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Towards a European small-scale fishing vessel tracking programme: Overview, challenges and opportunities

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ABSTRACT

Small-scale fisheries (SSF) represent over three-quarters of all active vessels in the European fleet yet remain largely invisible in marine spatial planning due to the lack of spatial data. This data gap has contributed to the marginalisation of SSF in policy and governance, despite their ecological, economic, and socio-cultural significance. The recent revision of the EU Fisheries Control Regulation (CR 2023/2842), mandating vessel tracking for all fishing vessels—including those under 12 metres by 2029—offers a critical opportunity to integrate SSF into formal spatial and fisheries management processes. This paper synthesises insights from researchers across 24 institutions in Europe to assess the current state of SSF tracking, estimate existing coverage, and identify opportunities and challenges for implementing an EU-wide SSF tracking programme. We estimate that approximately 12% of the SSF fleet is currently tracked, primarily within net, trap, and dredge fisheries. While researchers broadly recognise the value of spatial data for improved spatial planning and ecosystem assessment, several challenges hinder implementation, including high implementation costs, limited institutional capacity, and fragmented or incompatible data infrastructures. We recommend: (i) the development of clear technical requirements and harmonised data protocols, (ii) leveraging tracking data to support participatory and adaptive

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management, and (iii) ensuring inclusive governance that reflects the socio-cultural dimensions of SSF. As EU Member States move toward full implementation of CR 2023/2842, early decisions will shape not only the technical architecture of tracking systems, but also the broader governance future of European SSF. A more equitable and integrated approach is essential—and achievable.

1. Introduction

Small-scale fisheries (SSF) have a significant social and economic value across all European coastlines, making notable contributions to food security, employment, cultural identity, the resilience of small-scale business and social cohesion in coastal communities [1,2]. In 2021, the small-scale coastal fleet[1] comprised 76% of the number of active vessels in the European fishing fleet. This translated into roughly 41,200 vessels (out of 71628 vessels, of which 54213 were active) and 60,000 active fishers (out of 121,917 directly employed fishers) in the region [3]. Despite their importance, SSF in Europe face several challenges that jeopardize their sustainability, including depletion of stocks, poor data provision for and poorly developed stock assessments and management procedures, limited access to fishing rights and markets, and limited participation or representation in decision making, which often results in the formulation and implementation of unfavourable policies to SSF fishers [4,5].

Fishers, particularly those from SSF, are the largest group of ocean users, however, they are often marginalised and not included in the marine spatial planning process [6,7]. Squeezed between the expansion of a "blue economy" agenda, which aims to stimulate sustainable economic growth from the oceans [8], and current legislation and policy commitments such as the Habitat Directive, Strategic Environmental Assessment Directive, Marine Strategy Framework Directive and Maritime Spatial Planning Directive, SSF frequently experience physical displacement or restricted access to fishing [9–12]. For example, in the UK, maintaining access to fishing grounds is recognised as one of the greatest future challenges for SSF [13].

This situation demands objective spatial and temporal evidence of marine space use by SSF and "value" (economic, social and cultural) derived from such use [14]. Improved spatial data can also directly benefit fishers by strengthening socio-economic impact assessments related to competition for space, supporting claims for continued access, compensation, or mitigation where displacement occurs – providing them with a just spatial representation in maps where they are usually absent. These data are critical to informed decision making if SSF are to be adequately represented [15–17].

Recognizing this challenge, several initiatives have aimed at mapping space utilisation in SSF, using data from interviews with experts, sightings from shore, logbooks data, or aircraft patrolling [18–20]. While these sources provide information on main fishing grounds they are often based on records of limited duration (snapshots in time), the location of the vessels over time is insufficiently spatially resolved for use in inshore spatial planning and they are of limited value in determining fishing effort or fleet responses to management actions. In Large Scale Fisheries (LSF), the introduction of Vessel Monitoring Systems (VMS) and Automated Identification Systems (AIS) resulted in increased reporting of fishing vessel positional data at finer temporal and spatial scales than previously possible. This enabled the identification of the main fishing grounds and the footprint of fishing across habitats, which improved our understanding of the impacts of fishing on the seabed [21–24] and enhancing monitoring, surveillance and compliance, particularly with regards to spatial regulations [25]. The recent reduction in the cost of these systems and the development of other cost-effective technologies such as mobile apps for the collection of fisher's data (see [26,27]), prompted several pilot trials and initiatives for tracking SSF vessels in Europe to bring insights into the potential use of these technologies for spatial planning and to evaluate impacts of fishing activities. However, these trials have occurred in isolation, with limited coordination between different countries and the outputs have often not been formally documented. In addition to those trials, for some SSF fleets, real time reporting of position during a fishing trip is mandatory, such as the razor clam fishery in Ireland [28], the hydraulic dredge fishery in Italy [29] or the gillnet fishery targeting cod (*Gadus morhua*) in Germany during 2018 [30]. In the UK, tracking is mandatory for all < 12 m vessels in Wales, and in England this legislation came into force in May 2025.

In November 2023, the European Parliament and the European Council approved Regulation 2023/2842 [31], from now on CR 2023/2842). Recognising the value of SSF in the EU, from a biological, economic and social perspective, and considering the impacts that SSF can have on stocks, this regulation highlights the importance of monitoring compliance of smaller vessels within the rules of the Common Fisheries Policy (CFP) and amends Council Regulation No1224/2009 [32] which establishes a control system for ensuring compliance with the CFP. Under the EU Common Fisheries Policy (CFP), the management of small-scale fisheries (vessels <12 m) is primarily the responsibility of individual Member States, although it operates within the broader EU regulatory framework. The revised CR states that Member States should be able to track all fishing vessels, including vessels less than 12 m in length and to receive position data from them at sufficiently short intervals. These vessel tracking systems should be either developed at a national or EU level and should enter into force gradually from 10 January 2026–2029. There is a provision in CR 2023/2842 to exempt some vessels of less than 9 m from tracking until 31 December 2029.

In line with this impending shift in reporting obligations for SSF in Europe, the current study aims to describe the status of SSF vessel tracking in Europe, by compiling information on the extent and types of fleets currently being tracked. We then gather existing experiences from researchers working with vessel tracking systems and data to assess the challenges and opportunities that might arise from the establishment of a Europe-wide mandatory vessel tracking programme. We provide recommendations to prepare and enhance the implementation of CR 2023/2842, including an urgent call for system requirements and harmonisation of data handling protocols to enhance services and data provision for SSF that will increase the scope for sustainable management of these fisheries.

2. Methods

2.1. Overview of vessel tracking experiences in Europe

To get an overview of the extent and status of SSF vessel tracking in Europe, including EU and non-EU countries, we surveyed a network of experts attending the second ICES Workshop on Small-Scale Fisheries and Geospatial Data (WKSSFGEO2) [33], 13–17th March 2023. The workshop participants were from 24 research institutions from 15 EU and non-EU member states countries and are responsible for the deployment of tracking systems and/or analysis of tracking data and/or providing fisheries management advice. We decided to include selected non-EU countries (e.g., Iceland and the UK) to broaden the range of expert perspectives, particularly because these countries have already implemented national mandatory tracking systems for all vessels.

[1] These estimates only include vessels under 12 m using static gears. "*Fishing carried out by fishing vessels of an overall length of less than 12 m and not using towed fishing gear*" (Commission Regulation (EC) No. 26/2004

Respondents were selected based on their direct involvement in vessel-tracking data within each country, as only these experts can accurately identify the number of vessels monitored and the fisheries in which tracking occurs. Questions included information on the types of tracking systems used to obtain geopositional data, together with specific information on the fleets being tracked (e.g. number of vessels, gear used, species targeted, purpose of tracking and temporal resolution) (see Sup. Mat. 1). While recognising that the definition of SSF varies across countries, for the purposes of this study and to facilitate discussions concerning the CR2023/2842, we have constrained the definition of SSF to all commercial fishing vessels $<=$ 12 m in length. The systems were grouped into three main categories that all use the Global Navigation Satellite System (GNSS) to provide global positioning: VMS (which uses satellite linked communication to transmit messages), AIS (which uses radio frequency transceivers) and other tracking devices (e.g. iVMS or generally called GPS tracking devices) that use mobile communications technologies (MCT) such as General Packet Radio Service (GPRS) or Global System for Mobile Communications (GSM). Fishing gears were classified using FAO fact sheets (https://www.fao.org/fishery/en/geartype/search). Percentage of vessels tracked was estimated using the number of vessels identified as tracked through the survey divided by the number of $<$ 12 m vessels per country taken from the EU Fleet Register (https://webgate.ec.europa.eu/fleet-europa/index_en).

2.2. Opportunities and challenges

A semi-structured interview was conducted with researchers with experience of vessel tracking systems and data analyses in their country's fishing fleets (11 researchers from 11 institutions). The interview aimed to identify strengths and opportunities (hereafter opportunities) and challenges and threats (hereafter challenges) that could arise from implementing a mandatory (nationwide) vessel tracking system in SSF (Sup. Mat. 2). Responses were presented in the plenary of the WKSSFGEO2 [33] and validated through a group discussion with all workshop participants (38 researchers from 24 institutions). Three authors (LS, AMC, and TM—who were not among the interviewees) independently grouped the responses into major themes. They then met to review each theme, discuss discrepancies, and reach a consensus on the final classification. A word cloud was produced using Python wordcloud library to visualize the main themes discussed by participants (https://pypi.org/project/wordcloud/). In the word cloud, the font size depicts the number of responses that were categorised into one of the agreed themes.

2.3. Vessel anonymity rule in SSF

The Regional Coordination Groups agreed in 2018, that, in agreement with the General Data Protection Regulation directive [34] each unit of confidential fisheries data published must contain at least three distinct individuals [35]. The EU Control Regulation (1224/2009) Article 113 on 'Confidentiality of professional and commercial secrecy' states that Member States and the EU Commission shall ensure that data are treated in accordance with applicable rules on professional and commercial secrecy. In practical terms, and for the purpose of depicting spatial fisheries data, it was agreed that when data are published as maps, sensitive values should be suppressed from maps if there are less than three different vessels operating in each grid cell or the data should be aggregated so that each aggregation contains at least three different vessels [36]. The problem becomes larger the more finely scaled and disaggregated (e.g., per quarter, month, day, meter level) the data are to be presented. We assessed the potential implications of this directive on the depiction of fishing activities in SSF. This is extremely important in fisheries using gears such as traps or longlines, which usually are highly territorial, or in fisheries that are not concentrated in a few areas, and where therefore the probability of having less than three vessels would be higher.

AIS data from longline fisheries in Iceland was used to assess the implications of using the "three vessel rule" by mapping the distribution of all fishing activities into two spatial grid resolutions: 1 $\times$ 1 km and 5 $\times$ 5 km. Aggregating data into spatial grids is the most common approach to show fishing activities to date [37]. The positional and speed data are collected at around 10-minute resolution. This information was used in conjunction with captains reporting of start and end time of a setting to spatially demarcate the fishing event.

3. Results

3.1. Overview of vessel tracking experiences in Europe

Survey responses indicated that currently, around 6080 vessels ($<$12 m LOA) are being tracked across Europe (Fig. 1), representing approximately 12% of the total SSF fleet (50,265 vessels, including 4159 in the UK and 1800 in Iceland) [38,39]. This high proportion is primarily driven by countries that have already implemented nationwide mandatory tracking. In the UK, tracking programmes have been introduced in Wales (~350 vessels) (Fishing [40]) and England (~1800 vessels) [41]. In Iceland mandatory use and reporting via AIS is in place (1800 vessels, Hjorleifson, pers. comm). Norway has recently (2023) started mandatory tracking for vessels between 10 and 12 m (1785 vessels). Some countries have adopted fleet or region-wide tracking programmes, for example, in Portugal, Denmark, Ireland and Scotland all fishing vessels using dredges, or particular types of dredges, to catch bivalves are equipped with positional trackers [42–44]. In Scotland, position and effort are collected for all vessels in the electrofishing fleet targeting razor clam [45]. In France, vessels using nets, trawl and dredges in some regions are required to install VMS systems [46,47]. In Ireland, vessels using pots and set nets and providing self-sampling data for scientific purposes are tracked as a condition of contract and payment for self-sampling data. Additionally, regional tracking programmes are being implemented in Spain: in Andalucia, the system started for some fleets in 2005 [48], while in other Spanish regions implementation has started more recently such as in Murcia (2016), Balearic Islands (2019) and Cantabria (2021) [49–51].

European vessel tracking programmes for SSF primarily rely on MCT to transmit data (Fig. 1). In most cases, spatial reporting is not conducted in real time except when within range of mobile networks. However, positional data continues to be recorded throughout vessels' trips and is then transmitted when the vessel is within range of a mobile telephone network. In Norway, both satellite and mobile communication technologies are used, depending on the operational range of vessels. AIS systems were only mentioned by scientists in Denmark and Iceland, despite evidence from Global Fishing Watch (GFW) public data portal (https://globalfishingwatch.org/data-download/) indicating that approximately 1341 vessels $<=$ 12 m using these devices in 2023 [52]. It is unclear whether these are the same vessels currently tracked with MCT or VMS technologies or if they constitute additional tracked vessels.

SSF vessel tracking primarily covers vessels using nets, pots and traps, and dredges, which represent the gears commonly used by SSF in Europe (Fig. 1). The main target catch assemblage groups were demersal fish, molluscs and crustaceans. The frequency with which vessel positions are recorded may be prescribed as well as the frequency with which the vessel positions are transmitted via mobile or satellite communication to a server. Survey responses indicated that VMS tracking systems used in SSF acquired position data every 5–60 min (Fig. 2). MCT tracking systems mostly acquired data every 3 min, although this mainly represents the frequency set in England. The temporal resolution varied between gears, with dredges, pots and traps, gillnets, and hooks and lines generally tracked with frequencies of less than 10 min, compared to trawls, which had a lower temporal frequency, related to the use of VMS for tracking trawlers in France.

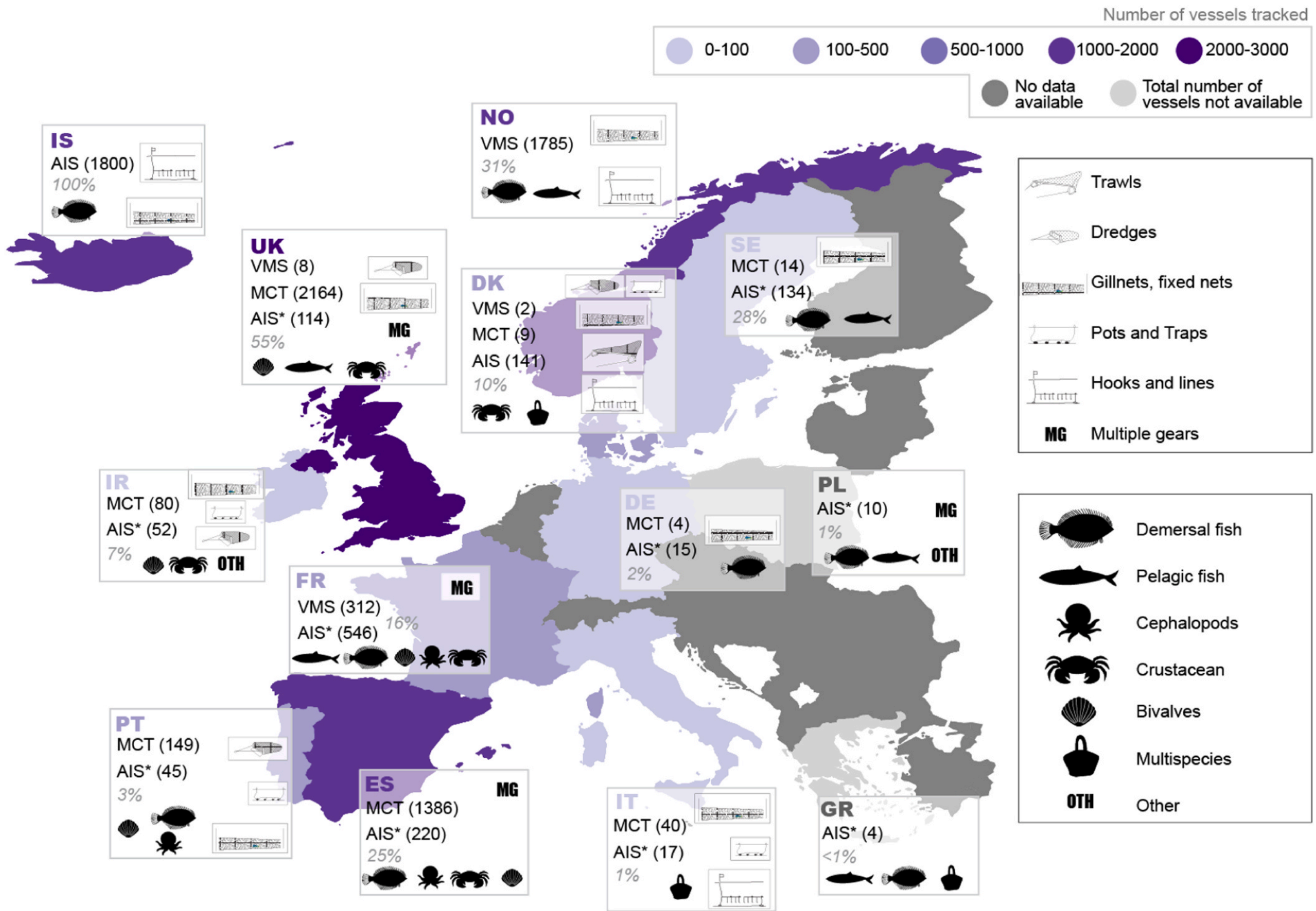

Fig. 1. Overview of fishing vessel tracking devices (VMS, AIS or MCT) in Europe by type of gear and target species. Numbers in brackets indicate the number of vessels being tracked. Percentage values indicate the percentage number of vessels < 12 m being tracked in each country. For AIS, * indicates data provided by Global Fishing Watch, otherwise data were obtained from respondents to the survey.

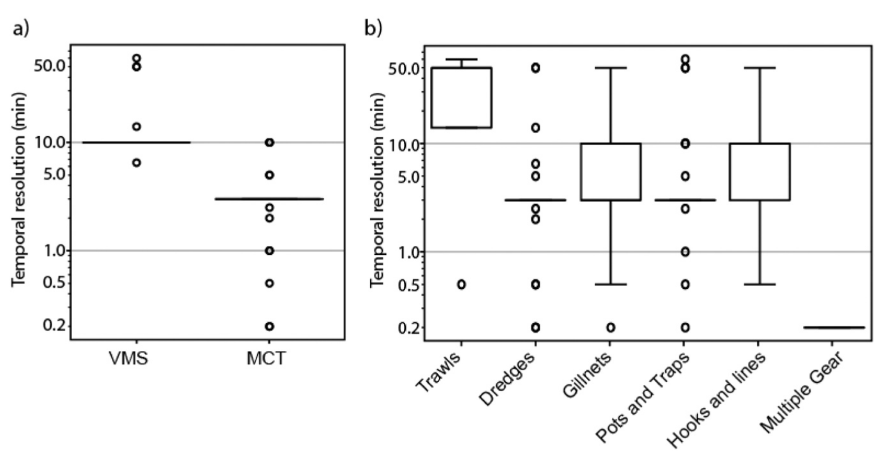

Fig. 2. Boxplot of temporal resolution for a) tracking systems and b) gear type. Note vertical axis is depicted in logarithmic scale.

3.2. Opportunities and challenges

The benefits of implementing a mandatory, nationwide vessel tracking system in SSF were widely recognised by interviewees. Perceived benefits included enhancing spatial management (mentioned 19 times out of 89), promoting sustainable fisheries (11 mentions) and improving the assessment of fisheries' ecological impacts (9 mentions, Fig. 3a). Improved knowledge of the spatial dynamics of fishing fleets was highlighted as a critical factor for effective marine spatial management and planning. This included the ability to resolve spatial conflicts (5 out of 89)—both among different fishing fleets and between fisheries and other sectors, such as offshore renewable energy developments, marine protected areas, aquaculture farms, and recreational, tourism or leisure activities. Participants mentioned the ability to identify the most important fishing grounds (through fishing effort proxies or being able to link landings value to effort) to inform decision

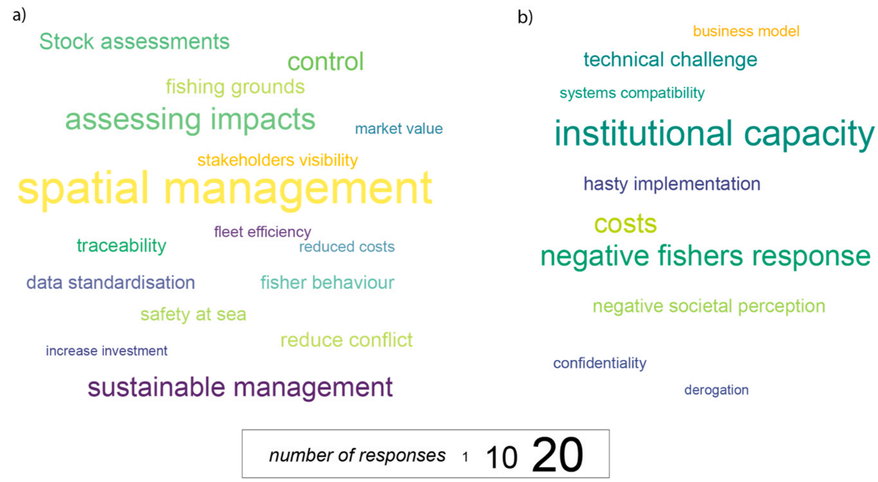

Fig. 3. Word cloud indicating the main themes around a) opportunities and b) challenges of the implementation of a nationwide vessel tracking system.

makers (4 out of 89).

Sustainable management of SSF was also emphasised (11 mentions), particularly the value of increased data availability to enhance fisheries effort assessments, improve fisheries advisory processes, and support the designation of exclusive SSF zones. Interviewees suggested that tracking data could also be beneficial to fishers, as it could enable them to access new fishing grounds, as long as the track data was not publicly available. An example of a tracking system that has benefitted fishers is the German programme using the smartphone MOFI-app for self-reporting of fishing activities. Using this app, fishers successfully regained access to previously closed areas by demonstrating that their fishing activities were conducted strictly in waters shallower than 20 m. [27].

The ability to accurately estimate the ecological impacts of fisheries—including assessment of the risk of bycatch by overlaying SSF activity on endangered and protected species distribution model layers, on benthic ecosystems, and overall fishing footprint—was identified as a key benefit, ranking third in importance (9 out of 89).

The analysis of the challenges associated with implementing a nationwide vessel tracking system identified 10 themes with a total of 54 mentions during the interviews. Institutional capacity as the most frequently mentioned concern among respondents (15 out of 54, Fig. 3b). This challenge encompassed issues related to the lack of appropriate databases and data architectures capable of handling large volumes of information, including data storage, preprocessing, analysis, and long-term database maintenance. Cybersecurity risks were highlighted as a critical concern, necessitating robust measures to safeguard sensitive data and prevent system vulnerabilities.

Several interviewees highlighted the risk of negative reactions from fishers (10 out of 54), particularly if reporting requirements are perceived as burdensome, which could further contribute to attrition from the sector. The financial burden of implementing a nationwide tracking system was another major challenge (9 out of 54). Respondents noted that costs extended beyond the initial purchase and installation of tracking equipment to include expenses related to data transmission, ongoing technical support, and database management.

Another key challenge in advancing the monitoring of SSF in Europe was the lack of integration of vessel tracking data into statutory or commonly accessible databases (5 out of 54). While several regional and pilot initiatives have been undertaken, these efforts remain fragmented, with (e.g. AIS, VMS, MTC). Interviewees emphasised persistent compatibility issues, as users often struggle to merge datasets derived from disparate systems into a coherent and interoperable format (2 out of 54). Concerns were also raised regarding the reliance on private service providers, whose financial instability could jeopardise long-term data continuity and system maintenance. Premature implementation of monitoring systems—prior to the definition of standardised data types and formats—was perceived as a risk that may result in unnecessarily complex data structures, complicating downstream processes such as data analysis, management, and enforcement. Ambiguity around technical requirements was identified as a risk factor, particularly in relation to defining an optimal reporting resolution of vessel position which is still sufficiently frequent to detect fishing activity.

3.3. *Vessel anonymity rule in SSF*

The Icelandic case study demonstrates that the application of vessel anonymity rules significantly affects the spatial representation of AIS-derived fishing effort data. For the Icelandic longline fleet, the requirement that each grid cell must contain data from a minimum of three vessels to maintain anonymity leads to substantial information loss when mapping fishing activity. When using a 5×5 km grid, 30**%** of the annual fished area contain one distinct vessel, and 22% two distinct vessels (cells that would be retained shown in yellow, Fig. 4a), while at the finer 1×1 km resolution, the values are 58% and 24% respectively (Fig. 4b). This pattern is consistent with findings from the ICES WGSFD, which noted that implementing a three-vessel threshold for data aggregation led to the removal of 27–72% of spatial cells, with the greatest data loss occurring in peripheral areas and among smaller metiers [36].

4. Discussion

The overview of vessel tracking initiatives across Europe reveals an uneven landscape of SSF coverage. Although approximately 6080 vessels are currently tracked—around 12% of the European SSF fleet—coverage remains strongly influenced by national regulatory frameworks. Countries that have implemented mandatory, nationwide programmes, such as England, Wales, Iceland and Norway, contribute disproportionately to overall tracking numbers. These countries typically use reporting frequencies of around 10 min, with England adopting a higher-resolution 3-minute interval, suggesting that in these countries, tracking is intended to support fisheries management rather than solely used for monitoring and control.

Most systems rely on mobile communication technologies (MCT), which remain the primary means of transmitting positional data. While some AIS data are available, limited integration to other data sources might be explained by issues such as the lack of coverage in some areas [53,54], the vessel's ability to intentionally disable it's AIS device [55,56], and the absence of a standardised link between AIS unique identifiers and primary vessel registration numbers (e.g., common fleet register identifier) [57,58]

Researchers widely recognised the significant opportunities offered by nationwide vessel tracking in small-scale fisheries, particularly for

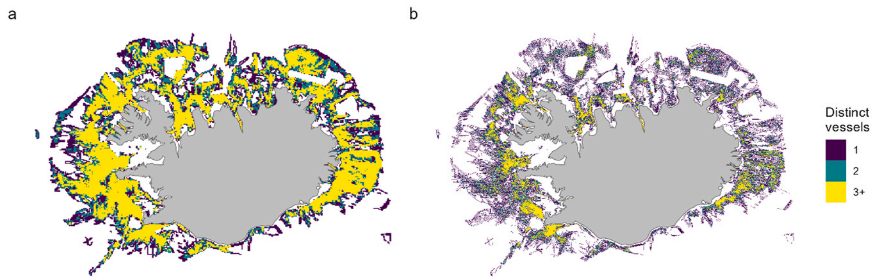

Fig. 4. Spatial distribution of longline fisheries in Iceland showing number of distinct vessels operating in: a) 5 × 5 km and b) 1 × 1 km grid cell resolution. Under the current "three vessel rule" recommendation, only the yellow shaded cells would be presentable.

improving spatial management and supporting sustainable fisheries. By enhancing the accuracy of spatial fishing effort data, tracking strengthens stock assessments, ecosystem-based management, transparency, and marine spatial planning, thereby contributing to more effective implementation of the Common Fisheries Policy. In a worldwide review of marine spatial plans, Trouillet et al. [7] found that about half of plans contained no information on the distribution of fishing activities. Vessel tracking data could assist in identifying stakeholders, in mapping existing fishing activity and its associated metrics against existing and proposed areas of human activities and in minimising opportunity costs for SSF in marine spatial planning trade-offs generally [59]. Vessel tracking data have already been used in LSF to estimate impact on benthic habitats and ecosystems [60,61], improving understanding of bycatch risk [62], and overall fishing footprint [54, 63], demonstrating the potential relevance for SSF.

Despite these opportunities, several challenges may hinder wider implementation. Key concerns include institutional capacity and the financial burden associated with device procurement, data transmission, and long-term maintenance. The nationwide tracking application and procurement programme in England reported over 80% of the English under-12 m fleet having purchased and installed a device and claiming back £ 1.3 million from the European Maritime, Fisheries and Aquaculture Fund (EMFAF) by December 2023. The Maritime Management Organisation stipulated that purchase and installation costs of up to £ 1050 (~1270€) would be covered by EMFAF funding. As about 80% of vessels have been equipped, we estimate a cost of ~ £ 720 per device. If the same business model was applied to all remaining European vessels (All EU vessels, not including Iceland and the UK - 44306) £ 31.9 million or €41.9 million would be claimed from the Fund. Although lower-cost alternatives—adapted from the vehicle transport sector—have been successfully tested in SSF [64,65], MCT systems vary in cost, durability and failure rates, implying trade-offs. The true long-term costs of maintenance, service provision, and data management will become clearer as more systems are implemented.

5. Recommendations to enhance CR 2023/2842 implementation

Given that CR 2023/2842 is expected to be operationalised within the coming years, we outline a set of recommendations aimed at enhancing its uptake and implementation (Fig. 5).

a) ***Urgent call for system requirements specification and harmonisation***

The lack of clear guidance on the requirements and technical specifications for vessel tracking systems across the EU or at Member State level one year before the implementation of the CR 2023/2842 is a significant weakness that needs to be clarified promptly**.** Data formats required for reporting (e.g. timestamp in UTC, latitude and longitude formats in degrees, positional accuracy) are required to guarantee interoperability between Member States. Harmonised data standards including metadata protocols that clearly define when, how, and by whom data can be stored, transmitted, and utilised are needed [66,67]. These practices align with the FAIR data principles by ensuring that data is also findable through consistent metadata, accessible via standardized protocols, and reusable due to clear documentation and provenance. Device specifications need to be agreed on, including, for example, whether the device can incorporate geofence alerts, where changes in reporting frequency are triggered or notifications are sent triggered when inside a define spatial perimeter [25,68]. Another important specification needed is whether the device must be able to connect to fishing winch equipment, to enable the identification of gear deployment [65]; or camera systems, to quantify fishing effort, catches, and discards [69]. These specifications are critical to fisheries management, specifically identify fishing operations and/or to validate models to infer fishing operations (see section below). Leadership in implementing harmonized data standards and device specifications should come from EU-level bodies such as The Directorate-General for Maritime Affairs and Fisheries and The Joint Research Centre, supported by advisory

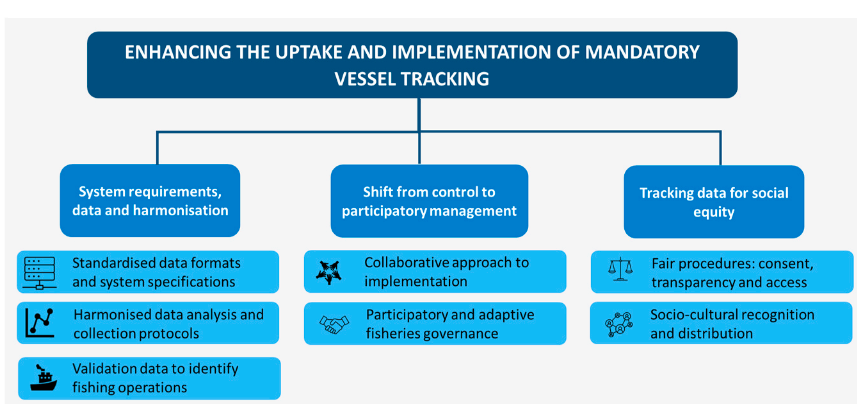

Fig. 5. Recommendations aimed at enhancing the uptake and implementation of mandatory vessel tracking for SSF in Control Regulation 2023/2842.

organizations like ICES and the Scientific, Technical and Economic Committee for Fisheries. These entities can coordinate with Member States and technology providers to ensure interoperability, compliance with FAIR principles, and integration of SSF spatial data into EU advisory frameworks. This is undoubtedly a challenge, but there are ongoing initiatives (e.g. "Enhancing Monitoring for Sustainable Small-scale Fisheries project" funded by the European Maritime, Fisheries and Aquaculture Fund) that provide an important foundation for coordination, knowledge exchange, and the development of common technical approaches. Building on such initiatives could accelerate the establishment of harmonised standards and practical guidance, reducing fragmentation across Member States.

Standardised workflows for data cleaning, quality control, and analysis are needed to integrate SSF tracking data from VMS, AIS, and MCT systems. Currently, research groups apply procedures independently, and although efforts to standardise analyses have begun [43,70,71], integration into EU advisory bodies remains limited, as spatial SSF data are not yet requested in annual data calls. Clear guidelines and considerations are also needed for the outputs generated. A persistent challenge is maintaining vessel anonymity, particularly for static gears while producing relevant information (e.g. maps) for spatial planning. Using fishing-operation metrics, such as engine power or Swept Area Ratio [72], offers a way to preserve confidentiality while providing spatial effort information. However, such approaches may be less suitable for passive gears, underscoring the need for alternative strategies that balance data utility with confidentiality requirements.

CR 2023/2842 stipulates that "*Member States should be able to … receive position data from them at regular and sufficiently short intervals*", though the exact interval is not yet defined. ICES WGSFD recommends an acquisition frequency of position data of every 30 s for SSF [33,73] to accurately capture effort metrics for passive gears, such as soak time, hook or trap counts, and net length. This recommendation is based on case studies showing that decreasing the frequency to five minutes can lead to a reduction in the estimated area fished by over 30% [43,74,75], with the largest discrepancies observed in smaller vessels. Such underrepresentation has significant implications: vessels under 8 m in length, which typically conduct shorter fishing operations and more spatially constrained fishing trips, are particularly affected by lower-resolution data. While concerns exist about data storage and management, empirical evidence indicates that 30-second tracking generates only ~75 MB per vessel annually, far less than the data produced by camera-based electronic monitoring systems (ranging from 500 MB to over 300,000 MB per hour, depending on environmental light conditions - Gildas Glemarec and Helen Holah, pers. comm.).

Finally, vessel tracking data alone is insufficient to determine when a vessel is actively fishing and several methods have been developed to infer fishing operations [43,76,77]. To assess which method performs best, it must be linked with validation data from sources such as logbooks, onboard observers, or sensors to accurately identify fishing operations and the specific gear used. While validation may involve additional effort, many countries already have on-board observer programmes and remote electronic monitoring (REM) systems in place. The key task is to collate and integrate these existing data to inform and validate models for inferring fishing activities. Importantly, this validation should be incorporated into Member States' research activities to ensure that fishing-detection methods are accurate, consistent, and aligned with national monitoring and management objectives.

b) ***Shift from control to participatory management***

Vessel tracking programmes are usually implemented for MCS rather than as part of a broader, participatory fisheries management strategy, which can be a barrier to the acceptance and beneficial use of these technologies (e.g. [78]). CR 2023/2842 exemplifies a top-down governance approach that aligns with regulatory trends observed in other national and regional contexts, including England, Wales, Iceland, and Norway. While tracking programmes represent a significant step towards improved MCS, they frequently sideline opportunities for co-management and collaborative governance. Achieving widespread deployment of tracking systems for SSF may be a challenge but it is also an opportunity for SSF. Control cannot be seen as the one and only reason for use of these systems. SSF stakeholder buy in is crucial in this respect.

Involving fishers in the co-design, deployment, and oversight of tracking programmes can build trust, increase adoption, and support long-term sustainability [79–81]. CR 2023/2842 lacks explicit provisions for stakeholder input or technical specifications, potentially limiting legitimacy and uptake among SSF communities. Privacy concerns and data ownership remain significant issues, as many fishers consider their fishing locations commercially sensitive [82,83]. Clearly communicating the purpose of data collection, ownership, access, and potential benefits is essential and should ideally be co-developed with fishers prior to implementation [80]. Our study engaged only with researchers, and further work is needed to understand fishers' concerns, preferences, and priorities, to ensure that tracking programmes are designed in a way that is acceptable, practical, and beneficial for SSF communities.

Low-cost, widely accessible digital technologies—coupled with rapid data processing and analysis systems—present new opportunities to enhance stakeholder engagement and support adaptive management frameworks. Traditional forms of top-down fisheries governance will need to be reassessed and adapted to accommodate the ability of more localised and data rich management structures to take decisions relevant to the sustainability of the fisheries locally and regionally [84]. Providing fishers with access to their own data, alongside relevant benchmarks, positions them as active participants rather than passive data providers, increasing trust, legitimacy, and compliance. Artificial intelligence (AI) further expands these possibilities by automating analyses, tailoring outputs for diverse stakeholders, and enabling real-time or near-real-time feedback [26]. Such systems have the capacity to transform unidirectional information flows—typically from fisher to regulator—into dynamic, iterative exchanges of knowledge. In doing so, they lay the foundation for co-produced, adaptive governance mechanisms that respond more effectively to local realities and rapidly changing environmental and socio-economic conditions and encourage greater buy-in and uptake of innovative fishery-dependent data technologies (see [26]).

c) ***Tracking data and social equity***

As vessel tracking becomes central to fisheries monitoring and spatial planning, equity considerations—such as inclusive participation, transparency, and data access for fishers—are critical [79]. Although CR 2023/2842 encourages financial support for small-scale fisheries (SSF) via the European Maritime Fisheries and Aquaculture Fund, historically most funding has favoured large-scale operators [85] raising concerns about equitable access.

Mandatory vessel tracking data will likely be used to generate maps of fishing activity for management and spatial planning. Currently, fishing effort—estimated from vessel positions and inferred fishing activity—is the main variable used, typically aggregated into spatial grids [86]. However, simply summing effort can unfairly weight areas with more vessels or longer fishing durations as more important, potentially misrepresenting the relative value of different fishing grounds [86]. Such maps may also fail to recognise culturally significant grounds or customary rights, particularly for SSF [7,87]. Low tracking frequency and the "three-vessel anonymity rule" can further underrepresent smaller vessels, leading to skewed depictions of space use. Incorporating socio-economic data, such as dependency or vulnerability indexes, could help address some of these inequities, but their development relies on the successful integration of SSF landings data, which remains limited and lacks a clear implementation timeline [88].

6. Conclusions

The introduction of mandatory tracking of SSF fleets in Europe through CR 2023/2842 opens many opportunities for these fisheries including adaptive and participatory fisheries management, improved evaluation of the importance of these fisheries to EU coastal communities and capacity to integrate SSF in all spatial planning and policy decisions. Put simply, SSF will be on the map. By enabling consistent, high-resolution monitoring of SSF activity, the regulation has the potential to support more adaptive and participatory fisheries management, ensure that the true spatial and socioeconomic importance of SSF is recognised, and meaningfully integrate these fleets into marine spatial planning and broader policy processes. If implemented effectively, SSF will finally be fully visible in EU decision-making—an essential step for safeguarding the resilience of coastal communities.

Realising this potential, however, depends on the rapid development and adoption of harmonised systems for data collection, integration, analysis, and modelling, alongside strong engagement with fishers and national administrations. With tracking systems already being rolled out across Member States, ensuring fitness for purpose is urgent—not only for monitoring and control but also for management, planning, equity, and long-term sustainability. Achieving a complete, standardised overview of SSF activity at EU scale would be a landmark achievement, but it requires coordinated guidance, technical coherence, and trust-building with stakeholders to ensure that the system delivers meaningful benefits for both fisheries management and the SSF sector itself.

CRediT authorship contribution statement

Tania Mendo: Writing – original draft, Validation, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Anna Mujal-Colilles:** Writing – review & editing, Validation, Methodology, Formal analysis. **Einar Hjorleifsson:** Writing – review & editing, Methodology, Formal analysis. **Pamela Lattanzi:** Writing – review & editing, Methodology, Investigation. **Luca Marsaglia:** Writing – review & editing, Formal analysis, Data curation. **Mark James:** Writing – review & editing, Conceptualization. **Marta M. Rufino:** Writing – review & editing. **Helen Holah:** Writing – review & editing. **Oliver Tully:** Writing – review & editing. **Jose Rodriguez-Gutierrez:** Writing – review & editing. **Patrik Jonsson:** Writing – review & editing. **Estanis Mugerza:** Writing – review & editing. **Josefine Egekvist:** Writing – review & editing. **Timothy Emery:** Writing – review & editing. **Hannah Ladd-Jones:** Writing – review & editing, Investigation, Data curation. **Grant Course:** Writing – review & editing, Investigation. **Julien Rodriguez:** Writing – review & editing. **Maria Mateo:** Writing – review & editing. **Christian von Dorrien:** Writing – review & editing, Validation. **André N. Carvalho:** Writing – review & editing. **Anna Nora Tassetti:** Writing – review & editing. **Lara Salvany:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation.

Declaration of Competing Interest

The authors declare no conflicts of interest.

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Data availability

Data will be made available on request.

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