Identifying the recent spatial distribution of fishing activities in the UK EEZ – a report on methods used

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Document Control

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Executive Summary

The report provides a brief description of the analytical methods used to identify the recent distribution of fishing activities in the UK EEZ. The report describes the datasets used, how data from Automatic Identification Systems (AIS) and Vessel Monitoring Systems (VMS) were merged into a single dataset, and how the maps to depict fishing activities were produced. Most importantly this report summarises the main caveats and limitations of the fishing effort maps produced. This report is intended to be used as an accompanying document that provides more information on the metadata for the fishing effort layers which will be made publicly available in the WEBTOOL.

1. Introduction

The growing competition for marine space and the development of new spatial management frameworks, especially in coastal regions, require objective spatial and temporal data on how these areas are used and the economic, social, and cultural "value" derived from such activities. This information is essential for informed decision-making to ensure that fisheries are adequately represented in these processes (Campbell et al. 2014; Metcalfe et al. 2018). Additionally, these data can provide insights into the potential impacts or displacement caused by the expansion of maritime activities, such as Marine Protected Areas or offshore wind farms (Cabral et al. 2017).

The mandatory use of Vessel Monitoring Systems (VMS) to track fishing vessels was introduced in the UK in 2012 for enforcement purposes. VMS use satellites to transmit positional data for a vessel every 2 hours in European waters. However, VMS does not directly indicate when a vessel is engaged in fishing activities, leading to the development of various methods to infer fishing activity from vessel movement patterns. One of the simplest methods is a speed-based rule, where vessel speeds above or below a certain threshold are assumed to correspond to fishing operations (Lee et al. 2010; Palmer 2008). This technique is commonly used to classify VMS data into fishing and non-fishing activities. Despite its widespread use, this approach has faced criticism, primarily due to the low frequency of data collection in VMS in most areas. For example, Muench et al. (2018) demonstrated that using speed thresholds led to misrepresentation of fishing grounds for fisheries other than bottom otter trawling even using a higher VMS frequency (20min-1h depending on the gear used) than the one commonly used in Europe. Similarly, Katara and Silva (2017) found that in the Portuguese purse seine fishery, increasing the time interval for recording positional data from 10 minutes to 2 hours resulted in a 42% loss of recorded trips by the fleet. For inshore fishing vessels (<12 meters in length), Mendo et al. (2019a) showed that an optimal data acquisition frequency of 60 seconds was necessary to accurately identify all hauling events and determine the total area fished.

In the UK, the depiction of fishing activities on a high spatial resolution is currently mainly achieved using VMS data only. The limitations of VMS data, particularly for smaller vessels and fisheries with more complex fishing patterns, have prompted efforts to supplement it with other positional data sources, such as Automated Identification Systems (AIS). The International Maritime Organization (IMO) requires AIS use by all vessels >500GT, for any vessel >300GT that is on an "international voyage" and for all passenger vessels. As of 2011, all UK flagged fishing vessels over 15 meters in length are required to be equipped with AIS. AIS reports position with a frequency which depends on the vessel's speed and manoeuvring status and ranges from every 2 seconds to every 3 minutes. Whilst some vessels under 15 metres in length will carry AIS, it is not mandatory, and fishers are known to switch off their AIS during fishing operations to avoid being observed (by other fishing vessels). AIS uses radio frequencies to transmit information on the position of a vessel, from every few seconds to minutes, to a transceiver located in other vessels, or on ground stations. For instance, Russo et al. (2016) demonstrated that combining VMS and AIS data significantly enhanced the spatial representation of fishing activity distribution in Italy. A similar task was undertaken by CEFAS, which concluded that integrating AIS and VMS data would improve the spatial representation of fishing effort (Martinez et al. 2022). However, this integration was applied to only one day of fishing activities in southern England, as the authors noted that the absence of a common vessel identifier between VMS and AIS data made the integration process difficult (Martinez et al. 2022).

As part of the Fisheries Sensitivity Mapping and Displacement Modelling project (FiSMaDiM), data, methods and tools available to map fishing activities in the UK EEZ were reviewed (Mendo et al. 2023). This report concluded that the most readily available data to be used during the project was VMS and AIS data and that the integration of these data streams could provide an improvement to represent fishing activities in the UK. Therefore, the project aimed to join VMS and AIS data for all vessels operating in the UK EEZ for which these data were available.

The main objectives of this report are:

1) Document the data and methods used to merge AIS and VMS datasets
2) Document the workflow behind the production of fishing effort maps
3) Highlight the limitations and caveats associated with the data used to create the fishing effort maps
4) Provide metadata to adequately understand fishing effort maps provided in the **WEBTOOL**.

2. Fishing activity data

Active fishing vessels in the UK Exclusive Economic Zone (EEZ)

A list of active fishing vessels operating from 2012-2021 in the UK EEZ was provided by the Marine Management Organization (MMO). This dataset contained information on 7,120 common fleet register (CFR) numbers which are unique identifiers given to any fishing vessel which enters the European Union for the first time. Of these vessels, 6,705 were operating under a UK flag, and 415 were operating predominantly under other European country flags, mainly Ireland (178), Norway (82), Belgium (44) and France (43). This dataset also contained information on vessel name, vessel length, main species targeted, and main gear used.

Vessel Monitoring Systems (VMS)

Vessel Monitoring System (VMS) data was provided by the MMO via CEFAS for 2012-2021 only for UK fishing vessels and only for the purpose of this project. This data contains a vessel reference identifier, which can be linked to the CFR number. For the United Kingdom, adding the prefix GBR000 to the vessel reference identifier, makes the CFR number. VMS data is mandatory in the UK since 2012 for vessel over 12 metres in length. In addition, this dataset contains information on the vessel length, vessel position approximately every 2 hours (longitude and latitude), time stamp, speed and heading among others.

Automatic Information System (AIS)

AIS satellite data was provided by CEFAS for 2018-2021 by exactEarth Europe (now Spire Global). This dataset contains the Maritime Mobile Service Identity (MMSI) number field as a unique vessel identifier. This identifier consists of nine digits, three Maritime Identification Digits (country-codes), concatenated with a specific identifier. In addition, this dataset provides information on vessel name, vessel length, vessel position (longitude and latitude) reported usually every few seconds to minutes, time stamp, speed and heading among others. The use of AIS has been a legal requirement in the UK since 2011 for vessels over 15 metres in length.

Linking VMS and AIS data

VMS data contains a unique identifier (vessel reference identifier) that can be related to CFR. In turn, AIS data contains an MMSI number for the device which hypothetical can be moved between different vessels by the owner of the device. To match the vessel tracking data from vessels within the AIS dataset with the VMS dataset, we used four sources of information:

1) MMO-provided list. This list contained information on the CFR number and associated MMSI numbers. We could match 400 CFR with corresponding MMSI numbers.
2) Maritime Coastguard Authority- provided list: 112 CFR and MMSI matched.
3) European Fleet registry database (https://webgate.ec.europa.eu/fleet-europa/index_en) is a database where all fishing vessels with an EU flag must be registered. Any changes in the status of a fishing vessel, for example if it has been scrapped, need to be registered by the member country in the Fleet Register. This database provided matching information for 424 vessels.
4) Global Fishing Watch database (Park et al. 2023), provided matching information for 1652 vessels. The list provided by GFW on many occasions returned many possible MMSI numbers per CFR. We used the Marine Traffic website (www.marinetraffic.com) to identify which was the correct MMSI number associated to each vessel's CFR. The marine traffic website does not provide CFR numbers, so the approach consisted of matching vessels per country flag and name first, and then proceeding to manually inspect the photographs available on the website for each vessel. In these photographs, we could identify the Plate License Number (PLN) of the vessel, which was available from the initial list of active fishing vessels provided by the MMO. We considered a match to be correct if the PLN was observed in any of the photographs.

At the end of this process, VMS data could be complemented with AIS data for 569 vessels. 1,788 new vessels with AIS data only were added to the dataset for estimation of fishing effort, 1,245 of these with a UK flag. Most vessels above 12 metres in length had information on the corresponding AIS device, while only about 24% of vessels below 12 metres length had AIS units (Figure 1). For vessel below 12 metres in length, the main gears used were pots and traps, followed by nets.

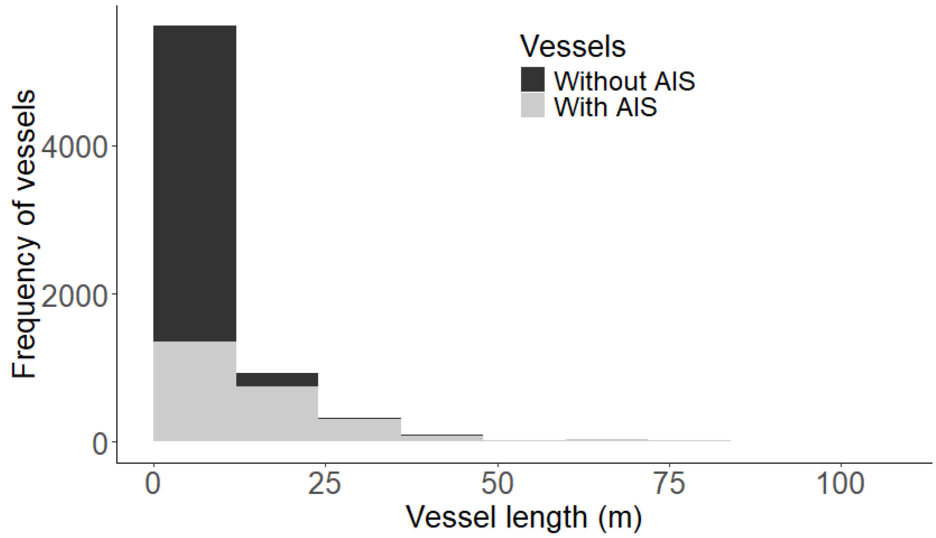

Figure 1 Frequency of vessels with AIS devices per vessel length grouped in bins of 12 metres each.

Merging AIS and VMS data

Once the CFR and MMSI numbers were matched, AIS data was merged with VMS data on a per-vessel basis for each year. The data was separated into three main groups for further analysis: one dataset with vessels for only VMS data was available (from now on VMS only), one dataset with vessels for which VMS and AIS data was available (VMS+AIS) and a last dataset containing vessels for which only AIS data was available (AIS only).

Creation of gear groups

For vessels with VMS, information on gears used on each fishing trip was obtained from iFish (MMO fisheries activity data), which uses FAO gear codes. For vessels for which only AIS data was available, the gear was assigned on a per vessel basis, using information from iFish, and selecting the gear group that was used most frequently. When no gear information was available from iFish, information provided by Global Fishing watch (see https://globalfishingwatch.org/datasets-and-code-vessel-identity/ to understand how gear class is assigned) and by the EU fleet registry were used to select gear. The gear classification in these two sources is not at the level of detail provided by FAO, therefore, "gear groups" were created (Table 1). Gear groups were only assigned where both sources of information (GFW and EU Fleet Registry) matched. Eight gear groups were created to represent main fishing activities around the UK EEZ (Table 1).

Table 1 Gear groups assigned to vessels using CEFAS, GFW and EU Fleet registry information

Gear group assigned	Gears included in MMO fisheries activity database list	Other codes included in GFW and EU Fleet registry
Traps	"FPO","FAR","FIX","FPN","FYK"	"POTS_AND_TRAPS"
Dredges	"DRB","DRH","HMD"	"DREDGE_FISHING"
Demersal trawls	"OTB","OTT","PTB","TBB","PUL","TB","TBN","TX","OT"	"TBB|TRAWLERS", "OTB|TRAWLERS", "TBN|TRAWLERS"
Hooks and lines	"LHP","LHM","LLD","LLS","LTL","LL","HF","LX"	"SET_LONGLINES", "DRIFTING_LONGLINES","POLE_AND_LINE"
Seine nets	"SB","SDN","SPR","SSC","SV","SX",	"OTHER_SEINES"
Gillnets and entangling nets	"GNC","GND","GNS","GTN","GTR","GN","GEN","GNF"	"SET_GILLNETS", "GNS"
Surrounding nets	"PS"	"PURSE_SEINES"
Pelagic midwater trawl	"OTM","PTM","TMS","TM"	"OTM|TRAWLERS", "PTM|TRAWLERS"

3. Inferring fishing operations

Identifying individual trips

We used the workflow developed by Mendo et al. (2024) to identify individual vessel trips and infer fishing activities from highly resolved geospatial data (Figure 2). Briefly, data are segmented to study area, duplicates removed, points on land removed, unrealistic velocities (>25 knots) deleted. To segment the datasets into individual trips, VMS data was assigned trip identifiers provided by CEFAS and therefore trip information was available in the VMS only and VMS+AIS datasets. Trip identifiers from logbook data are assigned to the VMS data, for each vessel, where VMS signals are recorded between the departure and return date of a trip. For the AIS only dataset, we used information on vessel anchorage points provided by Global Fishing Watch (https://globalfishingwatch.org/data-download/). Trips were segmented each time a vessel entered and left one of these anchorage points. Tracking data for vessels in port and spurious trips (trips shorter was 5 km or 1 hour, and trips for which only 5 points were available) was deleted.

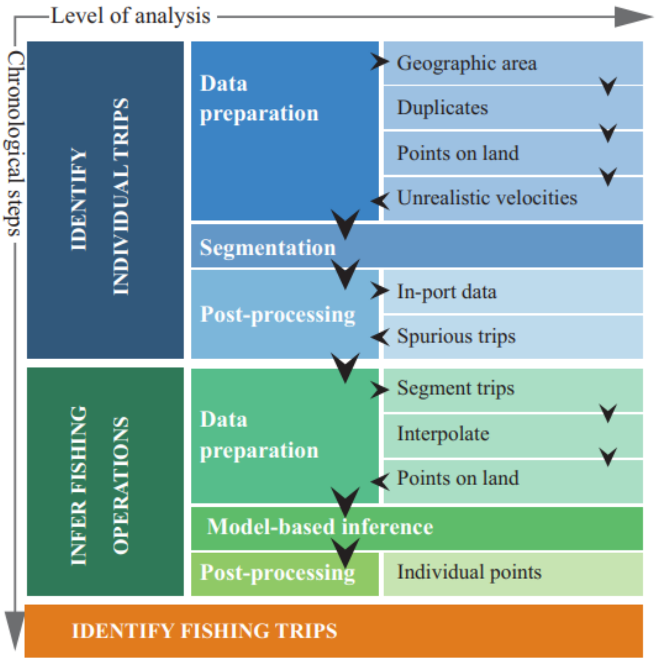

Figure 2 Workflow to identify fishing trips, figure from Mendo et al, 2024

Inferring fishing operations (hauling gear or actively fishing)

Once individual trips were identified, trips were segmented into those where there was no positional information for more than 4 hours or if the distance between consecutive locations was greater than 60 km. Once trips were segmented, the data was interpolated to every 20 minutes, using a method adapted from (Russo et al. 2011).

An Expectation Maximisation (EM) algorithm was used to infer fishing activities for each vessel in each gear group, following Mendo et al. (2019b). For passive gear groups (traps, hooks and lines, seine nets, gill and entangling nets and surrounding nets), the first underlying normal distribution was assumed to correspond to hauling events (smallest mean). The upper threshold for hauling activities was calculated as the estimated mean of the hauling speed distribution plus two times the estimated standard deviation. For active gears (dredges, demersal trawls and pelagic midwater trawlers), the second normal distribution was assumed to correspond to fishing activities (second highest mean value). For these, in addition to the upper threshold, a lower threshold was calculated as the estimated mean of the hauling speed distribution minus two times the estimated standard deviation.

For some vessels, lower and upper thresholds inferred by this method produced unrealistic values for hauling gear or fishing, therefore a further rule was applied by calculating the 90th percentile of all thresholds identified for all vessels within a gear group and setting this as a gear group threshold, below or above which the threshold inferred from the data were overridden and replaced by these values. The vessel speeds which the EM algorithm identified as fishing were validated by fishing representatives in the Project Advisory Group and using scientific literature (Lee et al. 2010; Muench et al. 2018; Murray et al. 2011).

4. Producing fishing effort maps

Once hauling gear activities (for passive gears) and fishing (for active gears) was inferred per vessel, we joined the three datasets (VMS only, AIS + VMS, and AIS only) to produce combined maps of fishing effort. For each gear group, all positions associated either with hauling or fishing, were added onto a 5x5 km grid. For each grid cell, the time spent hauling or fishing was summed. VMS data were available for 2012-2021, while AIS data were only available from 2018-2021.

Due to commercial sensitivities associated with some of the data, fishing effort data is only shown in grid cells for which at least 3 vessels were operating during 2012-2021. These maps will be made publicly available in the webtool to be published at the Cefas Spatial data hub. And an example map is shown in Figure 3.

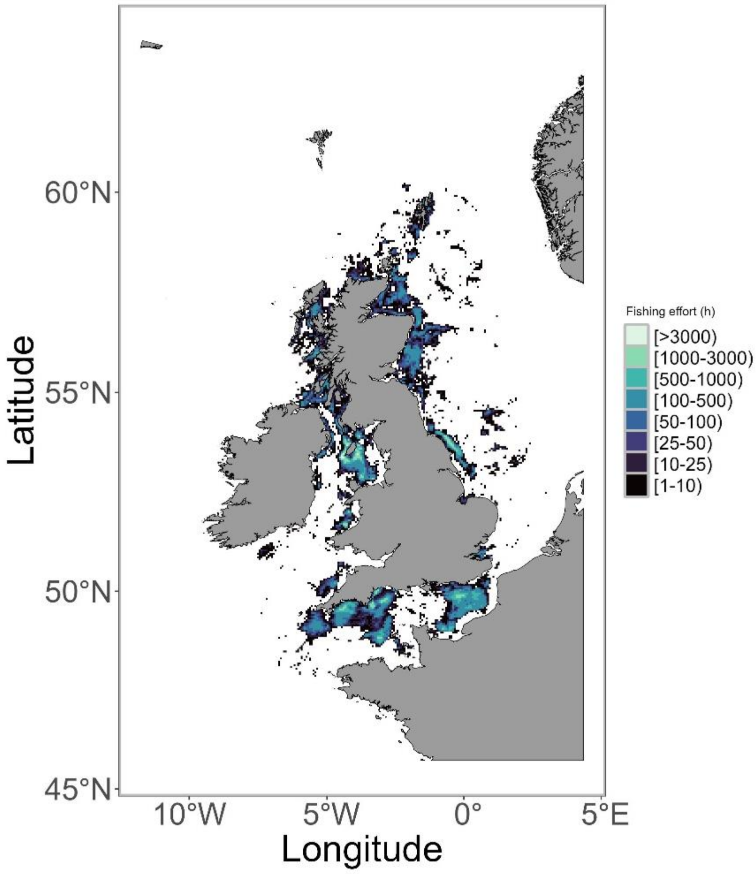

Figure 3 Fishing effort (hours) from 2012-2021 for vessel using dredges

5. Main caveats and limitations

While representing the most complete spatial depiction of fishing effort for vessels operating in the UK EEZ to date, there are several caveats and limitations of the data that need to be highlighted.

1) VMS data are only mandatory for vessels greater than 12 metres in length, therefore smaller vessels are mostly not included in this dataset.
2) VMS data were only available for UK flagged vessels, VMS data from other countries operating in the UK EEZ was not available for the current analysis.
3) AIS data were only available from 2018-2021, not for the whole duration of the study period (2012-2021). AIS is only mandatory for vessels greater than 15 metres in length, and, while some vessels below

this size threshold might have installed AIS units, not many smaller vessels will be represented by this dataset.

4) AIS data were available for all vessels operating in the UK EEZ, that included non-UK flag vessels. While this data can inform fishing effort, corresponding catch information is not available for this fishing activity only identified by AIS.
5) AIS data was assigned to augment VMS data based on the last vessel currently identified to have carried the AIS device, past vessels and transferring the AIS device between vessels were not included.
6) The current data processing framework includes interpolating every 20 minutes between spatial locations, an approach that is not currently used by CEFAS.
7) For active gear groups (dredges, demersal trawls and pelagic midwater trawlers) hours actively fishing (e.g. dredging, trawling) are depicted, while for passive gear groups (traps, hooks and lines, seine nets, gill and entangling nets and surrounding nets) hours actively retrieving gear are depicted as fishing effort, not soaking time. As fishing effort is depicting in two different ways for active and passive gear groups, the data presented in final maps are not comparable and should only be used to represent each fishing gear group separately.
8) Fishing or hauling/retrieving gear activities are inferred using mainly speed thresholds – these thresholds have been revised with fisheries representatives of the Project Advisory Group and by looking at the scientific literature, however, no data-based validation was conducted. Due to lack of data on fishing activity on a wider base, a participatory approach to validate resulting is recommended to validate the results.
9) Due to commercial sensitivities associated with some of the data, fishing effort data is only shown in grid cells for which at least 3 vessels were operating during 2012-2021.

6. Conclusions and recommendations

The project has generated the best possible representation of fishing activities from vessel tracking data by merging two sources of information: VMS and AIS data to current standards. First, it added positional information on 1,788 vessels that were previously not included in the VMS dataset, 1,245 with UK flag. Most of these vessels were vessels smaller than 12 metres length using mainly pots and traps and nets. Second, it added higher frequency positional data to 560 vessels for which VMS data was available every 2 hours. The method (and associated R scripts) to merge VMS data and AIS and produce maps depicting fishing effort has been developed and shared with CEFAS.

While adding AIS data included positional data for vessels for which previously no data had been available, most vessels smaller than 12 metres in length are still not included when trying to represent fishing activities using vessel tracking data. Wales is currently tracking the whole fleet (including inshore fishing vessels) (Welsh Statutory Instruments 2022), and England has rolled out a process for mandatory tracking in all fishing vessels (MMO 2022). These data should be incorporated into the depiction of fishing activities as soon as possible to adequately represent fishing activities in the UK.

Vessel tracking data provides information on the location of the vessel, but fishing activities must be inferred. Currently, most fishing activities are inferred using speed thresholds, however, the accuracy of these methods needs further investigation. On-board observer data collected regularly by CEFAS and Marine Scotland could be used to validate which methods are more adequate for each gear group. For static gear, effort metrics could be improved by estimating soak time coupled to a suitable metric of number (for pots and traps), length and number of hooks (for hooked lines), length of net (for static nets).

Due to commercial sensitivities associated with some of the data, final fishing effort maps only portray information in grid cells for which at least 3 vessels were operating during 2012-2021. The number of cells omitted due to this current practice varies per gear group and is associated to the spread in fishing activities around the UK. For example, in pots and trap fisheries, fishers tend to use core fishing grounds that will not be used by other fishers. This might lead to underrepresentation of fishing areas for this gear group, which might be amplified further when grid cell size is decreased to areas that might be more informative for offshore wind developments. For example, Stelzenmueller et al. (2022) showed that even resolutions of 0.05 degrees of gridded fishing effort tend to overestimate the actual overlap between fishing activities and offshore windfarms. It has been noted that to appropriately represent fishing activities, fine scale depictions of effort (0.01 x 0.01 degrees, roughly 1 x 1 km) are needed, as some offshore wind sites can cover areas of only few squared kilometres (Stelzenmüller et al., 2022).

This work is focused on improving the spatial resolution of documented fishing effort. There is more work to be done to link the fishing location to fishing landings and other metrics important for fisheries management as well as social and economic impact assessments if to be integrated into marine management.

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