_00002_5
VE_00002_6
VE_00002_7
VE_00003_2
VE_00003_4
LATITUDE
LONGITUDE
STATUS
hauling
not_fishing
setting


Portuguese case study speed plots (CCMAR)
VE_00001_1
VE_00002_3
VE_00002_5
VE_00002_6
VE_00002_7
VE_00003_2
VE_00003_4
SPEED
DATE_TIME
STATUS
hauling
not_fishing
setting

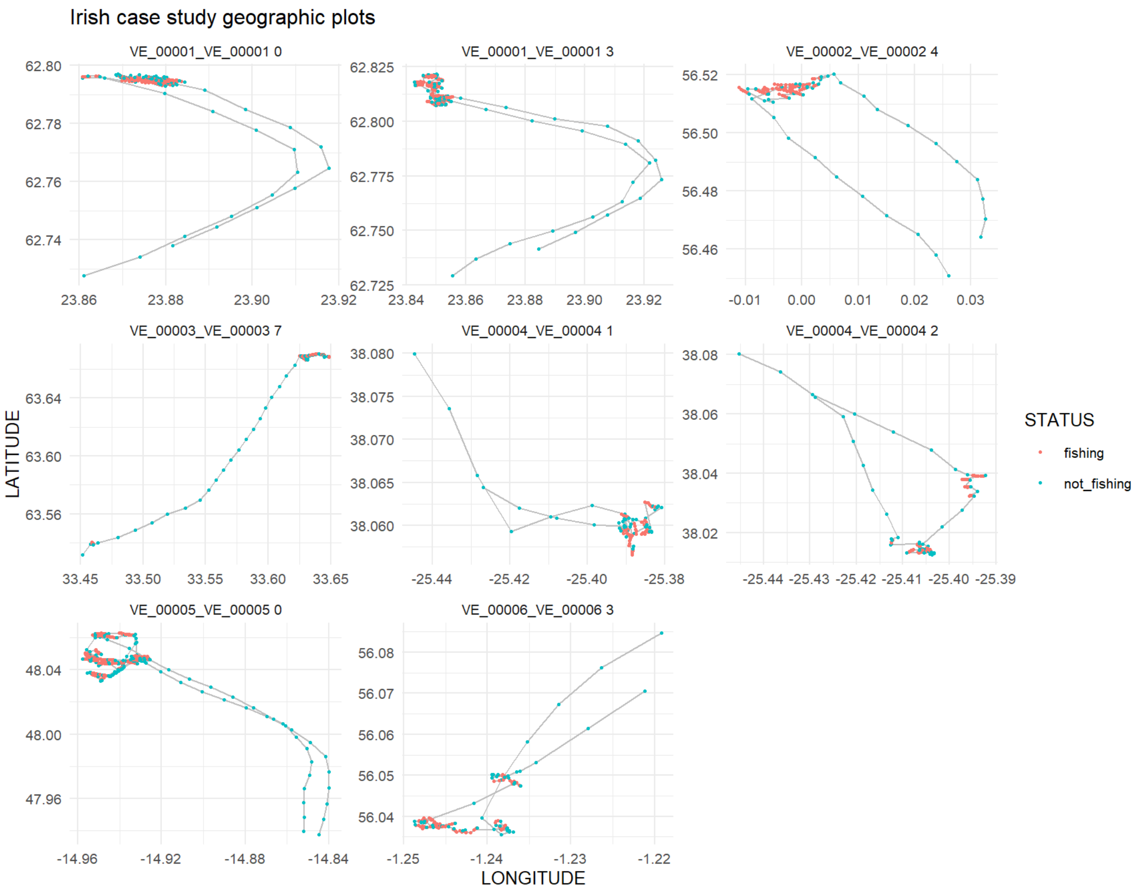


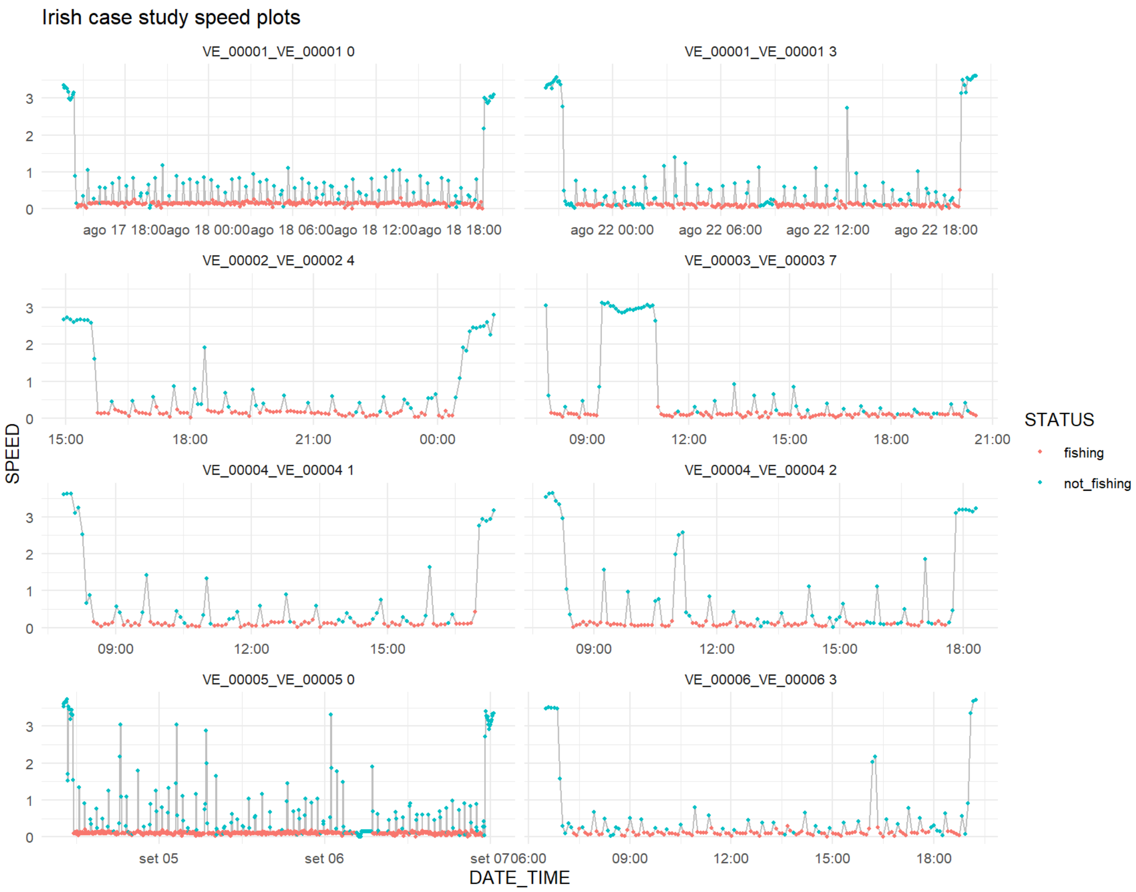

```
## # A tibble: 5 × 3
##   tim.int diff.time.s     n
##     <dbl> <drtn>      <int>
## 1      20  20 secs     7109
## 2     -40 -40 secs     2481
## 3      80  80 secs     1068
## 4       0   0 secs        7
## 5     200 200 secs        1
```

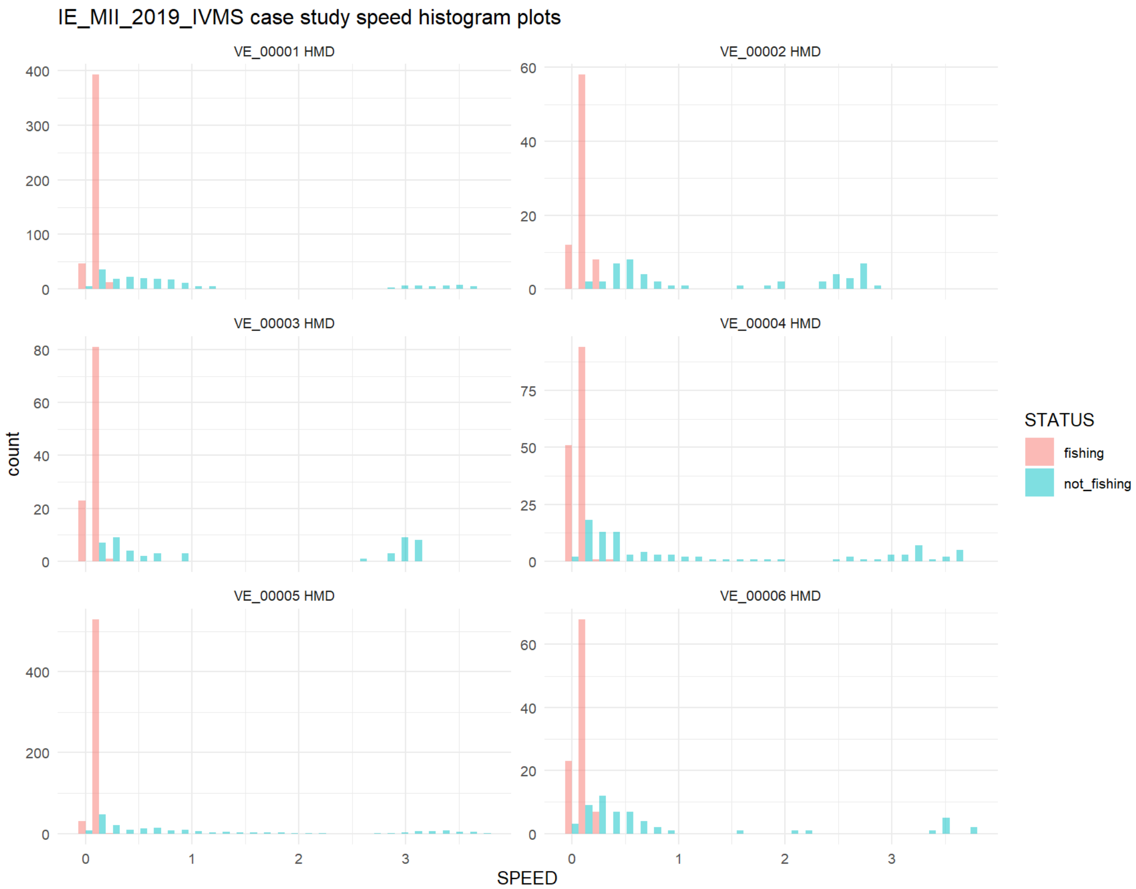
Irish dataset (MII)

IE_MII_2019_IVMS

BOAT_ID	TRIP_ID	GEAR	n
VE_00001	VE_00001 0	HMD	371
VE_00001	VE_00001 3	HMD	288
VE_00002	VE_00002 4	HMD	126
VE_00003	VE_00003 7	HMD	154
VE_00004	VE_00004 1	HMD	115
VE_00004	VE_00004 2	HMD	127
VE_00005	VE_00005 0	HMD	750
VE_00006	VE_00006 3	HMD	154


Irish case study geographic plots
VE_00001_VE_00001 0
VE_00001_VE_00001 3
VE_00002_VE_00002 4
VE_00003_VE_00003 7
VE_00004_VE_00004 1
VE_00004_VE_00004 2
VE_00005_VE_00005 0
VE_00006_VE_00006 3
LATITUDE
LONGITUDE
STATUS
fishing
not_fishing


Irish case study speed plots
VE_00001_VE_00001 0
VE_00001_VE_00001 3
VE_00002_VE_00002 4
VE_00003_VE_00003 7
VE_00004_VE_00004 1
VE_00004_VE_00004 2
VE_00005_VE_00005 0
VE_00006_VE_00006 3
SPEED
DATE_TIME
STATUS
fishing
not_fishing




```
## # A tibble: 2 × 3
##   tim.int diff.time.s     n
##     <dbl> <drtn>      <int>
## 1       5 300 secs     2077
## 2       0   0 secs        8
```

French dataset (IFREMER)

Qualified geolocation dataset of a fishing vessel operating nets in the English Channel

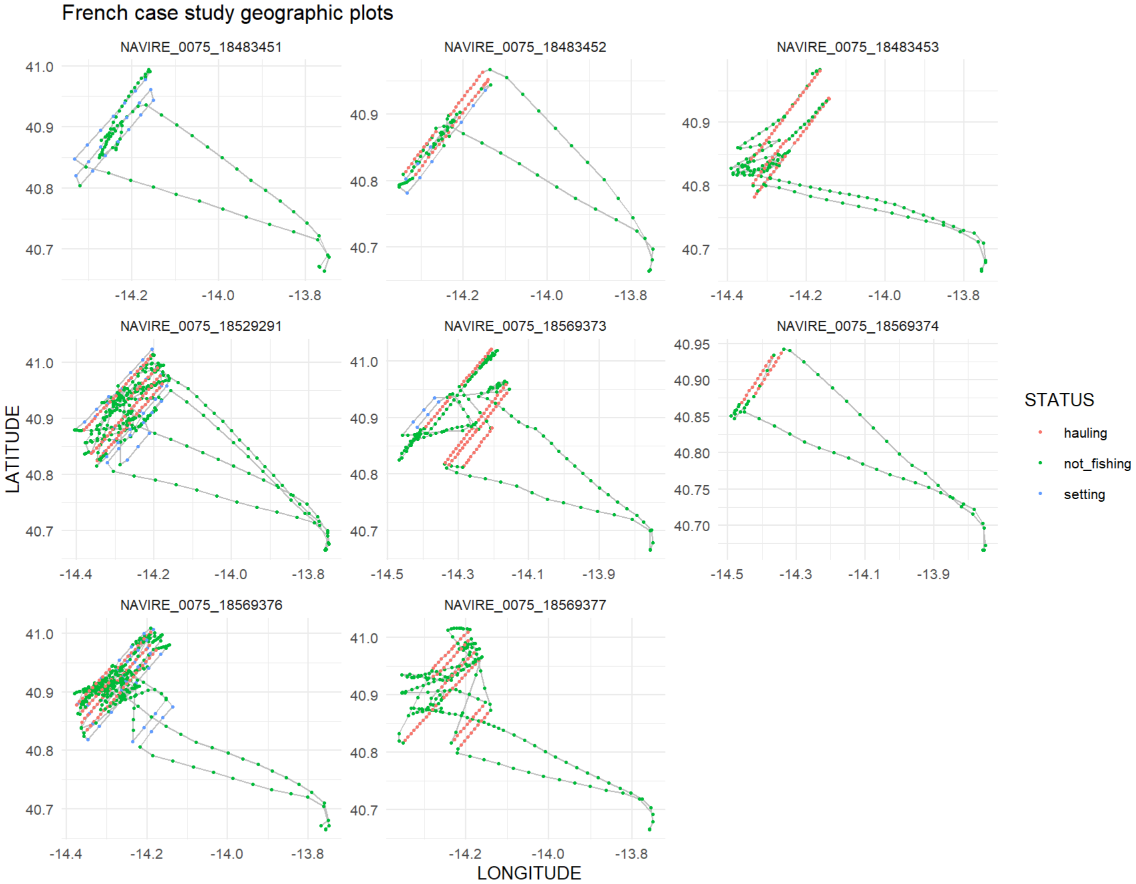
Authors: Ifremer HISSEO, Martial LAURANS, François DANHIEZ, Mathieu WOILLEZ, Julien RODRIGUEZ

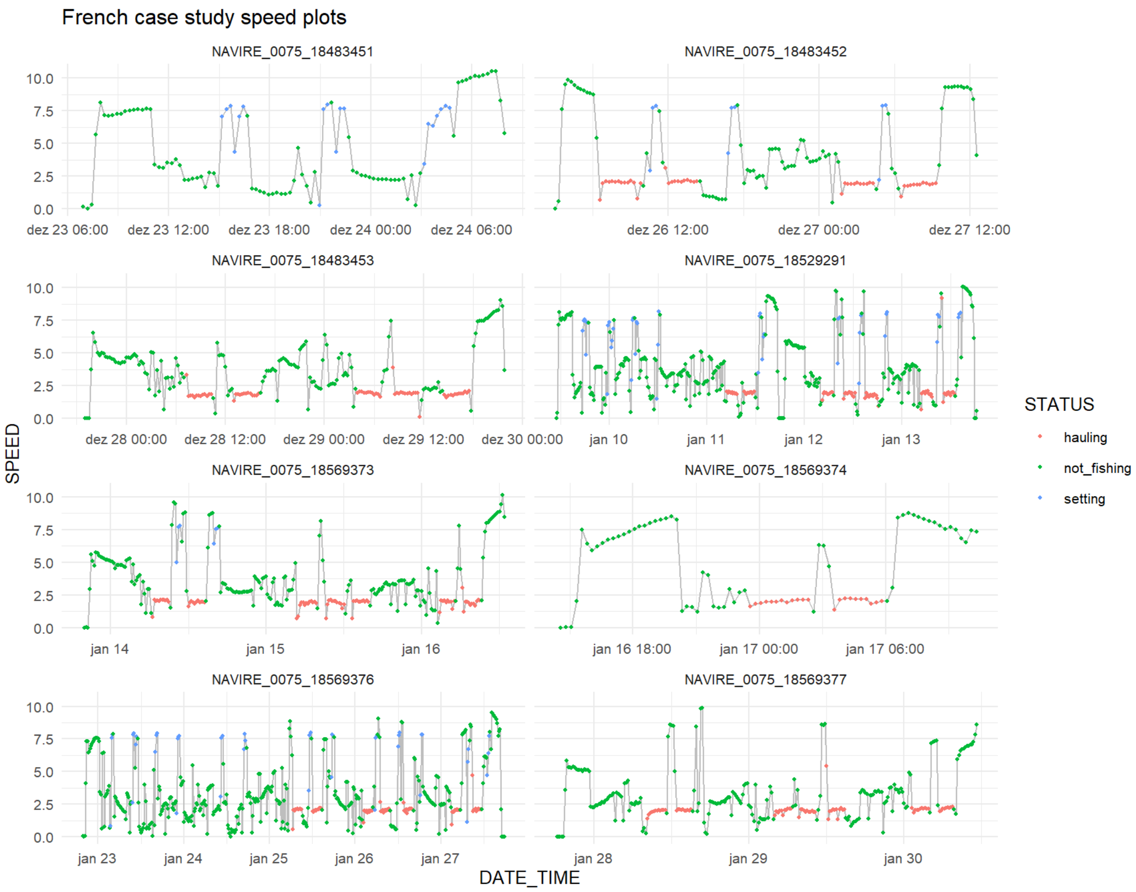
This dataset is a subset of Ifremer RECOPESCA database, for which the fishing operations have been identified and validated with the fisherman. Set provided in iapesca package: https://archimer.ifremer.fr/doc/00819/93094/ (https://archimer.ifremer.fr/doc/00819/93094/)

This database has been anonymized: identity have been changed and spatial geolocation randomly translated.

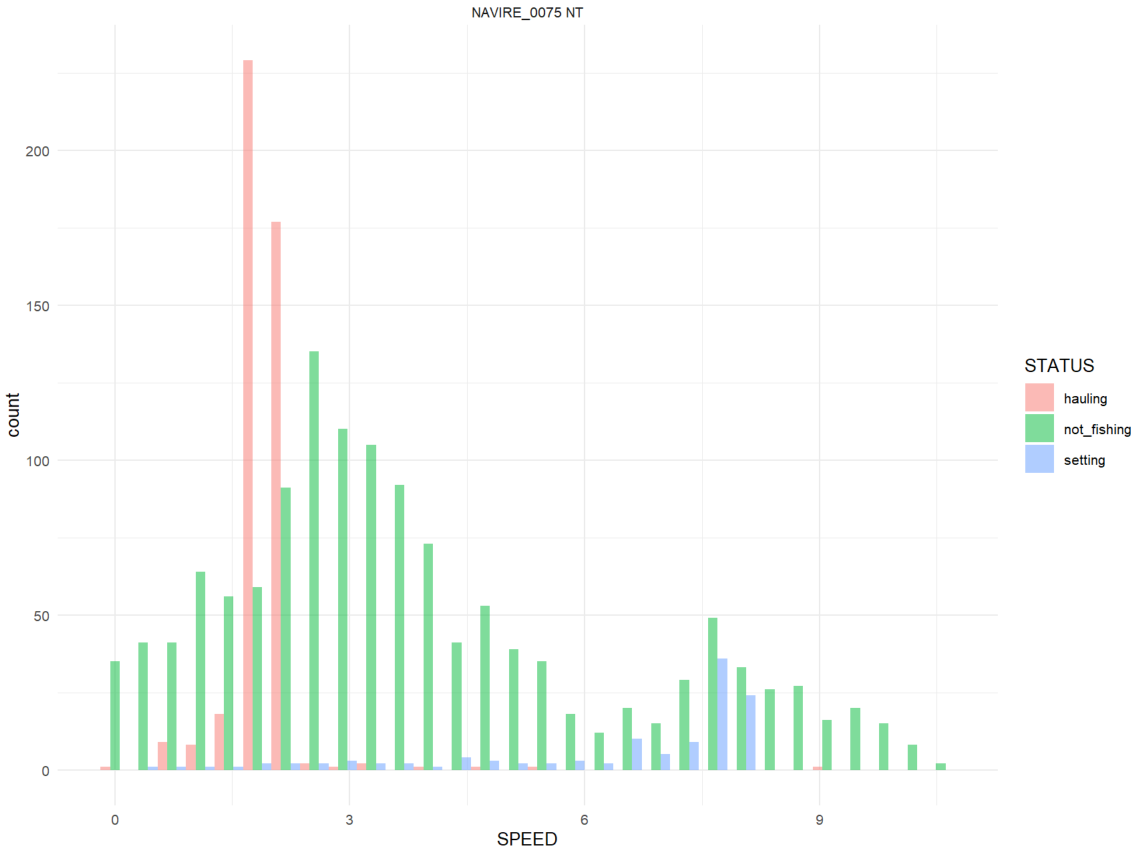
FR_IFR_2021_GP

BOAT_ID	TRIP_ID	GEAR	n	order
NAVIRE_0075	18483451	NT	102	1
NAVIRE_0075	18483452	NT	136	2
NAVIRE_0075	18483453	NT	205	3
NAVIRE_0075	18529291	NT	416	4
NAVIRE_0075	18569373	NT	261	5
NAVIRE_0075	18569374	NT	81	6
NAVIRE_0075	18569376	NT	474	7
NAVIRE_0075	18569377	NT	262	8


French case study geographic plots
NAVIRE_0075_18483451
NAVIRE_0075_18483452
NAVIRE_0075_18483453
NAVIRE_0075_18529291
NAVIRE_0075_18569373
NAVIRE_0075_18569374
NAVIRE_0075_18569376
NAVIRE_0075_18569377
LATITUDE
LONGITUDE
STATUS
hauling
not_fishing
setting


French case study speed plots
NAVIRE_0075_18483451
NAVIRE_0075_18483452
NAVIRE_0075_18483453
NAVIRE_0075_18529291
NAVIRE_0075_18569373
NAVIRE_0075_18569374
NAVIRE_0075_18569376
NAVIRE_0075_18569377
SPEED
DATE_TIME
STATUS
hauling
not_fishing
setting

FR_IFR_2021_GP case study speed histogram plots



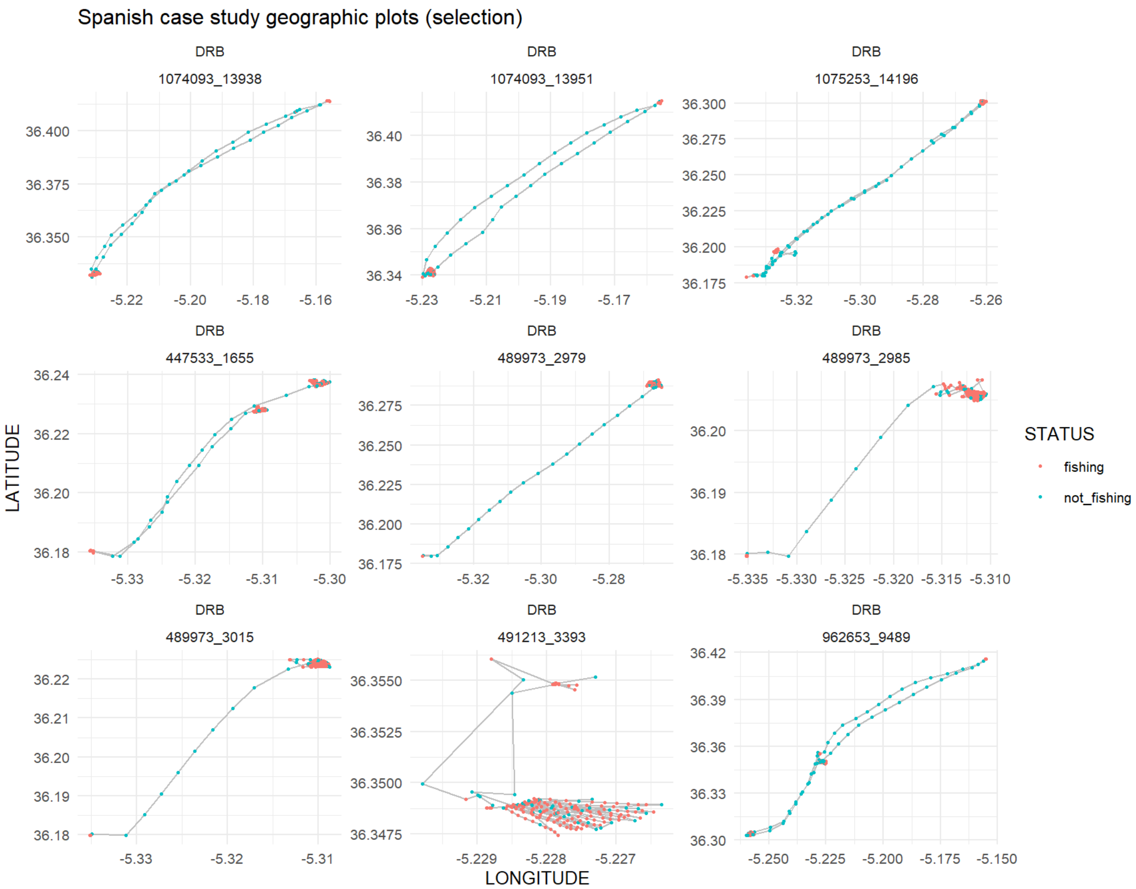

```
## # A tibble: 5 × 3
##   tim.int diff.time.s     n
##     <dbl> <drtn>      <int>
## 1    15   900 secs      738
## 2   900   900 secs      465
## 3    15.1 906 secs       86
## 4    14.9 894 secs       78
## 5   894   894 secs       45
```

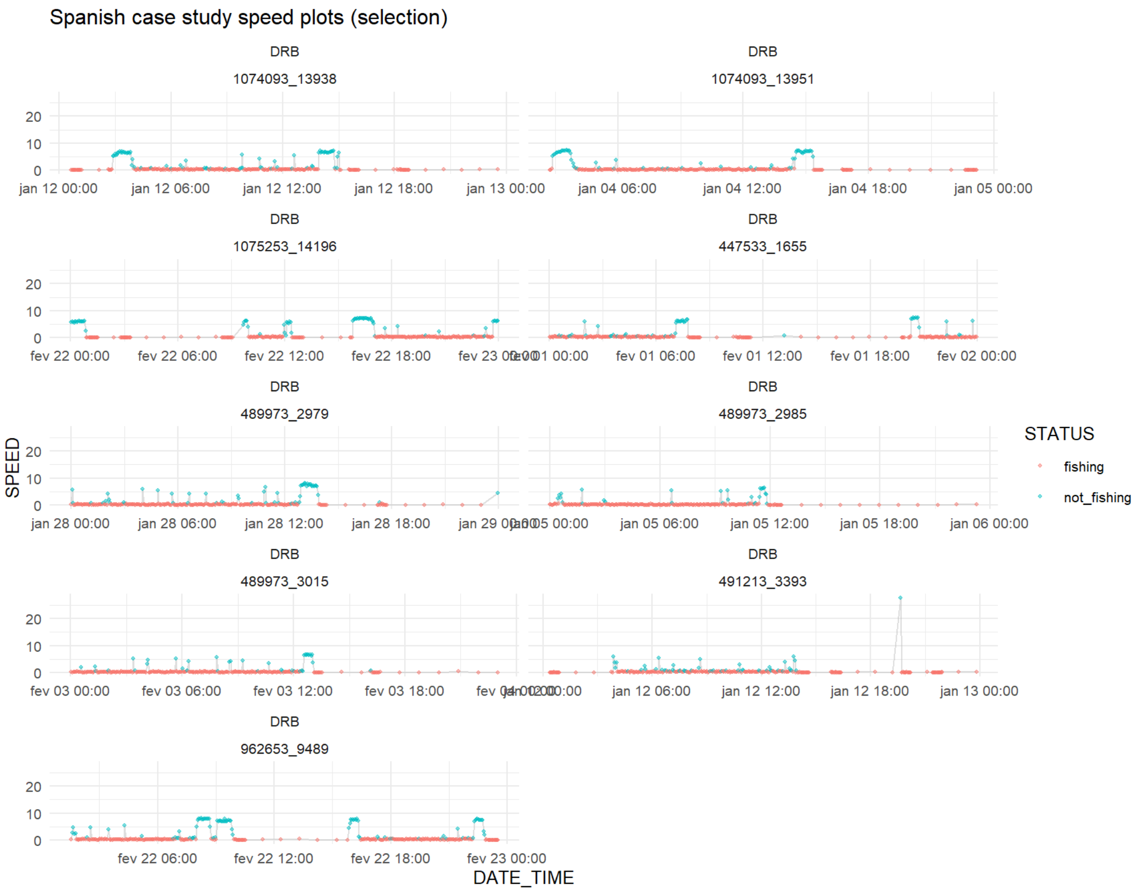
Spanish dataset (IEO)

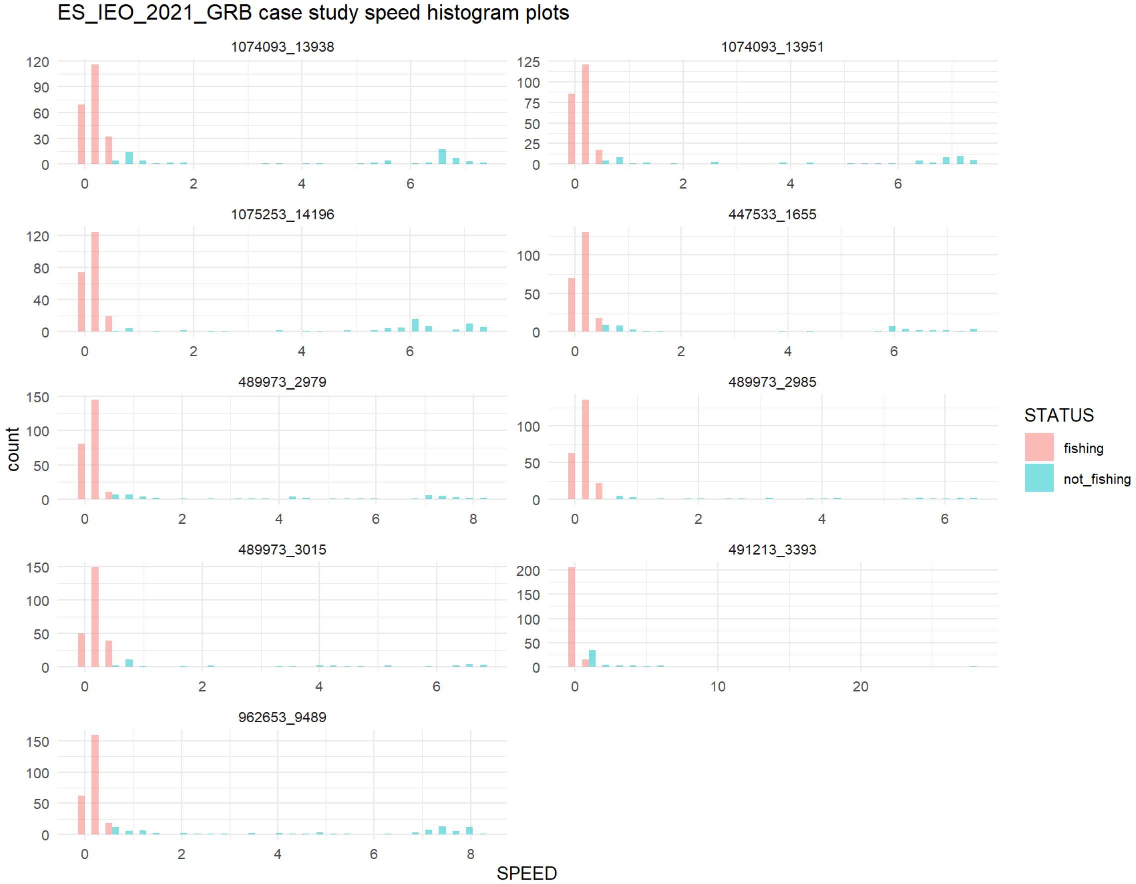
The Spanish data set has data obtained by Green Boxes located on SSF vessels in the South of Spain with different gears: boat dredges (DRB), pots (FPO), trammel nets (GTR), gillnets (GN) and longlines (LLS). However, LLS was not include in the data validation process due to the low number of records in the area. Temporal resolution is 180 secs. Only DRB data was visually validated by an expert, fishermen and on board observers (validation still in process).

ES_IEO_2021_GRB

GEAR	BOAT_ID	TRIP_ID	order
DRB	27	373	1


Spanish case study geographic plots (selection)
DRB
1074093_13938
DRB
1074093_13951
DRB
1075253_14196
DRB
447533_1655
DRB
489973_2979
DRB
489973_2985
DRB
489973_3015
DRB
491213_3393
DRB
962653_9489
LATITUDE
LONGITUDE
STATUS
fishing
not_fishing


Spanish case study speed plots (selection)
DRB
1074093_13938
DRB
1074093_13951
DRB
1075253_14196
DRB
447533_1655
DRB
489973_2979
DRB
489973_2985
DRB
489973_3015
DRB
491213_3393
DRB
962653_9489
SPEED
DATE_TIME
STATUS
fishing
not_fishing

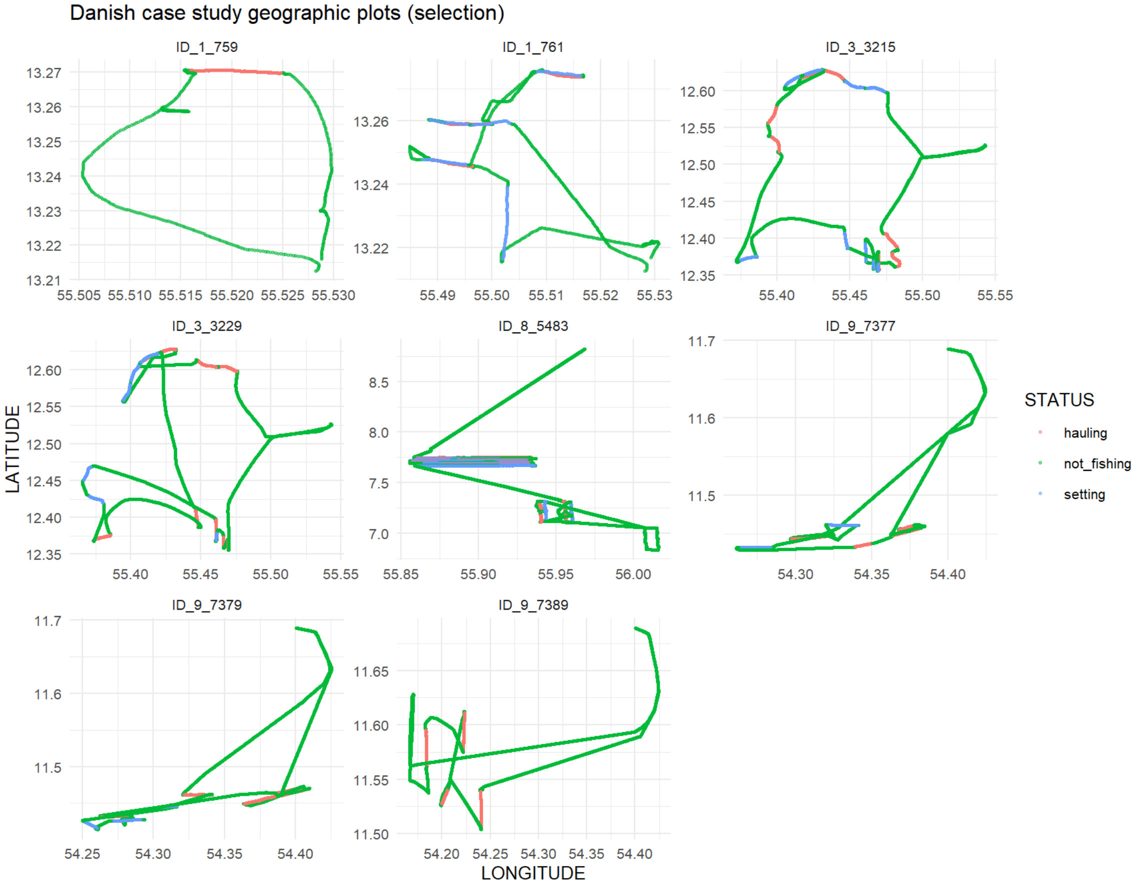



```
## # A tibble: 5 × 3
##   tim.int diff.time.s     n
##     <dbl> <drtn>      <int>
## 1      -3 -180 secs   11882
## 2       3  180 secs    8155
## 3      -4 -240 secs    2319
## 4       4  240 secs    1569
## 5      -2 -120 secs    1134
```

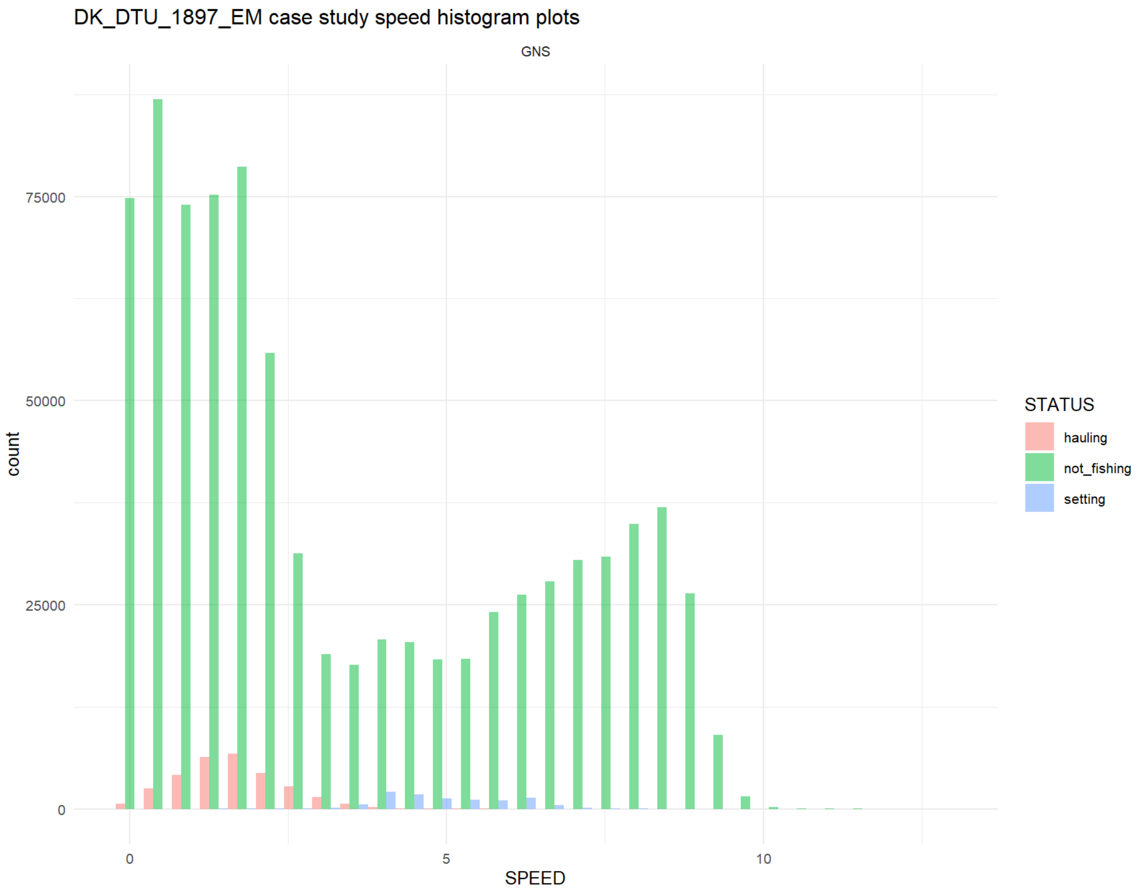
Danish dataset (DTU)

DK_DTU_1897_EM

GEAR	BOAT_ID	TRIP_ID	order
GNS	5	284	1


Danish case study geographic plots (selection)
ID_1_759
ID_1_761
ID_3_3215
ID_3_3229
ID_8_5483
ID_9_7377
ID_9_7379
ID_9_7389
LATITUDE
LONGITUDE
STATUS
hauling
not_fishing
setting


Danish case study speed plots (selection)
GNS
ID_1_759
ID_1_761
ID_3_3215
ID_3_3229
ID_8_5483
ID_9_7377
ID_9_7379
ID_9_7389
SPEED
DATE_TIME
mar 30 00:00
mar 30 12:00
mar 31 00:00
mar 31 12:00
abr 01 00:00
STATUS
hauling
not_fishing
setting




```
## # A tibble: 5 × 3
##   tim.int diff.time.s      n
##     <dbl> <drtn>       <int>
## 1      10 10 secs     826514
## 2      11 11 secs      51760
## 3       0  0 secs        284
## 4       9  9 secs         87
## 5      12 12 secs         66
```

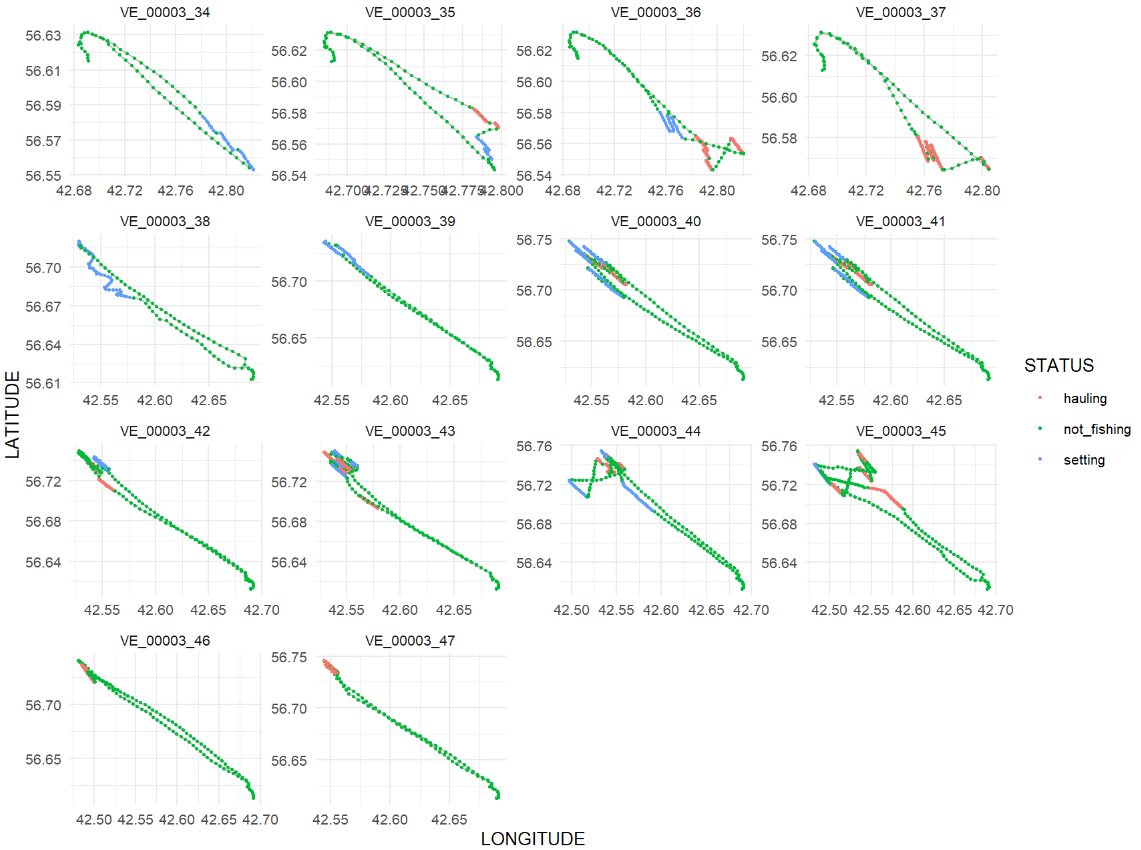
Italian dataset (CNR)

The Italian dataset has been obtained from GPS trackers (Teltonika devices) located on a small-scale fishing vessel employing pots and traps in the Adriatic Sea. Resolution is 1 minute. Data has been validated through expert opinion (interviews with fishermen).

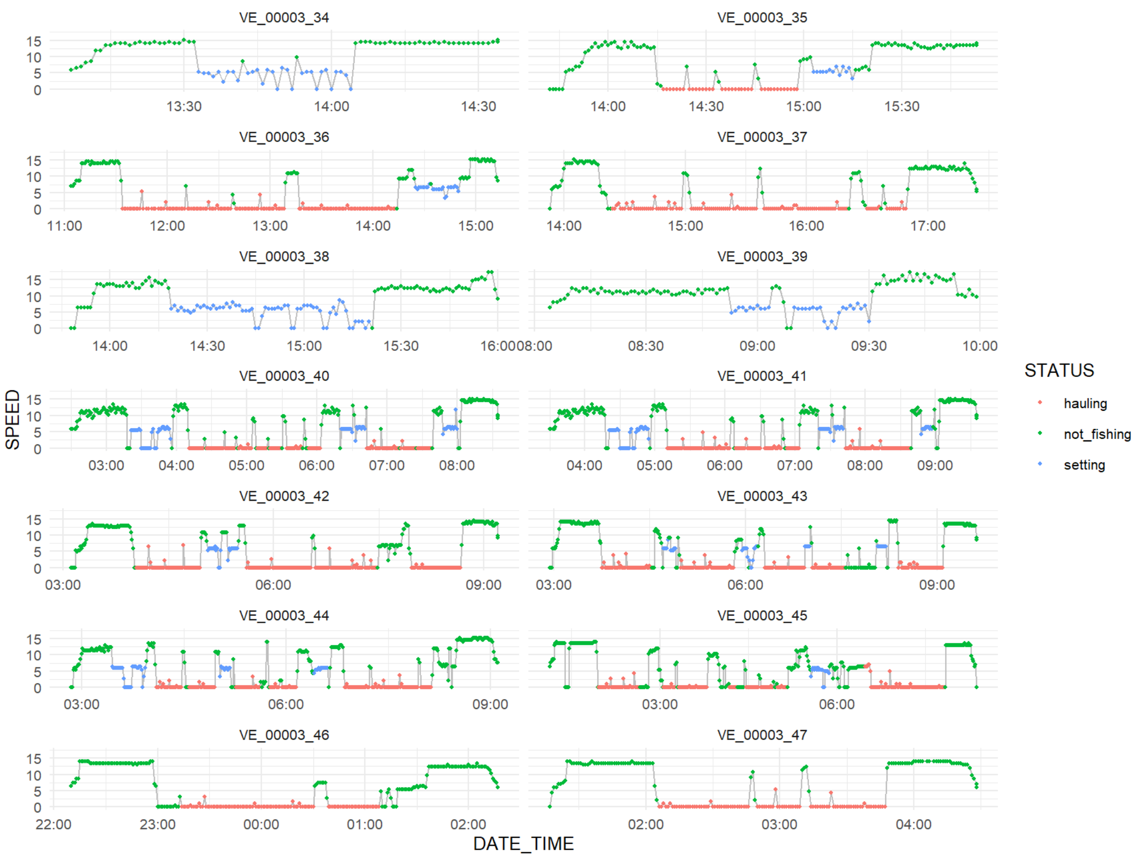
IE_MII_2019_IVMS

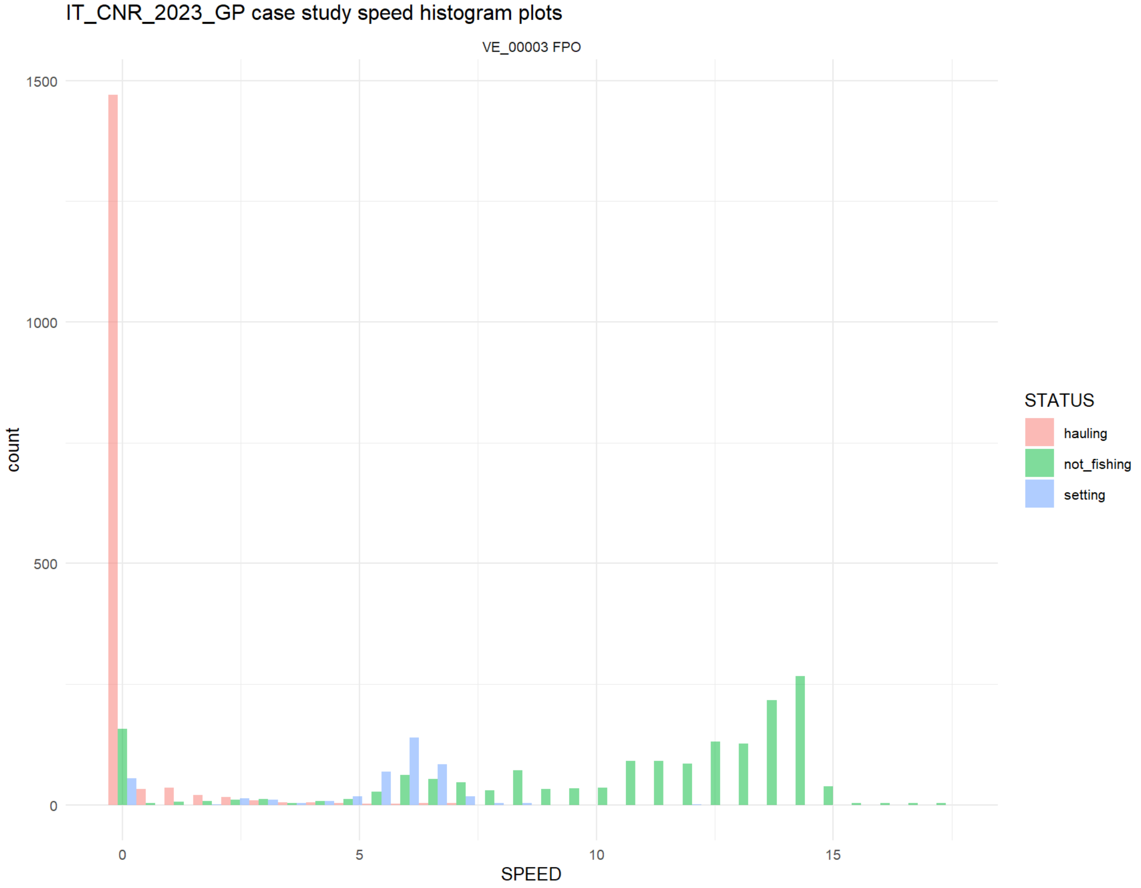
BOAT_ID	TRIP_ID	GEAR	n
VE_00003	34	FPO	90
VE_00003	35	FPO	134
VE_00003	36	FPO	251
VE_00003	37	FPO	213
VE_00003	38	FPO	134
VE_00003	39	FPO	118
VE_00003	40	FPO	367
VE_00003	41	FPO	367
VE_00003	42	FPO	367
VE_00003	43	FPO	403
VE_00003	44	FPO	378
VE_00003	45	FPO	434
VE_00003	46	FPO	250
VE_00003	47	FPO	193

Italian case study geographic plots



Italian case study speed plots



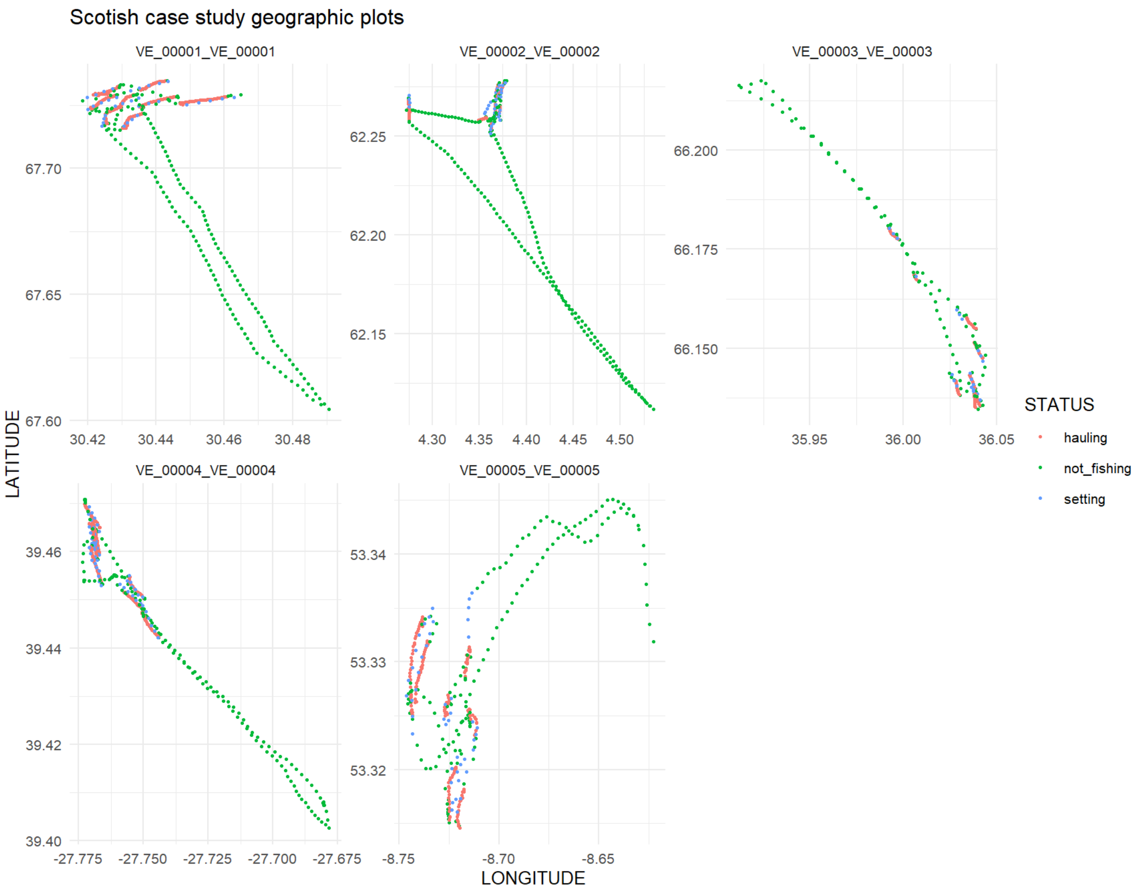


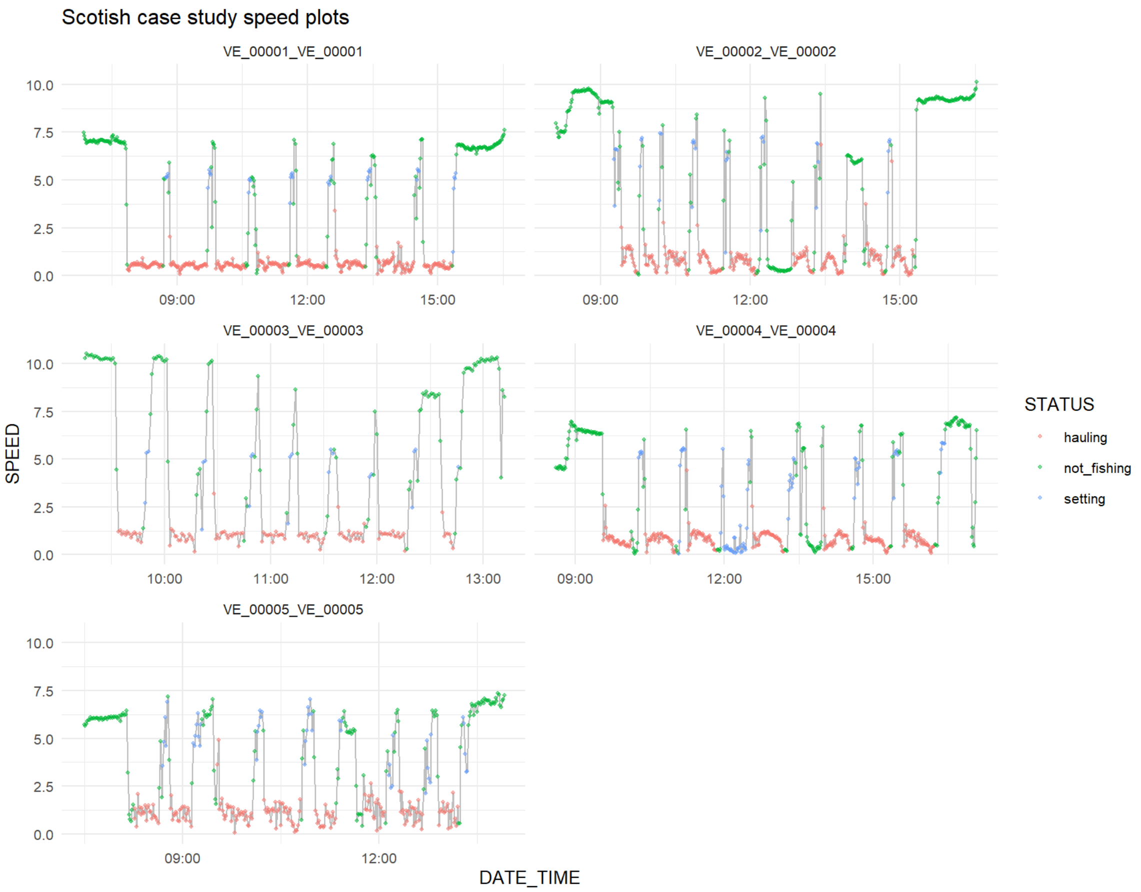

```
## # A tibble: 3 × 3
##   tim.int diff.time.s     n
##     <dbl> <drtn>      <int>
## 1      60  60 secs     3641
## 2       0   0 secs       44
## 3     120 120 secs       14
```

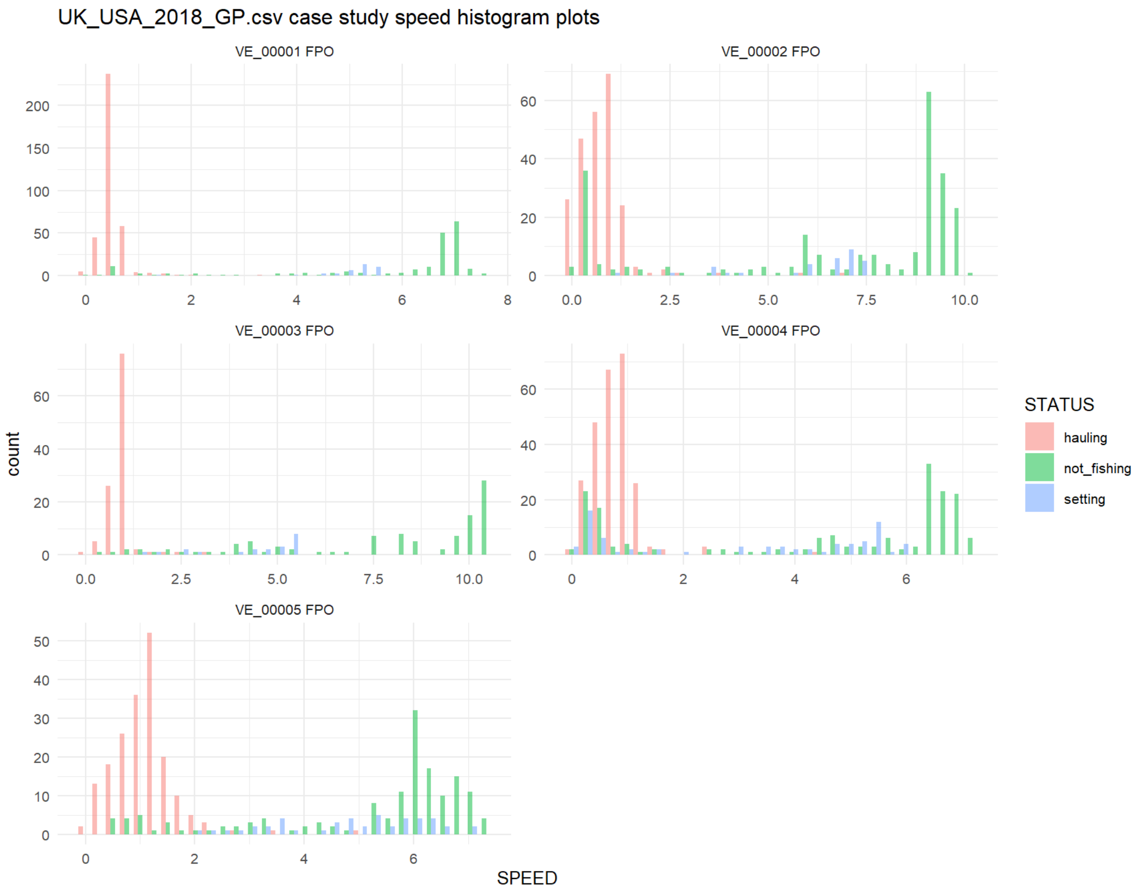
Scotish dataset (St. Andrews)

UK_USA_2018_GP.csv

BOAT_ID	TRIP_ID	GEAR	n
VE_00001	VE_00001	FPO	583
VE_00002	VE_00002	FPO	507
VE_00003	VE_00003	FPO	239
VE_00004	VE_00004	FPO	510
VE_00005	VE_00005	FPO	387


Scottish case study geographic plots
VE_00001_VE_00001
VE_00002_VE_00002
VE_00003_VE_00003
VE_00004_VE_00004
VE_00005_VE_00005
LATITUDE
LONGITUDE
67.70
67.65
67.60
30.42
30.44
30.46
30.48
62.25
62.20
62.15
4.30
4.35
4.40
4.45
4.50
66.200
66.175
66.150
35.95
36.00
36.05
39.46
39.44
39.42
39.40
-27.775
-27.750
-27.725
-27.700
-27.675
53.34
53.33
53.32
-8.75
-8.70
-8.65
STATUS
hauling
not_fishing
setting


Scottish case study speed plots
VE_00001_VE_00001
VE_00002_VE_00002
VE_00003_VE_00003
VE_00004_VE_00004
VE_00005_VE_00005
SPEED
DATE_TIME
10.0
7.5
5.0
2.5
0.0
09:00
12:00
15:00
10:00
11:00
13:00
STATUS
hauling
not_fishing
setting




```
## # A tibble: 2 × 3
##   tim.int diff.time.s     n
##     <dbl> <drtn>      <int>
## 1       1 60 secs      2221
## 2       0  0 secs         5
```

Bind into one global dataset

Examples files WKSSFGEO2

country	SOURCE	BOAT_ID	TRIP_ID	GEAR	boat.trip	REGION	RESOLUTION	TYPE
DK	DTU_AQUA	5	284	GNS	284	Greater North Sea, Baltic Sea, Black Sea	10	green box/black box/robot (GPRS or GSM communication (mobile phones - data and image))
ES	IEO	27	373	DRB	373	Western Mediterranean	180	green box/black box/robot (GPRS or GSM communication (mobile phones - data and image))
FR	IFREMER	1	8	NT	8	Greater North Sea	900	?
IE	MARINE.IE	6	8	HMD	8	Celtic Seas	300	iVMS
IT	CNR-IRBIM	1	14	FPO	14	Adriatic Sea	60	GPS (Teltonika)
PT	CCMAR	3	7	FPO	7	Iberian Coast	20	portable GPS (download the tracks after the trip)
PT	IPMA	8	8	DRB FPO	8	Iberian Coast	30	green box/black box/robot (GPRS or GSM communication (mobile phones - data and image))
UK	Univ_st_andrews	5	5	FPO	5	Celtic Seas, Greater North Sea	60	portable GPS (download the tracks after the trip)