Comparative methodologies to monitor Small-Scale Fisheries in the Atlantic Area

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Background

Small-scale fisheries (SSF) are important components of many fleets in the Atlantic Area (AA) and are receiving growing attention within the Common Fisheries Policy (CFP)-reform and Marine Spatial Planning (MSP) initiatives. Recently, several studies highlighted the need to improve the knowledge currently available of SSF in order to secure their sustainable development (Chuenpagdee et al., 2006; Salas et al., 2007; Chuenpagdee ., 2011; Guyader . et al., 2013; FAO, 2015). The European Commission stressed the intention to provide support to the small-scale sector under the reformed CFP and to promote small-scale coastal fishing activities. Maritime and fisheries policies are funded through the European Maritime and Fisheries Fund (EMFF). This fund includes many references to the small-scale coastal fishing. Article 25 for example notes that: "With a view to promoting small–scale coastal fishing, Member States having a significant small–scale coastal fishing segment should attach, to their operational programmes, action plans for the development, competitiveness and sustainability of small-scale coastal fishing".

There is no single definition of SFF, as any definition is linked to the end-user needs such as stock assessment, maritime spatial planning, socio-economic studies, Marine Strategy Framework Directive (MSFD), Marine Protected Areas (MPA), and management regulations . This report has adopted the view of the Nantes workshop ("Common understanding and statistical methodologies to estimate/re-evaluate transversal data in small-scale fisheries") on SFF (Anon. 2013) which refers to fleet segments by vessel length (LOA) ranges. The following SSF vessel length ranges will be considered for CABFishMAN project: <10m; 10m–12m and 12-15m. The under-10m fleet is considered as a separate fleet segment in relation to data collection because there is no Control Regulation [(EC) No 1224/2009)] obligation to supply EU logbooks for vessels under 10m. The Nantes workshop recommended retaining the LOA class 10–12 m as a separate fleet segment to ensure consistency in time-series and because they are not under the Vessel Monitoring System (VMS) regulation (which is critical for mapping of fishing activities for maritime spatial planning or other purposes needing data at specific spatial resolution). 12-15 m fleet segment might also need to be retained for proper consideration as many countries have exemptions within VMS data requirements for them and therefore full VMS coverage of >12 m vessels cannot be assumed in many cases.

These fleet segments are of high importance in all countries in the AA in terms of number of vessels and consequently in employment. SSF are generally composed by polyvalent fleets in terms of gears and target species (multi-gears, multispecies fleets), that develop a seasonal or part-time activity. Their contributions to total landings are often lower compared to other fleet segments; however, their share of TAC-quota or catches of regulated species can be significant and it must be stressed that underreporting of landings can give a truncated view of this contribution. The importance of SSF must be assessed by fishery, species and region because significant differences can occur between them. It should also be highlighted that the SSF fleet segments are highly important for fishery spatial management because they usually operate in coastal areas which include different activities and users and probably more sensitive habitats (e.g., nursery grounds). In addition, socio-economic studies indicate that the large number of vessels involved corresponds to a large number of people employed and dependent on these fisheries (Gonzalez-Alvarez et al, 2016).

Overview of possible data collection methods for Small Scale fisheries

SSF present many specific features (i.e. multi-gear, multispecies, broad spatial distribution, high seasonality, part-time activity in some cases, and direct sales.) that distinguish it from the Large-Scale Fisheries (LSF). Hence, SSF often have to be monitored differently and specifically through a separate census or a sampling approach adapted to their respective features.

Data collection methods fall into several categories:

- Census methods dependent on self-reporting of data by fishers, intended to have exhaustive coverage of the population (as far as possible). Quality issues are related to actual coverage of the scheme, response rates, and accuracy of data and validation schemes to evaluate these.
- Sampling schemes based on a random selection of a sample from the population surveyed and extrapolated to the total:

1) They could use similar data reporting methods as for the census, but applied to random samples of fishers who self-report. Additional quality issues related to the statistical soundness of the sampling design, problems arising at the implementation stage (e.g., sampling departs from randomness; refusals to provide data; strata with no or inadequate samples), and errors introduced by inappropriate estimation procedures or inaccurate information used to calculate sample probabilities.

2) Sampling schemes where the variables of interest (gear, fishing effort, fishing zones, landings etc.) are observed or surveyed directly on-site by trained survey staff (catch assessment survey) or recorded by new technologies (e.g. CCTV). In such cases, inaccuracies in self-reporting are eliminated but similar quality issues remain for design, implementation and analysis.

I. Census methods

In a fisheries context this usually refers to exhaustive coverage of the population from which data are required, for example fishing vessels. An example is the EU logbook that the Control Regulation (EC) No 1224/2009 requires to be submitted for all EU registered vessels of 10m and over, recording catches and associated effort, gear and area data by day for all fishing trips. Vessels under 10m are not required to keep such logbooks which are additionally not well adapted to their specific features. For these vessels a sampling plan is required unless the MS has required such vessels to keep an EU logbook (Article 16–3) or if sales notes are supplied (Article 16–4). In the latter case, the supply of sales notes (or sales slips) and catch declarations could be considered as census data. The use of sales notes as census data for small-scale fisheries is common practice in countries where it is mandatory for all commercial landings (irrespective of vessel size) to be sold at specific places (generally auctions within ports) and centrally registered in national databases. This register generally allows for full discrimination of the composition in species and weight of the landings of individual vessels. Several exemptions and conditions in the Control Regulation result in incomplete landings data in the logbooks (Article 65), triggering a requirement for a sampling scheme.

Sales notes are linked to commercial activity making them one of the most widely available data sources with, in some cases, long historical records and reasonably consistent contemporary records contributing to national statistics of economic performance. Like the logbooks, the accuracy of sales notes is strongly dependent on the degree of compliance but where they are systematically registered they provide an additional set of data that can be used to validate and even improve logbook data: (e.g., sales notes can be used to cross-check logbook records and associate to them commercial size categories and in some cases are used to determine which vessels were active in the absence of VMS data).

Apart from the Control Regulation, some Member States (MS) have set up systems of self-reporting forms intended to achieve an exhaustive coverage of the population, overcoming the limitations of official logbooks and sales notes. *Ad-hoc* logbooks or monthly declarations delivered to a whole fleet segment (i.e. vessels <10) are an example of this kind of census. They are usually adapted to the specificities of the SSF, and can exhibit different degrees of complexity (number and type of variables requested) and periodicity (daily, weekly, or monthly). In relation to these systems, the ICES expert working group on Commercial Catches (WGCATCH) highlighted the need to define how national declarative forms should be designed to ensure that key variables can be collected and recorded in a consistent way for SSF within each region considered. This is important in order to merge collected data and meet end-user needs. In addition, it has to be taken into account that self-reporting of fishing activity, landings or discards present particular logistical challenges for small vessels, and the reporting burden may have to be reduced as far as possible and technological solutions developed to minimize the work needed. Strong incentives may be required to ensure continued supply of data.

A general comment on the census approach is that the reliability/completeness of the data available has to be assessed. If unreliable/incomplete data are a major issue, a sampling approach should be adopted to estimate needed variables, or to assess the quality of the data available from the census.

II. Sampling methods

Different sampling schemes could be designed for different purposes, but they should address to the end-users needs. For example, data needed for maritime spatial planning may require a different design than data required for stock assessment.

In LSF, sampling is usually dedicated to biological variables (discards, length distribution, age and maturity), as their fishing activity variables are, in principle, covered by the Control Regulation. In contrast, for SSF there is a need to sample both fishing activity and biological variables. Data on fishing activity variables, are necessary for those fleet segments that are not covered by the Control Regulation (i.e. vessels <10m), and to improve the information on those segments whose data quality is limited by the exemptions in the regulation. Biological variables can only be obtained through a specific sampling programme.

The Control Regulation requires MS to implement sampling plans for under-10m commercial vessels, but allows exemptions, based on risk analysis, which prevents the complete documentation of landings (Annexes XIX and XX of the Commission Implementing Regulation EU No 404/2011). Appendix VIII of the EU Data Collection Framework Commission Decision 2010/93/EU also places a legal requirement for MS to collect fishing activity variables including vessel numbers, fishing effort, landings weight and value. The combination of the Control Regulation and Data Collection Framework requirements for providing data on effort and landings using sampling schemes, leads to a lack of clarity on what is acceptable as a sampling scheme. It is also noted that there are different purposes driving both regulations (control and scientific analysis), which may hamper the comparability of the results.

A broader insight is needed into how sampling schemes for SSF should be designed. An approach is needed which goes beyond the narrow interpretation of these two EU regulations and is in line with the Statistically Sound Sampling Schemes (ICES 2012a, 2013,). Sampling schemes for SSF have analogues in recreational fishing where the methods have been well tested internationally (ICES 2012b).

In general, two approaches are used to select the sample:

(1) Stratified sampling of vessels from a vessel list frame, which is possible thanks to the frequent availability of a more-or-less complete vessel register with details such as vessel length. These data allow the randomized selection of vessels for collection of data and also for the estimation of the number of active vessels per landings site. This is a major advantage for surveys of SSF relative to surveys of recreational fisheries. Data must be collected from all vessels randomly selected from the list, even if the vessel was not fishing. As with at-sea sampling schemes to estimate discards in LSF, recording and interpretation of non-responses and refusals is extremely important to evaluate potential for bias.

(2) A clustered sampling of fishing trips occurring on visits to landing sites (e.g. site-day sampling frame). This method (catch assessment survey) consists on a sampler recording on site the landings of all or a random sample of vessels landing at a site and day, which can be raised to all sites and days in the year using the hierarchical cluster sampling probabilities at

each stage (Vølstad et al. 2014, Demanèche et al. 2013). Possibilities also exist for other combinations of methods, such as the use of aerial surveys to estimate effort combined with intercept surveys to record catches and other data.

If self-reporting methods are used, validation schemes are needed to validate the supplied information in terms of completeness and reliability.

Quality evaluation

Data collected for SSF are intended to serve different purposes (stock assessment, maritime spatial planning, marine strategy framework. End users are interested in a relatively high-level overview of data quality, particularly the precision, the potential level and impact of bias.

In general, several quality issues can be highlighted depending on how data are collected (through a census or a sampling scheme).

Census methods

Census methods are dependent on self-reporting of data by fishers, and are intended to have exhaustive coverage of the population (as far as possible). Quality issues are related to actual coverage of the scheme, response rates, reliability and accuracy of data. All methods based on self-reporting require quality assurance schemes to validate the supplied information, in terms of reliability and completeness.

Sampling schemes

Sampling schemes are based in the random selection of a sample from the population, which is surveyed and extrapolated to the total. For those schemes based on self-reporting, accuracy of the data is also an issue, and the reliability/completeness of the data collected has to be assessed (as for the census methods).

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Summary of data collection methodologies

ICES WGCATCH expert working group (ICES 2016), summarized a range of possible data collection schemes for landings, effort and other fishing activity variables, and fleet-based biological variables such as length compositions or discards compiled in Table 1. This table is included in this report as it considers examples of different methodologies and quality issues for data collection from SSF for purposes of stock assessment and fishery management.

Table 1. Examples of methods and quality issues for data collection from small-scale commercial fisheries, for purposes of stock assessment and fishery management. Quality assurance and control schemes to detect errors in recorded data are assumed and not mentioned specifically (ICES 2016)

	Census		Sampling schemes	
Type of data	Method	Quality issues to address in guidelines	Methods	Quality issues to address in guidelines
List of vessels by LOA	EU register National fleet activity database	Accuracy and completeness of registers and databases.		
Spatio-temporal activity by gear type	Exhaustive logbook	Actual coverage; Refusals; Non-response; accuracy of self-declared information; low spatial resolution	Randomized vessel intercept scheme using a site x day area frame.	Design; implementation error1; refusals; accuracy of declared information during interviews; estimation method; accuracy of variables needed for sample raising; precision estimation
	Exhaustive use of VMS or other electronic sensors.	Actual coverage; Refusals; Reliability	Randomized issue of logbooks or other recording systems using a vessel list frame.	Design; implementation error; refusals; accuracy of declared information; estimation method; accuracy of variables needed for sample raising; precision estimation
	Exhaustive sales data	Actual coverage; Low aggregation level of gears used; Reliability	Randomized telephone survey of vessel owners.	Design; implementation error; refusals; accuracy of declared information; estimation method; accuracy of variables needed for sample raising; precision estimation
			Detailed data supplied by observers	Design; coverage; number of trips; refused access or permission by owner; estimation method; accuracy of variables needed for sample raising; precision estimation
			Data from CCTV, VMS or other electronic sensors fitted to samples of vessels.	As spatial fishing patterns can vary from vessel to vessel, it is difficult to extrapolate to the whole fleet.

Census			Sampling schemes	
Type of data	Method	Quality issues to address in guidelines	Methods	Quality issues to address in guidelines
List of vessels by LOA	EU register National fleet activity database	Accuracy and completeness of registers and databases.		
			Data from at-sea vessel inspection by patrol vessels and/or overflight data by enforcement agencies2	Frequency and coverage of observations; ability to extrapolate to whole fleet; availability of gear information
Catches (landings, discards and other bycatch, e.g. PETs)	Exhaustive logbook	Actual coverage Non-response Accuracy of self-declared information Absence of 0-landings trips where effort may have occurred	Randomized vessel intercept scheme using a site x day area frame, with fisher interviews and direct recording of catches on board.	Design; implementation error; refusals; accuracy of declared information such as discards; estimation method to raise from samples to full area and period; accuracy of variables needed for sample raising; precision estimation
	Exhaustive sales data	Actual coverage; Landings only; Accuracy of species identification	Randomized issue of logbooks or other recording systems using a vessel list frame.	Design; implementation error; refusals; accuracy of declared information; estimation method to raise from samples to full area and period; accuracy of variables needed for sample raising; precision estimation
			Randomized telephone survey of vessel owners.	Design; implementation error; refusals; accuracy of declared information; estimation method to raise from samples to full area and period; accuracy of variables needed for sample raising; precision estimation
			Randomized observer scheme using vessel list frame	Design; coverage; number of trips; refused access or permission by owner; estimation method to raise from samples to full area and period; accuracy of variables needed for sample raising; precision estimation
			CCTV cameras on random vessel selection	Design; coverage; number of trips; refused access or permission by owner; equipment resolution; estimation method to raise from samples to full area and period; accuracy of variables needed for sample raising; precision estimation

	Census		Sampling schemes	
Type of data	Method	Quality issues to address in guidelines	Methods	Quality issues to address in guidelines
List of vessels by LOA	EU register National fleet activity database	Accuracy and completeness of registers and databases.		
Length/age compositions	Exhaustive sales data with size categories	Actual coverage; Reliability of size categories reported; Accuracy of species identification	Port sampling scheme, e.g. using a site x day area frame.	Design; implementation error; refusals; estimation method to raise from samples to full area and period; accuracy of variables needed for sample raising; precision estimation
			Randomized observer scheme using vessel list frame	Design; coverage; number of trips; refused access or permission by owner; estimation method to raise from samples to full area and period; accuracy of variables needed for sample raising; precision estimation
			Self-sampling schemes for vessels selected from list frame.	Design; coverage; refusal; accuracy of declared information; estimation method to raise from samples to full area and period; accuracy of variables needed for sample raising; precision estimation

Best practice guidelines for data collection on Small Scale Fisheries

Best practice can be defined as sampling designs, implementation and data analysis that lead to minimum bias and an accurate estimate of precision, and which make the most efficient use of sampling resources. For example, probability-based sampling with accurate control of the inclusion probabilities would be considered an example of best practice. However, if logistical, legal, and economic constraints dictate the use of a non-probability based scheme to select primary sampling units (for example legal requirements in the selection of a reference fleet), it is good practice if the selection is done in a way that ensures representative coverage of the target population and minimises bias, and if this can be demonstrated with suitable diagnostics. Harmful practice would be an *ad-hoc*, non-probability-based sampling scheme, particularly where there are no census data to show how representative the samples are of the population or to re-weight the samples during analysis. Where bias is unavoidable, best practice requires collection of information that allows to investigate the form and level of bias, and to develop mitigation measures where possible.

In the fullest sense, best practice for catch sampling schemes on shore or at sea encompasses survey design, documentation of objectives, design and protocols, staff training, data collection and archiving, systems for monitoring sampling performance, and data analysis.

ICES WGCATCH (ICES 2016) drafted best practices guidelines for SSF data collection of fishing activity variables and biological data. It follows the structure presented in Figure 1. The most appropriate data collection methods and designs will depend primarily on the objectives of the scheme (i.e. what types, resolution, precision and quality of estimates, the domains of interest - are required by end users from the target population of vessels), and the practical aspects of collecting data (including available resources to collect the data) in a reliable, statistically sound and cost-efficient way. Resolution may refer to spatiotemporal strata; gear types, etc. An important initial step is the pre-screening or frame survey of the fishery which provides information allowing the development and evaluation of data collection methods based on factors such as accessibility of vessels, fishing and landing patterns, part-time activity, gears used, target species etc.

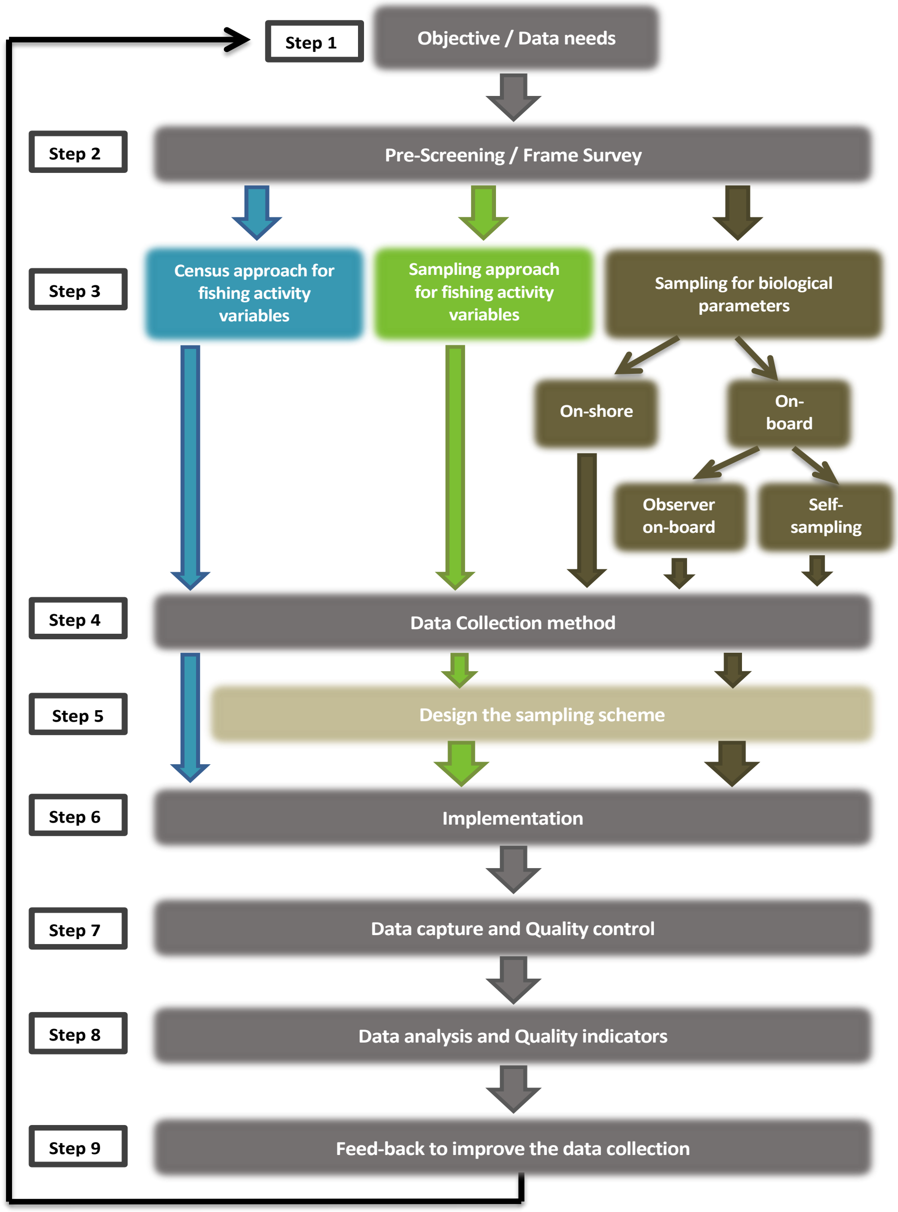

Figure 1. Diagram structure of SSF data collection best practices guidelines (ICES 2016)

WGCATCH detailed guidelines for the design, implementation and quality assurance of SSF data collection of fishing activity variables (including capacity, effort and landings estimates) and biological data (including length and age composition, discard rates and catches of Protected, Endangered and Threatened Species) are given in Annex I.

III. New technologies

Background

Most SSF activity takes place in coastal areas and there is a need to collect appropriate spatial and temporal data to inform both fisheries management and maritime spatial planning.

Whilst there are a variety of options for capturing highly spatially resolved data some of which are being implemented in the sub 15 m fleet, there is a need to consider and compare the utility of the range of systems and processes that could be used to capture fishing effort and catch data also. New technologies as Electronic Recording and Reporting systems (ERS) are a significant opportunity to improve SSF monitoring and data collection.

ERS are used to report, process, store and send fisheries data, such as catches, landings and positional information from fishing vessels. In Large Scale Fisheries (LSF), the introduction of Vessel Monitoring Systems (VMS) and Automated Identification Systems (AIS) has resulted in increased reporting of fishing vessel positional data at finer temporal and spatial scales than previously possible. Electronic catch reporting with e-logbooks is another widely used system, where catches are entered by the skipper into an electronic logbook system and transmitted to control authorities (James et al., 2019). Coupling the positional data with the e-log system has been used to produce fine-scale maps of catch and effort (Gerritsen and Lordan, 2011; Hintzen et al., 2012; Russo et al., 2014), to identify main fishing grounds (Jennings and Lee, 2012; Le Guyader et al., 2017); monitoring of compliance to regulations (McCauley et al., 2016), and estimate distribution of fishing impacts on marine habitats (Gerritsen et al., 2013).

Another widely used electronic reporting tool in LSF is electronic monitoring with video (EM). EM consists of a central computer linked to a Global Navigation Satellite System (GNSS) receiver, gear sensors and video cameras that record fishing activities (Course, 2015). Records are mainly used to monitor catch (Kindt-Larsen et al., 2011; Hold et al., 2015), fishing effort (Course, 2015), and to monitor gear type and use, bycatch and bycatch mitigation technologies (Ames et al., 2007; Kindt-Larsen et al., 2012).

SSF in Europe are generally exempt from reporting requirements using these technologies. Common characteristics of SSF vessels are that they are mostly smaller, their fishing grounds are located closer to shore, and they use predominantly passive gears (Guyader et al., 2013).

Vessels from 10 – 12 m are required to fill in a paper logbook and vessels above or equal to 12 meters, electronic logbooks, but vessels under 10m have no obligation under the Control Regulation (Regulation (EU) No 1224/2009 of 20 November 2009 and Commission Implementing Regulation (EU) No 404/2011 of 8 April 2011) to supply EU logbooks. However, this sector of the SSF corresponds to ~80% of the total number of vessels in the fishing fleet (European Commission, 2018). In addition, exemptions within EU regulations determine that nearly 80% of the 12-15 m fleet segment operates without VMS (EU Special No 08/2017).

Review and compilation of different Electronic Recording and Reporting Systems (ERS) for the SSF

This review considers the different devices that are being used for monitoring the SSF fleet and that are not required to be installed on board through the different EU regulations. Most of the devices are intended for boats with LOA less than 12 m, that is what at the European level is officially considered as SSF.

These devices are basically designed to collect data to inform fisheries compliance and management and increasingly, maritime spatial planning. However, much of the data collected could also be used to inform the fisher's with regard to the efficiency of their businesses and the seafood supply chain with data but, thus far, this has received little attention.

- **Geospatial data:**

Using Global Navigational Satellite System (GNSS) technology coupled to mobile phone (GSM/GPRS) or satellite communications technology, it is possible to collect latitude, longitude, speed and heading data that can be used to reconstruct the track of the fishing vessel. The data is normally transmitted using GSM/GPRS to a designated server where the data is stored and available for further analysis. Vessels operating areas without mobile telephone reception, further offshore for example, may use satellite communication. These tracking devices, sometimes referred to as iVMS are widely available and will usually have the ability to store and forward data to account for periods when the mobile telephone signal is insufficient to send data. The frequency with which data is recorded and transmitted is usually configurable. Many of these devices have anti-tamper attributes to help prevent or report interference or damage. As data is reported directly to a secure server, access to data can be restricted and managed. Whilst the necessary technology is widely available and relatively inexpensive, the cost of implementing these systems is highly variable depending upon the nature of the business model of the provider and whether they are including data transmission, storage and analysis. Costs can also vary subject to the required reporting frequency. Near real time reporting is possible with both mobile telephone (subject to reception) and satellite communications but the later can incur significantly higher transmission costs. For most static gear vessels, reporting with a frequency of 60 second intervals has been demonstrated to be sufficient to infer fishing activity (see Mendo et al., 2019).

The Automatic Identification System (AIS) is used for vessel collision avoidance, transmits vessel track data and primarily use radio frequency transmissions to communicate these data between vessels, to base stations (on land) and in some cases satellites. The radio transmission is approximately line of sight and can be acquired by anyone with an appropriate receiver within range. All vessels over 15m, over 300 tonnes or passenger carrying is legally required to carry an AIS Class A unit. Vessel under 15m may voluntarily carry a Class B AIS unit. Whilst the use of AIS has been explored as a means of collecting fishing vessel track data, there are a number of limitations to this system, not least, that fishers are reluctant to use technology that openly broadcasts their position (to other fishers!). Other potential caveats to the use of AIS for monitoring SSF are documented in James et al., 2018., but refer to patchy coverage of AIS reception in some areas, the inability to adjust the reporting frequency of these devices and the need for quality control with respect to the AIS data harvesting method and source .

- **Catch data**

In this case, the objective is to collect fisheries catch data (e.g. landings + discards + PETS bycatch) by these vessels and report the information collected electronically. These devices are the equivalent to the electronic logbooks that commercial vessels over 12m have installed on board, although for the 12-15m segment and due to the exceptions in the EU regulation, the number of vessels with the electronic logbook is not complete, with important differences between MS for this fleet segment .

To collect this information, electronic logbooks, apps, software adapted to this fleet have been developed, especially through laptops, tablets and smartphones. In most cases, in addition, geospatial information may also be collected.

The use of cameras (e.g. CCTV) for monitoring this fleet is gaining importance, adapting these CCTV devices to the characteristics of the SSF. The use of these cameras is quite common in some fisheries in the USA, Canada, and Australia, but are also being used in Europe in specific pilot studies. These pilots are more focused on collecting data of Protected, Endangered and threatened Species (PETS) such as marine mammals, turtles, birds, etc.

ERS review at European level

In 2019 WGCATCH ICES Working Group (ICES 2020 in prep.) conducted a review and a compilation of different Electronic Recording and Reporting Systems (ERS) used especially at European level for the SSF. With this aim in mind, Projects and Workshops reports carried out recently were considered where this topic was covered: 1) fishPi[2] project (MARE/2016/22) WP5 Report, 2) The report from the Workshop held in Brussels in December 2018 on digital tools for SSF.

I. fishPi[2] project (MARE/2016/22)

In fishPi2 under WP5, a review of different potential Electronic Recording and Reporting systems (ERS)and Electronic Monitoring (EM) for the SSF was conducted. To review ERS that can be installed on small-scale vessels manufacturers of systems currently available on the commercial market were interviewed. Initially, a list of manufacturers was drafted from broad Google searches using a combination of keywords: electronic reporting, electronic monitoring, recording, electronic, VMS, AIS, fishing, small scale fisheries, GPS, tracking, iVMS. Listed suitable manufacturers were then circulated and reviewed within the project coordination team and built on through recommendations and available online. After further review, 15 manufacturers were contacted and replied to the request to participate in an online or telephone interview about their systems. Eleven interviews were conducted with manufacturers of systems that recorded information on vessel position, catch and/or effort and biological data, and included questions about the general specifications of each system. Eight ERS feature in the described case studies in this review (Table 2).

Table 2. List of manufacturers interviewed and their ERS (MARE/2016/22)

Manufacturer	Product	Mobile phone application or installed on-board system?	Used in a stakeholder case study?
Anchor Lab K/S	MOFI App	App	Y
Anchor Lab K/S	Black Box R2	on-board system	Y
Marine Instruments	WatchMan Pro	on-board system	N

Marine Instruments	Electronic Eye	on-board system	N
Anon. 1	Anon. 1	on-board system	N
Archipelago Marine Research Ltd.	Observe hardware, Interpret software	on-board system	Y
SRT Marine Systems plc	VMS system – B300 AIS class transceiver	on-board system	N
AST Marine Sciences Limited	iVMS Guardian App	App	Y
AST Marine Sciences Limited	iCatch App	App	Y
AST Marine Sciences Limited	Autonomous VMS (aVMS)	on-board system	Y
SIFIDS - University of St Andrews	SIFIDS mobile phone App	App	Y
SIFIDS - SeaScope Fisheries Research	On-board Central Data Collection System (OBCDCS)	on-board system	Y
Anon. 2	Anon. 2	on-board system	N
Vericatch	FisheriesApp	App	N
WWF-US	Electronic Fishing Logbook	App	N

A detailed explanation of each of the devices/products mentioned in the table can be found in the final fishPi^2 report (MARE/2016/22).

Based on responses from both manufacturers and scientists, it was concluded that there are potential technologies available to improve the monitoring of SSF. However, depending on the devices, the cost of them could be important (e.g. CCTV), there could be technical difficulties in the installation of them depending of the length of the vessel, or the analysis of the data collected could be a huge task. Taking into account all these issues, in fishPi^2 a possible approach to follow when considering which devices should be installed was proposed. This approach is based on a “Risk Assessment Evaluation” (Figure 2). First of all, different gears used by this fleet are identified and their possible impacts detailed (e.g. impact on the seabed, bycatch rate, PETS bycatch etc.). Fleets operating close to sensitive areas or fishing grounds could also be identified (e.g. fishing grounds close to MPA or restricted areas etc.). The fleet could then be classified by risk category, from very low risk to high risk. Depending on the risk category, the level of compliance and data needed from the fleet would be different and consequently the devices to be installed, from very simple (simple track devices) devices to more complex devices (e.g. CCTV with track+ gear use sensor + catch information).

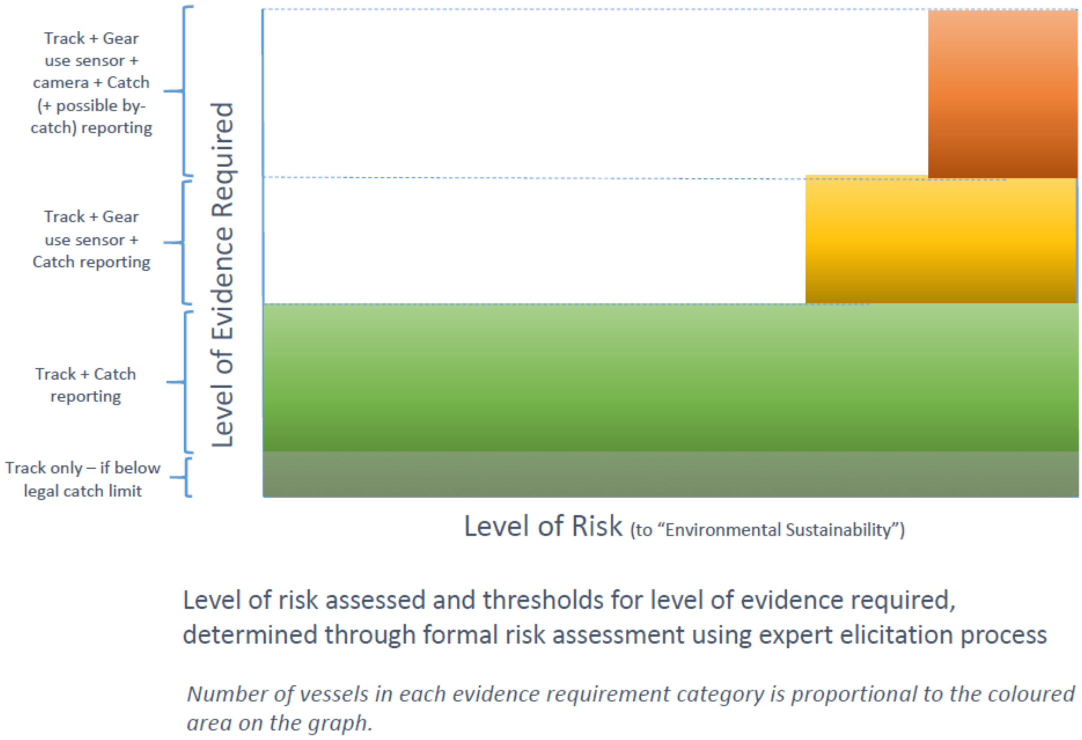

Figure 2. Breakdown of ERS that could be distributed across an SSF fleet based on an assessment of risk (adapted from SIFIDS Project for fishPi2 (MARE/2016/22).

With the data collected by these devices and some analysis of the vessels tracks and speed profiles, high resolution information about the effort, namely estimates of the amount of gear used, soak time, areas fished etc. could be estimated.

II. Workshop on digital tools for Small Scale Fisheries (Brussels, 4-5 December 2018)

The European Commission (DG MARE) in close cooperation with EU Member States (MS) organised a workshop on digital tools for small-scale fisheries (SFF) in Brussels on 4-5 December 2018. Representatives of DG MARE, MS, European Parliament, Council of the European Union, Advisory Councils and other EU stakeholders participated in the discussions. The workshop covered digital tools for vessel monitoring, catch reporting and a session focused on the European Maritime Fisheries Fund (EMFF) as a funding mechanism. The Workshop was divided in three different sessions. First session was focused on tracking devices to monitor the SSF, the second session covered digital catch reporting tools for the SSF and the third one was focused on EU funding digital tools for monitoring and reporting.

In this workshop, some devices identified under fishPi2 project were also presented (e.g. MOFI App, Blackbox etc.). These devices are not explained in this section to avoid redundancy with the section above.

Some pilot studies from several MS were presented in the mentioned sections:

1. **Spain**: Three pilots were presented. One from the Andalucia region, were a device called “green box” is used and the information is collected by the Andalucian regional government. It is similar to a VMS but adapted to the SSF. The resolution and frequency of the pings is higher compare to VMS. The other device is an App used and developed by a specific fishermen association called ACERGA. It is similar to an electronic logbook and it´s a catch reporting system. The last device is called “VMS Lite” and is used in 120 vessels in the Galician region. This position system is also approved and used by the Marine Management Organization in the UK.
2. **Croatia**: A device called “M-Logbook app is used by 100 vessels and planned to extend it in more vessels in 2020. It is an electronic or catch reporting system. The option of using drones for control purposes and detect illegal fisheries was also presented.
3. **Netherlands**: A electronic logbook/catch reporting system called “E-Lite app” was presented. This app is mandatory for all vessels under 12m in total length.
4. **Estonia**: Similar to the Netherlands, a voluntary based electronic logbook/catch reporting “ERS Lite app” system is used.
5. **Greece**: A Greek company presented a “Pelagic Data System”, a tracking device adapted for SSF.
6. **France**: A French company called “Fishfriender” developed a monitoring and catch reporting system tool currently used in the recreational fishery of seabass. It is a mobile app that combines passive GPS data with active catch data input.

The whole report and main discussions and conclusions from the workshop are detailed in the following link: https://ec.europa.eu/fisheries/press/outcomes-workshop-digital-tools-small-scale-fisheries-brussels-4-5-december-2018_en

In addition, another relevant paper that covers this topic was published by Darcy Bradley and colleagues (Bradley et. al, 2019). This paper covers the opportunities to improve fisheries management through innovative technologies is covered. It is not specific for the SSF although this fishing segment is also analyzed. A wide summary of main electronic monitoring programmes around the world and apps used to collect catch data, especially in the recreational fisheries, but applicable to the SSF is provided.

Rod Fujita and colleagues (Fujita et. al, 2018) also made an important review on Technologies for Improving Fisheries Monitoring. This study covers different alternatives to be used for SSF compliance and some case studies are also highlighted.

Annex I. Best practices guidelines for data collection on the SSF

Guidelines on best practices for SSF fishing activity data collection

These following guidelines are proposed for data collection on SSF fishing activities based on similar good practice guidelines established for general commercial fishery sampling schemes by WKPICS (ICES, 2013) and recreational fishery surveys by WGRFS (ICES 2012b).

Step 1: Objective/Data needs

The first step is to identify the types of estimates (domains of interest, landings, fishing effort, at the desired resolution such as spatiotemporal strata; gear types etc.) and the level of precision that the data collection system is required to deliver, and the types of data needed to calculate these estimates (see previous section).

Step 2: Pre-screening/Frame survey

The next step is to collect information on the target population of vessels including data on the access points in the coast where vessels can be sampled, and on the fishing activities of vessels. These data allow an evaluation of candidate methods of data collection (choice between census and sampling approach) and for the sampling scheme to implement. Most of the time, the frame survey consist of a census-based approach in which data is collected at all access points along the coast for all fishing vessels and gears.

The aim is to extensively describe the vessels constituting the SSF fishing sector: (i) their fishing activity patterns (% of full-time, part-time or inactive vessels); (ii) their spatial/temporal patterns and dynamic of fishing and landing; (iii) target species and the gears they used including extent of polyvalence and seasonality, etc. Identification of all possible landing sites, the numbers of vessels using them, and the daily, weekly and seasonal patterns of landing inside each site should be also surveyed especially to perform intercept surveys. The pre-screening survey also provides the opportunity for recording supplementary information useful for planning and implementation purposes such as, for example, fishing trip schedules pattern.

The pre-screening survey will constitute the general framework of the data collection. Based on it, a sampling frame must be clearly identified and fully documented (e.g., list frame of vessels or vessels x time period, or an area frame of landing sites). The primary sampling units of the frame should be clearly described. If the frame excludes part of the population for practical reasons (for example issues related with accessibility of the landings sites), this should be documented so that potential for bias can be evaluated.

The pre-screening survey should also identify existing data sources that are available, such as sales notes or any existing declarative forms; position data from AIS systems or geo-localization tools; etc.

Step 3: Census, sampling or a combination of both?

The next step is to evaluate the most appropriate method for the data collection. The choice between census, sampling, or a combination of the two approaches to provide information on SSF fishing activity and catches (e.g., capacity/gear information/fishing effort/landings per species in weight and value) will be done based on the information compiled in first step. The approach chosen will depend on (i) the objective (in particular the desired level of precision and desired resolution) of the SSF fishing activity data collection, (ii) the issues of cost efficiency, (iii) the available means to collect the data and (iv) the outcomes of the pre-screening survey (including the potential pre-existing data sources available).

The cost efficiency of census or sampling approaches to estimate SSF fishing activity variables has to consider all the costs linked with each procedure and needs to be assessed case by case considering their specificities.

A census approach implies, among other things, costs for data inputs, data quality assurance and quality control (input error detection, reliability of self-reporting data, completeness of the information and other bias issues), data base development and data archiving, data processing and reporting. Statistical / programming costs are involved in development of calculation procedures of final estimates at any desired resolution (e.g., spatial-temporal strata, gear types, etc.), with, *in theory*, a perfect result (no uncertainty).

A sampling approach implies, among other things, costs for designing, implementing and monitoring the programme (including acquisition of any auxiliary information needed for estimations), data base development and data archiving, quality assurance and quality control procedures, data processing and reporting. Statistical / programming costs are involved in development of estimation procedures including estimation of precision of final estimates through the application of sampling theory (where there is a sufficient number of samples to calculate the estimates at different desired resolutions (e.g., spatial-temporal strata, gear types, etc.).

All different factors linked with the approach chosen have to be taken into account before adopting a particular scheme. In some regions the use of declarative forms (manual or electronic) could be inappropriate whereas in other regions it could be the most efficient approach.

In conclusion, sampling or census approaches could be developed to survey SSF. The two approaches imply different issues, assumptions and specificities implicating that best practices guidelines are specified for each of them in steps 4, 5 and 8 taking into account their particularities.

Step 4: Data Collection method

Sampling approach

Several types of sampling scheme are possible, for example:

- A catch sampling survey where the primary sampling unit (PSU) is a landing location on a day, and PSUs are sampled using a clustered random sampling scheme in order to interview skippers of vessels landing throughout the day to collect data for that trip. The vessels trips are the secondary sampling units (SSU).

- Use of a known fishing fleet vessel register from which a list-frame of small-scale vessels is identified, and vessels are selected using a stratified random sampling scheme to collect data on their fishing activities and catches. This could be done by: i) direct interview for the last trip (PSU = vessel x day); ii) self-reporting of data for the full year using declarative forms (PSU = vessel); or iii) self-reporting of data for a shorter period using declarative forms (PSU = vessel x month for a monthly collection period). Option (ii) is equivalent to a reference fleet approach.

The data collection method should be identified.

If adapted declarative forms have to be used (random samples of vessels who self-report), they must be easy to complete, and capture the minimum sufficient data needed to calculate the required estimates (see census approach step 4 for more details). This could include e-adapted declarative forms, new smartphone applications and sales notes (if they are available).

Clear and easy-to-understand specific guidelines must be developed for fishermen to correctly complete the declarative forms (with some practical examples), or for trained survey staff completing interviews.

At this stage, it is important to develop an inventory of available resources in terms of budget, staff, data processing, analysis and any equipment costs such as electronic data capture tools, and any requirements that need to be met with regards to time schedule or accuracy of survey estimates.

It is critically important also to consult widely with fishermen in this process, to discuss the feasibility and practicalities of data collection and highlighted the benefits and objective of such data collection. A consideration is needed of incentives to encourage all the fishermen in the scheme to provide data and to ensure the data are as accurate as possible. An initial pilot study to trial data collection methods should be performed and the methods adapted where necessary.

Finally, other indicators as reliability of self-reported data expected, spatial distribution and seasonality, accessibility of the landings sites, etc. have to be taken into account to define the most adapted sampling scheme to survey SSF fishing activity variables. This should be assessed by region/gear/fleet as in some of them one type of sampling scheme could be inappropriate when, in other, it could be the more efficient approach to use.

Census approach

A census approach for SSF data collection method needs an adapted declarative form to collect fishing data (like logbooks for large scale fleets). Based on the 2015 WGCATCH (ICES 2015) overview of the SSF data collection schemes used in ICES area, the conclusion was that EU logbooks are not well adapted to the characteristics and special features of the SSF fleet. In particular multi-gears/multi-species fleet (polyvalence both between and within trips), importance of fixed gears (nets, pots/traps, lines, on-shore fishing, etc.), daily fishing trip schedules (sometimes twice day), when logbooks have been designed rather for active gears (especially trawlers) and several days fishing trips. Therefore, adapted declarative forms (named differently in each country as coastal logbooks, coastal registers, monthly reports, monthly declarative forms, etc.) are preferred.

Adapted declarative forms must be easy to complete, and capture the minimum sufficient data needed to calculate the required estimates. This could include **e-**adapted forms, new smartphone applications.

Clear and easy-to-understand specific guidelines must be developed for fishermen to correctly complete the declarative forms (with some practical examples).

At this stage, the system in place to collect logbooks for large scale fleets (data capture software, data base) has also to be taken into account to insure cost efficiency.

Landings declaration and sales notes data constitute, when available, another source of data to estimate SSF transversal data but are insufficient as they usually do not capture information on fishing effort, details on gears used, or fishing location. They have to be combined with additional data collection methods (census or survey).

Data on landings declarations and sales notes constitute also a useful source of information to improve estimates resulting from the analysis of the adapted SSF declarative forms on fishing activity, by cross-validation methods.

It is important to consider that the EU Control Regulation (Regulation (EU) 1224/2009 of 20 November 2009 and Commission Implementing Regulation (EU) 404/2011 of 8 April 2011) allows the possibility for fishermen to dispose of small landings without documentation. Communication with fishermen on the necessity to report all landings (including small landings) has to be considered in order to improve the estimates from adapted declarative forms. At this stage, it is important to develop an inventory of available resources in terms of budget, staff, data processing, analysis and any equipment costs, such as electronic data capture tools, and any requirements that need to be met with regards to time schedule or accuracy of survey estimates.

It is also critically important to consult widely with fishermen in this process, to discuss the feasibility and practicalities of data collection and highlight the benefits and objectives of such data collection. A consideration is needed on incentives to encourage all fishermen in the scheme to provide data and to ensure data are as accurate as possible. An initial pilot study to trial data collection methods should be performed and the methods adapted where necessary.

Step 5: Design the sampling scheme

Sampling approach

The choice of sampling frame and data collection method must be made before specifying a probability-based sampling design and sample selection mechanism.

Extensive information on types of sampling designs for fisheries is given in the reports of WKMERGE (ICES, 2010), WKPICS 2011 – 2013 (ICES 2012a, 2013a), SGPIDS (ICES 2011, 2012c), WGCATCH (ICES 2015, 2016) and WGRFS (ICES 2013b). These reports should be consulted to help design a scheme that meets the criteria for statistical soundness, which could be found in the WKPICS2 guidelines for good practice and that has been adapted here for SSF data collection.

The need for pre-stratification of the PSUs in the sampling frame should be considered very carefully to ensure that it is really necessary (e.g., to address particular end user needs for specific domains of interest, such as more precise estimates for particular regions). However, sufficient number of samples per stratum is necessary to provide robust estimates and to bring advantages by improving precision and cost-efficiency. The method for selecting sampling units or PSUs such as vessels or "site x days" should be chosen to ensure that the samples are as representative as possible of the population.

An appropriate sample size can be determined based on the design itself and on any specified requirements for the spatial-temporal resolution and statistical precision of estimates, taking into account resources available for sampling.

If a reference fleet approach is used where a representative selection of vessels is made within a defined area, gear, target species or other strata and fishermen are asked to record data continuously throughout the year, it is better to stagger any replacement of vessels rather than changing them all at the same time. Several examples of inshore reference fleets can be found in literature from Norway (e.g., Pennington and Helle, 2011).

Step 5 Census approach

This step is not applicable to the census approach.

Step 6: Implementation

It is good practice to establish a system to monitor the performance of the data collection scheme, firstly to identify and if possible rectify problems emerging, secondly to allow an evaluation of the potential for bias if the problems cannot be rectified. This monitoring system should provide diagnostics on non-response or refusals to supply data (and reasons if known) and on inadequate coverage of the data collection scheme.

Where necessary, fishermen should be contacted at an early stage to try to improve the data collection.

Quality issues are also related to reliance on buyers and sellers documentation (confidence in self-reporting data). Statistical comparison of vessels data within fleets and metiers, could be a good way to identify outlier vessels, for which data must be checked. On-site or at-sea observations, by randomly selecting trips, can be made to validate self-reported data, bearing in mind possible observer effects on quality of reported data.

Step 7: Data capture and quality control

A national database is needed to compile SSF sampling and/or census data in a format that is compatible with any regional standards requirements (e.g., European Commission databases for uploading). To account for the requirements of sampling, the database should also include the input of variables needed for probability-based estimation in what will typically be a hierarchical cluster sampling design.

A quality assurance/quality control system should be implemented to identify and clean individual data errors (including input-error detection). For example using the R-codes for implementing range checks and other validation rules developed in the 2016 fishPi research project (EU MARE/2014/19, Anon. 2016), and to report on identified errors (including identification of outliers with statistical methods, etc.). Adequate software for data capture (for example with allowable ranges for numerical fields) could limit these tasks.

Additional methods should be developed and implemented to provide diagnostics on data quality in completion of the annual data collection cycle. These may include methods used for within-year monitoring of the data collection in Step 6, including achieved vs planned sampling;

stratum coverage; non-response and refusal rates; information from on-site or at-sea data validation exercises or any other form of cross-validation for data available (could be position data from AIS systems or geo-localization tools, sales notes, existing declarative forms, etc.), which could be a good means to improve the final estimates of precision. For example, adapted declarative forms could be cross checked with sales note to strengthen the species composition in the landings.

Step 8: Data analysis and quality indicators

Sampling approach

Data analysis should exactly follow the sampling design and probabilities at each stage of sampling, as specified in the WKPICS 2012 (ICES 2012a) guidelines which has been adapted here for SSF data collection.

Quality indicators should be provided related to: i) potential for bias and representativeness of the sample (direction and possible magnitude of bias, potential part of the fleet not represented in the sample), and ii) precision of estimates (e.g., standard errors or a proxy such as numbers of PSUs sampled). See Annex 3 of WKPICS 2013 for a detailed review (ICES 2014).

Quality issues depend also on the good use of adapted estimation procedure and on accurate information to calculate the sample probabilities. Therefore, methodologies to calculate the estimates have to be checked and reviewed regularly.

Statistical imputation or raking methods could be used, at this stage, to improve the estimates and their precisions.

A common technique for handling item non-response is imputation, whereby the missing values are filled in with a replacement/substitute values (e.g., last observation carried forward, imputing an assumed outcome, imputing the mean, imputing based on predicted values from a regression analysis, etc.) to create a complete data set that can then be analysed with traditional analysis methods. Because missing data can create problems for analysing data (introduce a substantial amount of bias, make the handling and analysis of the data more arduous, and create reductions in efficiency), imputation is seen as a way to avoid pitfalls involved with deletion of cases that have missing values. Some imputation methods replace the missing data and account also for the fact that these were imputed with uncertainty (e.g., multiple imputation, simple imputation methods with adjustment to the standard error). A few well-known attempts to deal with missing data include: hot deck and cold deck imputation; listwise and pairwise deletion; mean imputation; regression imputation; last observation carried forward; stochastic imputation; and multiple imputation (Cochran 1977; Higgins and Green, 2011). Raking (otherwise known as iterative proportional fitting sample balancing or 'raking ratio' estimation) is a method for adjusting the sampling weights of the sample data based on known population characteristics, so that its marginal totals match control totals on a specified set of variables. The difference may arise, for example, from sampling fluctuations, from non-response, or because the sample design was not able to cover the entire target population. By adjusting these weights, the survey sample is essentially forced to resemble the population, therefore 'making'' possible the inference to the entire population (Battaglia et al., 2009).

Census approach

WGCATCH considers that the assessment of coverage/completeness of the estimates reached by the data collection is an issue that will require much attention when census approach is used to survey SSF. This is linked with the evaluation of potential for bias, especially if part of the fleet could not be surveyed. Diagnostics are needed on non-response or refusals to supply data and reasons if known.

Frame survey outcomes (in particular level of active/part-time and inactive vessels inside the SSF fishing sector) constitute a good input to evaluate potential bias. However, frame survey outcomes have to be updated regularly as they could change year to year. Cross-validation of data available (when different sources of data exist) also constitutes a good procedure to verify the completeness of the information received and to calculate quality indicators associated. Specific coverage' validation surveys could be also implemented.

WGCATCH stresses that fishing fleet registers include SSF vessels and, as quality insurance, concludes that first step will be the calculation of the % of vessels covered by the declarative data available. WGCATCH advises a specific check on vessels without any information or with part-time information to verify the completeness of their data and assess the reality of their inactivity.

The aims of this analysis are the following: (i) define which part of the total fleet is surveyed or not, (ii) estimate the share of activity not covered by the declarative forms and (iii) constitute a basis to apply some statistical techniques to treat the non-respondents (statistical imputation or raking methods could be used, at this stage, to improve the estimates, see previous section) and then limit the potential bias of the estimates.

WGCATCH notes that some countries use annual preliminary survey (annual frame survey) to assess, among others things, the global inactivity of the vessels which is particularly useful for checking the completeness/coverage of the declarative data collected and encouraged others to develop such approach.

Step 9: Feed-back to improve the data collection

The achievements and issues emerging from the data collection scheme should be summarised, and the design and implementation of the scheme modified where needed to rectify problems, improve data quality and cost efficiency. Feed-back and consultation with fishermen participating in the scheme is important to maintain their interest and contribution.

Guidelines on best practices for biological data collection on SSF

The sampling methods to collect SSF biological data (length and age composition, discards rates and catches of PETS) should be based on (i) statistically sound sampling scheme, (ii) cost-efficiency, (iii) available means, (iv) reliability, and (v) should be defined to meet the data resolution (spatial, technical or temporal) and the level of precision required.

Extensive detailed information on sampling design for biological data and related issues is given in the reports of WKMERGE (ICES, 2010), WKPICS 2011 – 2013 (ICES 2012b, 2013b), SGPIDS (ICES 2011, 2012c,), WGCATCH (ICES 2015, 2016) and WGRFS (ICES 2013c). These reports should be consulted to help designing a sampling scheme that meets the criteria for statistical soundness. These criteria can be found in the WKPICS2 guidelines for good practices. Best practices guidelines addressed in these previous reports will not be repeated here (only the principal bullet points will be mentioned). SSF on-shore and on-board sampling programmes face the same issues as for LSF. However, SSF biological data collection has also some specific issues related to their specific features (as high spatial distribution, heterogeneity, seasonality, part-time activity or frequent direct sales) which will be detailed here. These is-sues may represent other potential difficulty to survey SSF biological data.

Step 1: Objective/Data needs

As for fishing activity data, the first step is to identify the target population and the type of estimates (domains of interest, such as species composition, length and age compositions, maturity, sex ratio, discards rates, catches of PETS, etc.), the resolution of the estimates (e.g., spatial-temporal strata; gear types etc.), the level of precision that the data collection system is required to deliver and the types of data needed for these estimates. Several types of sampling schemes can be performed to collect SSF biological data:

- An **on-shore sampling scheme** which includes:
    (i) Market sampling: SSF landings may be sold directly to the public at the landing site, or sold at another auction than the corresponding landing site after transportation. Random sampling at markets/auctions may therefore not capture all SSF landings. LSF landings may also be sold at these auctions. Biological data to be recorded with this sampling scheme is the same as for large scale fleets and include species lengths and age compositions, landings and Below Minimum Size (BMS) composition of trip. Sampling should follow the best cost-effective sampling design considering that it may not be possible, for instance, to sample small but important landing sites for SSF where fish could be sold directly and not through markets. Some assumptions may have to be considered in these cases depending in what are biological variables to collect.
    (ii) Landing site surveys (inquiries to fishermen): This sampling scheme allows potential for collecting data and biological samples from all landing sites for SSF that are included in the frame, irrespective of where the catch is sold. It strongly depends on cooperation from fishermen and a good compliance/relation between observer and fishermen should exist to obtain reliable data. Important information on SSF biological data can be potentially obtained about discarded or BMS species compositions and weights, presence of PETS in trip besides landed species information, etc. It is also possible to ask for gears used, effort and spatial information from trip. Data on length and age distributions are difficult to obtain with this approach unless fishers are intercepted during landing and can make their catch available for sampling.

Cross validation procedures should be performed using census data when it exists or with sporadic onboard sampling whenever possible.

(iii) Purchase of samples: Species specific biological data like lengths, weights, sex-ratio, maturity and age can be obtained by purchasing independent samples from SSF, referring to lengths/age composition of landings (species specific/total); association to gear(s) used in trip. There are also examples of arrangements where fishers also bring samples of discarded catch ashore for sale to the fisheries laboratory (with suitable dispensations), from which information on discarded catch can also be obtained (see next section). Sample purchasing schemes need to follow sound statistical design principles to reduce bias. For logistic and administrative convenience, a sample of fishers may be recruited to provide catch samples at intervals in a similar manner to the use of a reference fleet, and in this case the sample needs to be picked in a way that is as representative as possible of all the fishers in each sampling stratum.

- An **at-sea (on-board) sampling scheme** which includes:
  (i) Onboard sampling: This sampling scheme, where an observer goes onboard to sample trips, is potentially the most reliable way to obtain complete biological data concerning species and lengths composition for catch, weights, discard rates, catches of PETS, along with fishing activity variables (fishing areas, effort, gears used, etc.). However, issues of safety and space for observers on small vessels (which could be linked with existing regulation) can lead to exclusion of many vessels from an observer sampling frame, and this can lead to bias if these vessels operate in areas with different size/age compositions of fish than the remaining larger vessels.

  (ii) Self-sampling schemes (ICES, 2008): This type of sampling is an alternative option to record onboard biological data from SSF. Several approaches of self-sampling can be used but all should be designed according to a statistically sound sampling scheme so that sampled vessels are as representative as possible of the non-sampled vessels within strata. It should include validation procedures for data quality control, and cross-checking of data using adequate quality indicators (data obtained from sampled vessels using the same gears, operating in the same areas, landing in the same ports, etc.) to evaluate bias:

     a. *"Onboard self-sampling":* Fishermen themselves do the sampling of the catch (measures the catches by fractions 'landed', 'BMS' and 'discarded') onboard and record gear, effort and spatial related information. This approach requires training courses for fishermen to know what and how to record the information needed and again data quality evaluation and validation procedures. Sampling coverage must be routinely analysed to assess the effectiveness of the scheme.

     b. *"At-site self-sampling of discards":* In the onboard catch sorting process, fishermen sort catches from hauls and keep discards to deliver them to an observer when arriving at port. This arrangement requires the good will of fishermen to cooperate, which may require additional incentives such as payments provided this does not lead to any incentive to bring non-representative samples ashore. Fixed-value samples of discarded fish seem to be the appropriate approach to get the most representative data. In this sampling scheme, biological data related to discards is collected in laboratory by biologists/observers/technicians. Information on landings species composition, weights and fishing activity variables should also be supplied by fishermen. One important issue in this type of self-sampling is how the discard fraction from catch is collected: random subsample of discards vs total discards? Are the samples collected from a single haul (or subset of hauls) according to a sample selection rule, or from the overall trip? Clearly understandable, written instructions must be given to fishermen on how to collect the samples. Data collected should be validated by cross-checking with species or lengths composition from e.g. onboard sampling in other vessel trip operating with the same fishing gear in the same area.

The other steps to follow for conducting a biological data survey are summarised below, with a specific attention to SSF features which implies some specific issues*:*

Step 2-3: Pre-screening/Frame survey and selection of the type of sampling scheme

The next step is the evaluation of candidate data collection method. The choice between on-board, on-shore sampling scheme or a combination of both, to survey SSF biological data, will be done based on the outcomes of the pre-screening survey (see previous section), and on issues of cost efficiency, desired level of precision and the resolution needed. From there, the identification of the primary sampling unit (PSU); vessel/trip or site/day; will be performed.

At this stage, fishing activity variables estimates provide auxiliary data on fleet structure, activity and catches, which is valuable to implement the most appropriate sampling scheme. This is needed also for raising the biological sampling estimates for sampled trips to the whole fleet, within any defined sampling strata.

The choice between the different sampling scheme methods should take into account the potential existence of a sampling scheme of fishing activity variables: a sampling scheme for biological data collection could then be easily linked with it if there is one (see previous section).

At this stage, identification of specific regulation issues linked to safety and space for observers on board, should also be taken into account in order to evaluate the possibility to develop or not an on-board sampling program. If not, it could mean high difficulties to assess the overall discard rate of SSF and the catches of PETS by SSF, especially when alternative method as self-sampling program *(as described above)* could not be put in place.

Step 4: Data Collection method

<u>Stratification of the sampling frame</u>: Information from pre-screening survey (see previous section) such as list of all landings sites (including large and small ports) and fishing activity data estimates (see previous section) such as fishing effort distribution, spatial and temporal distributions, evaluation of heterogeneity in landings composition and in landed weights from SSF between ports/regions, can be used to identify which strata should be considered to plan SSF biological sampling design. Stratification may be advantageous for delivering estimates that might be required for specific fleet segments or regions, but should clearly link with any strata used in surveys for estimating fleet activity and landings whilst avoiding under-sampling of any stratum. The minimum number of PSUs to be sampled within each strata should be defined.

Specific analysis on spatial distribution of SSF vessels and their landing and sales sites should be done in the pre-screening survey to determine if landing sites for this SSF fleet are being covered by a general sampling scheme that includes both LSF and SSF, constituting then a most cost-efficient sampling scheme for SSF. However, an additional specific sampling scheme may be needed to target non-sampled ports where SSF fleets dispose of their catches directly and not through markets covered by the general sampling scheme. This is needed if a significant amount of the SSF catch is landed in small non sampled ports.

Step 5: Design the sampling scheme

Establish and describe criteria for sampling effort distribution. The most cost-efficient design for the main species caught throughout the frame could be to distribute sampling effort proportional to total landed weights/value or number of sales/trips in each port (see simulation examples in the fishPi project). However, needs for less common, more locally distributed species estimates should also be considered and may require a more complex optimisation scheme. Accessibility of observers to specific ports should also be considered when distributing sampling effort, with the decision *a priori* to include or not less accessible landings sites in the list of ports to visit. The screening survey should be used to evaluate how much of the catch of each species may be excluded in this way.

The next step is to identify a method for randomised selection of PSUs within each stratum. This is discussed in detail in previous ICES reports of WKPICS, WGCATCH, SGPIDS, which should be consulted.

The representativeness of the samples should be assess taking into account that for SSF, in some cases, fishing activity data are not exhaustively collected (needing alternative procedures as that used for LSF).

Steps 6-9: Implementation, Data capture and Quality control, Data analysis and Quality indicators, Feed-back to improve the data collection.

Note: see also previous section for fishing activity data collection as these steps are generic steps for data collection best practices

All these steps must be routinely assessed in order to try to overcome possible constrains relating with SSF biological data sampling which could be the consequence of specific features of the SSF fishing sector. One important task is to document well the proposed sampling design in order to provide an efficient tool to evaluate its feasibility and consistency through time.

Step 10: Comparison of biological data from SSF and LSF

Based on the first results of the sampling scheme or previous data collection, a comparison between catch species composition and length and age compositions of SSF and LSF landings in comparable gear/mesh/area/time groupings should be performed. This may suggest ways in which the sampling schemes for SSF and large-scale fleet biological data could be optimised to improve cost-efficiency. For example if there is no significant effect of vessel size, the data from sampling at markets or by observers on larger vessels could be applied to catch estimates for vessels too small to take observers onboard, or from small sites where SSF catches are sold direct to the public and not transported to markets. As always, potential for bias should be investigated and documented in relation to the savings in sampling cost.

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