Deliverable 5.1

Deriving fishing effort from high-resolution geo-spatial data using the {iapesca} R-package

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Executive summary

Assessment and mitigation of bycatch of Endangered, Threatened and Protected (ETP) species requires an understanding of where, when and how fishing activities overlap with the distribution of vulnerable species. While bycatch observations are often collected through on-board observers, electronic monitoring, self-sampling programmes or dedicated research projects, these observations typically cover only a small proportion of fishing operations. To estimate total bycatch and identify fisheries, gears, locations or seasons associated with higher risk, the observed bycatch events are scaled up to the fleet level using appropriate measures of fishing effort.

Effort data reported and used for bycatch assessments in ICES Working Group on Bycatch of Protected Species are generally available at the spatial resolution of ICES areas, with days at sea being one of the most commonly used fishing effort metrics. The purpose of this deliverable is to present a method for analysing high-resolution vessel position data, where available, to derive more detailed fishing effort metrics, including gear dimensions and soaking time. Such metrics can improve the identification of spatial overlap between fishing activities and the distribution of ETP species, thereby supporting more robust risk assessments. Analysis of high-resolution data from fishing vessel tracking systems makes it possible to derive spatially explicit estimates of fishing effort for both active and passive fishing gears.

Although high-resolution vessel position data, including AIS data, are available for some fisheries and regions, access to datasets with sufficiently high temporal resolution, spatial coverage and associated fisheries information for scientific fishing effort information remains limited. This deliverable therefore focuses on describing the methodology, the available R package, and the workflow developed within CIBBRiNA to apply such analyses where suitable data are available. The application of the method is further demonstrated through examples of net fisheries for which AIS data are available. The case study illustrates both the feasibility and the potential value of applying these methods where high-resolution vessel tracking data can be accessed.

The R package {iapesca}, originally developed as part of the multidisciplinary DELMOGES project aimed at gaining a better understanding of bycatches of common dolphins in the Bay of Biscay, has been adapted for a wider range of applications within the CIBBRiNA project. It provides tools for analyzing high-resolution geolocation data for vessels operating active or passive fishing gears, including data cleaning, fishing-trip detection, trajectory analysis, tools for simplifying the implementation of machine-learning models, fishing and gear effort computation, to produce usable outputs for the different case studies of the project, but also to be used more broadly whenever such data is

available. Above all, it enables the implementation of innovative methods combining machine-learning and geo-computation to describe the behaviour of passive gears based on fishing-vessel tracking data (Mendo et al., 2023).

In addition to the development of new methods and functions, a standardised workflow and a tutorial have been specifically written for the CIBBRiNA project's case studies. This step-by-step tutorial describing the workflow is one of the main components of this deliverable and is available at: https://doi.org/10.13155/112293 (Rodriguez, 2026). Dedicated training was provided during a workshop held in Lisbon in February 2026. During this workshop, high-resolution outputs were successfully generated where sufficient data were available. Whilst various applications demonstrate the technical feasibility of applying this type of approach, the issue of the availability and representativeness of high-resolution geolocation datasets remains a relevant concern for most fisheries.

In parallel, approaches for extrapolating results derived from high-resolution geospatial data analysis to fleet segments for which such data are not available have been developed and tested, thereby supporting broader application of fishing effort estimates in bycatch assessments.

This deliverable is primarily intended for researchers and analysts involved in CIBBRiNA case studies, but the methods, workflows, and tools presented are also relevant to a broader community working on fisheries monitoring, ecosystem-based fisheries management, marine spatial planning, and bycatch assessment. The principal limitation identified during CIBBRiNA was not the performance of the workflow itself, but the availability of sufficiently detailed vessel tracking data required for implementation.

Because high-resolution vessel tracking data may contain commercially sensitive information and potentially identifiable information relating to individual fishers or vessels, the analyses described in this deliverable were undertaken within the CIBBRiNA Safe Working Environment. This approach enables collaborative development and testing of methods using shared scripts and standardised workflows while ensuring that confidential fisheries data remain protected and that outputs comply with agreed data-sharing and anonymisation requirements.

Background to CIBBRiNA

The Coordinated Development and Implementation of Best Practice in Bycatch Reduction in the North Atlantic, Baltic and Mediterranean Regions (CIBBRiNA) project aims to minimise the bycatch of Endangered, Threatened and Protected (ETP) species in the North-East Atlantic, Baltic, and Mediterranean seas, working collaboratively as fishers, authorities, scientists, and other relevant stakeholders, to achieve this. The species that we focus on include a variety of marine mammals, birds, turtles, and elasmobranchs (sharks, skates, and rays).

Through cross-border and cross-sectoral collaboration involving stakeholders from 13 European countries, CIBBRiNA is establishing mitigation, monitoring, and assessment programmes in a selection of fisheries. Within a proactively fostered “Safe Working Environment” characterised by mutual trust, safety, and cooperation, we will build on a review of current approaches and learning from our Case Study fisheries to deliver an innovative toolbox designed to be integrated into policy and best practice in European fisheries management.

CIBBRiNA is funded by the EU’s LIFE programme and runs from 2023 to 2029.

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Acronyms

AIS	Automatic Identification System. A maritime safety and vessel tracking system that transmits vessel identity, position, course and speed. The reporting interval is variable (depending on vessel speed and navigation status), ranging from seconds to approximately 3 minutes. AIS can be switched off, and reception depends on availability of terrestrial or satellite receivers. Raw AIS needed to apply the {iapesca} method are not necessarily available to all scientific institutes. Although AIS data products may be accessible through platforms such as Global Fishing Watch, their coverage rate of fishing activity is variable depending on the region and period.
CIBBRiNA	Coordinated Development and Implementation of Best Practice in Bycatch Reduction in the North Atlantic, Baltic and Mediterranean Regions
DCF	EU Data Collection Framework
FDI	EU Fisheries Dependent Information
GNSS	Global Navigation Satellite System.
ICES	International Council of the Sea
RCG	EU DCF Regional Coordination Group
RDBES	ICES Regional Database and Estimation System
SIH	Système d'Informations Halieutiques. Ifremer French Fisheries Information System
VMS	Vessel Monitoring System. Requirement in EU control regulation to report positions with maximum 2-hour intervals. All vessels > 12 m loa (with some exemptions for vessels < 15 m loa)
WP	Work Package
WGSFD	ICES Working Group on Spatial Fisheries Data

1. Introduction

Understanding the spatial distribution and intensity of fishing effort is essential for fisheries management, ecosystem-based management, marine spatial planning, and the assessment of interactions between fishing activities and sensitive species and habitats. The increasing availability of high-resolution geolocation data, such as Automatic Identification System (AIS) data or other programmes collecting high-resolution position data, has created new opportunities to derive detailed indicators of fishing effort and fishing activity.

To support the use of available high-resolution position data for fishing effort estimation, CIBBRiNA Task 5.1 focused on the development, documentation, and application of a standardized workflow for deriving fishing effort metrics from high-resolution geospatial vessel tracking data. The main output of this work is the {iapesca} R package, which implements the workflow and provides a reproducible framework for processing tracking and fisheries data.

The objective of this deliverable is therefore not to generate fishing effort estimates for all CIBBRiNA case studies, but to provide a transferable analytical framework that can be applied where suitable geolocation data are available. This report documents the workflow, describes the functionalities of the {iapesca} R package, and demonstrates its application through examples.

Where high-resolution geolocation data are not available, alternative approaches may be required. Such developments are discussed in the perspectives section and represent a potential area for future work.

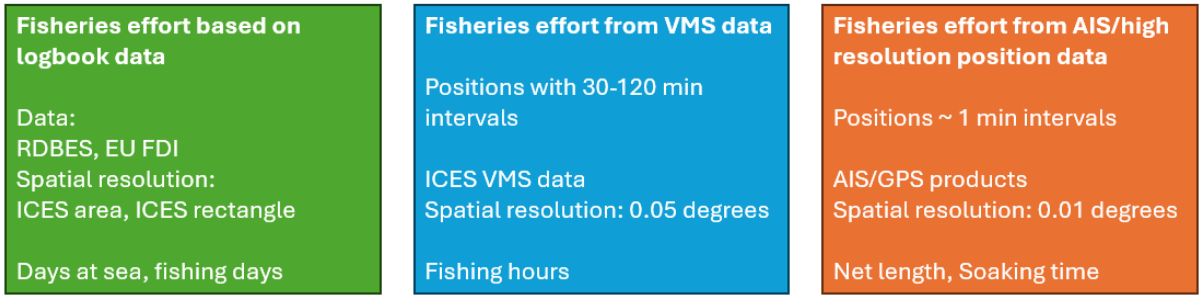


Figure 1. Conceptual relationship between vessel tracking data sources and the level of detail available for estimating fishing effort indicators. While conventional fishing effort metrics (days at sea and fishing days) can be derived from logbooks, high-resolution geolocation data such as AIS or onboard GNSS enable estimation of behaviour-based indicators including gear deployment, soak time and net length. The development of high-frequency vessel monitoring systems may further expand the applicability of these approaches.

CIBBRiNA deliverable 5.1 consists of:

- The development and adaptation of the open-source {iapesca} R package for deriving fishing effort from high-resolution geospatial data available to the CIBBRiNA project https://gitlab.ifremer.fr/iapesca/r-packages_iapesca;
- A documented and harmonized workflow for high-resolution vessel tracking position data;
- A tutorial supporting implementation of the workflow https://doi.org/10.13155/112293 (Rodriguez, 2026);
- This report documenting the methodology, workflow, applications, limitations and future developments.

2. Contribution of high-resolution geolocation in determining the fishing effort

2.1. Fishing effort data concepts and definition

To help understand the fishing effort data, some general concepts and principles are described. The concepts summarized below are generally agreed and applied by EU for reporting fishing effort data to data calls (RDBES, FDI etc.).

Nicosia report and principles

In 2016 the JRC initiated the 2nd Workshop on transversal variables, (see Ribeiro et al., 2016). The definition of the fishing effort measures *Days at Sea* and *Fishing days* were reviewed and agreed. In addition, several scenarios for calculating fishing effort were identified and the R package for calculating fishing effort {fecR} was started. This code is now maintained by the RCG ISSG on Metier and transversal variables and hosted at JRC GitLab: https://dcallnet.jrc.ec.europa.eu/gitlab/r-packages/fecR.

- **Days at Sea:** the number of 24-hour periods during which a vessel is absent from port and engaged in fishing activity. It is calculated as DaS = (arrival time – departure time)/24, and rounded up to nearest integer.

- **Fishing days:** counts of vessel fishing days (dates) that include active fishing operations.

During a trip there can be more fishing days (calendar dates) than days at sea (24-hour periods), as a vessel can depart in the evening, engage in fishing activity both before

midnight and after midnight and come back the next morning. This would result in 1 day at sea and 2 fishing days.

Vessel effort and gear effort

Fishing effort can be related to the vessel (as vessel tracking is) and to the fishing gear.

- **Vessel effort:** the effort by the fishing vessels, e.g., days at sea, fishing days or recording of the vessel positions , which allows for the calculation of fishing time.
- **Gear effort:** the effort and characteristics of the gear deployed in the water, e.g., net length, soaking time, net height, number of hooks, number of pots.

In the case of active gears, the gear effort is closely linked to the vessel effort. However, for passive gears, the vessel effort is related to its activity, namely setting and hauling of the gear, while the gear effort is not directly linked to the vessel's activity. Both measures are essential, as the vessel effort is used by economists, e.g., to calculate fuel cost, while the gear effort is used by scientists e.g., to relate to catches or risks of bycatch of ETP species, for marine spatial planning and ecosystem impacts. For small-scale fisheries, where logbook data are not available, and in the absence of contradictory information, the commonly applied assumption used is: 1 sales note = 1 fishing trip = 1 day at sea = 1 fishing day.

2.2. Current use of geolocation data to assess the vessel fishing effort

Under EU control regulation (EU 1224/2009), the requirement for vessels larger than 12 m LOA (with some exceptions) to be fitted with geolocation equipment, initially for control purposes, provided opportunities for fisheries science to gain a better understanding of the spatial distribution of fisheries.

A collaborative study initiated at European level led to the development of robust and harmonised methods for analysing these data, with the creation of an R package {vmstools} to make these methods available (Hintzen et al., 2012). ICES WGSFD is maintaining a data processing workflow provided to data submitters for answering the ICES VMS/logbook data call (ICES, 2025).

A simplified overview of the processing of vessels geolocation data is shown in Figure 2, taken from Rufino et al. (2025).

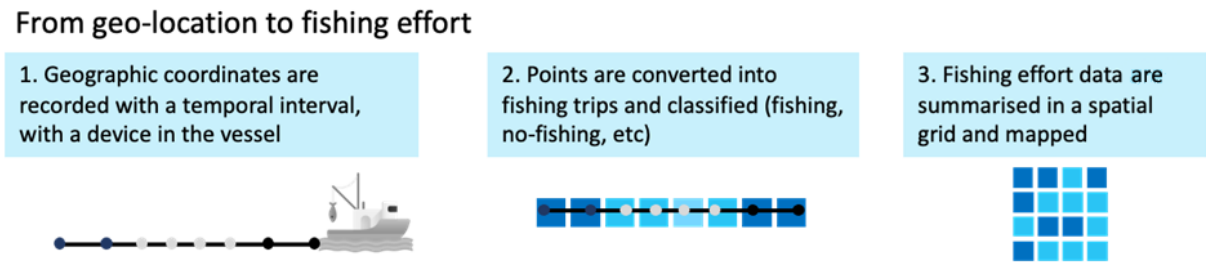


Figure 2. Summary of the main steps in producing fishing effort indicators from tracking systems. VMS, AIS, or GNSS (e.g. GPS); geolocation consists of the recording of the time stamp and geographic position, namely, by tracking the vessels. (Rufino et al., 2025).

For active fishing gears, vessel speed provides a reliable basis for distinguishing fishing from non-fishing activity and for estimating fishing effort in terms of fishing hours. Classification algorithms typically apply threshold values to either instantaneous vessel speed or the average speed calculated between two successive positions (Ifremer, SIH, 2024). While thresholds based on instantaneous speed can often be defined using expert judgement, these decision rules tend to diverge as the time interval increases, while the classification becomes less accurate.

Although this issue has historically been associated with VMS data, it is fundamentally a consequence of reporting frequency rather than a limitation of the technology itself. Recent discussions within WGSFD and WKSSFGEO have emphasised the advantages of higher-frequency vessel tracking data, with reporting intervals of approximately one minute offering substantial improvements for spatial analyses. However, under the revised EU Fisheries Control Regulation, vessel positions will be generally reported at 30 minutes intervals, which may constrain the spatial and behavioural resolution that can be achieved from these data.

2.3. Using hauled length as a proxy for the dimensions of passive gears

The operations of passive gears, especially for small-scale fisheries, are characterised by events that are:

- Short, frequent and specific (hauling and setting events), often lasting less than one hour.
- Spatially complex (sinuous trajectories, deployment in groups).
- Unlike towed gears, the fishing action of passive gears is not directly linked to the vessel's behaviour after deployment. Once deployed, the gear remains in the water while the vessel may move elsewhere. The duration of immersion (soaking time) is therefore a crucial variable that is not directly observed in vessel position data and must instead be inferred from setting and hauling events.

Converting position data into indicators of fishing effort is therefore a challenge, particularly for passive gears, for which fishing effort cannot be deduced solely from the vessel's behaviour, as the gear's fishing action is distinct from that of the vessel.

Although hauled length is most readily interpreted for net fisheries, it may also serve as a meaningful proxy for fishing effort in longline and pot fisheries. In particular, hauled length appears to reflect the number of hooks or pots deployed more accurately than conventional effort indicators such as fishing time or days at sea. Analyses presented by Mendo et al. (2023) across several case studies suggest that hauled length provides a reliable estimate of the variable of interest, whereas time-based measures perform less well (Figure 3).

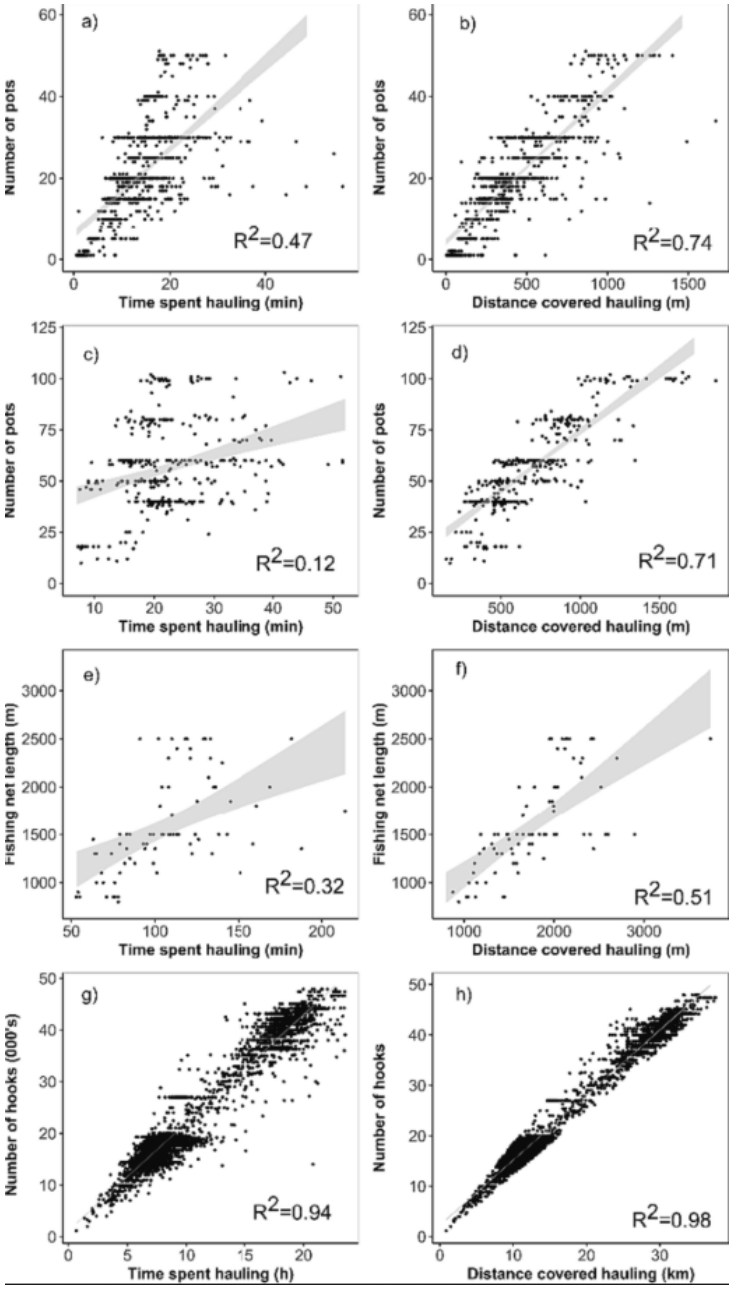


Fig. 3. Relationship between estimated time spent hauling (left) and estimated distance covered during hauling (right) and observed fishing effort based on five cases studies from Scotland, Peru, Denmark and Iceland with fisheries targeting lobsters and crabs using pots (a,b), Norway lobster using pots (c,d), hake using gillnets (e,f), Icelandic longline fisheries (g,h). (Mendo & al, 2023)

The identification of fishing operations for passive gears is generally more challenging than for active gears, as hauling events are often brief and vessel movement patterns are more complex. Consequently, simple speed-based classification rules are usually insufficient, and more sophisticated approaches are required. Several studies have demonstrated the potential of machine-learning methods to identify hauling events by incorporating additional covariates describing vessel movement patterns, environmental conditions, or characteristics of the fishing grounds. However, the

effective application of these methods depends on the availability of high-resolution tracking data (Rufino et al., 2025; Sans and Rodriguez, 2023).

Existing applications have largely converged on the need for position data recorded at temporal resolutions ranging from seconds to a few minutes. As VMS data are typically available at intervals of one to two hours, they generally lack the temporal resolution required for these approaches. Consequently, broader implementation often relies on complementary data sources, such as AIS or GNSS/GPS tracking systems, that provide positions at much higher reporting intervals.

2.4. Geocomputation approach for determining the soaking-time for passive gears

In Mendo et al. (2023), an analytical method based on vessels' past trajectories is proposed to determine the soaking time of a passive gear. The approach is based on the prior detection of hauling operations from the vessel trajectories, which are generally easier to identify than setting operations as they are performed at lower speeds. Spatial buffers are constructed around these detections, and candidate setting operations are identified through spatial overlap with positions from the same vessel from earlier trajectories. As several candidate overlaps may be detected, a ranking procedure is applied to identify the setting operation most likely associated with each hauling event. This process is illustrated in Figure 4, taken from Mendo et al. (2023).

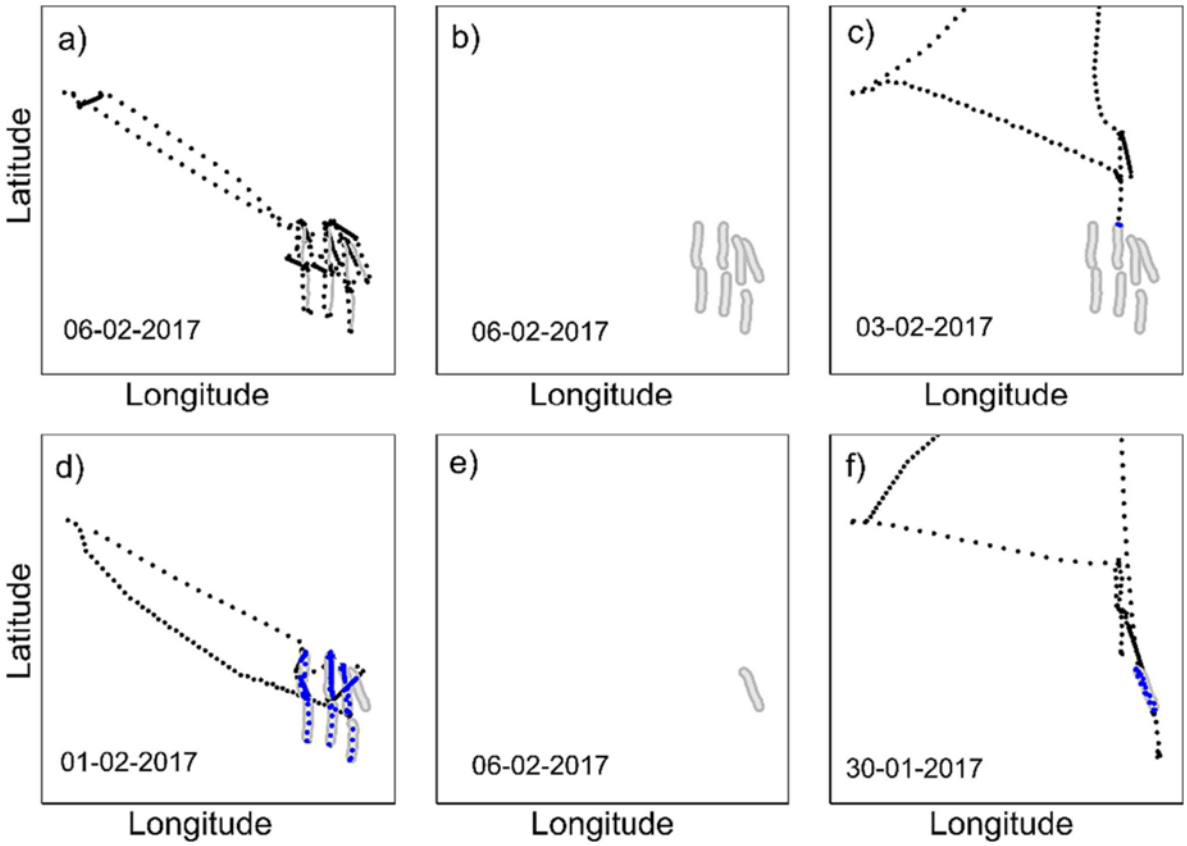


Fig. 4. Proces used to infer soak time from geo-positional data only. Figures a – f show steps taken to infer soak time for a trip conducted on 06-02-2017. Coordinates not shown for confidentiality reasons. Grey lines or polygons represent hauling events, black dots represent non-hauling events, and intersections between a hauling event and a deployment event are presented in blue. The journey on 6 February is analysed (a) enabling the detection of seven hauling events (b). Past journeys are then examined to identify the associated setting events for passive gears: no relevant cross-matches were found for the 3 February trip (c). On 1 February, however, six associated settings were detected (d). One of the gear hauled on February 6 was not deployed during this fishing trip (e); it may be associated with a setting carried out on 30 January (f). (Mendo et al., 2023).

2.5. Technical feasibility, conditions for application and current limitations for the roll-out of such approaches

As part of the DELMOGES programme, which focuses on the study of dolphin bycatch in the Bay of Biscay (Authier et al., 2026), research aiming at improving gear effort metrics for French netters has provided a proof of concept for these principles through a study carried out on around twenty netters. Using a cross-validation method on a vessel-by-vessel basis, it was demonstrated that the proposed approach enabled the reliable determination of hauled length and soaking time for vessels that had not participated in the model calibration (Sans and Rodriguez, 2023).

Following comparison of several machine-learning approaches, an XGBoost model was selected and calibrated for the detection of fishing events. Methods for processing vessel trajectories were subsequently implemented in the first versions of the {iapesca} package, enabling their large-scale application to a dataset combining VMS and AIS sources (Deslias et al., 2026).

The application of these methods may be constrained by the limited availability of sufficiently detailed geolocation data. In Bay of Biscay, for example, the vessels under 12 metres are rarely equipped with vessel tracking devices, despite representing the majority of the vessel fleet. Furthermore, even among vessels for which geolocation equipment is mandatory, coverage is not always complete. This is illustrated in Figure 5, which compares the number of fishing trips available from consolidated logbooks generated by the SIH's SACROIS algorithm (Demanèche et al., 2022) with the corresponding coverage provided from VMS, AIS or Global Fishing Watch (GFW) data sources.

As a result, analysis based on vessel-tracking data can only be applied to a subset of the fleet and may be affected by uneven representation of vessels, with smaller vessels often being under-represented or absent. Given the very limited coverage of geolocation data for vessels under 12 metres in length, this segment could not be be included in the analysis and is therefore not represented in Figure 5, although SACROIS data for these vessels are considered close to complete. Along the Atlantic coast, coverage of vessels under 12 metres in SACROIS is estimated to exceed 95 %.

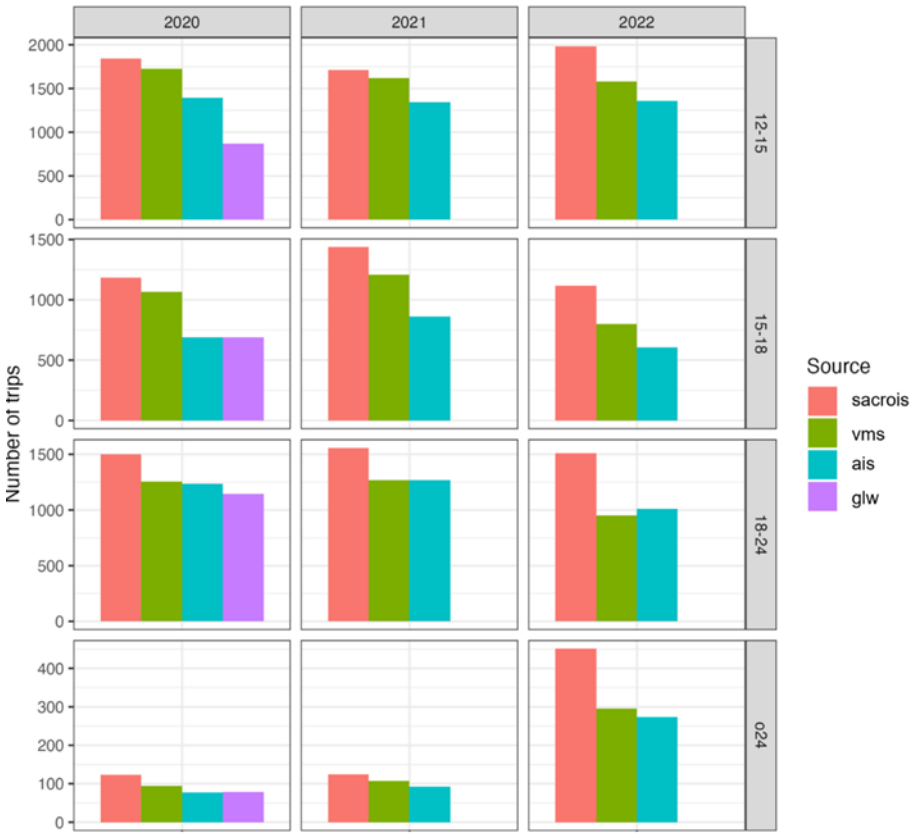


Fig. 5. Number of trips by year and vessel size class detected in the available datasets. The size class corresponds to the overall length of the vessels in meters. ‘‘o24’’ means over 24 m (Deslias et al., 2026). Given the very limited availability of geolocation data, vessels under 12 m, are not included in this figure

The implementation of the revised EU Control Regulation will require vessels under 12 metres to be equipped with geolocation devices, creating new opportunities for the application of these methods across a larger proportion of the fleet. However, accurate detection of fishing activities, will require position data at a substantially higher frequency than the 30 minutes reporting interval specified in the new Control Regulation Implementing Act (EU 2025/2196). Under the previous Control Regulation, vessel positions were reported via VMS (Vessel Monitoring System) with positions transmitted via satellite communication. Because each transmission entails a cost, increasing the reporting frequency would increase the cost for the fishers. The revised EU Control Regulation (EU 2025/2196) allows the use of alternative tracking technologies that do not rely solely on satellite communication, making it possible to collect higher-frequency position data at significantly lower cost, for example through onboard data storage and subsequent transmission via mobile communication networks.

A further limitation concerns data confidentiality requirements. While these rules are necessary for the protection of individual fishers and fishing operations, they may restrict the spatial resolution at which results can be disseminated, as illustrated in Figure 6, taken from Mendo et al. (2026).

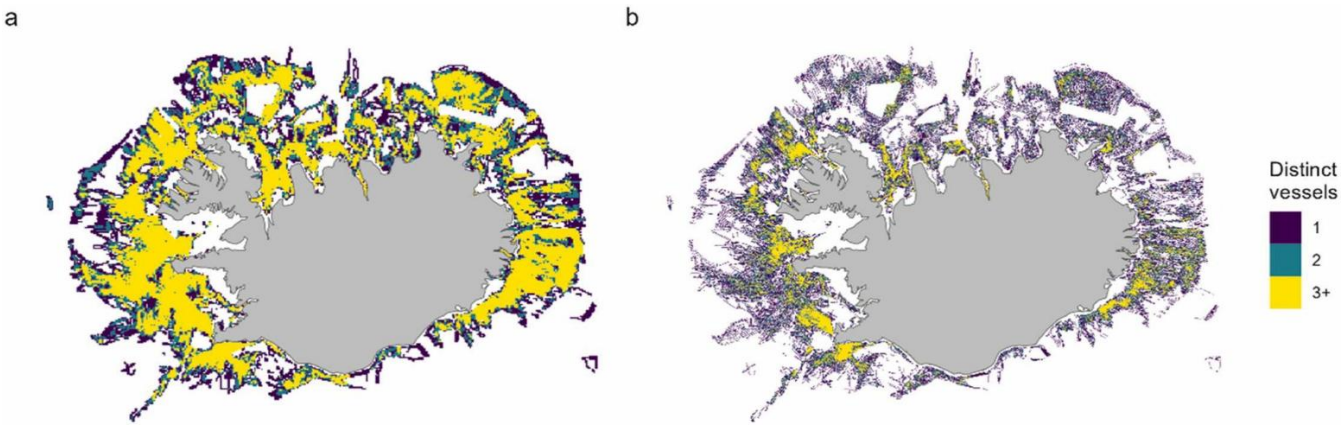


Fig. 6. Spatial distribution of longline fisheries in Iceland showing number of distinct vessels operating in: a) 5 × 5 km and b) 1 × 1 km grid cell resolution. Under the current "three vessel rule" recommendation, only the yellow shaded cells would be presentable. (Mendo et al., 2026)

Despite these limitations, which currently constrain the large-scale implementation of trajectory-based effort estimation methods, their application within the CIBBRiNA project case studies demonstrates their potential to improve the interpretation of bycatch risk through the use of high-resolution spatial information where suitable data are available. To facilitate broader uptake, user-friendly and well documented tools will be required to ensure the consistent production of reliable and harmonised outputs. Such tools would support both the wider application of these methods and their integration into the bycatch estimation toolkit being developed under CIBBRiNA WP6.

3. {iapesca} R-package purpose and development

The {iapesca} package has been designed as a comprehensive software suite for analysing geolocation data from fishing vessels, implementing the methodological framework as described in Mendo et al. (2023) and applied in Sans and Rodriguez (2023). It is not intended to replace the existing {vmstools} package (Hintzen et al., 2012) but provide complementary tools designed for the analyses of high-resolution geolocation data, with particular applications and methods for passive gears fisheries.

This package includes functions for data cleaning, detecting fishing trips, resampling positions at constant time intervals, covariate calculation and vessel trajectory description. It also offers useful functions for computing covariates describing vessels' behaviour, optimizing hyperparameters for machine-learning models, creating behavioural diagnoses and analysing the data, e.g. geo-computation methods to analyse passive gears with appropriate fishing effort metrics. Finally, it provides methods for summarizing, aggregating and mapping the fishing effort and vessel trajectories.

The first version of the package was developed within the DELMOGES program (Authier et al, 2026), building on methods and experiences shared during the ICES Working Groups WKSSFGEO in Lisbon in December 2021 (ICES, 2022) and WKSSFGEO 2 in Faro in March 2023 (ICES, 2023).

Since its initial release in January 2023, the package has been updated. Version 1.2 includes several new features specifically developed for being applied to CIBBRiNA cases studies including tools for machine-learning processing, fishing effort computation and mapping and harmonizing different datasets.

The package is maintained and publicly available through a GitLab repository hosted by Ifremer:

https://gitlab.ifremer.fr/iapesca/r-packages_iapesca

To ensure that the package could be applied across different CIBBRiNA case studies, substantial development work was devoted to improving usability and enabling compatibility with datasets collected in other formats or through other data sources. Examples of application of the {iapesca} method can be found in section 6 of this report. The format of the data that is needed to apply the R package can be found in Annex 1.

Among the specific developments required:

- *Positions2CIBBRiNA*: converts fishing vessel positions into the data template used in the CIBBRiNA case studies The function also tests if the data meets the prerequisites expected for the workflow and performs quality control.
- *tune_RF*: owing to its strong performance, ease of optimisation and robustness against overfitting, the random-forest has been established as the benchmark method for the development of machine-learning models. Other types of methods may be better suited to certain cases, but they may require greater technical expertise and are more difficult to implement. This function provides a simplified, automatic and fast optimization of hyperparameters used in a random forest model.
- *plot_CART_tree:* plots the decision tree from a CART (Classification And Regression Tree) model that provides an indirect way to interpret the model.
- *RF_autodiagnosis*: a function that generates a self-diagnosis report for random forests, which allows an interpretation of these complex models.
- *Calc_ModelAccuracy*: a function that computes scores to assess the relevance of classification models.

- *Calc_VesselFE*: a function that allows the computation of vessel fishing effort metrics: hours and days at sea, fishing hours and days and, if relevant, effort by gear summarised at the fishing-trip level.
- *Rasterize_FE2ICESRect:* a function that rasterizes either the fishing or gear effort metrics desired from spatial objects on a customized ICES Rectangle grid automatically created (*iapesca::ICESRect_Grids*).

Through discussions with various users, particularly those at DTU Aqua, existing functions and methods have also been improved or adapted.

4. Harmonized workflow and tutorial

As part of the EU LIFE CIBBRiNA project, within WP5.1 – which focuses on fishing effort data for bycatch assessment– a standardised workflow based on {iapesca} was developed to apply to the various case studies included in the project. In this package, a small anonymized dataset is provided for demonstration purposes, but the workflow has been designed to be applicable to any dataset relating to fishing operations where part of them are fully described (start and end times and positions of operations). Figure 7 presents the overall workflow. Starting from a geolocation dataset for which fishing activity has been partially described, machine-learning models are calibrated and subsequently applied to classify vessel behaviour for all recorded positions. For passive gears, an additional geo-computation step is used to reconstruct gear deployment and retrieval and to estimate gear-specific effort metrics. The resulting outputs can be generated at the fishing-trip level or spatially across standardised grids such as C-squares (Concise Spatial Query And Representation System, Rees, 2003) or ICES rectangles.

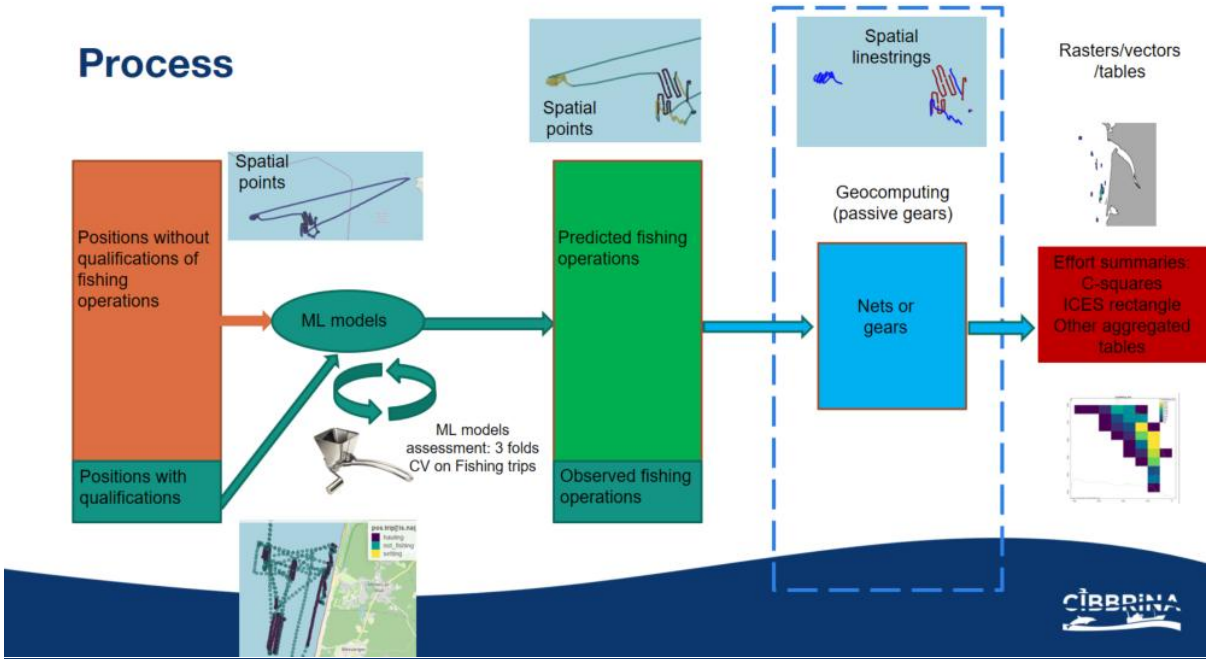


Fig. 7. Description of the workflow with these various stages.

The main output of this deliverable is a step-by-step tutorial describing the workflow using an anonymized example dataset. The tutorial has been developed and is publicly available at:

https://doi.org/10.13155/112293 (Rodriguez, 2026), together with the source code used to generate the tutorial:

https://gitlab.ifremer.fr/iapesca/r-tutorial_iapesca/-/blob/main/CibbrinaWP5_HarmonizedFormat-Script.Rmd?ref_type=heads).

The tutorial provides a detailed description of the input data format, including the following mandatory variables: vessel identifier, trip identifier, date and time, latitude and longitude, gear and activity. Optional variables include speed, course, heading and quality.

Various outputs may be generated by the workflow upon request:

- Tables providing data on the vessel's and gear's fishing effort at the fishing-trip level.
- Aggregated outputs at different time scales or spatial coverages (C-squares at different resolutions or ICES rectangles).
- Many of the effort variables identified as relevant to WP6 can thus be reported as follows:
    - For all types of gear: the number of vessels, days and hours at sea, and days and hours spent fishing.
    - For passive gear only: the hauled length and the soaking-time.

During the CIBBRiNA WP5.1 workshop on fishing effort data that was held 3–5 February 2026 in Lisbon, hands-on training and practical implementation were offered to CIBBRiNA partners across WP5 (Data collection toolkit), WP7 (Case studies), as well as to the #REDUCE project. The CIBBRiNA case studies include different gear types: gillnets (Northern gillnets from Denmark, Germany, Iceland, Norway, Poland and Sweden, Southern gillnets from Spain and UK), longlines (Portugal and UK), pelagic trawlers (UK, Netherlands, Ireland, Denmark) and bottom trawlers (Netherlands and Belgium).

To facilitate implementation during the workshop, a dedicated R script implementing the workflow was prepared and made available via the Microsoft Teams channel for Subgroup 1. Participants were also given a presentation introducing the main functionalities of {iapesca}, the structure and rationale of the workflow, and supporting reference dataets including harbour locations from {vmstools} (Hintzen et al., 2012) and the Ifremer French Fisheries Information System (FIS).

To support specific requirements and in view of the intended applications, additional developments within {iapesca} appeared to be necessary. In particular, outputs of fishing effort by fishing trip, days at sea, and ICES rectangles, together with vessel counts, will be essential for linking datasets and ensuring compliance with anonymization requirements.

Issues and development needs for {iapesca} were identified during and after the workshop and have been documented in the project issue tracker:
https://gitlab.ifremer.fr/iapesca/r-packages_iapesca/-/boards

- Interest in a function that allows positions to be qualified regarding vessel behaviour based on on-board observation data. The function *match_Obs2Pos* was created for this purpose.
- Integration of a method developed by DTU Aqua (J. Olsen and J. Stounberg) for estimating the fishing effort in Danish seine fisheries.
- Aggregation on an ICES rectangle grid: a function similar to the one that creates *SpatRaster* C-squares grids was built: *Rasterize_FE2ICESRect*. This development was necessary to link between the data available in data calls and outputs from high-resolution data.
- *Positions2Cibbrina*: management of issues reported by users.
- *Char2Time:* handling of different date formats depending on the data sources.
- *Create_NetsByBoat:* function optimisation
- Rasterize DaS: compute the link between DaS and the right effort metrics by fishing trips and DaS or fishing days - Link between the data available in data calls and outputs from high-resolution data.
- HEADING column renamed to COG: based on a remark by Tania Mendo from St-Andrews University: the value of this computed variable corresponds to the course over ground and should be renamed.

At the time of writing, all developments identified and following the workshop had been implemented and released in version 1.3 of the {iapesca} package.

5. Integration and outcomes

For active gears (CS7 and CS8), typically used by larger vessels, extensive observational datasets that can be used to train and validate the models are already available through self-sampling programs. Combined with high-resolution position data for a larger part of the fleet, these data enable the production of accurate, high-resolution effort maps. In contrast, for the small-scale fisheries, the availability of position data covering the fleet is not consistent across all gears and countries.

Applications of the {iapesca} workflow were conducted for northern gillnets (CS1) and UK longlines (CS6). High-resolution fishing effort outputs were successfully produced for Danish gillnet fisheries. However, additional calibration data and, potentially, further developments of the package will be required to improve performance and resulting outputs for longline fisheries. For most case studies, the availability of suitable calibration datasets, comprising both detailed descriptions of fishing operations and high-resolution geolocation data, will be essential.

Overall, the generation of high-resolution fishing effort outputs using the {iapesca} tool appears feasible across case studies if data are available. This requires the availability of high-resolution positional data at the fleet level (e.g., AIS/GPS) together with observations of fishing activities that can be used to train and validate the model using known fishing events. Some outputs are already available, allowing preliminary applications to be tested within the project.

Depending on the fishery, gear type and management objective, different fishing effort metrics may be required to adequately describe fishing activity. To integrate information from the FDI, RDBES, and, where relevant, ICES VMS/logbook data calls, it is essential that outputs from these different sources, available at varying spatial and temporal resolutions, can be linked. *Days at Sea (DaS)* provides a key common metric enabling this integration.

The RDBES database offers broad coverage for most CIBBRiNA case studies. To align high-resolution {iapesca} outputs with RDBES data, the high-resolution results should be aggregated to a quarterly or annual temporal scale. Furthermore, DaS derived from high-resolution datasets must be available at a spatial resolution that allows identification of the proportion of fishing effort that can be reliably described at a common spatial unit, namely the ICES statistical rectangle.

6. Achievements and applications of the {iapesca} workflow

The achievements include:

- Development and enhancement of the open-source R package {iapesca}, including the implementation of developments identified during the CIBBRiNA fishing effort workshop held in February 2026.
- Successful implementation of the workflow in multiple regions: for Danish gillnet fishery with AIS, French netters operating in the Bay of Biscay and small-scale netters in the Spanish Basque Country.

- Delivery of practical training on the workflow during the CIBBRiNA fishing effort workshop.
- Demonstration that machine-learning models trained using Electronic Monitoring (EM) and observer data can be successfully applied to AIS datasets.
- Integration of the workflow within the CIBBRiNA case study on Northern Gillnets.
- Production of fishing effort outputs that can be linked with other effort data sources EU FDI, ICES RDBES and VMS through common variables and aggregation levels.

6.1. CIBBRiNA Case Study 1: Danish gillnets with AIS data

The {iapesca} workflow was applied to Danish gillnet vessels equipped with AIS. The underlying model was trained using data from gillnet vessels equipped with Electronic Monitoring (EM) systems. Tests of the model using 5-fold cross validation showed a 94 % accuracy in classifying fishing operations, and a mean error of 2.4 hours when predicting the soak time. Before applying the model to the remaining fishing fleet for which AIS data were available, including small-scale fishing vessels, the AIS was given a quality score based on coverage of the specific vessel, of which around 40 percent of the gill-net fleet where covered.

The resulting outputs were formatted to ensure compatibility with other fishing effort datasets used within the CIBBRiNA project. Outputs were generated across multiple aggregation levels, providing complete fishing effort information at aggregation level 1, and the more detailed fishing effort on aggregation levels 2a, 2b and 3 (figure 8). To comply with confidentiality requirements, data relating to fewer than three vessels were removed, and the percentage of effort data removed indicated in complementary tables.

	Aggregation level 1 {iapesca}	Aggregation level 2a {iapesca}	Aggregation level 2b {iapesca}	Aggregation level 3 {iapesca}
Data (removed if less than 3 vessels)	Case study Year ICES/FAO area Days at Sea Fishing days Fishing hours Length hauled Soak time Soaktime*net length Number of vessels	Case study Year ICES/FAO area Quarter Days at Sea Fishing days Fishing hours Length hauled Soak time Soaktime*net length Number of vessels	Case study Year ICES/FAO area ICES rectangle Gear Days at Sea Fishing days Fishing hours Length hauled Soak time Soaktime*net length Number of vessels	Case study Year ICES/FAO area ICES rectangle Spatial reference (0.01/0.05 degrees) Gear Days at Sea Fishing days Fishing hours Length hauled Soak time Soaktime*net length
Coverage	Case study Year % Days at Sea confidential % Fishing hours confidential % Length hauled confidential % Soaktime*net length confidential	Case study Year Area % Days at Sea confidential % Fishing hours confidential % Length hauled confidential % Soaktime*net length confidential	Case study Year Area % Days at Sea confidential % Fishing hours confidential % Length hauled confidential % Soaktime*net length confidential	Case study Year Area % Days at Sea confidential % Fishing hours confidential % Length hauled confidential % Soaktime*net length confidential

Fig. 8. Data structure of {iapesca} outputs aligned RDBES, FDI and ICES VMS datasets.

The figures below show the results of fishing effort indicators aggregated to the 0.05° c-square, obtained by applying the {iapesca} workflow to the Danish gillnet vessels for which with AIS data are available.

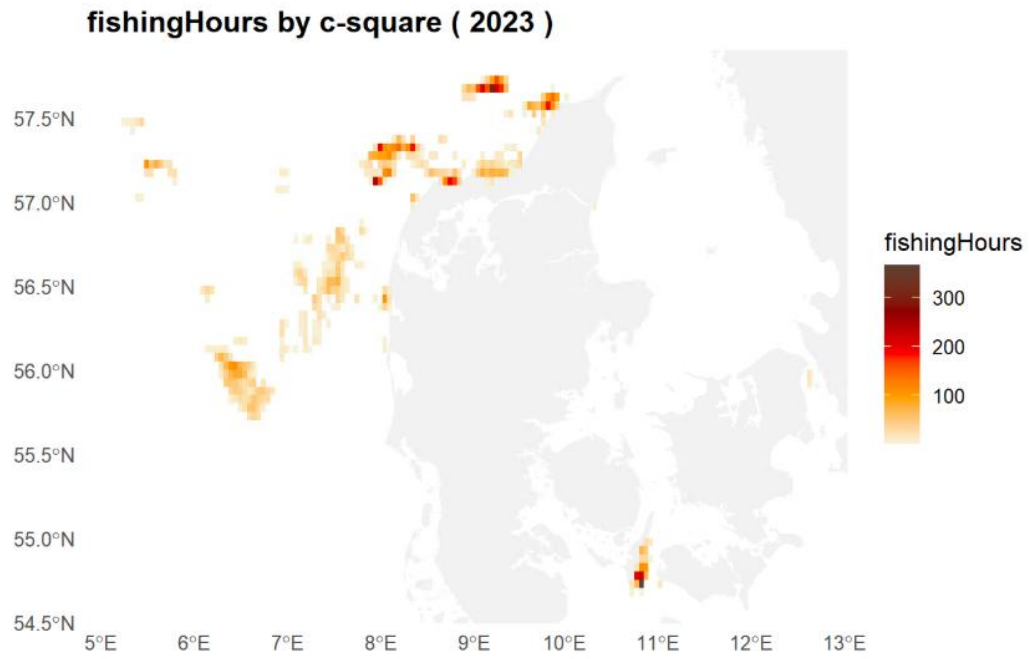


Fig. 9. Results from {iapesca} on Danish gillnet vessels with AIS. Fishing hours by 0.05 degrees c-squares.

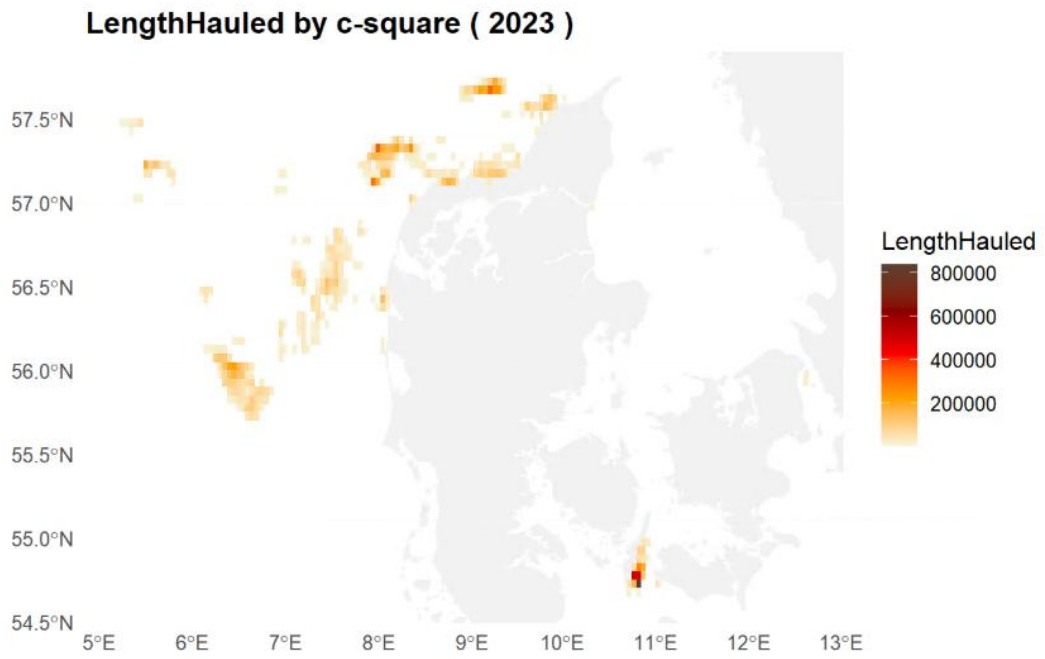


Fig. 10. Results from {iapesca} on Danish gillnet vessels with AIS. Length hauled by 0.05 degrees c-squares.

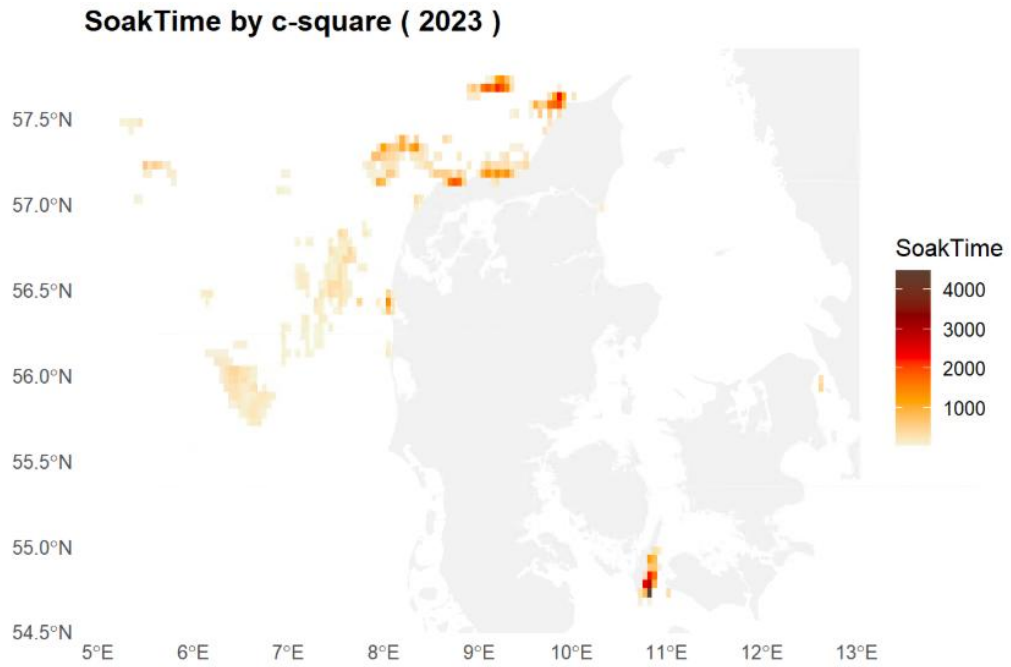


Fig. 11. Results from {iapesca} on Danish gillnet vessels with AIS. Soak time by 0.05 degrees c-squares.

6.2. An application to French netters operating in the Bay of Biscay with AIS data (Deslias et al., 2026)

Common dolphin (Delphinus delphis) bycatch is a major conservation issue in the Bay of Biscay, driven by interactions with fishing gears including passive gears (gillnets and trammel nets). Conventional fishing effort metrics, based on vessel-speed thresholds or

"fishing hours", poorly reflect the reality of static gears. In Deslias et al., 2026 high-resolution AIS geolocation data are integrated with onboard observer data to build an effort metric incorporating soak time, net length and net height, applied over 2016–2023. The authors used the first {iapesca} R-package and workflow version together with the machine-learning models calibrated in Sans and Rodriguez, 2023 to manipulate and interpret the high-resolution vessel geospatial data and to identify fishing operations from AIS positions. This study has thus enabled the first large-scale spatio-temporal mapping of fishing effort metrics appropriated to passive gears in this region. However, the relevance of these results for routine use is subject to the limitations imposed by the availability of geolocation data. The availability of such data is extremely limited for vessels under 12 metres in length. Nevertheless, this study serves as a proof of concept for a large-scale application of this workflow.

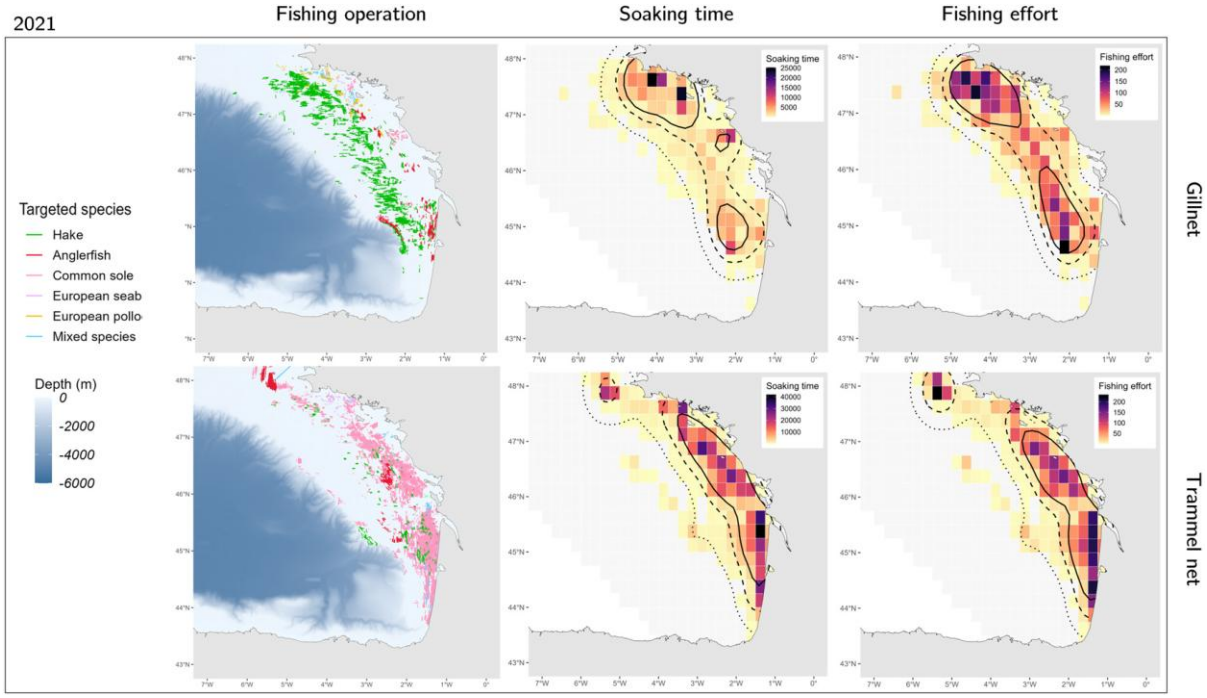


Fig. 12. Spatial representation of the estimated fishing operations, soaking time and fishing effort for gillnets and trammel nets in 2021. The operations are represented in accordance with the dominant species targeted by the vessel throughout the year. The soaking time and fishing effort were summed by rectangle of 0.25° × 0.25°. The solid line indicates 50% of the effort, the long dotted line indicates 75% of the effort, and the short dotted line indicates 95% of the effort.

6.3. Applying {iapesca} to small-scale netters (Spain Basque Country)

The {iapesca} workflow was applied to the Basque small-scale netter fleet (gillnets and trammel nets) to derive spatially explicit fishing-effort metrics from high-resolution AIS Class B data. The analysis covered 15 vessels between 8 and 14.6 m LOA during 2018–2020, representing approximately 40% of the fleet, and combined AIS positions with

logbook and sales-note information to identify fishing gear by vessel and day. Vessel behaviour was classified using a Random Forest model calibrated and evaluated using onboard observer data from 22 fishing trips conducted by three vessels. The model's performance was assessed using leave-one-out vessel cross-validation. Hauling events identified from vessel trajectories were subsequently used to reconstruct gear setting and net geometry and to estimate fishing effort in terms of fishing time and net length at a 0.01° spatial resolution. The resulting workflow demonstrates the potential of high-resolution geolocation data to characterise passive-gear fishing effort, while the limited number of vessels and trips with observer data means that estimates extrapolated to the remaining vessels should be considered exploratory and require further validation.

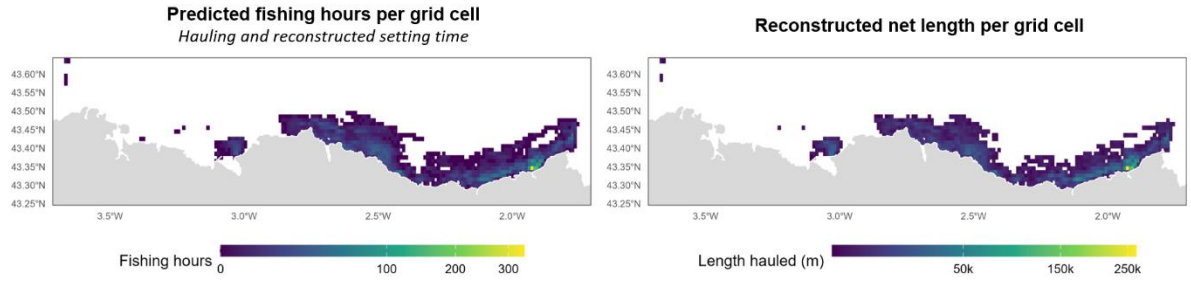


Figure 13: Results from applying the {iapesca} to small-scale netters in the Spain Basque Country. The left map shows predicted fishing hours and the right map show reconstructed net length per grid cell.

Collectively, these applications demonstrate the capacity of the {iapesca} workflow to generate high-resolution fishing-effort information across different passive-gear fisheries and geographical regions. While further work is needed to increase coverage, improve calibration datasets and address confidentiality constraints, the case studies confirm that the approach can produce harmonised effort indicators that complement existing fisheries data sources and support bycatch-risk assessments within CIBBRiNA.

7. Future developments and perspectives

The work undertaken within CIBBRiNA demonstrates that high-resolution vessel tracking data can provide effort indicators that are substantially more informative for bycatch risk assessment than traditional fishing effort metrics alone. The {iapesca} workflow and package provide a transferable framework that can be applied across fisheries where suitable geolocation data are available.

Nevertheless, the coverage of high-resolution geolocation data remains limited for many fleet segments, particularly for small-scale vessels, resulting in datasets that may be heavily biased towards the largest vessels (Mendo et al, 2026, Deslias et al., 2026), which could significantly limit the ability to scale effort indicators to the entire fleet or to total fishing effort within an area. Future developments therefore focus on methods that can

extend the benefits of high-resolution fishing effort estimation to fleets for which detailed geolocation data are unavailable.

Beyond their direct use for fishing effort estimation, the outputs generated by the {iapesca} workflow for vessels equipped with AIS or other high-resolution position data can also provide a valuable basis for developing extrapolation methods. Fishing effort indicators such as net length, soaking time, fishing activity patterns, and spatial distribution can be estimated for vessels with high-resolution geolocation data and subsequently linked to variables available in logbooks, fleet registers and landings data to develop predictive models. Such models may enable the estimation of fishing effort indicators for vessels lacking high-resolution tracking data, thereby extending the applicability of the approach to a much larger proportion of the fleet.

Following this principle, an alternative approach has been tested and validated using data from French netters operating in the Bay of Biscay. The approach uses effort indicators derived from on-board observations and relates them to information commonly available for all vessels, including vessel characteristics, logbook data and landings composition. To a certain extent, the principle is similar to that used to determine the width of towed gears in Eigaard et al. (2016), and is also inspired by the approach proposed by Henriques et al. (2024), whilst allowing more detailed modelling that takes into account the species composition of landings at the fishing-trip scale.

Using on-board observation data from approximately 4,800 fishing trips, random forest models were developed to predict net effort indicators, cumulative net length, soaking time, and net height, based on vessel size, gear, distance to fishing areas, and species composition of landings. Net length is primarily influenced by vessel size and target species, while the species composition is strongly associated with soaking time. Net height depends largely on the type of gear and the target species. These indicators can be estimated from information available in logbooks over long periods and for every vessel including small-scale fleets which are very poorly covered by suitable geolocation data. This work will shortly be the subject of a separate report setting out the methodology and the results obtained, but is not part of this deliverable report.

Combined with the high-resolution effort indicators generated through the {iapesca} workflow, this approach offers a promising pathway towards improved effort indicators for bycatch assessment across a much broader proportion of the fleet and could support future applications within CIBBRiNA case studies and beyond, depending on data availability.

8. Conclusions

This deliverable documented the development and application of the {iapesca} R package and associated workflow for deriving fishing-effort metrics from high-resolution vessel-tracking data. The workflow provides a reproducible framework for processing, analysing and aggregating geolocation data and for generating fishing-effort indicators relevant to bycatch-risk assessment and spatial analyses.

Applications conducted demonstrated the feasibility of deriving meaningful effort metrics for passive-gear fisheries, including indicators such as hauled length and soaking time that are not available through conventional fisheries data sources. The workflow was successfully applied to Danish gillnet fisheries and has also supported large-scale applications to French net fisheries operating in the Bay of Biscay as well as small-scale netters in the Spanish Basque Country.
The principal limitation identified was not the performance of the workflow itself but rather the availability and coverage of suitable high-resolution geolocation data. For many small-scale fisheries, insufficient tracking coverage remains the main obstacle to large-scale implementation. Nevertheless, the methods, workflow and harmonised outputs developed within CIBBRiNA provide a strong foundation for future applications and further methodological developments.

As geolocation requirements under the revised EU Control Regulation are progressively implemented and additional vessel-tracking data become available, the applicability and value of these approaches are expected to increase substantially, even though the suggested 30 minutes interval is not high enough for direct implementation. Combined with emerging methods for extrapolating effort indicators to vessels without high-resolution tracking data, the {iapesca} workflow offers a promising pathway towards improved fishing-effort characterisation for bycatch assessment and fisheries management.

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Annex 1: Input data format for the {iapesca} package

Variable	Required	Description
VESSEL_ID	Yes	Unique vessel identifier (alphanumeric code)
TRIP_ID	Yes	Trip identifier (numeric value)
DATE_TIME	Yes	Date and time in UTC of the point in ISO STANDARDS 8601 (YYYY MM-DD HH:MM:SS)
LATITUDE	Yes	Decimal format in EPSG:4326 CRS
LONGITUDE	Yes	Decimal format in EPSG:4326 CRS
GEAR	Yes	Gear code. ICES codes (https://vocab.ices.dk/?ref=1653)
PASSIVE_GEAR	Yes	Logical field. Passive gears (TRUE) or active gears (FALSE)
ACTIVITY	Required for qualified fishing trips	For passive gears: setting/hauling/not_fishing; For active gears: fishing /not_fishing.
SPEED	No	Instantaneous speed of the vessel (knots). Values that are provided by the device.
COURSE	No	Course over ground (degrees), defined as the angle with respect to north and clock-wise of the vessel direction provided by the device.
HEADING	No	The angle (degrees) 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.
QUALITY	No	A field to flag some possible quality issues on the classified/validated data, such as possible wrong classification, uncertainties, etc, regarding the ACTIVITY field. If provided, should be defined as a boolean, a “TRUE” indicating a valid value when “FALSE” for data about which there may be some doubt

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Project website	https://cibbrina.eu/

Deliverable	**No.**	D5.1	**Title**	Effort R-package
Work Package	**No.**	5	**Title**	Data collection toolkit
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Lead Beneficiary	DTU Aqua and FixFish			
Authors	Julien Rodriguez, Josefine Egekvist, Sébastien Demaneche, Estanis Mugerza			
Reviewer(s)	Marije Siemensma, Graham Pierce			
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