ICES Journal of Marine Science, 2025, Vol. 82, Issue 8, fsaf130
https://doi.org/10.1093/icesjms/fsaf130
Received: 29 July 2024; **revised:** 27 June 2025; **accepted:** 27 June 2025
Review Article

ICES CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Relevance of European small-scale fisheries trapped by data limitations

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Abstract

Landings by species and their associated fishing effort are crucial for stock assessment and estimating fishing mortality. While large scale fisheries (LSF) have historically received more attention, interest in standardized data from small scale fisheries (SSF) has increased significantly over the last decade. This study characterizes SSF and ongoing fishing activity data collection across 17 European countries, from the Baltic Sea to the Mediterranean, using 2019 as a reference year. The analysis reveals that 88% of commercial active fishing vessels are smaller than 15 m in total length and that such SSF (as considered in this study) accounts for over 83% of the total days at sea and 12% of the landed weight. However, fishing activity data collection for SSF is less comprehensive compared to LSF. Vessels larger than 10 m typically report their fishing activities in logbooks and sales notes, whereas for <10 m vessels, only 40% provide additional data sources to sales notes, namely with declarative forms. This results in significant data gaps and inaccuracies, especially regarding fishing effort, gears used, or fishing locations. This is especially true for vessels smaller than 10 m, likely as a product of having comparatively less ongoing requirements put in place, whereas vessels between 10 and 15 m also present fewer data reporting obligations (e.g. large part of this fleet is not covered by geo-localization data especially for the [10–12) m vessels) compared to vessels above 15 m (LSF). In the end, SSF fisheries have not only less data available than LSF, but their provided information is also consequently subject to more inconsistencies and inaccuracies. Therefore, a concerted effort will be needed to improve SSF data quality through coordinated, harmonized, and comparable data collection efforts across countries. Recommendations include enhancing data reporting requirements for smaller vessels, implementing supplementary technological solutions, and conducting cross-checks of census information with sampling data. Additionally, the development and use of geolocation devices and apps are recommended to enhance the accuracy and completeness of SSF fishing activity data collection.

Keywords: small-scale fisheries (SSF); data collection; data sources; sampling; census; fishing capacity; fishing effort; landings and economic value; best-practice guidelines

Introduction

Landings by species (in biomass and in value) and their associated fishing effort (by fishing gear and area) are crucial for stock assessments and estimating fishing mortality. While large scale fisheries (LSF), which accounted for ∼12% of the total number of active vessels of the surveyed countries, have historically received more attention for data collection (e.g. strong funding support), the interest in standardized data from small-scale fisheries (SSF) has increased over the last decade (FAO 2015). For instance, the European Maritime and Fisheries Fund (EMFF) regulation (EU 2014) encouraged Member States (MS) with a significant small-scale coastal fishing segment to implement action plans for the development, competitiveness, and sustainability of their fishing activity. Subsequently, the European Maritime, Fisheries and Aquaculture Fund (EU 2021) considers the contribution of MS to the development of sustainable small-scale coastal fishing when assessing programmes for fisheries data collection. On the other hand, in 2018, the United Nations General Assembly (United Nations 2018) declared 2022 as the International Year of Artisanal Fisheries and Aquaculture (FAO 2023b). In addition, SSF have received growing attention within Marine Spatial Planning (MSP) initiatives because they are the least powerful stakeholder among other marine users and at the same time the most vulnerable to external pressures (Jentoft 2017).

SSF definition

Despite recent global attention, no single harmonized definition of SSF could be found in the literature (Smith and Basurto 2019), with various interpretations depending on the end-user needs, such as stock assessment, MSP, socio-economic studies, Marine Strategy Framework Directive (MSFD), Marine Protected Areas (MPA), or management regulations. For instance, the EMFF 1198/2006 regulation defines 'small-scale coastal fishing' as activities carried out by (a) marine and inland fishing vessels of an overall length of <12 m and not using towed fishing gear or (b) fishers on foot, including shellfish gatherers' (Article 2; EU 2021). FAO defines SSF in the FAO Fisheries Glossary (FAO Terminology Portal; https://www.fao.org/faoterm/collection/fisheries/en/) as 'artisanal fisheries, sometimes referred to as SSF, as traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amounts of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption; these can be subsistence or commercial fisheries, providing for local consumption or exportation'. At the same time, FAO acknowledges the diversity of SSF and the lack of a single agreed definition (FAO 2015, 2023a); considering that no unique definition is able to capture the diversity and complexity of what constitutes SSF (https://ssfhub.org/group/39/about) (Pascual-Fernández et al. 2020).

This work adopts the SSF definition from the ICES Expert Working Group on Commercial Catches (Anon 2013, 2017, ICES 2016): commercial vessels with a length overall (LOA) below 15 m. This definition is practical and well adapted to the context of data collection at the European Union (EU) level, addressing the lack of information sources for this fleet category (ICES 2019). Therefore, ICES WGCATCH considered it as the most adjusted for data collection purposes in the context of fisheries management. It does not consider gear type, as fishing activity data collection issues are similar regardless of the gear (active or passive, European Parliament 2007). Recreational fishing vessels, which could face similar issues but have some specificities and a separate legal framework (Hyder et al. 2020), are excluded.

Fishing activity data

This work focuses primarily on 'fishing activity variables data' considering landings by species (in biomass and value) along with their associated fishing effort (especially vessels' days at sea) detailed by fishing gear and area.

Fisheries data collection regulations in European countries by fleet segment

In the EU, according to the Control Regulation (EU 2009), vessels larger than 15 m are obliged to report their fishing activity by electronic EU logbooks [as defined in the Article 14 of the Control Regulation (EU 2009)] and to be fitted with an approved satellite-based vessel monitoring system (VMS) device on board. In contrast, for SSF, regulations are different and depend on the length of the vessels. Based on ongoing regulations, three fleet length categories could be defined: the segments of vessels with LOA < 10 m, [10–12) m, and [12–15) m. The vessel segment of LOA < 10 m (defined for <8 m in the Baltic) has no legal obligation for direct reporting of fishing activity using fishing EU logbooks (either paper or electronic) and to be fitted with VMS. Lack of obligation applies also to LOA [10–12) m vessels for VMS requirements and reports of EU logbooks in electronic format. Finally, the LOA [12–15) m vessels, although they have the same requirement as vessels larger than 15 m for electronic EU logbooks reporting and VMS, may be subject to exemptions (EU 2017) especially when trip duration is <24 h and if the fishing occurs within national waters (EU 2009).

Therefore, limited requirements associated with European SSF currently restrain their potential to provide the same level of detail in the data as the LSF, both in terms of quantity and quality. Indeed, electronic logbooks report circumstantial fishing activity information almost instantly and can provide greater details than paper logbooks. While geolocation data (e.g. GPS, AIS, VMS, …) allows for mapping fishing activities with relatively high spatial resolution when appropriate reporting intervals are chosen [as detailed in the WKSSFGEO2 reports (ICES 2023), which recommend a temporal resolution interval of at least 1 min, especially for SSF]. Currently, the ongoing VMS resolution interval is only 1–2 h, a level of detail not available in logbooks. Such type of data is highly relevant e.g. for fisheries management or MSP. These insufficient data collection requirements from SSF result in data limitations when it comes, e.g. to calculating fishing activity variables' estimates considering especially the quantification/evaluation of their bias, precision, or accuracy/reliability (ICES 2019). This uncertainty can have potential negative consequences for the quality of e.g. stock assessments or fisheries management (Honey et al. 2010, Rehren et al. 2021).

Objective of the study

This study builds on the work performed by the ICES WGCATCH over the past years. The ICES Working Group on Commercial Catches (WGCATCH) contributes to ensuring the quality of fishery data, which underpins stock assessments and advice. A subgroup specifically addresses issues related to the SSF sector. Detailed reports from the working group are available on the ICES website. By providing a concise summary of these works, along with new visuals that offer a clearer view of the SSF sector and a preliminary attempt to categorize the diversity of available data, this study aims to characterize European SSF and ongoing data collection by country. It compares data sources and identifies key gaps and limitations. Accordingly, it provides recommendations and suggestions for best practice guidelines for fishing activity variables data collection. 17 European countries, from the Baltic Sea to the Mediterranean, reported data for the study, covering different types of vessels, fisheries, or fishing gears/métiers.

Materials and methods

Data collection methods for fishing activity data

Data collection methods, either for LSF or SSF, are based on two main different approaches: census and sampling (sometimes combined). Census methods refer to exhaustive coverage of the population from which data are required, e.g. in a fisheries context, vessels or fishing trips. Sampling methods are applied when data are collected from a statistically representative sample of the population (ICES 2019).

One example of a census approach regards the collection of self-reporting data on fishing activity provided by active fishers through the EU logbooks (EU 2009), defined as official EU declarative forms where information regarding vessels' fishing trips, including landings in volume by species, as well as their associated fishing effort, gear, and area, should be recorded by day, as detailed in Article 14 of the Control Regulation (EU 2009). For vessels for which EU logbooks are not required, especially SSF vessels, nine countries have developed other self-reporting approaches, like EU logbooks but in a way that is more suitable for their specific characteristics (e.g. multi-gear, fixed gears …), using SSF adapted declarative forms. Such self-reporting data sources can differ between and/or within countries, e.g. coastal logbooks, coastal journals, monthly declarative forms, etc. (ICES 2017). Another census method regards the collection of fishing activity data through sales notes (e.g. Bachiller et al. 2024), which contain the record of vessel landings sold in specific places (generally auctions within ports) and are centrally registered in national databases with detailed information about landed species' weight and value.

In contrast, an example of a sampling approach regards the data collection on SSF fishing activities data (landings by species in biomass and in value with their associated fishing effort, gear, and area) through a vessel-sampling survey. Although their similarities with data reporting methods from census, sampling surveys are applied to a statistically representative random sample of vessels. Catch assessment surveys are another example of a sampling method, carried out through random representative clustering sampling of fishing trips. In this case, SSF fishing activities are observed or surveyed directly on-site by trained scientific observers when the fishers come back to harbour (i.e. interviewing the skippers about their daily fishing trips).

Compilation of available national fisheries data

A structured questionnaire (Table S01), circulated through ICES WGCATCH members among ICES MS national fishing statistical offices, was used to characterize the status of data availability from the SSF fleets in Europe and to identify major gaps and deficiencies. 17 European countries (among the 26 European coastal countries with a sea border) reported data for the reference year of 2019 (Fig. 1). Data from France have been collected for FAO area 27 (Atlantic) and 37 (Mediterranean) when data from Spain was only collected for the Atlantic. Although the questionnaire was populated widely in all the potential countries involved, some countries' data were still missing for the study especially for the Mediterranean (e.g. Italy or Spain). Several explanations can be put forward like the difficulties for some countries to elaborate such statistics especially for SSF, or the lack of an ICES WGCATCH member to bring the request to the right audience. Nevertheless, the 17 European countries involved reported information of a large spectrum of European countries and regions from the Baltic Sea to the Mediterranean, encompassing various types of vessels, fisheries, or fishing gears/métiers, building a valuable representation of the European SSF sector, reflecting its diversity. The questionnaire was designed to collect data in a standardized format covering both SSF and LSF. It asked for variables regarding effort and landings, i.e. number of vessels in the official national fleet register, number of active vessels (defined as vessels with at least 1 day at sea in 2019), number of fishing trips, number of days at sea, total landings weight, and economic value. Official 'fishing activity' data from national commercial fishing fleets were requested, which could be derived from declarative forms (e.g. logbooks or coastal logbooks), sales notes, or other sources (e.g. sampling programs, vessel fishing licences, positional data); and in some cases, combined. This was depending on the data collection method applied by each country (see below).

All data were aggregated by FAO area and country, limited to vessels operating in FAO areas 27 and 37, and classified into the following fleet segments according to vessel length overall: <6 m, $6\leq8$ m, $8\leq10$ m, $10\leq12$ m, and $12\leq15$ m for SSF; and ≥15 m for LSF. As we focused on SSF in this study, we provided further details on the vessel length range of <10 m, especially because structural differences appear between vessels <6 m and, for example, those between 8 and 10 m. All the figures provided below are based on the data provided in the questionnaire. The data were controlled using two approaches: (1) consistency checks and (2) comparisons with the official EU fleet register (EU 2003). The consistency checks involved inter-countries diagnostics of average price, landings in weight and in value by trip, and number of trips or days at sea by vessel focusing on outlier's detection to identify potential issues in the data provided. The EU fleet register database (https://webgate.ec.europa.eu/fleet-europa/index_en) was then used to check the consistency between nationally reported and EU-registered vessel numbers. Inconsistencies and identified outliers were considered and resolved country by country, through direct communication with data submitters.

Based on EU fleet register database, the 15 EU countries surveyed represented ~66% of the total ~75 000 EU fishing vessels registered in 2019. In addition, data from Great Britain and Norway are included in the study (~13 500 vessels in 2019), as European countries fishing in the ICES region (Fig. 1).

Characterization of the fishing activity

Days at sea and landings' weight and value were analysed in total numbers and by average per vessel and trip, for each country. Days at sea were considered given the data available and the difficulty in obtaining more detailed information on

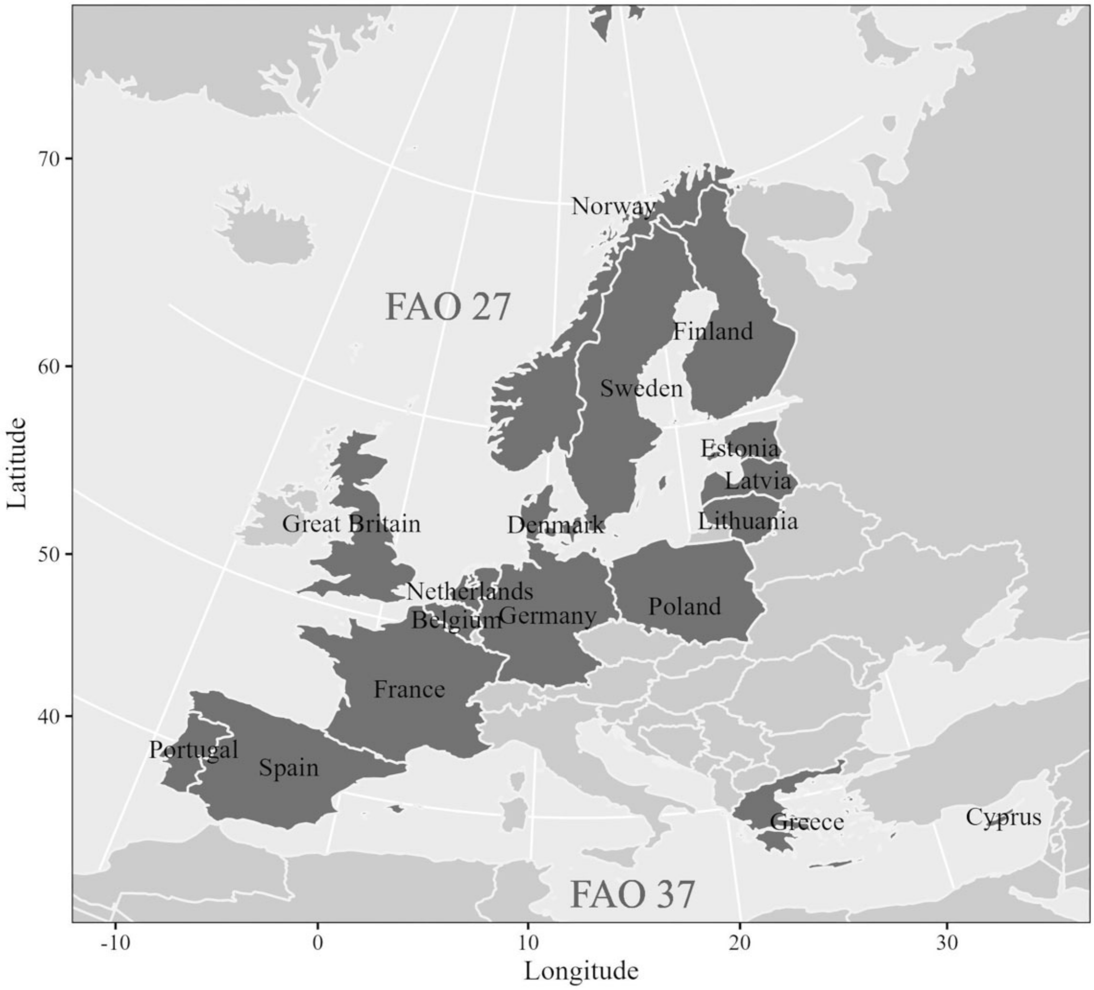

Figure 1. 17 European countries provided 2019 fisheries data for this study (marked in dark grey).

Table 1. Characterization of the diversity of fisheries data sources available.

Fisheries data sources available	Data sources' diversity codification
Logbooks/coastal logbooks, sales notes and other sources	A+
Logbooks/coastal logbooks and sales notes	A
Logbooks/coastal logbooks and other sources	B+
Logbooks or coastal logbooks	B
Sales notes and other sources	C+
Sales notes	C
Sampling programs	X

∗A '+' indicates an availability of additional data sources.

fishing effort for SSF (e.g. hours at sea or fishing hours). Nevertheless, it should be noted that a 'day at sea' does not have the same interpretation between SSF, where fishing trips often last <24 h, and LSF, where fishing trips may span multiple days (i.e. counted as 24 h).

Two-way ANOVAs were performed to test the effect of the country and the LOA (vessel length) range in the total number of days at sea (days at sea ∼ LOA range + Country + LOA range ∗ Country) and the economic value of landings (landings' value ∼ LOA range + Country + LOA range ∗ Country).

Characterization of the diversity of fisheries data sources available

To identify and highlight the fleet segments potentially affected by data gaps or limitations, a second questionnaire (Table S02) collected information on the methods applied by each country to collect 2019 SSF fishing activity data. Based on the analysis of the completed questionnaires, the diversity of available data sources was categorized by country and vessel length ranges (Table 1).

The codification reflects varying levels of diversity and completeness in the available data sources. An 'A' or 'A+' (A '+' indicates an availability of additional data sources e.g., positional data (such as GPS, AIS, VMS, …), supplementary samplings or surveys [e.g., fishing activity calendar survey (Berthou et al. 2008)], vessel fishing licences data, etc.) classification indicates the availability of both sales notes and logbooks or coastal logbooks, which could potentially be combined. When only one primary data source is available, logbooks or coastal logbooks were considered more informative (i.e. B or B+) than sales notes, as the latter do not adequately capture data on fishing effort, details of gears used, or fishing locations (i.e. C or C+), although they do provide information on value not available elsewhere. Finally, in the absence of census data, alternative applied sampling approaches were assigned a level X, as it is a completely different method which should be assessed specifically.

Software and statistical packages

R software v.4.2.2 (R Core Team 2023) has been used for all analyses and graphical representations, using especially the packages 'ggplot2 v.3.2.1' (Wickham 2009) for figures and 'data.table v1.14' (Dowle and Srinivasan 2022) for data summarizing.

Best practice guidelines for data collection on SSF

Based on the obtained results, as well as on ICES WGCATCH members' experience and expertise, best practice guidelines, presented within the discussion section, were then developed (ICES 2020).

Results

Different national legal requirements and practices in collecting SSF data occurred leading to inconsistent and sometimes partly incomplete fisheries data across nations and/or vessel length ranges (ICES 2017). Furthermore, the high heterogeneity of SSF data, ranging from logbooks or monthly declarations to sales notes, prevents a direct comparison between fleet segments and/or countries.

Sources of information for European SSF fisheries data collection in 2019

For SSF vessels with LOA between 10 and 15 m, the common method used for fishing activity data collection was a census-based approach, used by all the 17 surveyed countries (Table 2). Logbooks (hardcopy and/or electronic) were the common declarative data source available in all countries except Norway. In fact, logbooks were the exclusive source of information in 8 countries (Estonia, Finland, Germany, Greece, Latvia, Lithuania, Poland, and Portugal). Another 8 countries (Belgium, Cyprus, Denmark, France, Great Britain, the Netherlands, Spain, and Sweden) applied cross-checking methodologies to validate and/or complete logbook data with sales notes (Germany was also developing methods to point into that direction). Norway applied a census approach based on sales notes, but those included additional information, e.g. on the main gear and main fishing area, and are completed with catch assessment surveys for specific species (e.g. cod, haddock, and saithe). Finally, in some countries, fisheries research institutes used other additional data sources for re-evaluation (combined approach) and/or complementation, such as geolocation devices (GPS, AIS, VMS, …) in part of their fleet (Basque Country, Denmark, France, and Greece), sales notes from fishermen associations and a dedicated sampling program (Basque Country, Murillas-Maza et al. 2023), reference fleet surveys (Norway), or monthly fishing activity calendars exhaustive survey (France, Berthou et al. 2008, Weiss et al. 2018) (Table 2).

For SSF vessels below 10 m (Table 3), a much greater diversity of data sources was used than in larger SSF vessels. Census-based approach was the common approach used preferentially, applied by thirteen countries. Nine countries (sometimes only in certain regions, e.g. only Scotland in Great Britain) completed SSF-adapted declarative forms with their own formats (e.g. coastal logbooks, coastal journal, monthly declarative forms, etc.) established for control purposes under corresponding national legislations. Three countries (France, Great Britain, and Sweden) cross-validated/completed these declarative forms with sales notes (Germany was also developing methods to point into that direction). Six countries (Estonia, Finland, Germany, Latvia, Lithuania, and Poland) use these declarative forms as the unique fishing activity data source. On the other hand, six countries (Cyprus, Denmark, the Netherlands, Norway, Portugal, and Spain) based their SSF data mainly on sales notes, sometimes complemented with another data source depending on the country: Norway, for instance, completed their sales notes data with an on-site sampling program and a vessel sampling program (reference fleet) for specific fisheries or species (i.e. cod, haddock, and saithe); whereas Great Britain completed their sales notes data with indirect reporting of vessel activity based on local knowledge. In the case of the latter, and regarding non-Scottish regions, a self-reporting program was also under development, including weekly landings declarations. In contrast, Basque Country, Cyprus, and Portugal used a combined approach mainly based on sales notes but also incorporating data from other sources, such as sales notes from the fishermen association for Basque Country, on-site sampling program for Basque Country and Cyprus, and vessels' fishing licences data for Portugal. France (FAO area 37) also used a combined approach reassessing/re-evaluating/complementing the available declarative data (from sales notes and forms) on the basis of the monthly fishing activity calendars exhaustive survey (Weiss et al. 2018).

Finally, it should be noted that in Cyprus, Great Britain (excluding Scotland), Greece, Poland, and Sweden, special regulations were in force for specific fleets and/or fisheries, for which better quality data might be available. In Greece, a sampling program-based approach as the main data source to calculate SSF activity estimates was applied. Additionally: (1) France reported for Area 27 the use of a monthly fishing activity calendars exhaustive survey as a complementary data source to complement and improve the coverage and precision of the available declarative data [Berthou et al. 2008 and (2)] Basque Country, Denmark, France, and Great Britain (except Scotland) indicated that SSF data collection was or could be completed (i.e. data quality improvement) by using innovative and/or new technologies information (geolocation devices and/or app-based self-reporting tools).

Characterization of SSF vs LSF fisheries (2019)

Within the 17 European countries analysed, a total number of 38 591 SSF vessels operated actively for at least one day, which accounted for 88% of the total number of active vessels (Fig. 2). In the Mediterranean Sea (i.e. FAO area 37) Greek SSF represented > 28% of the total SSF fleet of the analysed EU countries, whereas in the Atlantic area, Norway had the highest number of SSF vessels for the countries analysed (16%), followed by Spain (11%), Great Britain (10%), France (9%), and Portugal (8%). In all countries, SSF was much higher in vessel number than the LSF (F-test, $P < .01$) and was dominated by the fleet segment <10 m (except for Belgium, the Netherlands, and, to a lesser extent, Norway) (Fig. 2).

The European SSF fleet considered (apart from the Norwegian fleet for which days at sea were not available for the analysis) had in total more than 3.4 million days at sea in 2019, which represents 83% of the total fishing effort, considering both SSF and LSF (Fig. 3). Furthermore, <8 m fleet segment

Table 2. Sources of declarative data collected for the SSF vessels with LOA between 10 m (8 m in the Baltic region) and 15 m, which are under the EU logbooks requirements.

Country	FAO area	Fleet register	EU Logbooks (landings declaration)	Sales notes	Sales receipts[a]	On-site sampling program[b]	Vessel-sampling program[c]	New technology program[d]	SSF census survey[e]	Data collection type[f]	Datacategory rank
Belgium (BEL)	27		*	*						Census	A
Germany (DEU)	27	*	*	*[g]						Census	B
Denmark (DNK)	27	*	*	*				*[h]		Census	A+
Spain (ESP) (Basque Country)	27		*	*	*	*		*		Combined	A+
Spain (ESP) (Others)	27		*	*						Census	A+
Estonia (EST)	27		*							Census	B
Finland (FIN)	27		*							Census	B
France (FRA)	27	*	*	*				*[i]	*	Census	A+
Lithuania (LTU)	27		*							Census	B
Latvia (LVA)	27		*							Census	B
Netherlands (NLD)	27		*	*						Census	A
Norway (NOR)	27			*[j]		*[k]	*[l]			Census	C+
Poland (POL)	27		*							Census	B
Portugal (PRT)	27		*							Census	A
Sweden (SWE)	27		*	*						Census	A
Great Britain (GBR) (Scotland)	27		*	*						Census	A
Great Britain (GBR) (Others)	27		*	*						Census	A
France (FRA)	37	*	*	*				*[i]	*	Combined	A
Cyprus (CYP)	37		*	*						Census	A
Greece (GRC)	37		*					*[m]		Census	B

'*' denotes presence of the corresponding data source. Note that France has operating vessels in both FAO areas 27 and 37.
[a]e.g. sale notes from fishermen association.
[b]e.g. catch assessment survey.
[c]e.g. reference fleets survey.
[d]e.g. new apps, geolocation devices.
[e]e.g. monthly fishing activity calendars exhaustive survey.
[f]i.e. SSF official fishing activity data collection type applied.
[g]In development: new database to cross-check EU logbooks (landing declarations) vs. sales notes.
[h]Additional data to improve census data: BlackBox system for mussel dredgers.
[i]Additional data to improve census data: GPS devices for specific fleets.
[j]Extended data: main gear and main fishing area declared in sales notes.
[k]Additional data to improve census data: Catch assessment survey for Cod, Haddock, Saithe.
[l]Additional data to improve census data: Coastal reference fleet survey: 7 vessels < 12 m.
[m]Additional data to improve census data: VMS devices for special licences (e.g. LLD, LHM for large pelagic fish, SB).

Table 3. Sources of declarative data collected for the SSF vessels with LOA <10 m (<8 m in the Baltic region).

Country Country	FAO area area	Fleet register	SSF adapted declarative forms[a]	Sales notes	Trip summary tales	Sales receipts[b]	On-site sampling program[c]	Vessel-sampling program[d]	Economic sampling program[e]	Vessels self-sampling program[f]	New technology program[g]	Specific regulations[h]	Vessels' fishing licenses data	Indirect reporting of vessels activity[i]	SSF census survey[j]	Data collection type[k]	Data category rank
Belgium (BEL)	27															No vessels	NA
Germany (DEU)	27	*	*	*[l]	*				*							Census	B
Denmark (DNK)	27	*		*							*[m]					Census	C+
Spain (ESP) (Basque Country)	27			*		*	*				*					Combined	C+
Spain (ESP) (Others)	27			*												Census	C+
Estonia (EST)	27		*													Census	B
Finland (FIN)	27		*													Census	B
France (FRA)	27	*	*	*							*[n]				*	Census	A
Lithuania (LTU)	27		*													Census	B
Latvia (LVA)	27		*													Census	B
Netherlands (NLD)	27			*												Census	C
Norway (NOR)	27			*[o]			*[p]	*[q]								Census	C+
Poland (POL)	27		*[r]									*[s]				Census	B
Portugal (PRT)	27			*				*[t]					*			Combined	C+
Sweden (SWE)	27		*	*								*[u]				Census	A
Great Britain (GBR) (Scotland)	27		*	*												Census	A+
Great Britain (GBR) (Others)	27		*[v]	*							*[w]	*[w]		*		Census	A+
France (FRA)	37	*	*	*							*[n]				*	Combined	A
Cyprus (CYP)	37			*		*[x]	*					*[x]				Combined	C+
Greece (GRC)	37							*		*	*[y]	*[y]				Sampling	X

'*' denotes presence of the corresponding data source. Note that France has operating vessels in both FAO areas 27 and 37.
[a] e.g. monthly or weekly landings declaration, coastal fishery forms, logbooks or journal, monthly declarative forms or catch reports, etc.
[b] e.g. sale notes from fishermen association.
[c] e.g. catch assessment survey, gear/métier survey.
[d] e.g. questionnaires, reference fleets survey.
[e] e.g. fishing effort survey.
[f] e.g. monthly self-reporting in local fisheries inspection.
[g] e.g. new apps, geolocation devices.
[h] i.e. Specific regulations for data provision applied for some peculiar fisheries or fleets.
[i] e.g. fishing gears and/or areas assessed through survey via merchants/local knowledges on a vessel by vessel basis.
[j] e.g. monthly fishing activity calendars exhaustive survey.
[k] i.e. SSF official fishing activity data collection type applied.
[l] In development: new database to cross-check monthly landings declaration vs. sales notes.
[m] Additional data to improve census data: BlackBox system for mussel dredgers and AIS data (test phase).
[n] Additional data to improve census data: GPS devices for specific fleets.
[o] Extended data: main gear and main fishing area declared in sales notes.
[p] Additional data to improve census data: Catch assessment survey for Cod, Haddock and Saithe.
[q] Additional data to improve census data: Coastal reference fleet survey: 7 vessels < 12 m.
[r] Limited data: <8 m vessels without catch composition since 2017; data estimated from 2016 8-10 m vessels data basis.
[s] Additional data to improve census data: Logbooks for Baltic Cod fishing.
[t] Additional data to improve census data: Effort assessment survey in the Azores to complete sales notes.
[u] Additional data to improve census data: EU logbooks for vessels < 10 m using active gears.
[v] In development: Introduction of weekly landing declarations for other vessels in Great Britain, as done in Scotland.
[w] Additional data to improve census data: Monthly Shellfish Activity return (MSAR) for shellfish fishing licensed vessels & Introduction of low-cost VMS for SSF.
[x] Additional data to improve census data: Sales receipts considered in complement of sales notes & Census landing declarations for the category 'C' fleet.
[y] Additional data to improve sampling data: Logbooks and/or VMS devices for special gear licences (e.g. LLD, LHM for large pelagic fish, SB).

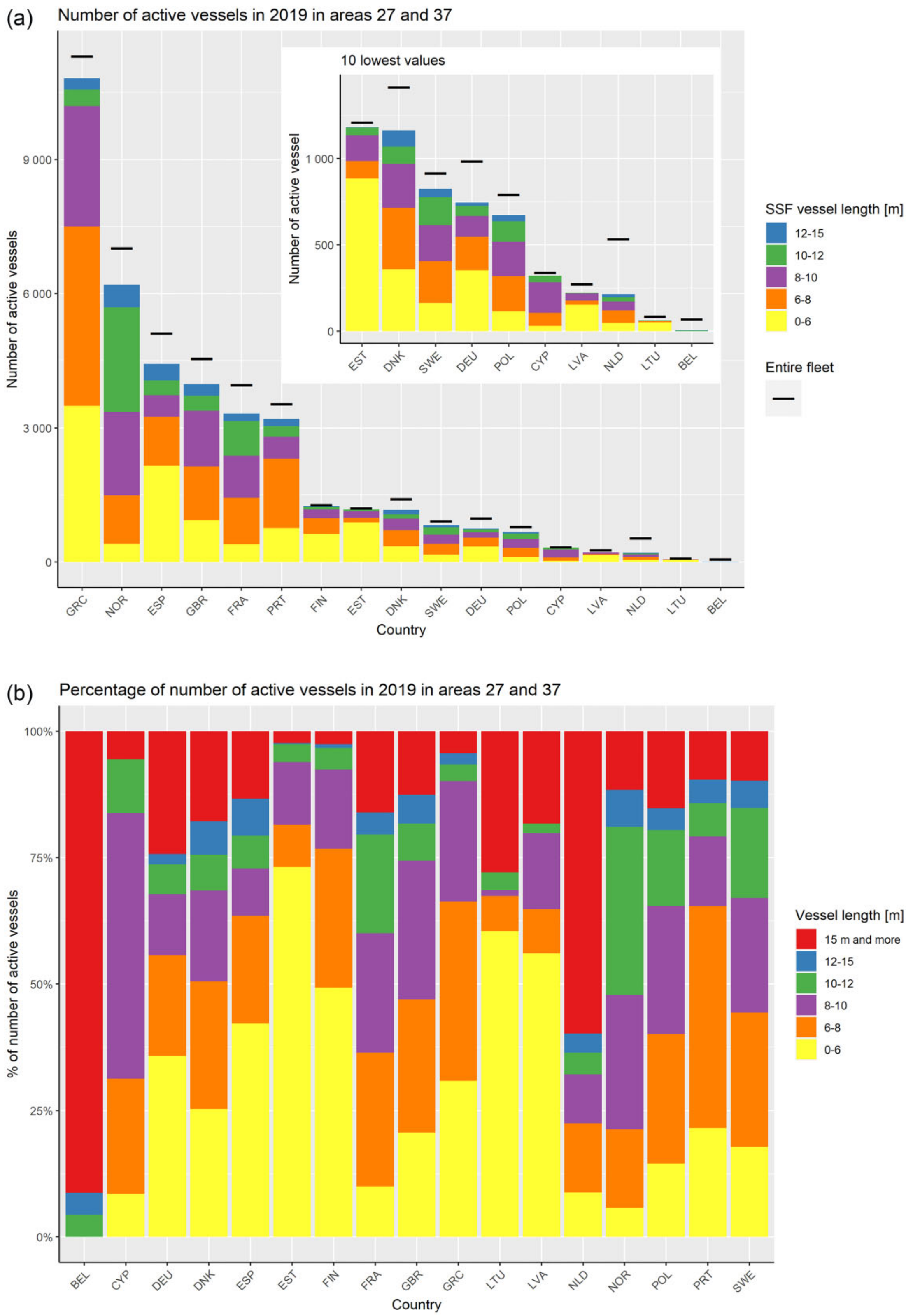

Figure 2. (a) Total number of active SSF vessels operating in FAO areas 27 (Atlantic and Baltic) and 37 (Mediterranean) during 2019, coloured by vessel LOA (m) and separated by country. The black horizontal bar indicates the total number of active vessels considering the whole fishing fleet, i.e. both SSF and LSF, and (b) Number of active vessels coloured by vessel LOA (m) and separated by country in terms of percentage. Country acronyms and their corresponding operating FAO areas are defined in Tables 2 and 3.

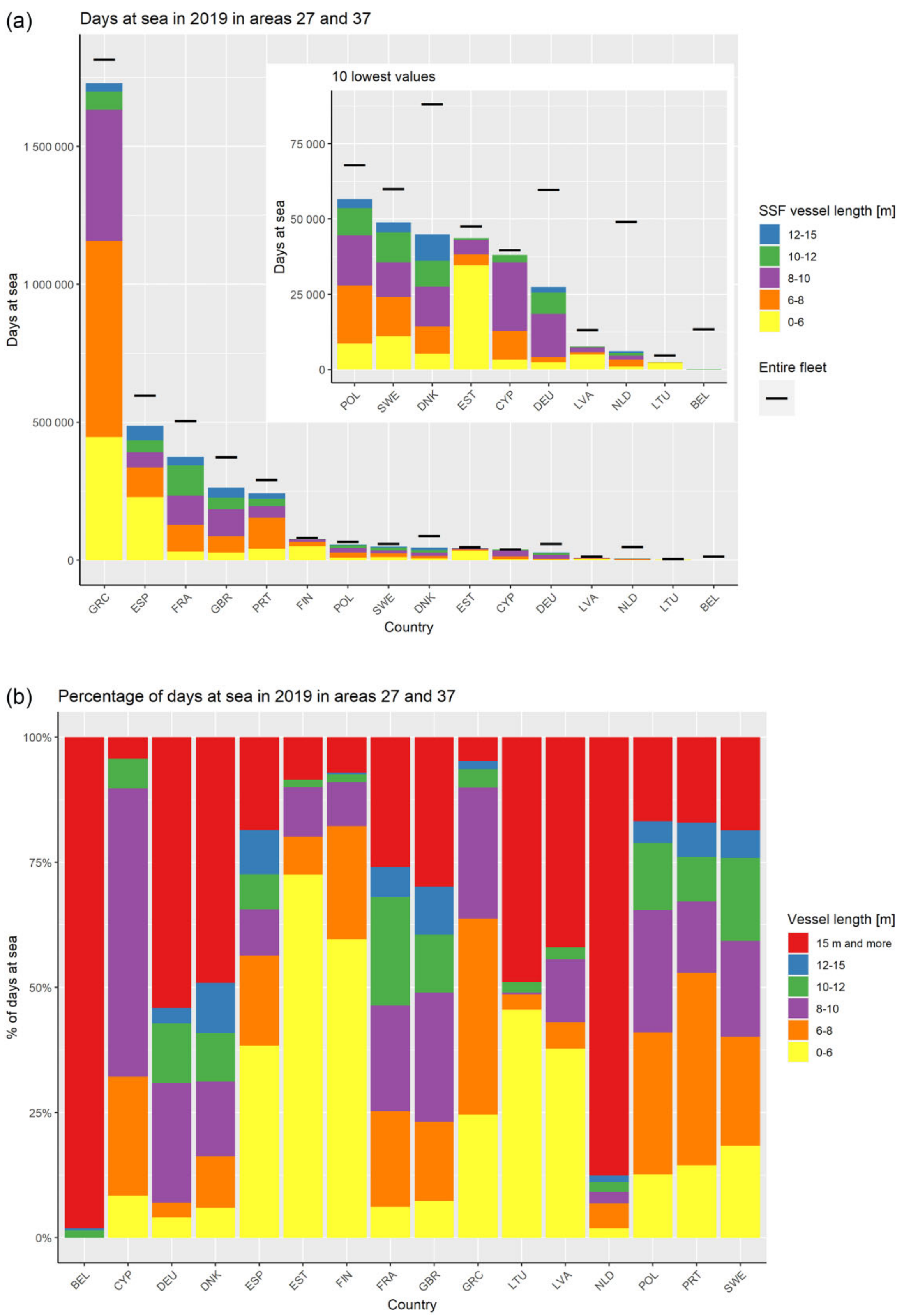

Figure 3. (a) Total number of days at sea of SSF active vessels operating in FAO areas 27 (Atlantic and Baltic) and 37 (Mediterranean) during 2019, coloured by vessel LOA (m) and separated by country. The black horizontal bar indicates the total number of days at sea considering the whole fishing fleet, i.e. both SSF and LSF. (b) Number of days at sea coloured by vessel LOA (m) and separated by country in terms of percentage. Country acronyms and their corresponding operating FAO areas are defined in Tables 2 and 3.

operated around 50% of the total number of days at sea, with Greek vessels showing the highest activity (Fig. 3). In contrast, British SSF seemed to operate less frequently (around, on average during the year, <70 days at sea), with lower days at sea than, for instance, Spanish or French fleets (around, on average during the year, more than 100 days at sea) (Figs 2 and 3). For the Baltic region, the relative importance of SSF was lower both in terms of fleet size and fishing activity but remained significant. The Estonian SSF fleet showed in fact the highest ratio (72%) of <6 m active vessels (even higher percentages than all other European SSF fleets). Denmark and the Netherlands showed the highest numbers of LSF fleet days at sea in comparison with SSF (Figs 2 and 3).

Concerning the average number of days at sea per trip, the SSF fleet segments operated with one-day fishing trips in almost all cases (frequently few hours), with a few exceptions. For example, German vessels (8–15 m LOA), British vessels (10–15 m LOA), or Polish vessels (12–15 m LOA) operated fishing trips with an average of around 2 days (Fig. S02). LSF fleets' fishing trips were longer (around 1.5 days at sea per fishing trip on average) than those for SSF, especially in Belgium, Great Britain, Lithuania, and the Netherlands (more than 3 days at sea per fishing trip on average; Fig. S02).

The average total number of days spent at sea by vessel differed by fleet segment and country (two-way ANOVA; LOA range: $F = 61.076$, $d.f. = 5$, $P < .01$; Country: $F = 9.165$, $d.f. = 16$, $P < .01$; LOA range ∗ Country interaction: $F = 2.570$, $d.f. = 16$, $P < .01$): the largest vessels spent on average a higher total number of days at sea (around 162 days at sea per vessel on average) than the smaller fleet segments (around 105 days at sea per vessel on average) in all the sampled countries (Fig. S03).

In terms of landings, Norway was the country with the largest landings of both SSF and LSF, either in terms of weight (Fig. 4a) or economic value (Fig. 4b). Total landings in weight and in value in terms of percentages are presented as Supplementary Material (Fig. S04). SSF account for 12% of the total landed weight for the 17 European countries surveyed. All countries showed much higher landed weight by LSF vessels than SSF (Fig. 4a) as well as higher landings economic value obtained by LSF (Fig. 4b). Such economic values depended on country and fleet segment (two-way ANOVA; LOA range: $F = 22.185$, $d.f. = 5$, $P < .01$; Country: $F = 2.037$, $d.f. = 16$, $P < .05$; LOA ∗ country interaction). Concerning SSF, Norway, France, Great Britain, Spain, and Portugal accounted for the most important European landings. Greece had lower landings than these countries (Fig. 4a), but the economic value of such landings was relatively higher (Fig. 4b).

Average landings (both weight and economic value) per day at sea were assessed. Landed weight per day at sea was higher in LSF (>15 m) than in any of the <15 m segments (around 7.2 t per day at sea on average for LSF against 0.4 t for SSF). Concerning LSF, days at sea from Finland and Estonia landed the highest weight (on average), followed by Sweden, Poland, Denmark, and Lithuania (Fig. 5a). Concerning SSF, the landed weight per day at sea was in countries higher in its larger fleets, despite four exceptions Belgium, Finland, the Netherlands, and Latvia (Fig. 5a). The economic value of LSF landings was the highest for Lithuanian days at sea. Considering SSF, days at sea from Belgium vessels with LOA 10–12 m had the highest economic value, followed by the fleet segment from Sweden and France with LOA 12–15 m (Fig. 5b).

The average landed economic value per vessel showed similar results as those calculated per day at sea and are therefore only presented as Supplementary Material (Fig. S05).

SSF fisheries data sources diversity evaluation (2019)

For the assessed fishing activity variables (i.e. number of trips, days at sea, landings weight, and landings economic value), information derived from potentially combined data sources (i.e. sources classified as 'A+' or 'A'; see the 'Materials and methods' section) was available for all fleet segments, but not equally across fleet segments. Fleet segments with LOA below 10 m were by far the most challenging, with a substantial share of data calculated primarily from sales notes (i.e. classified as 'C+' or 'C') (Fig. 6; Figs S06 and S07).

Fleet segments with fishing activity data derived mainly from logbooks or coastal logbooks, sometimes combined with sales notes (i.e. classified as 'A+', 'A', 'B+', or 'B') accounted for more than 50%–60% of the total landings weight and economic value in segments above 8 m in LOA, but <40% in those below 8 m. Excluding Greece (classified as 'X'; see the 'Materials and methods' section), values for segments below 8 m remained under 50%. These same fleet segments contributed over 75% of the total number of fishing trips in the fleet above 10 m, but <25% in the fleet below 10 m, and under 40% when excluding Greece (Fig. 6; Figs S06 and S07).

Discussion

Best practice guidelines for data collection on SSF

Sources of information overviewed from the 17 surveyed European countries highlighted that, overall, the methodologies, data formats, and data storage involved in monitoring the SSF fishing activity data are widely diverse (Pascual-Fernández et al. 2020, FAO 2023a), creating challenges to its standardization and harmonization (Anon 2013, 2017, ICES 2016). For data collection harmonization, and for sake of consistency and comparability, it would be beneficial for countries to share procedures and principles assessed by data quality indicators and quality check methodologies. Moreover, best practice guidelines on design, implementation, and quality assurance of SSF data collection methods would allow reducing bias, increasing precision on catch and effort estimates. The most important data gaps or caveats identified above, such as using data sources (e.g. sales notes) to monitor SSF fishing activity, which do not accurately assess information on the gears used or fishing location, highlight the need to share good practices between countries to help improve data quality. Considering members' experience and expertise, ICES WGCATCH proposed such best practices guidelines illustrated in Fig. 7 (ICES 2020).

According to that, the first step (1) is to define the main end-users and their data needs regarding SSF, which will allow to identify the objective/data needs of the data collection: types of estimates, resolution (e.g. spatio-temporal strata, gears), required precision, and quality of estimates from the target population of vessels (the domain of interest). The second step (2) is the pre-screening or frame survey of the fisheries, which provides information allowing to evaluate the best data collection method (considering, e.g. access to vessels, fishing and landing patterns, frequency of fishing activity, gears, target species) and will constitute the general framework of the data

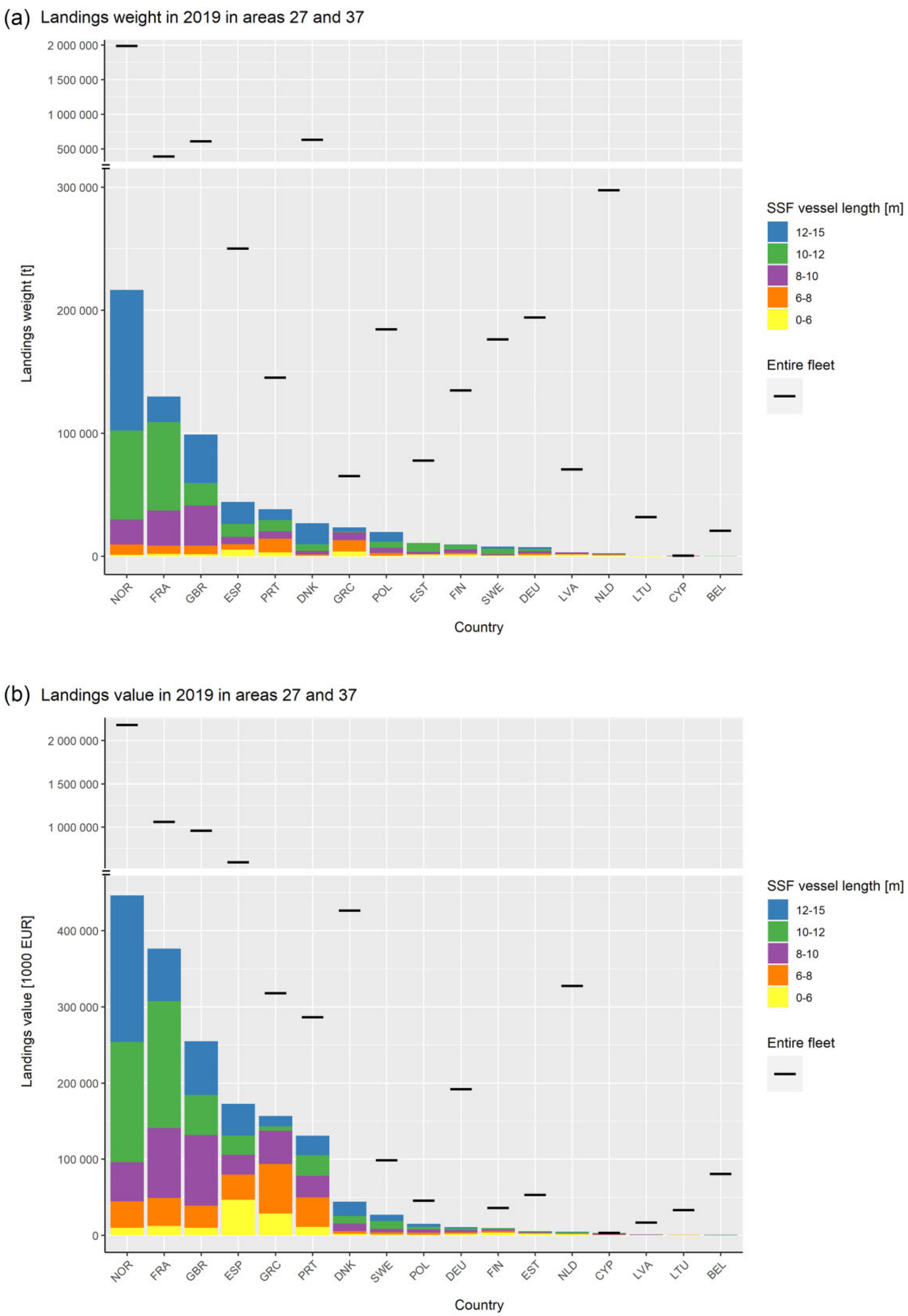

Figure 4. Total landings in terms of (a) weight and (b) economic value (in euros) by SSF vessels operating in FAO areas 27 (Atlantic and Baltic) and 37 (Mediterranean) during 2019, coloured by vessel LOA (m) and separated by country. The black horizontal bar indicates the total landings considering the whole fishing fleet, i.e. both SSF and LSF. Country acronyms and their corresponding operating FAO areas are defined in Tables 2 and 3.

collection. The third step (3) is to evaluate the most appropriate method for the data collection, i.e. census, sampling, or a combination of the two approaches, to provide information on SSF fishing activity and landings. The choice will be done based on the information compiled in the first two steps. In the fourth step (4), the choice for a data collection method (census or sampling approach) is done. The fifth step (5) states that the design of a sampling scheme is only required

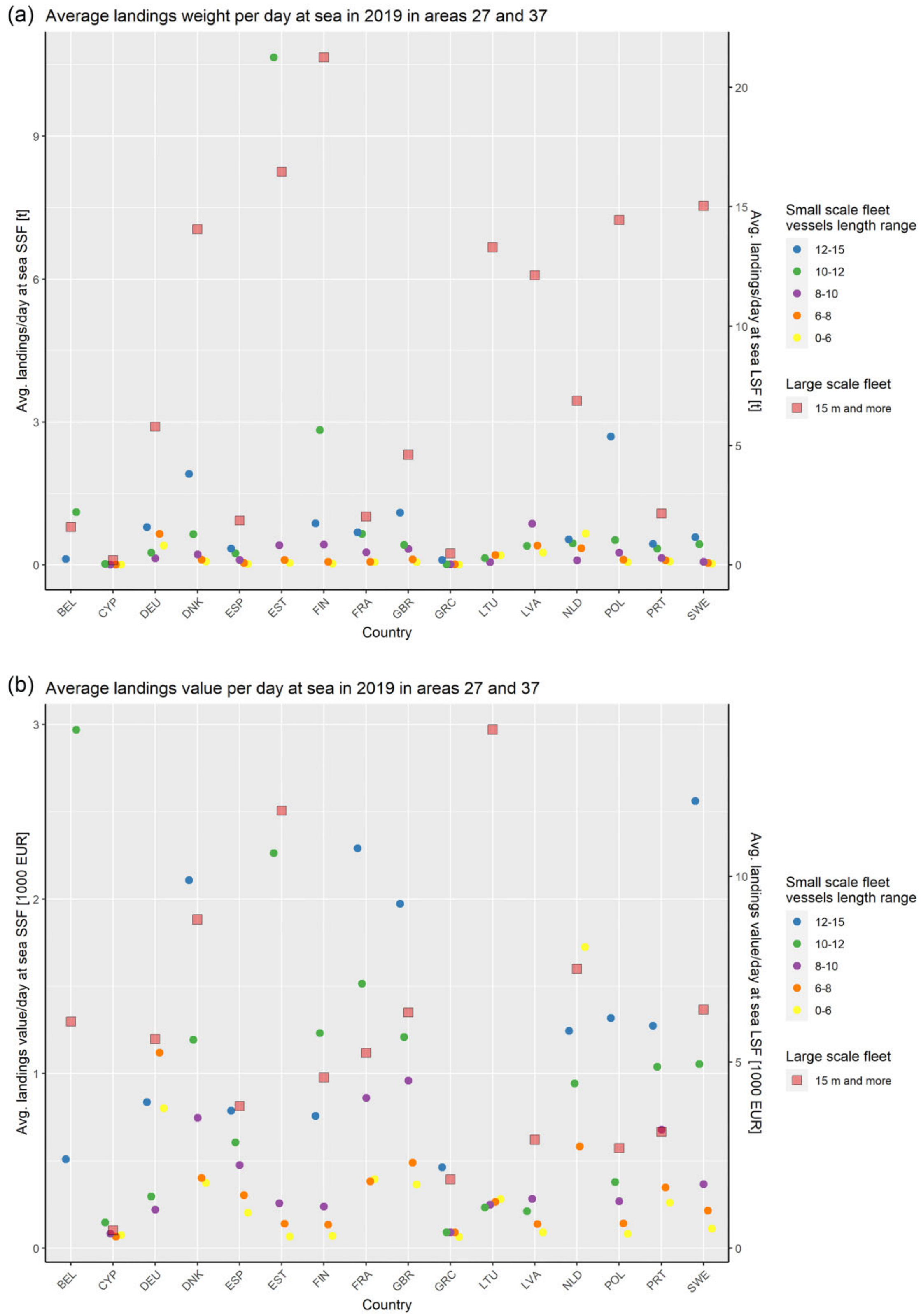

Figure 5. Average landings per day at sea, in terms of (a) weight and (b) economic value (in euros) by active SSF vessels operating in FAO areas 27 (Atlantic and Baltic) and 37 (Mediterranean) during 2019, coloured by vessel LOA (m) and separated by country (sorted alphabetically). The LSF fraction of the fleet is represented with red squares. Country acronyms and their corresponding operating FAO areas are defined in Tables 2 and 3.

if sampling is chosen as a data collection method. The sixth step (6) involves the practical implementation of the data collection, including the deployment of the fishery observers if needed. The following two steps concern key data quality issues: step seven (7) concerns data capture and quality control, and step eight (8) concerns data analysis and quality indicators. Data quality indicators and data quality check methodologies will assess (i) data coverage/completeness (main po-

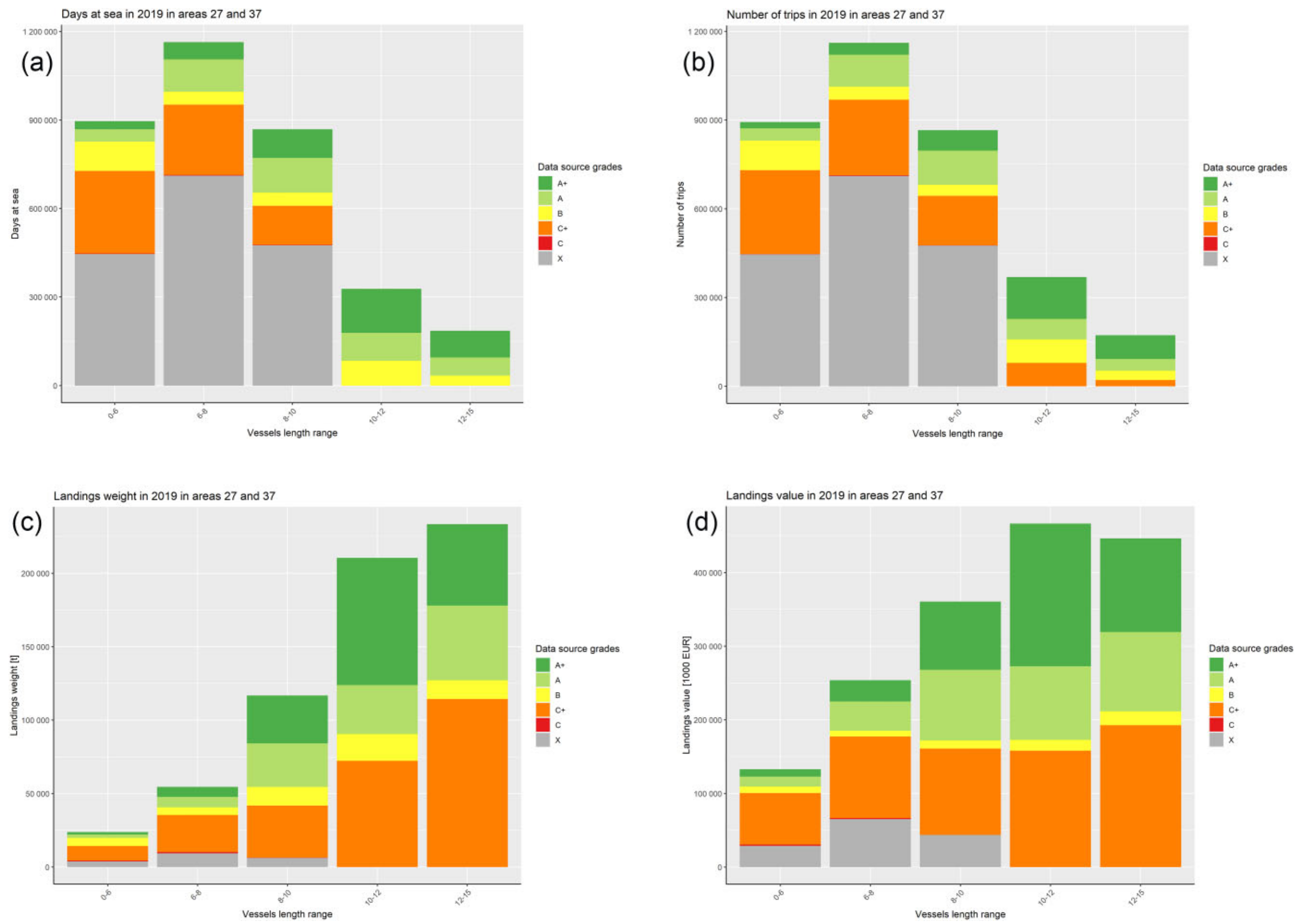

Figure 6. Categorization of (a) total number of days at sea, (b) total number of trips, (c) total landing weight, and (d) total landing value, based on the classification (see the 'Materials and methods' section) of the diversity or nature of data source(s) available in 2019, for each SSF fleet segment (defined by precise vessel length ranges in meters), considering all countries together.

tential risk highlighted) and data accuracy/reliability in census approaches, and in addition (ii) statistical soundness will be also evaluated in sampling approaches. Finally, step nine (9) comprises the self-critical reflections to improve the data collection and feedback to steps one and three. Thus, the data collection approach becomes an iterative process.

Key issues to consider for census and sampling approaches for fisheries data collection

For census-based data collection methods, the main issue regards the full coverage/completeness, which may not be true and therefore, could lead to bias and affect the theoretically 'perfect' estimates' precision (ICES 2020). This issue comprises the coverage of the population (i.e. completeness) and the response rates (i.e. to consider the fraction replying and not replying from the whole sampling frame) (Baffour and Valente 2012, UNECE 2021). Furthermore, the accuracy and reliability of the collected data should be assessed considering the validation schemes to ensure high data quality (UNSD 2022).

For sampling-based data collection methods, the main issues impacting estimates' bias and precision are related to (1) the statistical soundness of the sampling design, (2) potential problems at the implementation stage (e.g. non-random sampling, refused provision of data, strata with no or inadequate number of samples), and (3) eventual problems at the data analysis stage (e.g. inappropriate estimation procedures or inaccurate information used to calculate sample probabilities) (Cochran 1977). Additionally, in the case where data sampling is based on self-reporting, the sampling data quality needs to be assessed. This requires (as for census-methods) to evaluate data accuracy/reliability associated with applied validation schemes (e.g. Machado et al. 2021). Furthermore, an undersized sample will be invalid to estimate accurately the fishing activity data of the fleet surveyed. Therefore, logistical and financial constraints that limit sampling coverage must be considered (Tillé 2020).

Data source diversity and data quality

A relevant hypothesis for further research may rely on the availability of multiple data sources to enhance data quality through cross-validation of fishing activity data and improved overall completeness. Although this could not be formally tested in the present study, our findings suggest that the potential for cross-validation is limited across many fleet segments, particularly those with a length overall (LOA) below 10 m, which often rely on a single data source.

Cross-validation may improve data quality and completeness in two key ways: (1) by enabling confirmation of core variables across independent data sources, and (2) by leveraging the complementary strengths of each source (e.g. sales notes typically include economic value data not available in

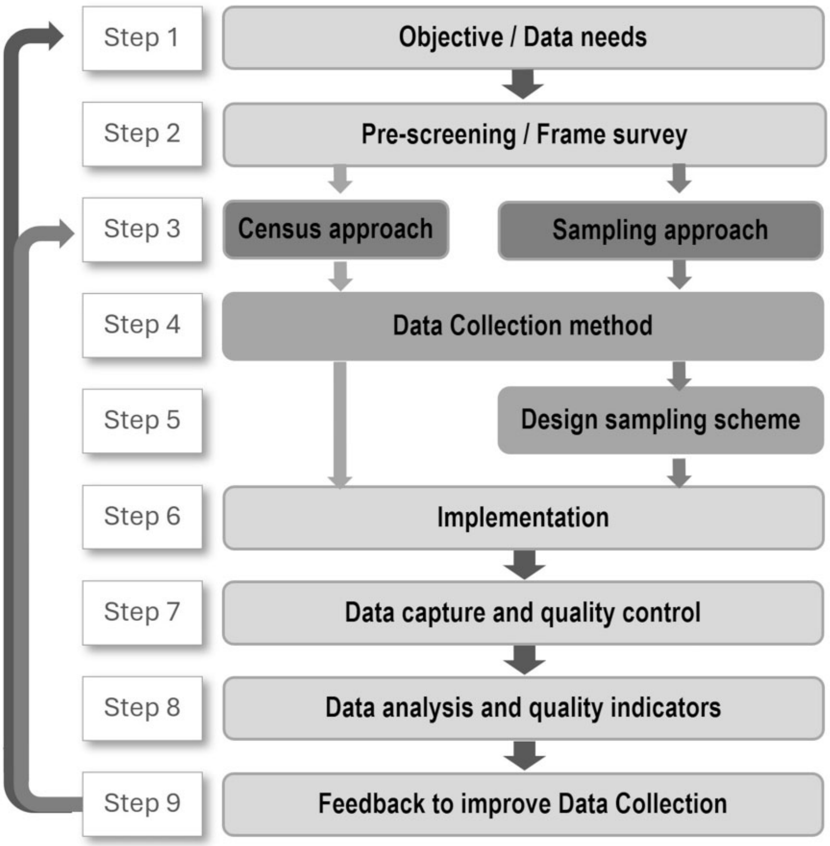

Figure 7. Flowchart of steps proposed in best practice guidelines for SSF fishing activity data collection. Modified from the ICES WGCATCH report (ICES 2019).

logbooks or coastal logbooks, while gear characteristics are generally only reported in the latter).

While increasing the diversity of data sources is not the only path to improving data quality—as a well-managed, centralized system with strong internal quality controls may also be effective—it could facilitate the development of robust cross-validation methodologies. In this context, new data streams, such as those described below and derived from electronic reporting systems, could play a valuable role in supporting future integration and validation processes.

SSF data limitations cycle

Characterization of the 17 surveyed fleets showed that SSF are an important component in nearly all countries (especially notable in some countries), not only in terms of the number of vessels and fishing trips but also in terms of their landings. SSF therefore constitutes an important component of the fishing fleet activity and landings to be considered in stock assessment and management advice, fishery spatial management, or socio-economic studies. Among others, their ecological and socio-economic impacts (e.g. employment) are often poorly understood and largely underestimated mainly due to data collection limitations (Pascual-Fernandez et al. 2020, FAO 2023a), compared to LSF (Guyader et al. 2013). Furthermore, SSF share of TAC-quota or regulated catches of species (including incidental bycatch or protected species) can therefore be remarkable (Panagopoulou et al. 2017).

At the same time, the study concluded that the SSF is characterized by significant data gaps, leading to a lower data availability than in the LSF. Moreover, reduced data reporting requirements are also linked to systematic underreporting of the existing SSF fishing activity data compared to the LSF (Pascual-Fernandez et al. 2020, FAO 2023a). All these issues can lead to lower perceived importance of the SSF sector in terms of days at sea and landings, affecting previous conclusions drawn regarding SSF characterization. Knowledge on SSF therefore appears to be trapped in a data limitation cycle where, due to incompleteness and/or lower quality of existing data, systematically lower importance is given to their characterization (e.g. down-weighting them in stock assessment and management advice) and sampling schemes when compared to the LSF (Fig. 8) (Demaneche et al. 2018).

Usefulness of electronic reporting systems in monitoring SSF

Electronic reporting systems have shown to be useful tools in monitoring fishing activities (for control and/or monitoring purposes) and have great potential to improve SSF data quality. This could range from (i) assigning registered vessels between inactive or active vessels, (ii) determining their fishing effort (i.e. fishing days, number of days at sea, hours at sea, soaking time of passive gears), (iii) estimating the dimension of their fishing gears, or (iv) calculating precise spatial information (ICES 2017, 2018). Consequently, the lack of spatial information on SSF fishing activities is one of the main problems in the context of MSP (Murillas-Maza et al. 2023) and evaluation of potential MPAs. Important SSF fishing grounds are not easy to map as for the LSF where VMS data are avail-

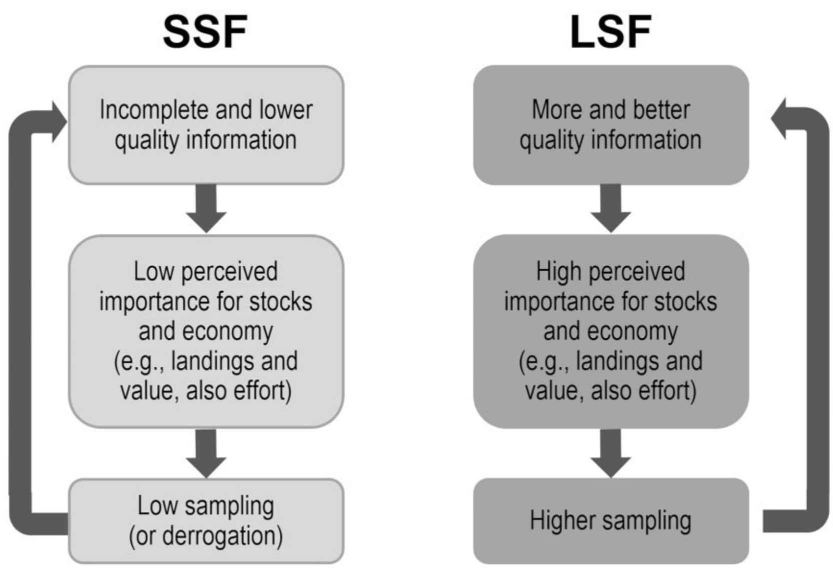

Figure 8. Information life cycle, represented as a comparison between SSF and LSF. Modified from Demaneche et al. (2018).

able. However, there have been cases of pilot projects where SSF have been successfully monitored using geolocalized data (Mendo et al. 2019, Torres-Irineo et. al. et al. 2021).

Such new technologies include tools such as electronic monitoring (e.g. cameras and sensors), apps for smartphones/tablets or geolocation devices (e.g. AIS—Automatic Identification System, GPS—Global Positioning System, RFID—Radio Frequency Identification) (ICES 2022a). They account for opportunities to improve SSF data collection (MASTS 2019). For example, geolocation devices allow access to detailed information on the fishing activity, especially about: (1) the fishing grounds, improving the spatial resolution of the available data (James et al. 2018, Mendo et al. 2024); and (2) the fishing effort (Behivoke et al. 2021, ICES 2022b, Rufino et al. 2023). New technologies can also provide a mean to evaluate the completeness/coverage of available declarative data by providing another data source to compare with conventional data. Apps for smartphones/tablets can also be used as an additional data source, both for (1) geolocation or (2) reporting of catches, discards and incidental bycatch of PETS (Protected Endangered and Threatened Species) (Glemarec et al. 2020, Dalskov et al. 2021). Furthermore, potential of satellite imagery should be assessed in SSF fishing monitoring specially to estimate fishing effort metrics (Geronimo et al. 2018, Longépé et al. 2018, Paolo et al. 2024).

Vessel-mounted geolocation devices work autonomously once installed, and do not require additional work from the fishers. They can be useful if analytical algorithms for geospatial data are well developed (ICES 2022b, 2023, Sales Henriques et al. 2023), while data registration into a smartphone app relies more on the willingness and work of the fishers. On the other hand, the adoption of electronic monitoring, such as cameras on vessels or devices connected with the fishing gears, is, unless made mandatory, highly dependent on the voluntary acceptance of fishers. And this is still controversial, e.g. due to data protection issues and implies other challenges (Van Helmond et al. 2020). It also implies challenges in terms of costs, hardware maintenance, demanding image processing and installation, especially for very small SSF boats. Despite the great potential, electronic monitoring tools are presently only used in case studies. The basic attitude that an enterprise that uses a public resource is obliged to report in detail about its activities is watered down by arguments such as historical claims, lack of space on board or excessive bureaucratic effort. If the EU, national and state governments want SSF data of higher accuracy and better quality, lower resolution data, both in space and time, are urgently required. And here, electronic monitoring tools can play a key role.

Concluding remarks, recommendations, and future steps

The overview of the SSF fishing activity data collection carried out in the 17 European countries surveyed (Fig. 1) for a reference year (2019) highlights that data collection regarding SSF fishing effort and landings is mainly based on data sources required under the EU Control Regulations, i.e. fleet register, sales notes, and EU logbooks for vessels over 10 m (8 m in the Baltic). In addition to that, and at the national level, different sources of complementary data could be used to monitor SSF, especially through adapted declarative forms in a census approach. This way, in all, the data formats and data storage involved in monitoring SSF are widely diverse across countries creating challenges to the standardization and coordination of SSF fishing activity data and a need for best practice guidelines. In terms of data source availability for SSF, fleet segments with vessels under 10 m were by far the most challenging, as data for these segments often derived from a single data source, frequently sales notes classified as ‘C’ or ‘C+’ (Fig. 6).

Within the 17 surveyed countries, SSF fleets accounted for 88% of the total number of active vessels (Fig. 2) and 83% of the total fishing effort. Norway, followed by Spain, Great Britain, France, and Portugal in the Atlantic area and Greece in the Mediterranean area, has the highest number of SSF vessels of the countries analysed.

In Europe, the multitude of SSF vessels and the local legislation issues contrast with complex multi-level governance by regulatory and monitoring bodies that cover national and shared fish stocks. These issues often overlook the potential impact on SSF. Therefore, it is crucial to improve SSF data collection and knowledge about SSF to ensure their sustainable development. Ultimately, it is clear (Anon. 2013) that it is essential to estimate the fishing activity of SSF in terms of capacity, fishing effort, volume, and value of catches/landings as minimum data requirements considering their relevance and current regulations (e.g. CFP, Control Regulation, Management Plan in the Mediterranean Sea, MSFD, Natura 2000, MPA, Water Directive, Data Collection Framework …).

On the basis of our results, SSF fishing activity data gaps, especially for vessels less than 10 m, have been highlighted. The need to evaluate the completeness/coverage of data available, especially in the context of a census approach, has been also underlined, as it could mask other data quality issues. Declarative forms to supplement information coming from sales note data have the potentiality to improve SSF data quality especially regarding fishing gear, area, and effort, as well as a pre-screening or frame survey of the fisheries to be surveyed (Berthou et al. 2008), which could help specially to assess the completeness of the data available constituting a framework for the data collection. A cross-check of census information based on sampling information reported by fishers through a dedicated SSF sampling program could also help to improve data quality providing at the same time biological data information (MASTS 2019). Furthermore, installing electronic or geolocation devices on SSF could be another option to solve some of these issues and helping improve the quality of the data available for SSF.

Our analysis underscores the critical importance of having high-quality fishing data from the SSF for effective management purposes. By identifying data gaps, countries can address challenges and work towards harmonizing and standardizing the fishing data collection from SSF. This ensures that the data is comparable and sufficient to meet the primary needs of end-users, ultimately enhancing its quality and effectiveness in supporting fisheries management efforts. Such improvement will also help to better understand not only the ecological but also the socio-economic dimensions of SSF in Europe, providing insights into their importance in terms of employment, food provisions, and contribution to the national economy.

Acknowledgements

We thank all the people who provided data from their corresponding countries. This work was co-funded by the European Commission Data Collection Framework. Finally, thanks are due to the anonymous reviewers for their useful comments, which contributed to improving the manuscript.

Author contributions

S.D. drafted the initial version of the manuscript, which was carefully reviewed and completed by R.P.V. and E.M. E.B. then revised and restructured the manuscript to improve its scientific clarity before sharing it with all co-authors (writing - original draft). E.B., R.P.V., E.M., J.E., A.C., and U.K. were each responsible for specific parts of the manuscript at various stages of drafting and revision (writing - review & editing). M.Ad. and M.K. served as leads for the data analysis and developed the graphical outputs (data curation, formal analysis and visualization). E.B., R.P.V., and S.D. coordinated both major and minor revisions during the peer-review process, with contributions from all co-authors—particularly during ICES WGCATCH general meetings, where subgroups worked on addressing reviewer comments (writing - review & editing). S.D., E.M., R.P.V., and E.B. were co-chairs of the ICES WGCATCH SSF subgroup during the study period (conceptualization). H.G., N.P., A.R.S., E.M., and K.M.G. were co-chairs of the ICES WGCATCH working group during the study period (supervision). All co-authors were, during the study period, active participants of the ICES WGCATCH SSF subgroup, where the idea for the paper was conceived and the results discussed. They all participated in data collection, analysis, and collaborated on the revision and writing of the manuscript (methodology, investigation, validation and writing - review & editing).

Supplementary data

Supplementary data is available at *ICES Journal of Marine Science* online.

Conflict of interest: The authors have no competing financial and/or non-financial interests in relation to the work.

Data availability

The main data underlying this article are available in the article and in its online supplementary material. Specific information will be shared on reasonable request to the corresponding author.

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Handling editor: Natalie Isaksson