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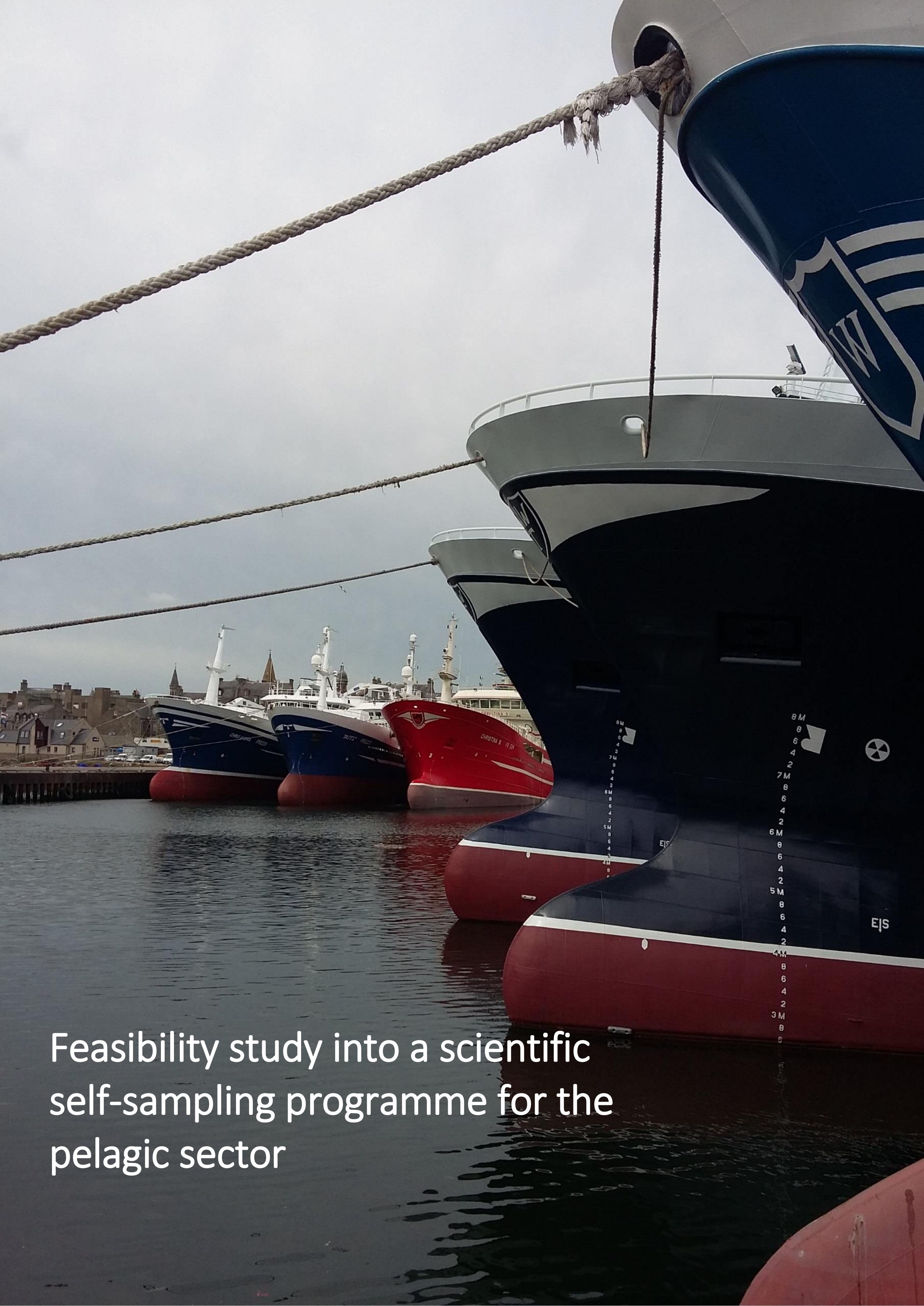

Feasibility study into a scientific self-sampling programme for the pelagic sector

A report for Fisheries Innovation Scotland (project no. 020) and the Scottish Pelagic Fishermen's Association

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How to read this report

This report consists of a main section and four appendices. The main section provides the why, what and how relating to opportunities for pelagic self-sampling and their relevance to other sectors. The appendices contain the detailed information and analyses used to support the findings documented in the main section, and thus are an integral part of the report.

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Executive Summary

Fishermen's perceptions of the shortcomings of scientific surveys and sampling schemes contribute to their lack of trust in the reliability of fish stock assessments. At the same time, scientists doubts about the reliability of catch data are responsible for a large degree of uncertainty in stock assessments. There are opportunities to improve both trust and data quality from both sides.

Taking new responsibilities for providing scientific data through self-sampling is seen by fishermen as a welcome opportunity to directly contribute to the continuous improvement of stock assessments. Experience shows that successful self-sampling schemes rely on effective feedback to fishermen, particularly in relation to what their data shows and how it is being used. This feedback helps to improve confidence in science and management, and reinforces effective collaboration between industry, science and management on achieving sustainable and profitable fisheries.

Using paper diaries and electronic plotter devices, Scottish pelagic fishermen already record substantial quantities of data that describe where and when they fished, what they caught, and in some cases, environmental and biological information. They are willing and have the capability and capacity to do more. The pelagic industry lends itself to a self-sampling programme because pelagic fishermen want to engage with science; have a direct stake in the information they generate; are capable and early adopters of new innovations; and they have the means for a well-organised and managed implementation.

The purpose of this report is to identify opportunities for the Scottish pelagic industry to collect and contribute relevant data to support the assessment of stocks and management of fisheries. In doing so, it describes the requirements of a scientific self-sampling programme and what such a programme might look like. It also discusses how self-sampling schemes might help to address information needs in less data rich situations, such as those in demersal and *Nephrops* fisheries.

The four vital elements of effective self-sampling programmes are: (1) matching data opportunities with incentives that create a lasting 'want to' attitude, (2) establishing practical processes that can be efficiently implemented to a high quality standard, (3) feedback on progress and results, and (4) achieving the intended impact.

The design process starts with having a clear view of what data are needed and how they can be used, so that any data provided by industry has the best possible chance of being used in scientific and management applications. Table 2.2 identifies scientific and management information needs and maps these needs onto a wide range of potential data contributions from a pelagic self-sampling programme. Table 3.1 is more specific, identifying the data provision opportunities and their scientific applications for mackerel, herring and blue whiting.

For all three species, the collection of biological data for every haul can provide benefits to science, management and business applications. Critically, it can provide the means to help evaluate the performance of current sampling activities, which is a starting point to identifying any gaps, biases and uncertainties that may benefit from improvement. For mackerel, the principal gains relate to the quality and resolution of data and evidence of the spatial distribution of fish and fishing. The same points apply to herring and blue whiting, but there are additional opportunities to provide relevant data describing stock structure. It is particularly important for blue whiting, where sampling is very low but the importance of the fishery to Scotland has been increasing recently.

The architecture, or design, of a pelagic self-sampling programme is presented graphically in Section 7, with a specific example given for mackerel. Implementation of the practical sampling methods on vessels should be relatively straightforward, with developments in efficient electronic recording and data capture systems playing an important part in the future. Sampling at factories offers an alternative way to obtain a range of useful scientific data through minor adaptations to existing quality control sampling procedures. In both situations, a central challenge will be ensuring that any industry-led sampling programme can be maintained over a period that is long enough to demonstrate its value to science and management.

The cost of time associated with collecting data at sea or at factories would be absorbed in to the daily operations of vessels and factories. Similarly, the industry would bear the costs for oversight of a self-sampling programme. Additional cost and effort from scientists would be necessary where specialist tasks such as age-reading of otoliths and data storage/ handling functions are required. Options for supporting these requirements, such as utilisation of scientific quota, an industry-science levy and project funding need to be discussed as a necessary next step. Further discussion on training needs is also required.

Like the pelagic sector, greater engagement of the demersal and *Nephrops* sectors in self-sampling schemes would be beneficial in a number of ways such as: quantifying effects of the landing obligation and identifying mitigation measures, filling biological information gaps (e.g. for Data Limited Stocks), providing samples for stock identification studies, aiding scientific survey planning and verifying perceptions in the changes in abundance and distribution of stocks. Although the size and diversity of the demersal and *Nephrops* sectors presents numerous challenges in implementation, there are opportunities for self-sampling programmes to routinely deliver scientifically valuable data. The architecture outlined here for the pelagic sector, is a useful guide to exploring in more detail the opportunities outlined in this report.

1 Introduction

1.1 Purpose and audience

The purpose of this report is to identify opportunities for the Scottish pelagic industry to collect and contribute relevant data to support the assessment and management of pelagic fisheries. In doing so, it describes the requirements of a self-sampling programme, and what such a programme might look like.

The report is targeted principally at the pelagic industry, Marine Scotland and research establishments, since it is only through their effective collaboration that a self-sampling programme would be made feasible. Self-sampling has obvious relevance to other fishing sectors in the UK and beyond, as well as organisations involved in defining information needs to assess fisheries sustainability. This report therefore considers how such a scheme could translate to other Scottish fishing sectors to help address their priority information needs.

During the study, the authors have engaged with Scottish pelagic vessel owners, skippers and crew, staff from the five Scottish pelagic factories (particularly in quality control), Marine Scotland policy and science staff, the Scottish Fishermen's Federation, the Scottish Whitefish Producers Association, NAFC Marine Centre (UHI), scientists at the Pelagic Freezer trawler Association (The Netherlands), Danish Fish Producers Association, the International Council for Exploration of the Sea, Joint Research Centre, research institutes in Norway, Ireland and Iceland, and members of the EU Pandora project.

1.2 Context

The study is founded upon the Scottish Pelagic sectors' commitment to actively engaging with science and management issues that underpin the sustainability of its business. Evidence for this is demonstrated by the success with Marine Stewardship Council (MSC) certifications and the appointment of a full-time scientist by the Scottish Pelagic Fishermen's Association (SPFA).

Why does the Scottish pelagic industry want to engage with science?

The industry recognises that engagement in science is more important now than ever. While resources for state-funded evidence gathering have reduced, the need for quality data to assess the sustainability of stocks, and the businesses that depend upon them, continues to grow. While science is more frequently turning to industry for help with monitoring and research, industry is turning to science for assistance with the professional skills it needs to operate effectively in a management system underpinned by science, and a market place that demands assurance of the sustainability credentials of fishing businesses.

What does industry hope to achieve in being proactive contributors of scientific data?

To be respected providers of scientifically credible data that's used to assess fish stocks, monitor changes in the pelagic ecosystem and support management decisions.

How does industry's self-sampling initiative fit with the UK's post-Brexit strategy?

Regardless of the outcomes of Brexit negotiations on future management and access to UK waters, scientific assessments of fish stocks will remain to be a key requirement, and will continue to require scientific collaboration at an international level.

Defra's White Paper on future fisheries policy provides the up to date policy agenda for thinking strategically about opportunities for industry engagement in science. As the precursor to a new Fisheries Bill, the White Paper provides an insight to possible future operational policies, and the extent to which they will be supportive of industry initiatives.

Our review of the White Paper suggests that there should be good support for industry initiatives that can provide data useful for science and management purposes. The paper states *"Our vision is that industry should take a greater, shared responsibility for sustainably managing fisheries, while making a greater contribution towards the costs. This can include, for example, work to develop new management practices and contributing to fisheries science"*. And, "*Defra will build on the existing close cooperation with the devolved administrations on data collection, while engaging with industry and others including NGOs, to gather the best available scientific evidence to inform policy and delivery."* Examples are given of specific data collection opportunities. In particular: *"enhancing the data collected from fish grading machines; and software that enable fishermen to collect data and meet reporting requirements".*

'Seafood 2040: A Strategic Framework for England', published by stakeholders from across the seafood industry, points in the same direction. In seeking to address "*a prevailing culture that favours scientific knowledge over practical knowledge – and thus fails to appreciate the merits and shortcomings of both"*, it proposes several actions that are pertinent here. It recommends that the current data programmes are maintained, or equivalent programmes developed, and that collaboration with European partners is continued. The report suggests utilising quota mechanisms as funding, and calls specifically for a well-funded, well-respected fisher/science programme that can play a valuable role in extending the data coverage of UK fisheries. Improved digital connectivity and software for data capture are seen as necessary to achieve this, as well as to improve enforcement and traceability. It envisages Producer Organisations having a crucial role to play in supporting the work so as to maximise wild catch opportunities.

Drawing on the good work already being delivered in other parts of the UK, for example Fisheries Innovation Scotland and Food Innovation Network, the Seafood 2040 report says that a new Seafood Science and Innovation Group (SSIG) will be established to provide the thinking space to deliver on these commitments, reviewing areas of academic research and assessing their practical application to industry challenges. The SSIG will *"facilitate an inclusive approach for the seafood sector, ensuring that research is co-*

designed and co-produced, with public and private funds targeted to areas of greatest good, and that research is both relevant and accessible across the supply chain".

How does industry's self-sampling initiative tie in with Scottish Marine Strategy and wider perspectives?

Since Brexit has changed the policy landscape, there have been no recent policy documents to indicate future directions on science and management in Scotland (Marine Scotland, 2017). Nevertheless, the most recent documents (Scotland's National Marine Plan (Scottish Government, 2015) and the Scottish Marine Science Strategy 2010-2015 (Scottish Government, 2011), show that industry's initiative could serve to facilitate Scottish strategic objectives for the marine environment by providing information to support a number of policy objectives that are of mutual importance:

(from Scotland National Marine Plan, 2015)

Objective 2: A fishing fleet which is seen as an exemplar in global sustainable fishing practices, is confident in securing a long-term income from the available sustainable fishing opportunities across all sectors, and **accounts for changes in species distribution and abundance due to climate change**.

Objective 7: An evidence-based approach to fisheries management which is underpinned by a responsible use of sound science and is **supported by the whole sector.**

Objective 8: Tackle discarding through **the avoidance of unwanted catches** and the implementation of the EU's obligation to land all catches of quota stocks **in a way which is workable and sensitive to the impacts on fishing practices** both offshore and onshore.

Objective 9: Management of removals rather than landings, **where necessary, through fully documented fisheries**.

Similarly, in defining its priorities for scientific research, The Scottish Marine Science Strategy 2010-2015 (Scottish Government, 2011) provides a welcome recognition that collaborative working with stakeholders is an important part of effective delivery. It states: *"Stakeholders are essential partners in carrying out science effectively. The aquaculture and fishing industries make important resource, expertise and data contributions to collaborative science projects through the Scottish Aquaculture Research Forum (SARF), the Scottish Industry Science Partnership (SISP)* [which evolved into the Fishing Industry Science Alliance (FISA, 2012-2016) and was a catalyst for Fisheries Innovation Scotland 2014-present]*, and the Rivers and Fisheries Trusts of Scotland (RAFTS). In addition, MASTS is a key partner in scientific research. We will work with these and other stakeholders to seek synergies, and to support our science and ensure it is relevant and of high quality".*

What approach is being taken by industry?

The industry's approach is to work in partnership with scientists and managers to ensure that any data they collect and provide has the best chance of being applied as evidence in fisheries management because it is relevant, scientifically credible and trusted by the institutions that use it.

The Scottish Pelagic Fishermen's Association is developing a Data Collection Strategy underpinned by two objectives (Figure 1.1). This report will make an important contribution to the strategy and how to implement it, because it addresses two important questions:

- What information is needed to assess stocks and manage fisheries that industry can provide?
- How can industry and science institutions work together to enable industry self-sampling programmes to deliver scientifically robust, useful and useable data?

The fundamental premise of SPFA's approach is facilitating a shift in fishermen's attitudes from '***have to*** provide data' to '***want to*** provide data'. The reason for this is that *having to* makes it feel like an imposed burden, and there is no ownership. And fishermen see it as enforcement. When fishermen *want to* collect data, they are taking responsibility. Ownership is key; it promotes learning and taking pride in providing information they believe in. In making this shift, any sensitive issues related to fishing practices have to be confronted directly. But if industry is responsible for finding the solutions, they will be more inclined to make that step.

Figure 1.1. High Level Objectives of the SPFA Data Collection Strategy.

1.3 Aims and Objectives of the study

In this project (FIS020), Fisheries Innovation Scotland (FIS) and the SPFA required research that:

- provides advice on the architecture of a pilot study on industry self-sampling in the pelagic sector, the priority information needs that a pilot should address and the requirements necessary to ensure that the data can be used in the ICES arena.
- provides advice on how this architecture can be used as a model for other sectors to address information needs in less data rich situations.

To achieve these aims this project proposed to undertake the following:

1) Identify sources of data that are currently available, but possibly not recorded in a systematic or useable format. This will require developing a data inventory at both the vessel and factory level.

2) Determine and prioritise the information needs for assessment and management of pelagic stocks through engagement with key stakeholders including Marine Scotland, ICES, MSC and the SPFA. This will necessitate ranking priorities for information. It will also establish the industry appetite and capacity to engage with self-sampling.

3) Define the potential amounts of geo-referenced data available from the pelagic industry by describing the spatial and temporal coverage provided by vessels in a normal fishing year and the amount of factory data generated annually through normal sampling activities. This descriptive information will be relevant to defining an appropriate sampling design and determining the 'information value' of on-vessel and factory data collection opportunities.

4) On the basis of 1), 2) and 3) develop a plan for a pilot study or studies for acquiring new data from pelagic vessels and factories through modification of current operational and reporting protocols. This will include:

    - defining factors relating to operational logistics efficiency;
    - identifying any training and education needs that are required to equip industry with the knowhow to make a self-sampling project successful;
    - considering quality assurance;
    - mapping the institutional pathways to ensure any data collected is relevant and useable for its intended purpose.

5) Advise on how self-sampling by the pelagic industry could be used as a model for other sectors to address information needs in less data rich situations.

1.4 Definitions

Industry surveys refer to industry vessels carrying out scientific surveys, initiated and planned either by themselves or in collaboration with other institutions.

Charter surveys refers to industry vessels being chartered out under contract to undertake specified scientific survey activities that are initiated, planned and led by a scientific institution.

Self-sampling on vessels or factories refers to industry members themselves undertaking the collection of scientific data (in whatever form) during the normal process of commercial operations, or during industry surveys.

1.5 Review of self-sampling programmes in other regions

This section reviews selected relevant examples of self-sampling programmes from around the world. Table 1.1. provides a brief description and key attributes to help inform development of the Scottish pelagic self-sampling initiative. For a more detailed description of each programme, we recommend reviewing the references provided.

Most of the reviewed self-sampling examples listed in Table 1.1 focus on demersal or shellfish species, although two successful pelagic programmes have been identified: the Norwegian pelagic reference fleet and the Dutch Pelagic Freezer Trawler Association (PFA). Logistically, these two fisheries operate very differently. PFA vessels fish for pelagic stocks in Europe, West Africa and South Pacific and all their catches are processed and frozen at sea. In contrast, operations of the Norwegian reference fleet more closely resembles that of the Scottish pelagic industry.

These Norwegian and PFA self-sampling programmes started in 2006 and 2015 respectively. They include the collection of haul information, species composition and length samples at haul level, with occasional collection of otoliths in the Norwegian reference fleet. The Norwegian reference fleet was initiated by the Institute Marine Research (IMR), while the Dutch programme was developed by the PFA as an extension of the existing quality control monitoring processes for documenting the catch and determining fish quality for every production batch. Handling and analysis of the self-sampled data lies within the PFA, whereas in the Norwegian reference fleet, scientists from the IMR are responsible.

Both the Norwegian and Dutch self-sampling programmes deliver data that can be used in stock assessment and also informs the fishing industry about their practices. In the Pacific fisheries targeted by the PFA, length compositions of the self-sampled data have been used to provide a more detailed impression of the catches throughout the fishing season, which particularly important given the limited coverage of observer programmes (SPRFMO, 2015, 2016). In the Northeast Atlantic, PFA data has been presented to ICES experts groups and discussion about the potential applications of the data is still ongoing. Self-sampled data from the Norwegian reference fleet is already being combined with other sources of commercial data and delivered to ICES for use in stock assessment. Self-sampled data from the Norwegian reference fleets has enhanced the precision of commercial catch data by increasing the spatiotemporal resolution and the amount of information (IMR 2016, Pastoors & Quirijns 2017) in a cost-effective manner. Fishermen have also provided estimates of discards and observation of species rarely covered during research surveys. These programmes have also facilitated the inclusion of fisherman knowledge in the sampling design and improved the communication with scientists.

The Norwegian reference fleet is self-financed by the allocation of a minor part of the fish quotas for research purposes. The vessel owner gets 50–60% of the quota value to cover the vessel's expenses in catching, producing and selling the fish. The other 40–50% covers the administration and running costs, and payment to the fishermen to take biological samples and data collection according to protocol.

Besides the two pelagic self-sampling programmes described above, Table 1.1 lists five different self-sampling schemes, of which the design, purpose and objectives vary greatly. In all cases, definition of clear quality control and quality assurance protocols that guarantee the validity of the data collected is regarded as one of the most important aspects to ensure the long-term success of self-sampling programmes. Self-sampled data in New Zealand fisheries is evaluated following the criteria for quality standards defined by the Ministry of Fisheries (Ministry of Fisheries 2011) and ranked according to different levels. Norwegian reference fleet data is cross-checked against other sources of fisheries-dependent data including satellite Vessel Monitoring Systems to assess the spatial/temporal representativeness of the reference fleet and electronic logbooks and observer programmes to check that sampling is conducted independently of catch size (IMR 2016). In the USA groundfish example, data is audited after every trip by scientists from the School for Marine Science and Technology (SMAST) (Roman et al. 2011). In several of the programmes, observers go on-board vessels at least once a year to ensure that all the equipment works correctly and that self-sampling protocols are implemented thoroughly (Hoare et al. 2011, IMR 2016, Lordan et al. 2011). Training for the collection of biological data is provided in most programs to the crew or the person responsible for the data collection (e.g. quality manager in the PFA example) (Pastoors & Quirijns 2017). Programmes which have been running for long periods of time (e.g. Norwegian self-sample reference fleet), deliver periodic workshops to ensure that sampling protocols are updated and implemented appropriately (IMR 2016). These examples emphasize the importance of well-thought-out project designs that define clear protocols for sampling as well as data handling, quality assurance and application in scientific arenas.

The success of self-sampling schemes in fisheries that operate over vast areas, using different gears and targeting different stocks relies on an adequate selection of vessels to ensure representativeness of the fleet. Because participation in self-sampling programmes is mostly voluntary, the limited number of vessels in the Norwegian reference fleet (IMR 2016) and some New Zealand fisheries (Ministry of Fisheries 2011, Starr 2010) raised concerns about the representativeness of the data considering the number of different metiers. These concerns emphasize the importance of establishing sampling designs that optimise the sampling effort required by the fisherman to ensure the necessary statistical representativeness and precision required for the defined applications. Since fish caught at a similar time and location can be similar (but aren't always), engaging a diverse range of vessels from different metiers is considered the best way to get a representative sample of the whole catch and reduce biases in fisheries data (Helle & Pennington 2004, Pennington & Helle, 2011). Depending on the application, involving many vessels can therefore result in lower levels of sampling required for any one vessel. This strategy is regarded as the most effective way to maintain precision levels while reducing sample sizes (Pennington & Volstad 1994).

Early development of appropriate communication channels for feedback and discussion has been shown to be a key aspect to ensure the long-term success of self-sampling programmes. Clear expectations and understanding of the level of commitment to self-sampling programmes have to be set and discussed with the industry at early stages (Kraan et al. 2013). In New Zealand's early experience of self-sampling in inshore demersal fisheries, the lack of opportunities for scientists and fishermen to discuss progress and results was believed to be responsible for the failure to maintain high levels of participation (Starr 2010).

Depending on the drivers for self-sampling and who initiates it, incentives for participants can be important to maintain sufficient activity of self-sampling programmes. Funding sources for the self-sampling programmes listed in Table 1.1 include direct payment for sampling supported by scientific/national government bodies, access to additional quota associated with the research, and self-investment from the industry. Discussion on options for funding self-sampling programmes should be held between industry and relevant management and scientific institutions, and take into consideration that needs may change over time due to modifications in regulations, management strategies and stock size.

Table 1.1. Table listing self-sampling programmes and details relevant for each programme. Sources of information: Norway (IMR 2016, Michael Pennington & Helle 2011), Netherlands (Pastoors & Quirijns 2017, SPRFMO 2016), Ireland (Hoare et al. 2011, ICES, 2007b, Lordan et al. 2011), New Zealand (Ministry of Fisheries 2011, Starr 2010, Sykes 2014, Trident Systems, Mackinson and Middleton 2018), USA (ICES 2007b, Roman et al. 2011).

	Norwegian self-sampling reference fleet	**Dutch Pelagic Freezer-trawler Association**	**Irish *Nephrops* self-sampling**	**New Zealand Rock Lobster and Paua**	**North Eastern USA SMAST reference fleet groundfish self-sampling**	**Norwegian self-sampling reference fleet**	**New Zealand demersal fish**
Target fleet	Pelagic	Pelagic	*Nephrops* fleet	Lobster and Paua fisheries	Groundfish fishery	Demersal	Demersal inshore
Years	2006-ongoing	2015-ongoing	1970-ongoing	1993-ongoing (depending on area)	2000-ongoing	2000-ongoing	Previous - Adaptive Management Program (AMP) from 1994. Current - Trident Systems Limited Partnership from 2012
Number of vessels	~14	16	Varies in time and area	Varies according to management area	~20	31	Varies according to management area
Drivers for data collection	Improvement of catch data and stocks assessment	Improvement of catch data and stock assessment. Industry responsibility.	High levels of unsorted landings	Historically data-poor fisheries Limited resources for data collection Industry able to provide high resolution, better quality data	Improvements of commercial catch spatial/temporal resolution Industry engagement in data-collection/management	Improvement of commercial catch data and stock assessment	Improvement of biological data for stock assessment. Sampling in a way that is more sympathetic to industry processes and more cost-effective.

	Norwegian self-sampling reference fleet	Dutch Pelagic Freezer-trawler Association	Irish *Nephrops* self-sampling	New Zealand Rock Lobster and Paua	North Eastern USA SMAST reference fleet groundfish self-sampling	Norwegian self-sampling reference fleet	New Zealand demersal fish
Target data	Length measurements at haul level of commercial species. Occasional collection of otoliths, stomachs and tissue	Haul information (incl. environmental variables) and fishing effort, species compositions and length samples	Catch, numbers, lengths, weights and discard ogives mostly processed at sea	Length measurements from certain pots within a haul. Sex and maturity for females	Catch (including discards), effort, weight, length and environmental (temperature, depth) data at haul level	Length measurements at haul level of commercial species. Occasional collection of otoliths, stomachs and tissue	Specific D species are measured, sex and otoliths collected
Initiator	Scientists (IMR)	Industry	Industry	Industry/Science	Scientist/Industry	Scientists (IMR)	Industry/ Science
Incentives	Scientific quota allocation	To be providers of marine data on pelagic fish	Direct payments for samples	Registered Research Provider Direct payments for samples (L&P) Quota increase	Direct payments for samples and penalizations for poor data-quality	Payment for scientific work and joint planning of research. Previously – allocation of scientific quota	Registered Research Provider sub-contracted by NIWA to coordinate catch sampling Payment for samples

	Norwegian self-sampling reference fleet	Dutch Pelagic Freezer-trawler Association	Irish *Nephrops* self-sampling	New Zealand Rock Lobster and Paua	North Eastern USA SMAST reference fleet groundfish self-sampling	Norwegian self-sampling reference fleet	New Zealand demersal fish
Training/ QA/ QC	Collection of biological samples Annual meetings with vessels owners and crew/Workshops Spatial and temporal representativeness Observers as QC in certain trips	Quality manager originally aimed at monitoring the sales process is now responsible of self-sampling data	Observers in selected trips as QC	Data QC based on MPI Research Science and Information Standards [1] Training provided on sampling biological data collection	Data collected by fishermen are compared against other fishery-dependent data (e.g. observers) Observers in selected trips	Collection of biological samples Annual meetings with vessels owners and crew/Workshops Spatial and temporal representativeness Observers as QC in certain trips	Data QC based on MPI Research Science and Information Standards[1] Fishers are trained to measure species and otolith collection NIWA involved in training and protocol development plus QC
Outcomes	Higher spatial and temporal coverage for increased precision Information of discards and rare species Inclusion of fisherman knowledge	Sustainable and reliable data Increased sampling levels for certain fisheries Cost-effective	Reliable data collected over a long period Increased sampling levels compared to traditional methods Cost-effective	High-quality data collected used for stock assessment and management decisions	Increase in the quantity, quality (precision) and resolution of fisheries dependent data compared to traditional sources	Higher spatial and temporal coverage for increased precision Information of discards and rare species	High-quality data collected for several species used for stock assessment and management decisions

[1] Ministry for Primary Industries. 2011. Research Science and Information Standard for New Zealand Fisheries.

	Norwegian self-sampling reference fleet	Dutch Pelagic Freezer-trawler Association	Irish *Nephrops* self-sampling	New Zealand Rock Lobster and Paua	North Eastern USA SMAST reference fleet groundfish self-sampling	Norwegian self-sampling reference fleet	New Zealand demersal fish
Limitations/ Concerns	Too few vessels in certain metiers/areas and seasons	Uptake of data in stock assessment arena?	Limited representativeness of certain areas/stocks Certain samples might be biased (Uncommon)	Limited participation for some areas over the long term Need to maintain level of commitment to industry Required supervision for success	Need to identify possible sources of biases including small sample sizes, vessel representativeness, and compensation issue	Too few vessels in certain metiers/areas and seasons	AMP had difficulties to maintain good coverage over the long term and fail to communicate level of commitment to industry. Poor communication. Trident – collaboration with govt science not always easy. Govt partnership approaches with industry remain sensitive to possible conflict of interest
Used in assessment?	Yes	Yes in relation to SPRFMO science)	Yes	Yes	No (but potential to do so)	Yes	Yes

2 Suitability of the Scottish pelagic industry to self-sampling

2.1 Characteristics of Scottish pelagic fisheries and target stocks

The main catching component[2] of the Scottish Pelagic industry consists of 21 vessels grouped in 3 harbours across Scotland Fraserburgh, Peterhead and Shetland (Figure 2.1). Vessels range from 38-87m overall length and include some of the most modern and technologically equipped ships of the Scottish fleet, with capacity for catches up to 3,200 tonnes. Pelagic trawl is the main gear, with three vessels also equipped for purse seining. Catches are generally landed in Scotland, Norway, Ireland, or Denmark depending on the fishery (Table 2.1). The five Scottish pelagic factories are: Lunar Freezing, North Bay Pelagic, Denholm Seafoods Limited and Pelagia Shetland (Figure 2.2).

[2] In addition to the large pelagic vessels, a small inshore fleet mainly catching mackerel by handline also exists.

Figure 2.1. Scottish pelagic fleet

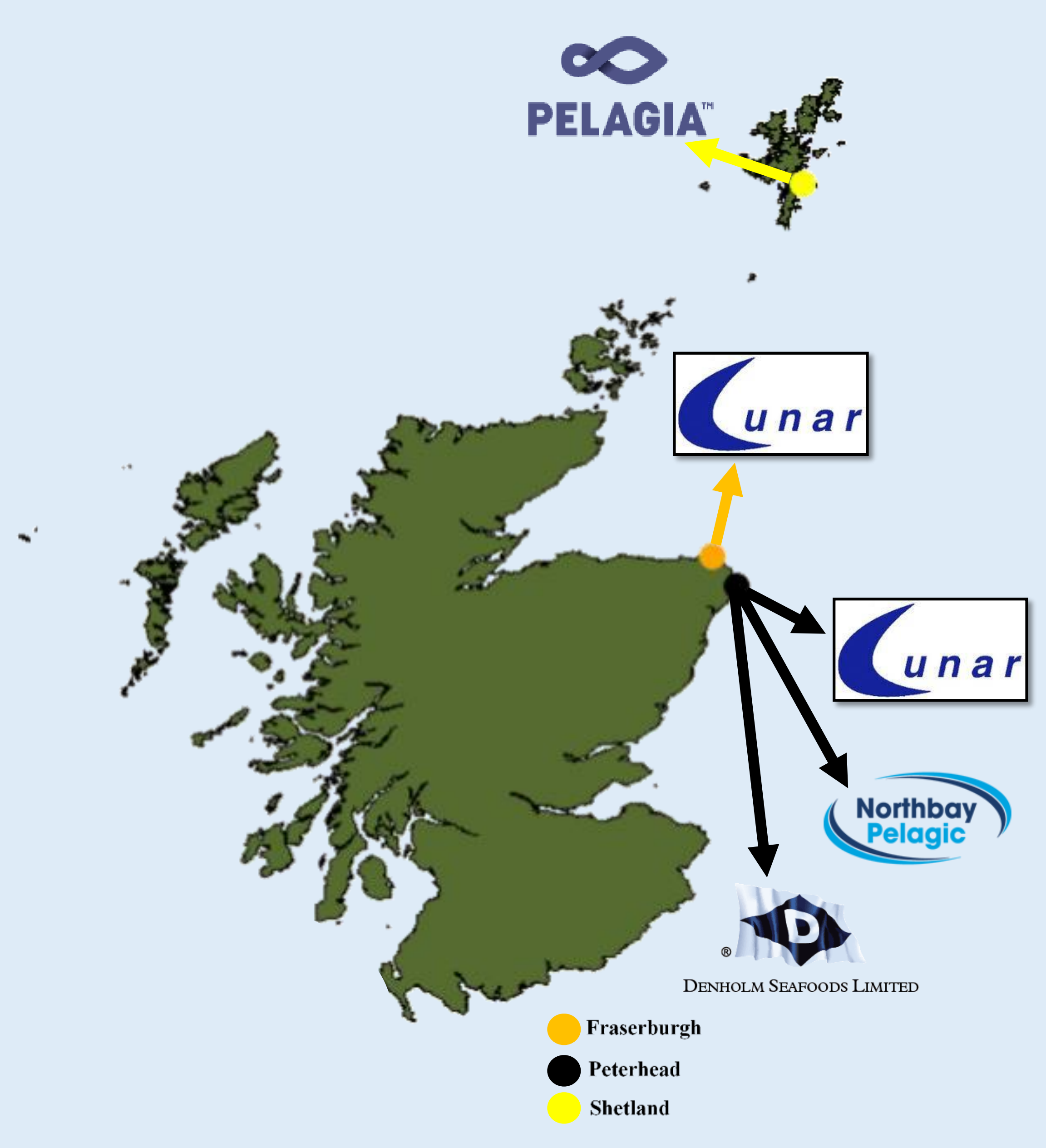

Figure 2.2. Pelagic factories

Principal stocks targeted include mackerel, North Sea herring and blue whiting, accounting in 2017 for 69%, 70% and 95% of the total UK quota respectively (Table 2.1). Western herring, Atlanto-Scandian herring and horse mackerel are also important stocks, while boarfish, sandeels or sprats are of minor importance with only a few vessels having quota. Mackerel is the most valuable species, accounting for 30% of the total value of all Scottish landings (Scottish Government, 2017).

Due to migratory patterns of pelagic stocks, fisheries tend to be separated in space and time (ICES, 2005, 2007a), resulting in different fishing periods throughout the year (Figures 2.3a-2.5a). Mackerel catches occur around Northern North Sea (ICES div 4.a) in October-November and West of Scotland (ICES div 6.a) in January-February (Figure 2.3b). North Sea herring is fished from July-September around Shetland and the northern

North Sea. Blue whiting are taken offshore on the shelf edge running from Ireland to the West of Scotland in March and April.

The distribution of pelagics recorded in international scientific surveys that take place around the same time as the principal fishing months (Figure 2.3b- 2.5b) gives an impression (albeit incomplete) of the wider distribution of stocks during that time. In the case of mackerel, the International Bottom Trawl Survey (IBTS) operating in the same waters as Scottish fisheries records similar areas of concentration on the West of Scotland in Jan-Feb. However, the absence of surveys in Oct-Nov (Q4) in the North Sea (ICES div IVa) highlights an apparent mismatch between what Scottish fishermen and scientists see. This is a source of frustration for fishermen who intuitively feel that scientific surveys should see the same thing as they do. This frustration is one of the drivers for the industry engaging in self-sampling – so they can provide evidence on the distribution of fish when they see it. In this case however, it is important to note that the IBTS surveys included in this comparison are designed principally for groundfish, with mackerel being caught in a mixed assemblage, and only the abundance of juvenile (0-1 year old) mackerel recorded by the IBTS survey is used in the mackerel stock assessment. An abundance index for adult mackerel is determined from a scientific survey using pelagic trawls that takes place earlier in the year when the mackerel are more widely distributed on their feeding grounds in the Nordic seas. This survey is known as the International Ecosystem Summer Survey of the Nordic Seas (IESSNS).

In the case of herring, the internationally coordinated acoustic survey for herring takes place in June-July during the early period of the fishery shows a good correspondence with the distribution of reported catches from July-Sept. Similarly for blue whiting, the acoustic trawl survey, which occurs at the same time as the fishery shows the concentration of fish along the shelf edge but also reveals a much wider distribution area at that time.

All of the major pelagic stocks are classified by ICES as Category 1 - Data rich, meaning that they have full analytical stock assessments and forecasts models that are used to provide advice on catch opportunities (see Box 1 and ICES, 2017b, 2017d, 2017g). Routine collection on data on landings, length, maturity, weight and age-composition is conducted by National marine laboratories in accordance with the requirement of the EU Data Collection Framework (European Commission, 2017). Subsequent sections of this report look closely at the level of sampling, the information it yields and where there are gaps or opportunities for improvement that might be serviced by industry self-sampling.

Box 1. ICES Categories of data availability and quality

ICES uses six categories (Figure B 1) to classify stocks according to the availability and quality of data required to assess their status. Category one stocks are data-rich, with a full analytical assessment, and include all the pelagic stocks targeted by Scottish fisheries and the main demersal stocks in the North Sea (haddock, cod, whiting, saithe). Category 2-6 stocks are referred to as Data Limited (DLS). Data Limited stocks includes those species for which there is an established TAC but lack of data and knowledge imply that more precautionary approaches are used set TACs (cat 2-4) and those for which no TAC is established (cat 5-6) (ICES, 2015).

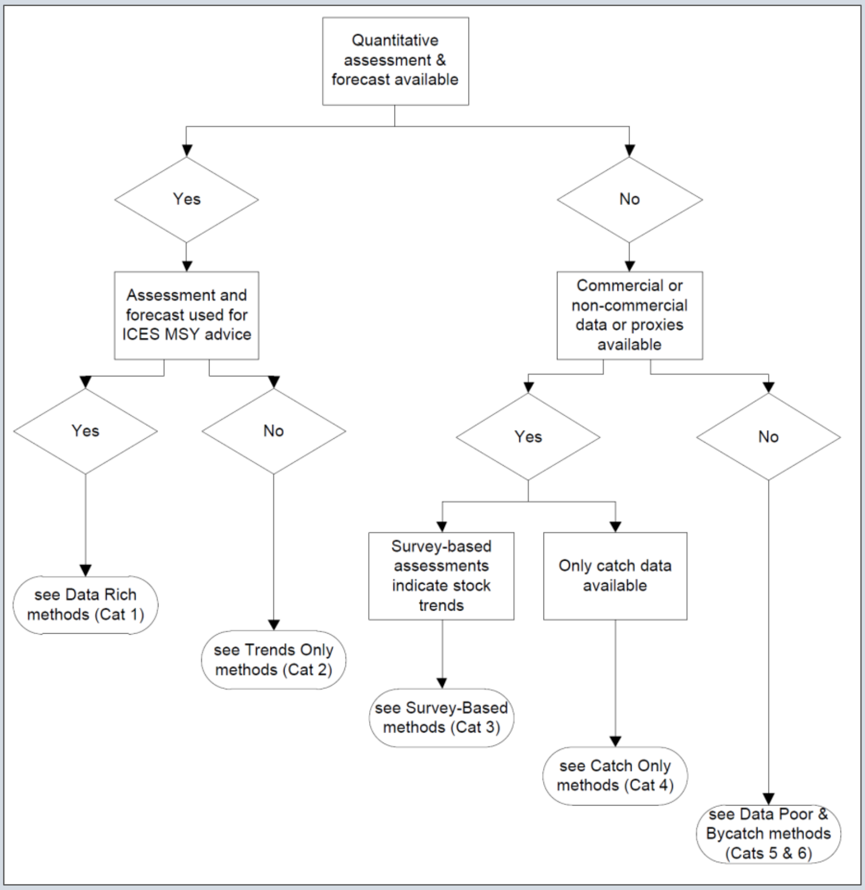

Figure B1. Overview of categories of ICES assessment types for data-rich (Category 1) and the data-limited stocks (DLS) (Categories 2–6). The availability of high quality data and proxies for the assessments decreases and the precautionary approach increases from left to right. (From ICES DLS guidance (ICES 2015).

Table 2.1. Scottish quota of principal pelagic species.

Stock	Year	TAC	UK Quota (% UK share)	Scotland Quota	Scotland % of UK quota	% Scottish landings abroad*[1]
Mackerel II(excl EU, Ice),Vb, VI, VII, VIII(excl c), XII(intl) & XIVb(intl)  ***Fishery:*** January-February (Q1) October-November (Q4)	**2014**	1,240,000	288,666 (23%)	200,120	71%	43.42% (NOR) 5.05% (DNK) 1.20% (IRE)
	2015	1,054,000	245,363 (23%)	171,648	71%	50.83% (NOR) 3.58% (DNK) 1.89% (IRE)
	2016	895,000	208,556 (23%)	153,915	75%	43.00% (NOR) 4.82% (DNK) 1.20% (IRE)
	2017	1,024,996	224,019 (22%)	154,175	69%	49.80% (NOR) 2..22% (DNK) 0.84% (IRE)
	2018	816,797	187,067 (23%)	128,013	68%	Not yet available
Herring IVa & IVb*  ***Fishery:*** July-August-September (Q3)	**2014**	470037	70,229 (15%)	44,962	68%	42.51% (NOR) 4.31% (DNK)
	2015	445329	66,964 (15.%)	47,329	71%	32.33% (NOR) 13.05% (DNK)
	2016	518242	75,894 (15%)	56,531	80%	44.74% (NOR) 4.77% (DNK)
	2017	481608	71,407 (15%)	49,900	70%	34.85% (NOR) 0.02% (DNK) 3.31% (IRE)
	2018	600588	81,685 (14%)	52,865	65%	Not yet available
Blue Whiting I-VIII, XII & XIV  ***Fishery:*** February-March (Q1) April (Q2)	**2014**	1,200,000	36751 (3%)	25,996	91%	48% (DNK) 15.02% (IRE)
	2015	1,260,000	39,065 (3%)	32,929	96%	31% (DNK) 26.80% (IRE)
	2016	776,391	41,137 (5%)	36,638	88%	42% (DNK) 25.30% (IRE)
	2017	1,343,330	68,119 (6%)	64,660	95%	26% (DNK) 52.27% (IRE)
	2018	1,387,872	75,545 (6%)	68,518	91%	Not yet available

Stock	Year	TAC	UK Quota (% UK share)	Scotland Quota	Scotland % of UK quota	% Scottish landings abroad
Herring **Vb (EU), VIa (North) & VIb**  ***Fishery:*** July-August-September (Q3)	**2014**	28,067	16,959 (60%)	12,228	72%	Included with North Sea herring
	2015	22,690	13,711 (60%)	10,298	75%	Included with North Sea herring
	2016	5,840	NA	NA	NA	NA
	2017	5,840	NA	NA	NA	NA
	2018	5,840	NA	NA	NA	NA
MINOR PELAGIC STOCKS (to Scotland)						
Horse Mackerel **IIa, IVa, Vb, VI, VII (excl d), VIII (excl c), XII (intl) & XIVb (intl)**  ***Fishery:*** February-March (Q1) April (Q2)	**2014**	116,912	10,458 (9%)	1,337	13%	-
	2015	85,732	5,508 (6%)	737	13%	-
	2016	106,721	8,077 (8%)	1,890	23%	-
	2017	95,500	3,781 (4%)	892	24%	-
	2018	101070	9,167 (9%)	1,879	21%	-
Horse Mackerel **IVb, IVc & VIId**  ***Fishery:*** February-March (Q1) April (Q2)	**2014**	31,720	5,236 (17%)	645	12%	-
	2015	15,200	5,314 (35%)	30	0.57%	-
	2016	15,200	5,715 (38%)	34	0.59%	-
	2017	18,247	5,134 (28%)	101	2%	-
	2018	15,179	1,916 (13%)	302	16%	-

Stock	Year	TAC	UK Quota (% UK share)	Scotland Quota	Scotland % of UK quota	% Scottish landings abroad
Atlanto-Scandian Herring I, II  ***Fishery:*** July-August-September (Q3)	**2014**	418,487	5968 (1%)	4,233	71%	-
	2015	Not established	4036	0	0%	-
	2016	316,876	4,519 (1%)	3,900	86%	-
	2017	646,075	9,213 (1%)	**-**	-	-
	2018	435,000	6,203 (1%)	**-**	-	-

*From 2016 onwards, quota for Herring stock Vb (EU), VIa (North) & VIb is limited as scientific monitoring TAC only.

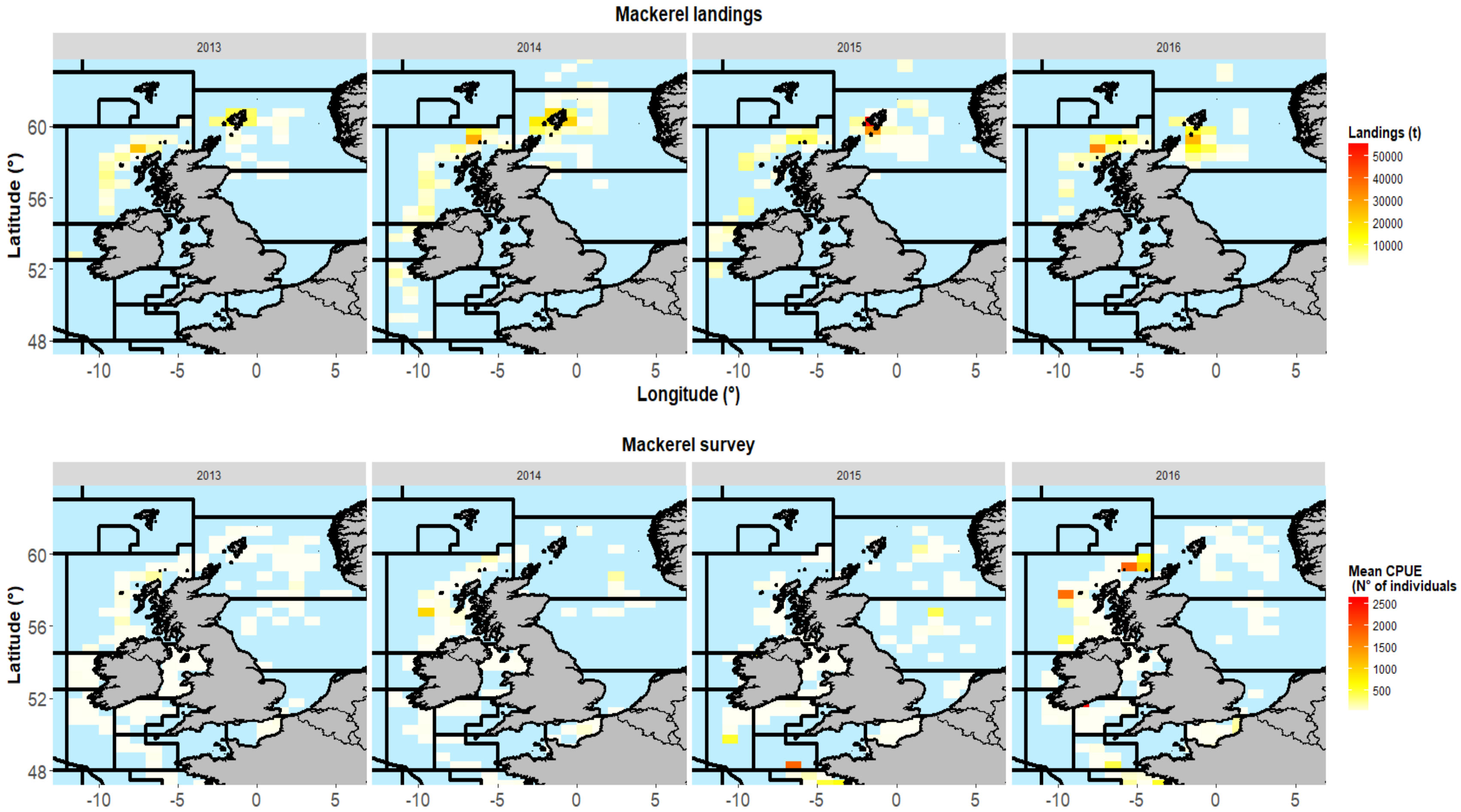

Figure 2.3. (a) upper panel: Mackerel landings from the Scottish pelagic fleet as landed weight (t) per ICES statistical rectangle from 2013-2015, and **(b)** lower panel: Survey data as mean CPUE (number of individuals caught) per ICES statistical rectangle. Landings data from the online data dissemination repository of STEFC. Survey data obtained from the DATRAS ICES repository includes values from Scottish West Coast Survey (Feb, Nov), North Sea International Bottom Trawl Survey (Jan, Feb), Irish Ground Fish Survey (Oct, Nov), Northern Ireland Ground Fish Survey (Oct), French Channel Ground Fish Survey (Oct), French Southern Atlantic Bottom Trawl Survey (Oct, Nov), Spanish North Coast Bottom Trawl Survey (Oct), Spanish Gulf of Cadiz Bottom Trawl Survey (Feb, Nov), Portuguese International Bottom Trawl Survey (Oct).

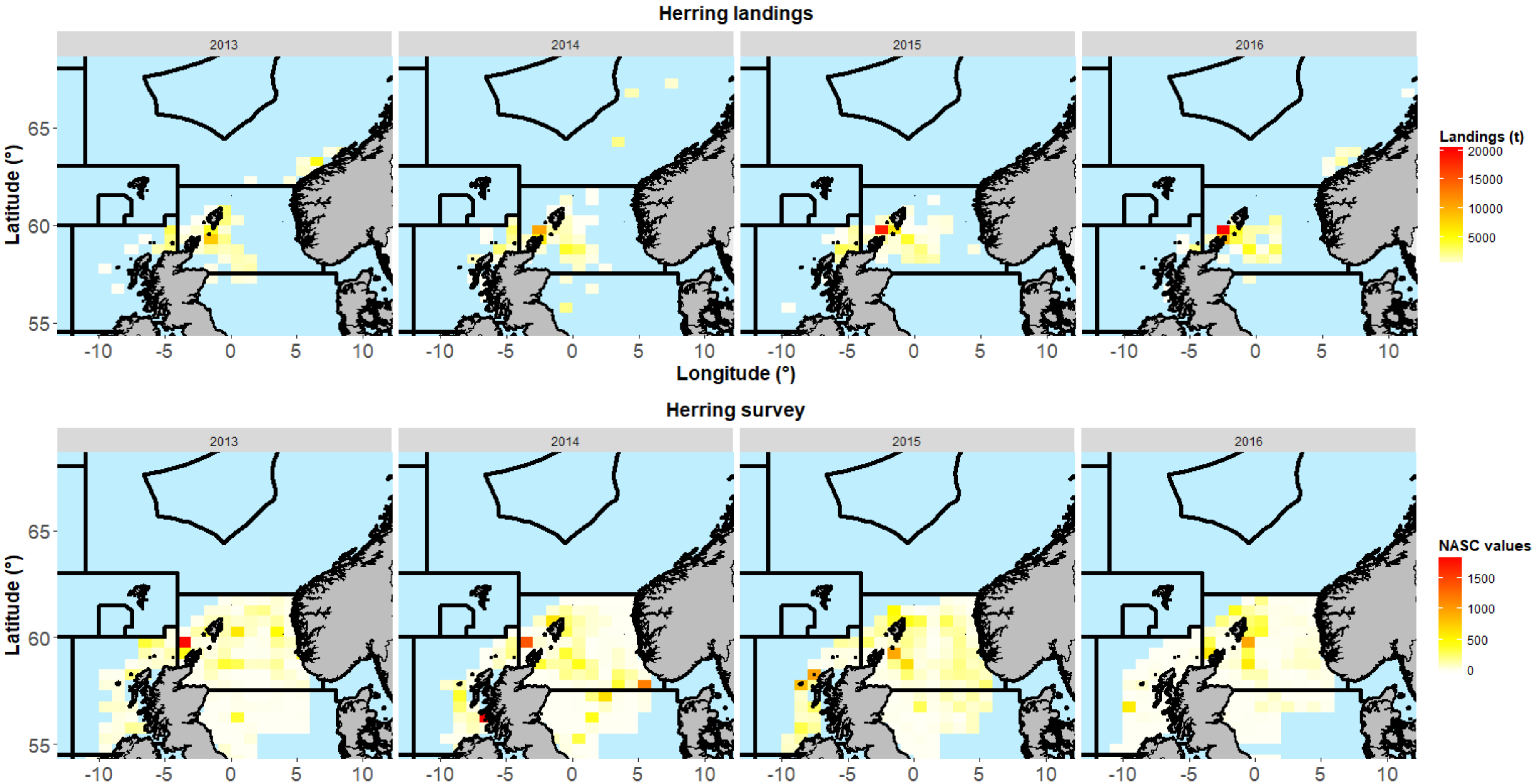

Figure 2.4. upper panel: **(a)** Herring landings from the Scottish pelagic fleet as landed weight (t) per ICES statistical rectangle from 2013-2015 and lower panel: **(b)** International herring acoustic survey (HERAS) data as mean Nautical Area Scattering Coefficient values (NASC) (m^2/nmi^2). Landings data from the online data dissemination repository of STEFC. Acoustic data obtained from ICES acoustic trawl survey data repository and requested directly from participating countries. Data covers surveys in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area from June- July.

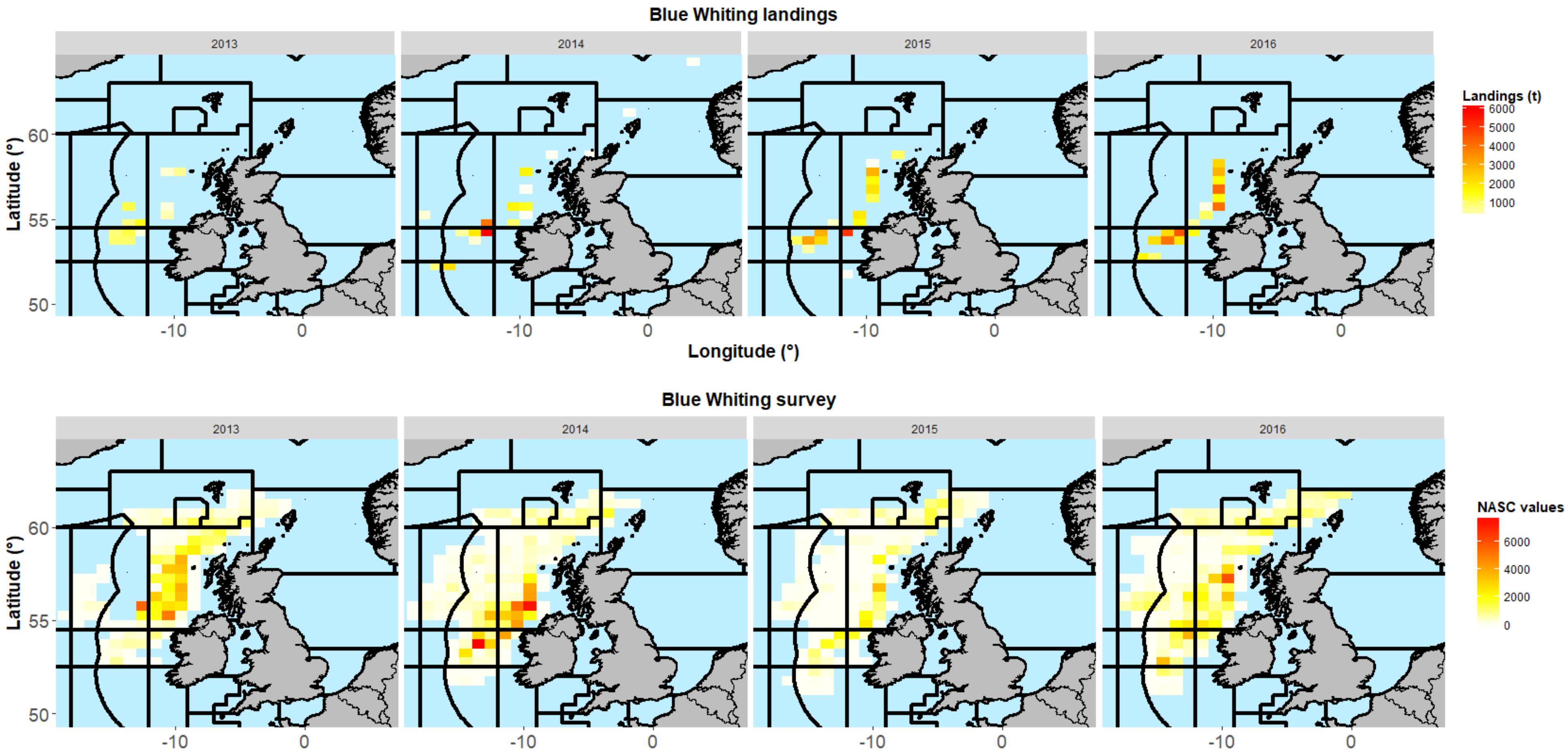

Figure 2.5. upper panel: **(a)** Blue whiting landings from the Scottish pelagic fleet as landed weight (t) per ICES statistical rectangle from 2013-2015, and lower panel: **(b)** International blue whiting spawning stock survey (IBWSS) acoustic survey data as mean Nautical Area Scattering Coefficient values (NASC) (m^2/nmi^2). Landings data from the online data dissemination repository of STEFC. Acoustic survey data obtained from ICES acoustic trawl survey data repository and requested directly from participating countries.

2.2 Existing data collection by the Scottish Pelagic Industry

Scottish pelagic vessels and factories routinely record information on their catches and operations. Assessing opportunities to make these industry data useful and useable in scientific and management arenas requires an understanding of what is currently done, and how established operational systems can be evolved to efficiently provide high quality information.

Before focussing on the opportunities for new data collection initiatives through self-sampling, this section briefly considers available historical data and discusses the opportunities and challenges it presents. The foundation for this section is the detailed data inventory for the pelagic fleet and factories which is given in Appendix 1.

Vessel information

Scottish pelagic vessels keep detailed records about their fishing operations using two main formats: paper diaries and plotter devices. Information stored includes date, time and location of catches, fishing tracks, and in some cases environmental and biological information.

In much the same way as spatial information from Vessel Monitoring Systems (VMS), and Electronic Logbook Software Systems (ELSS) have been previously used to assess patterns of stock and fishery dynamics (Quirijns et al. 2008) and develop estimates of fishing pressure (Piet et al. 2007, Lee et al. 2010), vessel records on the locations and duration of fishing activity can be used to reveal changes in pelagic fishing effort. It is also directly relevant to debates on the implications of zonal attachment for managing fishing access agreements in UK waters during Brexit negotiations. In the demersal sector, spatial data from the industry has been used to develop near real-time models of bycatch hotspots (Little et al., 2015; Marshall et al., 2017).

Compared to other fisheries-dependent sources of data, paper diaries and plotter devices present several advantages. For example, while VMS has revolutionized the study of fishing effort distribution, the challenges of assigning vessel activity to VMS records, combined with the need to assign catches that are reported on ELSS, at the level of ICES statistical rectangles, with VMS locations is technically difficult (Lee et al. 2010) and requires assuming the catch is distributed evenly over the VMS-defined fishing positions. This ends up in a loss of precision (Gerritsen & Lordan, 2011). Furthermore, in the case of pelagic fisheries, fishing activity can frequently take less than 2h, which is the minimum time frame for recording VMS data. Paper diaries and plotter devices on the other hand, include all the information currently being collected in VMS and ELSS separately, and direct communication with skippers is possible to solve any mistakes or errors in the data.

Nevertheless, it is important to consider the limitations of these industry sources of information. Skippers keep information in their paper diaries (some back to 1970s) using different formats based on their personal preferences (Figure 2.6). This means that significant effort would be required to standardise information across vessels and digitalize it for later analysis. Compared to paper diaries, plotter systems have the advantage of data being available in electronic form already (Figure 2.7), but there are challenges in accessing proprietary formats and rendering data from different systems mutually compatible. Doing so would require services of the electronic engineering companies that supply the software and have experience in data handling. Furthermore, plotter data rarely provide all the information required to get the full picture of fishing activity, so it's necessary to integrate it with other sources of information on catches. The resource requirements for such standardisation and harmonisation is considerable, thus developments in efficient electronic recording systems that support self-sampling are an important future priority.

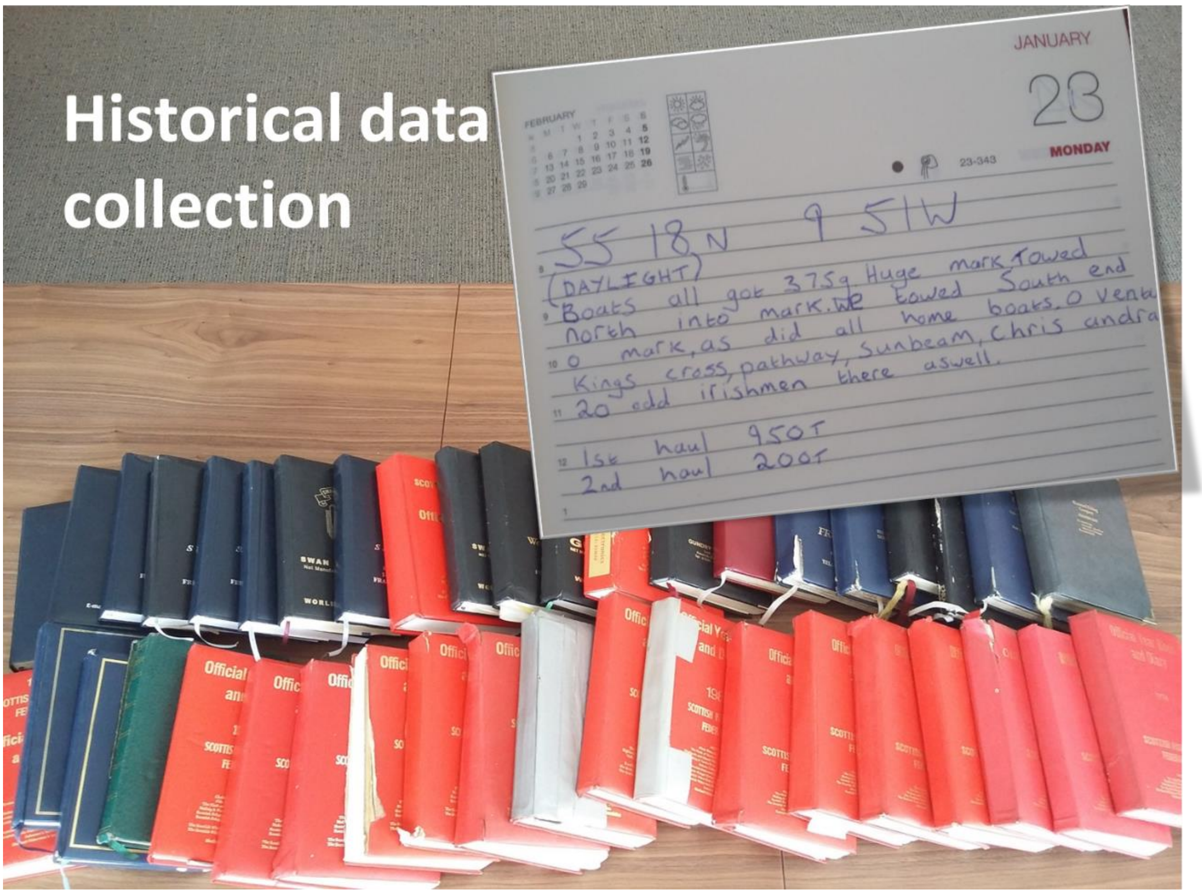

Figure 2.6. "Old school" and reliable recording of pelagic fishing activities back to 1970s.

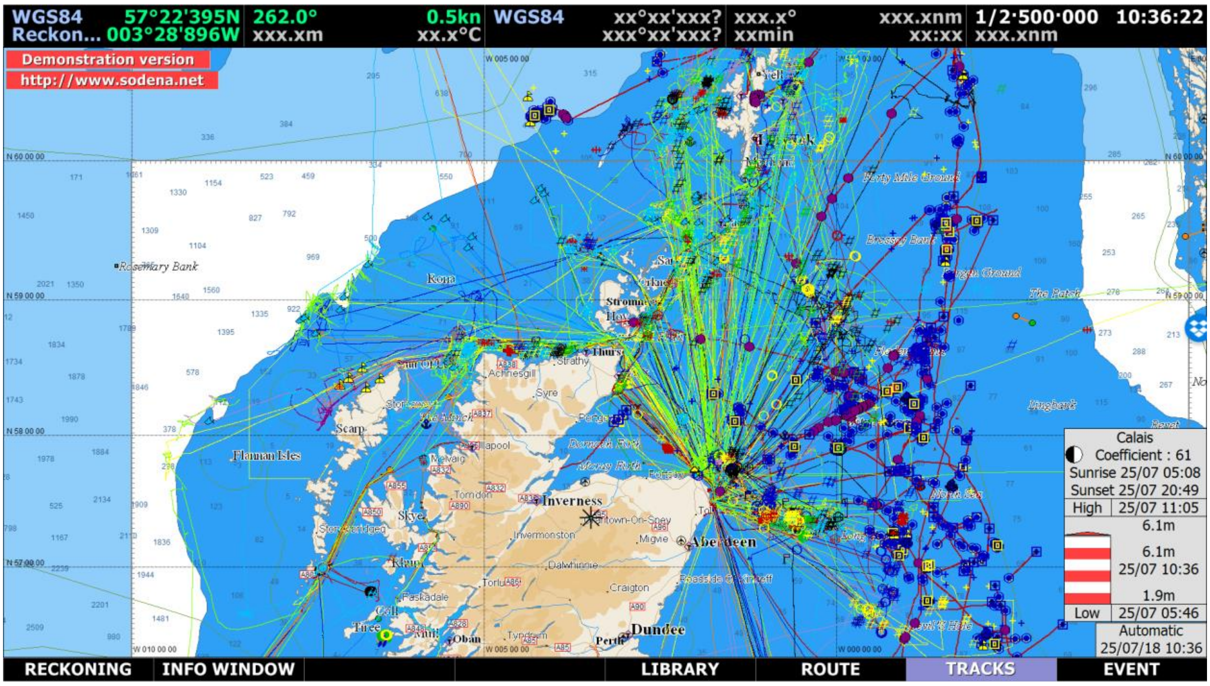

Figure 2.7. Snapshot of the type of data available from plotter recording of fishing activities

Factory information

In addition to detailed sampling of the individual weights of fish in the catch (Figure 2.8), pelagic factories record several attributes related to food quality and hygiene (see Appendix 1 for details). One of these is fat content (Figure 2.9), which is known to be an important indicator of changes in productivity of the marine environment in which pelagic fish feed. As major consumers of zooplankton in the northern North Sea and Norwegian Sea, mackerel, herring and blue whiting play an important role in linking different trophic levels (Dalpadado et al., 2000; Heino & Godo, 2002; Prokopchuk & Sentyabov, 2006; Zilanov, 1968). During this project, access to factory records on fat data records has been agreed and is now the basis for a PhD project at the University of Aberdeen, beginning in 2018 (Appendix 3).

Scottish pelagic vessels are required to report by species any bycatch greater than 50kg, but vessels are known to have almost negligible bycatch (ICES, 2017h). Significant bycatch occurs only when hauls have a mixture of herring and mackerel, and the landing is separated, processed and recorded against quota. Other species that appear in pelagic hauls, such as haddock and other demersals, generally occur in such low numbers (measured in individuals) that they are not reported by factories. Nevertheless, several pelagic factories noted that quantifying the bycatch would be feasible.

DESCRIPTION	Mackerel		
DATE	2017-10-29	TIME	13:23
NET	157.518	MIN/MAX	0.262 - 0.642
QUANTITY	360	AVERAGE	0.438

<table>
<tr><th>WEIGHTLIMITS</th><th>QTY</th><th>PCT</th><th>NET</th><th>PCT</th><th>SINGLE ITEMS</th></tr>
<tr><td>0.000 - 0.200</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.201 - 0.300</td><td>2</td><td>0.56</td><td>0.557</td><td>0.35</td><td>0.262 | 0.295</td></tr>
<tr><td>0.301 - 0.400</td><td>114</td><td>31.67</td><td>41.657</td><td>26.45</td><td>0.301 | 0.301 | 0.306 | 0.306 | 0.308
0.311 | 0.311 | 0.312 | 0.313 | 0.313
0.313 | 0.318 | 0.321 | 0.325 | 0.329
0.330 | 0.330 | 0.332 | 0.336 | 0.340
0.343 | 0.344 | 0.346 | 0.346 | 0.347
0.347 | 0.348 | 0.349 | 0.350 | 0.352
0.353 | 0.353 | 0.353 | 0.355 | 0.355
0.356 | 0.358 | 0.359 | 0.360 | 0.361
0.361 | 0.361 | 0.361 | 0.362 | 0.363
0.365 | 0.365 | 0.366 | 0.366 | 0.368
0.369 | 0.369 | 0.370 | 0.371 | 0.371
0.371 | 0.371 | 0.372 | 0.373 | 0.373
0.373 | 0.374 | 0.374 | 0.378 | 0.379
0.379 | 0.379 | 0.380 | 0.380 | 0.380
0.380 | 0.380 | 0.380 | 0.381 | 0.382
0.382 | 0.383 | 0.383 | 0.383 | 0.384
0.384 | 0.384 | 0.385 | 0.385 | 0.386
0.386 | 0.386 | 0.386 | 0.387 | 0.387
0.388 | 0.388 | 0.389 | 0.390 | 0.391
0.391 | 0.393 | 0.393 | 0.393 | 0.394
0.394 | 0.394 | 0.395 | 0.396 | 0.396
0.396 | 0.397 | 0.398 | 0.398 | 0.398
0.398 | 0.399 | 0.399 | 0.400</td></tr>
<tr><td>0.401 - 0.500</td><td>177</td><td>49.17</td><td>78.674</td><td>49.95</td><td>0.402 | 0.402 | 0.402 | 0.403 | 0.403
0.404 | 0.404 | 0.404 | 0.404 | 0.404
0.405 | 0.405 | 0.407 | 0.407 | 0.408
0.408 | 0.409 | 0.409 | 0.409 | 0.409
0.409 | 0.410 | 0.411 | 0.411 | 0.412
0.412 | 0.413 | 0.413 | 0.414 | 0.415
0.415 | 0.416 | 0.416 | 0.416 | 0.416
0.416 | 0.417 | 0.418 | 0.419 | 0.419
0.420 | 0.421 | 0.421 | 0.421 | 0.421
0.421 | 0.421 | 0.421 | 0.422 | 0.422
0.423 | 0.423 | 0.423 | 0.424 | 0.424
0.425 | 0.425 | 0.427 | 0.427 | 0.427
0.427 | 0.428 | 0.430 | 0.431 | 0.431
0.432 | 0.432 | 0.432 | 0.433 | 0.433
0.435 | 0.435 | 0.435 | 0.435 | 0.436
0.436 | 0.437 | 0.437 | 0.437 | 0.437
0.438 | 0.438 | 0.439 | 0.439 | 0.439
0.440 | 0.441 | 0.441 | 0.441 | 0.441
0.442 | 0.443 | 0.444 | 0.446 | 0.446
0.447 | 0.448 | 0.448 | 0.448 | 0.448
0.450 | 0.450 | 0.450 | 0.451 | 0.451
0.453 | 0.453 | 0.454 | 0.454 | 0.455
0.456 | 0.456 | 0.457 | 0.459 | 0.459
0.459 | 0.460 | 0.461 | 0.461 | 0.462
0.462 | 0.463 | 0.463 | 0.463 | 0.463
0.463 | 0.464 | 0.464 | 0.464 | 0.465
0.465 | 0.466 | 0.466 | 0.466 | 0.467
0.468 | 0.468 | 0.468 | 0.469 | 0.469
0.469 | 0.472 | 0.473 | 0.474 | 0.474
0.475 | 0.476 | 0.477 | 0.478 | 0.478
0.478 | 0.478 | 0.479 | 0.479 | 0.480
0.481 | 0.481 | 0.482 | 0.483 | 0.483
0.485 | 0.485 | 0.485 | 0.486 | 0.487
0.487 | 0.487 | 0.487 | 0.488 | 0.491
0.491 | 0.493 | 0.494 | 0.494 | 0.495
0.495 | 0.496</td></tr>
<tr><td>0.501 - 0.600</td><td>61</td><td>16.94</td><td>32.903</td><td>20.89</td><td>0.501 | 0.503 | 0.504 | 0.505 | 0.505
0.505 | 0.507 | 0.509 | 0.509 | 0.510
0.510 | 0.510 | 0.511 | 0.511 | 0.511
0.512 | 0.512 | 0.512 | 0.513 | 0.518
0.518 | 0.520 | 0.520 | 0.521 | 0.523
0.523 | 0.524 | 0.524 | 0.525 | 0.526
0.526 | 0.528 | 0.529 | 0.533 | 0.538
0.539 | 0.544 | 0.544 | 0.547 | 0.547
0.551 | 0.552 | 0.554 | 0.559 | 0.564
0.565 | 0.566 | 0.569 | 0.574 | 0.577
0.578 | 0.583 | 0.585 | 0.586 | 0.587
0.593 | 0.593 | 0.596 | 0.596 | 0.598
0.600</td></tr>
<tr><td>0.601 - 1.800</td><td>6</td><td>1.67</td><td>3.727</td><td>2.37</td><td>0.609 | 0.616 | 0.617 | 0.617 | 0.626
0.642</td></tr>
</table>

Figure 2.8. Example quality control weight measurements on box checks

Denholm Seafoods Limited

Fat Analysis

Date	08	01	2018	Production Code	EB	01	M	HH

Belt No.	1	2	3	4	5	6	Size: < 300g
Line No.	front	middle	back	Boxing Line	Filleting Line	VMK No3&4	

Intented Products: 70g+ BUTTERFLY FLAPS

	Sample 1		Sample 2		Sample 3	
Weight of Petri Dish	36.335	g	30.760	g	31.580	g
Weight of Petri Dish + Fish	46.620	g	40.842	g	41.701	g
Weight of Petri Dish + Fish *(after heating)*	40.100	g	34.401	g	35.266	g
Weight of Fish	10.285	g	10.082	g	10.056	g
Water Loss	6.520	g	6.441	g	6.435	g
% Water Loss	63.39	%	63.89	%	63.99	%
% Fat	16.61	%	16.11	%	16.01	%

Average Fat Content = 16 %

Controls

Are the three %Fat values with 10% of each other?

yes ☑

Action

Report sample as having the Average Fat Content % Value.

no ☐

Are two out of the three %Fat values within 1% of each other?

yes ☐

Action

Recalculate the Average Fat Content % Value using these two values only and report.

no ☐

Discard samples and repeat analysis.

Analysis carried out by:

Checked by:

Quality Control/ Assurance Document
Version: 004

Date of Issue: 30/09/2008
Issued by: HACCP TEAM

Figure 2.9. Example fat data sheet

2.3 Utility and applications of industry data

Making the case for industry self-sampling data that supplements the data routinely collected by scientific institutions requires identifying the need for information and exactly how the information can be used.

In the table below, specific applications are identified and ordered in terms of their value in contributing to improvements in scientific and management information needs, and the timescale that they might be expected to make an impact. The order of these would need to be considered in detail for each target species.

Table 2.2. The utility potential of data collected through industry self-sampling (Timescales: short – 1-3 years, medium 2-5 years, long 5-10 years)

Application	Value to science	Time-scale for impact	Data needs
• Improve quality of stock forecast and advice on fishing opportunities	Indicators of year class strength required to improve the estimate of recruitment used in the forward projection. Providing finely resolved (lat, long) spatial information on growth rates.	Short	1. Length and weight composition of catch for every haul by lat, long. OR/AND 2. Acoustic data on fish distribution and size composition.
• Improve quality of age structure in stock assessments	Better precision and reduced bias in the size and age composition of the catch. Improved consistency in tracking year classes should help reduce the year to year variability in stock assessments, which is a key frustration that undermines confidence in stock assessment and the people involved in it. Particularly relevant if surveys are not undertaken annually since it provides another index to track year-to-year changes.	Medium	Same as 1, (plus possible additional otolith samples or use of Length at age key based on otoliths from existing sampling)
• Develop new approaches for stock assessments	Spatially resolved stock assessment models would have the necessary spatial data on size structure and growth rates to improve their performance.	Long	Same as 1.
• Monitor changes in the marine ecosystem	Measures of the length, weight, age, fat content and gonad weight of fish provide condition and growth rate information. This can be linked to environmental variables	Medium to long term	Same as 1, plus 3. For every haul or landing at factory, record the key

	associated with fish catches/ distribution. Changes in growth rate would affect estimates of sustainable fishing rates.		environmental variables such as temperature and depth. 4. Fat content measured across full range of catch sizes
• Indicators of fisheries performance	Estimate the catch per unit effort for every trip, where effort could be the amount of time or distance, or fuel used for fishing.	Medium	5. Measure search effort. E.g Distance sailed to first haul and between multiple hauls taken on the same day (from plotter track data, ideally with link to eLog system). Time could be used as more crude indicator, but not ideal. Combined with 1 gives CPUE.
• Assist planning fisheries independent scientific surveys	Information on spatial distribution and biology could be used to assist in planning independent scientific surveys. For example, to establish the survey boundaries.	Short	Same as 1 & 3, plus 6. Acoustic information on fish distribution 7. Recording marks of fish that are not fished
• Fisheries dependent indices of abundance	Year-round information on relative abundance and spatial distribution could provide auxiliary data to compute relative abundance indices. This might be particularly relevant where scientific surveys cover wide areas or encounter bad weather conditions that compromise the quality of the survey.	Medium to Long	Same as 1 & 3, plus 8. Acoustic information on fish distribution 9. Recording marks of fish that are not fished
• Evidence spatial distribution of fishing fleet to support fishing opportunities decision making.	Data on annual variation and trends in distribution. Particularly relevant in the context of coastal state negotiations.	Short	Same as 1.

• Traceability of catch	Evidence to demonstrate the provenance of the catch – where it was caught and its quality	Short	Same as 1 & 4.
• Evidence environmentally responsible fishing practices	Estimation of the spatial overlap of by-catch with targeted fishing, providing information for real-time monitoring of fishing activities and decisions to fish in other areas. Evidence of avoiding undersized fish and areas where by-catch occurs.	Short to medium	Same as 1 & 7, plus 10. For every haul, record any non-retained by-catch.
• Quality of catch	Suite of metrics to inform on health of fish population (see monitoring marine ecosystem)	Short	11. Same as 4, plus TVBN, Histamines and others
• Evidence of economic efficiency and environmental footprint (carbon)	Trip level data on the economic efficiency of operations. Note: as new vessels replace old, it becomes more important to update efficiency indicators.	Medium	12. Economic indicators including: Fuel usage per trip, costs and landed value.
• Identify the geographical boundaries / separation of stocks and their migrations	Ability to identify stocks and migration patterns – relevant to ecology and management approaches.	Short to medium	13. Genetic samples from catches. For migration studies, with links also to samples taken from tagging programmes.
• Sociological snapshot of the fishing sector	An important factor, not included in most if not all impact assessments, is the resilience of the crews, other workers and communities dependent on fishing. This information would allow policy makers to make better informed decisions with regard to social impacts.	Medium	14. Age profile and professional qualifications of the crews, transferable skills, alternative occupations, etc.

2.4 Motivations and incentives

Following discussions with members of the SPFA, the specific reasons that motivate fishermen to want to engage in collecting relevant scientific information were ranked using a simple relative score system, as given below in brackets, and where a higher number indicates a higher priority.

- **Prospect of zero information and precautionary measures that arise (8)**

In the absence of information necessary to achieve a stock assessment considered to be good quality, the precautionary approach is used in scientific advice and this leads to poor quality advice that is not trusted. This can be mitigated by the industry providing information relevant for stock assessments. A good example is the west of Scotland herring, where the present scientific advice is for a zero TAC, but without any fishery there would be a paucity of information upon which to base future advice. It was clear from industry that no options were being put forward to obtain relevant data, so they needed to step-up to provide it. In short, 'if we don't provide data, no one will'.

- **Evidence of zonal attachment (8)**

Evidence of stock structure and distribution will be at the forefront of future debates on the implications of zonal attachment for managing fishing access agreements in UK waters. Highly resolved spatial information from each vessel haul could be made available to provide that information and evidence track record.

- **Gaining confidence in stock assessments (7)**

The quality and reliability of stock assessments has long been a concern for the fishing industry, often because changes in the scientific advice do not appear to match their perceptions of the changes they observe at sea. This brings in to question the quality and veracity of data sources and how they are used. Concerns grow (and spread) when errors are made in stock assessments, undermining the credibility of the institutions, processes and persons responsible for them. One way to help mitigate this is for industry to get more involved in generating the data used in stock assessment and as evidence for management decisions. Providing data where it is otherwise lacking or improving accuracy and precision (quality) makes a clear and visible connection between fishing activities and assessment. A better understanding of how information is collected, analysed and applied helps to improve confidence.

- **Market access (6)**

Getting involved in data collection for science is a good-news story for the pelagic industry. It is an outward demonstration of its sustainability credentials, which is good for business and good for building the confidence of industry and markets in the assessment and management system. It provides an opportunity to tell a story that goes beyond the benefits of third party sustainability certification schemes.

- **Maximising use of data opportunities (5)**

Industry vessels and factories already collect a high volume of spatially resolved data on fishing activity and biological parameters of their catch. Not making full use of the data and the opportunities for extending it is a woeful waste of the possibilities for improving ecological understanding and assessment of the state of stocks and the marine environment.

- **Watchmen of the sea (5)**

The marine environment changes continuously and the fish that swim it respond likewise. As watchmen of the sea, fishermen observations can serve as early warning indicators of change, such as strong recruitment, shifts in distribution, behaviour and timing of key events. This knowledge is relevant to improve the planning of specific scientific surveys that depend on observing specific events, or stock forecasts that depend upon assumptions about current state. Likewise, they provide a first sight of emerging problems, for example the trends in abundance of hake and its implications for being a choke-species.

- **Reversing the negative narrative (5)**

For all the efforts to improve the sustainability credentials of the fishing industry (e.g. MSC certification, Responsible Fishing Schemes, involvement in research, improvements in compliance), the fishing industry is still plagued by the narrative of irresponsible, short-term, selfish endeavour to catch as much fish as possible despite the environmental consequences. Pro-actively getting involved in data collection and provision of scientific evidence to support advice on sustainable fishing opportunities is a visible demonstration to rebut and reverse such a narrative.

- **Reversing the burden of proof (4)**

Reversing the burden of proof is the idea that industry could take responsibility for providing the data for scientific assessment, replacing the current sampling undertaken by government research institutes. The change in responsibility/ role shifts the burden of proof upon industry to provide evidence that the data it collects meets required standards for quality. The role of government institutes then becomes defining those standards and auditing the data collection procedures and resulting data quality to ensure standards are met. This idea is applied here to data provision, but others apply the concept to self-management. It is akin to the concept of Fully Documented Fisheries, which has widely used in discussions about how industry may take responsibility for documenting their performance in relation to recording of by-catch and discards.

3 Specific self-sampling opportunities

Specific opportunities for data collection by industry self-sampling are summarised for each species in Table 3.1, with supporting justification and discussion in preceding sub-sections.

Table 3.1. Industry sampling opportunities. **Mackerel (*Scomber scombrus*)**

What is currently done?	Assessment or information gaps	Industry opportunities	Solution(s)	How can industry self-sampling data be applied?
BIOLOGICAL DATA ON CATCHES • Market sampling measures lengths and ages in commercial landings, with spatial coverage representing ~98% of Scottish landings. • Data used in age-based analytical stock assessment model (SAM)	• Catch location reported at ICES statistical rectangle, not lat, long • While spatial coverage of sampled catches is high, only 50% of trips are sampled • Significant proportion of landings in foreign countries not sampled, thus relevant biological data is absent. • Individual fish weight information is routinely collected by vessels but rarely stored • Individual fish lengths in commercial catch currently not sampled by vessels	• Reduce variability or any biases in catch biological data by sampling more of the catch and adding information on length and weights, (and possibly maturity) at much finer spatial and temporal scale than currently available • Record fat content and maturation stage	• Record lat, long and ancillary information of every haul • Take biological samples every haul (or every landing)	**Stock assessment:** Biological catch data collected by industry can be used in the same way as current assessment and to in development of spatial assessment models. It can be used to increase accuracy and reduce variability of length-weight relationships and quantify spatial variability. Data on maturity and condition can be used to monitor temporal changes and avoid the need for static assumptions in the assessment model. **Management:** Evidencing distribution of fleet catches and relevance to zonal attachment. Also relevant to management strategies under changing oceanic conditions. (climate change adaptation) **Business:** Fishermen get to see the patterns in their activities. Plus additional evidence for markets on quality, traceability and provenance, thus providing a marketing story. **Ecological research:** Changes in environmental conditions and fish growth

What is currently done?	Assessment or information gaps	Industry opportunities	Solution(s)	How can industry self-sampling data be applied?
SCIENTIFIC SURVEY DATA **<u>Survey data sources:</u>** Triennial egg survey index (1992-2016), IBTS (Q1 & Q4), IESSNS, Tagging. • Triennial mackerel egg survey, sometimes with participation of industry vessels. • IESSNS and tagging data used for estimating adult stock. Information on juveniles from Quarter 1 IBTS survey used for estimating recruitment. • Biological sampling during surveys measures lengths, weights and ages in stock and provides information on growth and maturation	• When stocks are large and widely distributed, the limited resources for scientific surveys make it challenging to get the coverage necessary to assess the age structure and distribution of the stock. And because fisheries target adult fish, catch data cannot provide the necessary information on younger ages.	• Take scientific survey approach to sample the age structure and distribution of the stock more completely.	• Engage in the summer trawl survey below 60 degrees N • Undertake specific surveys to estimate year class strength required for stock forecast	**Stock assessment:** Contribute directly to survey indices used in assessment.
BYCATCH & DISCARD DATA • Estimates of total fish catch is a large source of uncertainty in stock assessment • Bycatch in Scottish pelagic fisheries very low but not routinely recorded. Discard observer trips used to occur on pelagic but now infrequent.	• Bycatch data not provided • Quantity of fish slipped and or released from nets after pumping not known	• Record any non-fish by-catch • Quantify any catches not landed.	• Estimate quantity of discarded catch • Record non-target fish by-catch at factory	**Management:** Data on bycatch & discards for stock assessment and evidence issues for mitigation measures where relevant, e.g. choke species and TEP species issues. **Business:** Evidence responsible fishing practices

Herring (*Clupea harengus*), North sea and Western

What is currently done?	Assessment or information gaps	Industry opportunities	Solution(s)	How can industry self-sampling data be applied?
BIOLOGICAL DATA ON CATCHES • North Sea: Market sampling measures lengths and ages in commercial landings, with spatial coverage representing ~89% of Scottish landings. • Data used in age-based analytical stock assessment model (SAM) • Stock identification issues are problematic for management because the structure of herring meta-population has significance for stock assessment and ecology	• Catch location reported at ICES statistical rectangle, not lat, long • Sampling effort <1 sample per 1000 t of catch, which is lower than ICES recommends • Significant proportion of landings in foreign countries are not sampled, thus relevant biological data is absent • Individual weight information is routinely collected by vessels but rarely stored. • Individual lengths in commercial catch currently not sampled by vessels	• Reduce variability or any biases in catch biological data by sampling more of the catch and adding information on length and weights, (and possibly maturity) at much finer spatial and temporal scale than currently available • Record fat content and maturation stage	• Record lat, long and ancillary information of every haul • Take biological samples every haul (or every landing) • Take specific targeted genetic samples from selected hauls/trips on a needs basis	**Stock assessment:** Biological catch data collected by industry can be used in the same way as current assessment and to in development of spatial assessment models. It can be used to increase accuracy and reduce variability of length-weight relationships and quantify spatial variability. Data on maturity and condition can be used to monitor temporal changes and avoid the need for static assumptions in the assessment model. Stock identity information used to determine appropriate assessment boundaries and management units **Management:** Evidencing distribution of fleet catches and relevance to zonal attachment. Also relevant to management strategies under changing oceanic conditions. (climate change adaptation) **Business:** Fishermen get to see the patterns in their activities. Plus additional evidence for markets on quality (e.g matjes), traceability and provenance, thus providing a marketing story. **Ecological research:** Changes in environmental conditions and fish growth

What is currently done?	Assessment or information gaps	Industry opportunities	Solution(s)	How can industry self-sampling data be applied?
SCIENTIFIC SURVEY DATA **<u>Survey data sources: North Sea:</u> HERAS, MSAS, IBTS (Q1 & 3), IHLS. Western: MSHAS, Scottish West IBTS Q1&4** • ***North Sea:* HERAS, IBTS and IHLS are used to provide indices of adult stock stock size. Information on juveniles from Quarter 1 are used for estimating recruitment. *Western:* MSHAS and IBTS used as adult stock indices** • **Biological sampling during surveys measures lengths, weights and ages in stock and provides information on growth and maturation** • **Industry vessels often chartered to carry out additional acoustic survey work on HERAS**	• When stocks are widely distributed, the limited resources for scientific surveys make it challenging to get the coverage necessary to assess the age structure and distribution of the stock. Because fisheries target adult fish, catch data cannot provide the necessary information on younger ages.	• Take scientific survey approach to sample the age structure and distribution of the stock more completely. • Collect samples for genetic studies on stock identification. Of particular importance for Western herring where stock identification issues are problematic for current assessment and management [NB: A specific programme is underway to address issues for Western herring (see detail below)	• Participation of industry vessels in existing acoustic surveys for herring	**Stock assessment:** Contribute directly to survey indices used in assessment, and provide information on stock identity relevant to assessment and management. **Management:** Zonal attachment, management boundary issues

<table>
<tr><th>What is currently done?</th><th>Assessment or information gaps</th><th>Industry opportunities</th><th>Solution(s)</th><th>How can industry self-sampling data be applied?</th></tr>
<tr><td>BYCATCH & DISCARD DATA
• Estimates of total fish catch is a large source of uncertainty in stock assessment
• Bycatch in Scottish pelagic fisheries very low but not routinely recorded. Discard observer trips used to occur on pelagic but now infrequent.</td><td>• Bycatch data not provided
• Quantity of fish slipped and or released from nets after pumping not known</td><td>• Record any non-fish by-catch
• Quantify any catches not landed.</td><td>• Estimate quantity of discarded catch
• Record non-target fish by-catch at factory</td><td>Management: Data on bycatch & discards for stock assessment and evidence issues for mitigation measures where relevant, e.g. choke species and TEP species issues.
Business: Evidence responsible fishing practices</td></tr>
</table>

Blue whiting (*Micromesistius poutassou*) 

What is currently done?	Assessment or information gaps	Industry opportunities	Solution(s)	How can industry self-sampling data be applied?
BIOLOGICAL DATA ON CATCHES • Market sampling by other nations measures lengths and ages in commercial landings. Countries with major catches considered well sampled (WGWIDE) • Stock assessed as one single unit using age-based analytical assessment (SAM)	• Catch location reported at ICES statistical rectangle, not lat, long • Limited sampling of Scottish landings (approx. 13% in 2017) • Areas of major catches from Scottish vessels not sampled (6.a) and 50% of Scottish vessels not sampled in 2017 • Individual weight information is routinely collected by vessels but rarely stored. • Individual lengths in commercial catch currently not sampled by vessels • Lack of data to disaggregate stocks into two potential units	• Contribute new length and weight data from Scottish catches. • Reduce variability or any biases in catch biological data by sampling more of the catch and adding information on length and weights, (and possibly maturity) at much finer spatial and temporal scale than currently available • Factories record fat content, weight and length	• Record lat, long and ancillary information of every haul. • Take biological samples every haul • Take specific targeted genetic samples from selected hauls/trips on a needs basis • Factories sample every landing	**Stock assessment:** Biological catch data collected by industry can be used in the same way as current assessment and to in development of spatial assessment models. It can be used to increase accuracy and reduce variability of length-weight relationships and quantify spatial variability. Data on maturity and condition can be used to monitor temporal changes and avoid the need for static assumptions in the assessment model. Stock identity information used to determine appropriate assessment boundaries and management units **Management:** Evidencing distribution of fleet catches and relevance to zonal attachment and boundary. Also relevant to management strategies under changing oceanic conditions. (climate change adaptation) **Business:** Fishermen get to see the patterns in their activities. Plus additional evidence for markets on quality, traceability and provenance, thus providing a marketing story. **Ecological research:** Changes in environmental conditions and fish growth

What is currently done?	Assessment or information gaps	Industry opportunities	Solution(s)	How can industry self-sampling data be applied?
SCIENTIFIC SURVEY DATA **<u>Survey data sources:</u>** IBWSS (2004-2018). • IBWSS is an acoustic and trawl survey used in the stock assessment to provide and index of abundance for ages 1-8, with age 1 used as a recruitment. • Other indicators are estimates of recruitment from surveys: IESSNS, IESNS, Norwegian bottom trawl survey in the Barents Sea, Faroese bottom trawl surveys in spring and the Icelandic bottom trawl survey in spring • Biological sampling during IBWSS measures lengths, weights and ages in stock and provides information on growth and maturation	• The large distribution area of the blue whiting stock requires an internationally coordinated survey. The survey takes place during the fishery so any gaps in coverage might be filled by involving industry vessels.	• (If needed) Support or supplement the IBWSS using acoustic data recorded by industry vessels following agreed scientific protocols.	• Participation of industry vessels in existing acoustic surveys for blue whiting (if needed)	**Stock assessment:** Contribute directly to survey indices used in assessment, and provide information on stock identity relevant to assessment and management. **Management:** Zonal attachment, management boundary issues

What is currently done?	Assessment or information gaps	Industry opportunities	Solution(s)	How can industry self-sampling data be applied?
BYCATCH & DISCARD DATA • Estimates of total fish catch is a large source of uncertainty in stock assessment • Bycatch in Scottish pelagic fisheries very low but not routinely recorded. Discard observer trips used to occur on pelagic but now infrequent.	• Bycatch data not provided • Quantity of fish slipped and or released from nets after pumping not known	• Record any non-fish by-catch • Quantify any catches not landed.	• Estimate quantity of discarded catch • Record non-target fish by-catch at factory •	**Management:** Data on bycatch & discards for stock assessment and evidence issues for mitigation measures where relevant, e.g. choke species and TEP species issues. **Business:** Evidence responsible fishing practices

Key to acronyms
ICES: International Council for the Exploration of the Sea
WGWIDE: ICES working group on widely distributed stocks
HAWG: ICES Herring assessment working group
SAM: state-space assessment model
IBTS: International Bottom Trawl Survey
IESSNS: International Ecosystem Summer Survey of Nordic Seas
IESNS: International Ecosystem Survey in the Nordic Seas in May
HERAS: Herring acoustic survey
IHLS: International Herring Larvae Surveys in the North Sea
TEP: Threatened, Endangered or Protected
IBWSS: International blue whiting spawning stock survey

3.1 Mackerel

Sampling coverage

The sampling of mackerel by EU countries is quantified by the ICES Working Group of Widely Distributed Stocks (WGWIDE) as the *'percentage catch covered by the sampling programme'* (further referred to as 'sampling programme coverage'), and the number of samples collected. The 'sampling programme coverage' simply means how much of the landings from each area and quarter had the possibility to be sampled[3]. In 2015, 98% of the Scottish landings were 'covered' by the sampling scheme. Looking in more detail, in this report we look at how many fishing trips made by the Scottish fleet are sampled. The number of trips sampled can be low compared to the sampling programme coverage because when vessels fish in similar areas at similar times, sampling just a few vessels ensures that an area / quarter has been sampled.

To use the biological information from samples in stock assessment (Box 2), the sample data is applied to all the catch data from an area and quarter. This is called raising the sample to the catch. This 'sample raising' approach is the same for all pelagic species. Sample raising assumes that fish (and samples) taken from the same area/quarter combination are biologically more similar than those from adjacent areas/quarters. To provide the most accurate representation of the overall composition of the stock, it is more important to have a spread of samples from all the combinations of areas/quarters rather than to have lots of samples from a few areas/quarters. A self-sampling scheme could provide the opportunity sample all trips, ensuring full spatio-temporal coverage and sufficient numbers of samples to reflect the biological diversity.

Sampling coverage from Scottish landings of mackerel has been historically high, reaching 98% of the catch in 2015. In comparison, the percentage of trips with landings to Scottish ports that have been sampled in the past five years has been around 50%, with a reduction towards approx. 33% in the past year (Figure 3.1 and 3.2). Note that a large proportion (approx. 50%) of Scottish trips land their catch abroad (typically Norway) (Table 2.1). With the exception of Norwegian authorities which have sampled between 15-30% of the Scottish landings since 2012 (Figure 3.1 and 3.2) during the November fishery as part of the mackerel tagging programme, few if any of the remaining abroad landings are sampled.

Drilling down to the vessel level, the sampling scheme has historically missed samples from several boats (Table 3.2). Almost 50% of the boats that landed from ICES statistical areas 4.a and 6.a were sampled, with an increase to almost 70% of the vessels in the past two years. ICES areas with minor catches (e.g.: 2.a, 4.b, 7.c) have not been sampled. Because some boats tend to land their catch outside of Scotland they are not available to Scottish sampling scheme.

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[3] An example of the calculation would be: If the sampling scheme was applied to all catches from quarter 1 and quarter 4, when say 80% of the catch is taken, and no sampling is undertaken in quarter 2 and quarter 3. Thus the sampling coverage would be 80%.

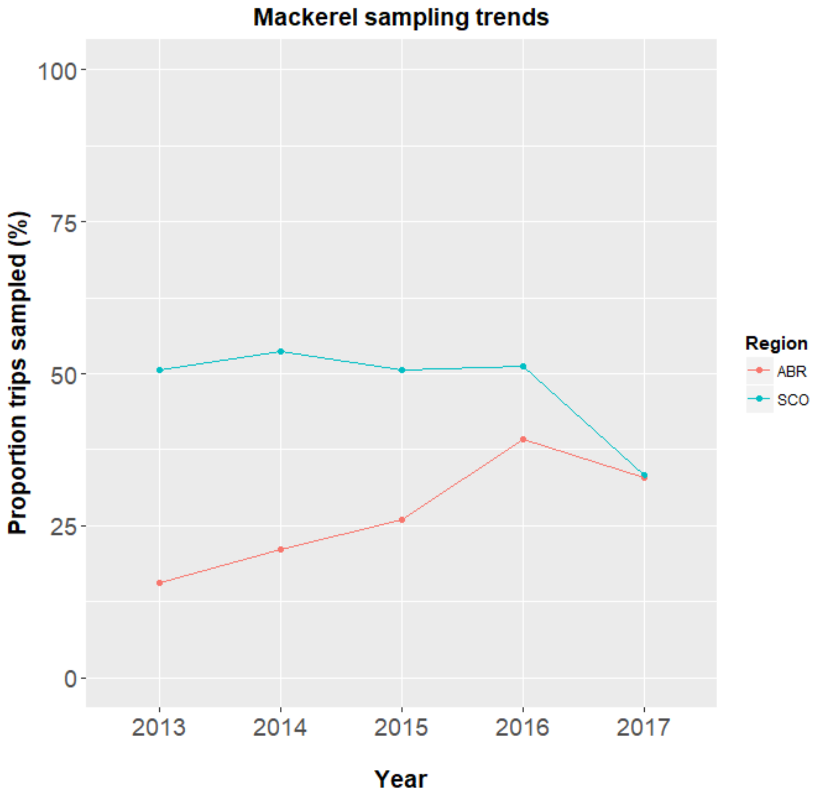

Figure 3.1. Proportion of mackerel landings sampled in Scotland (SCO) and abroad (ABR) from 2013-2017.

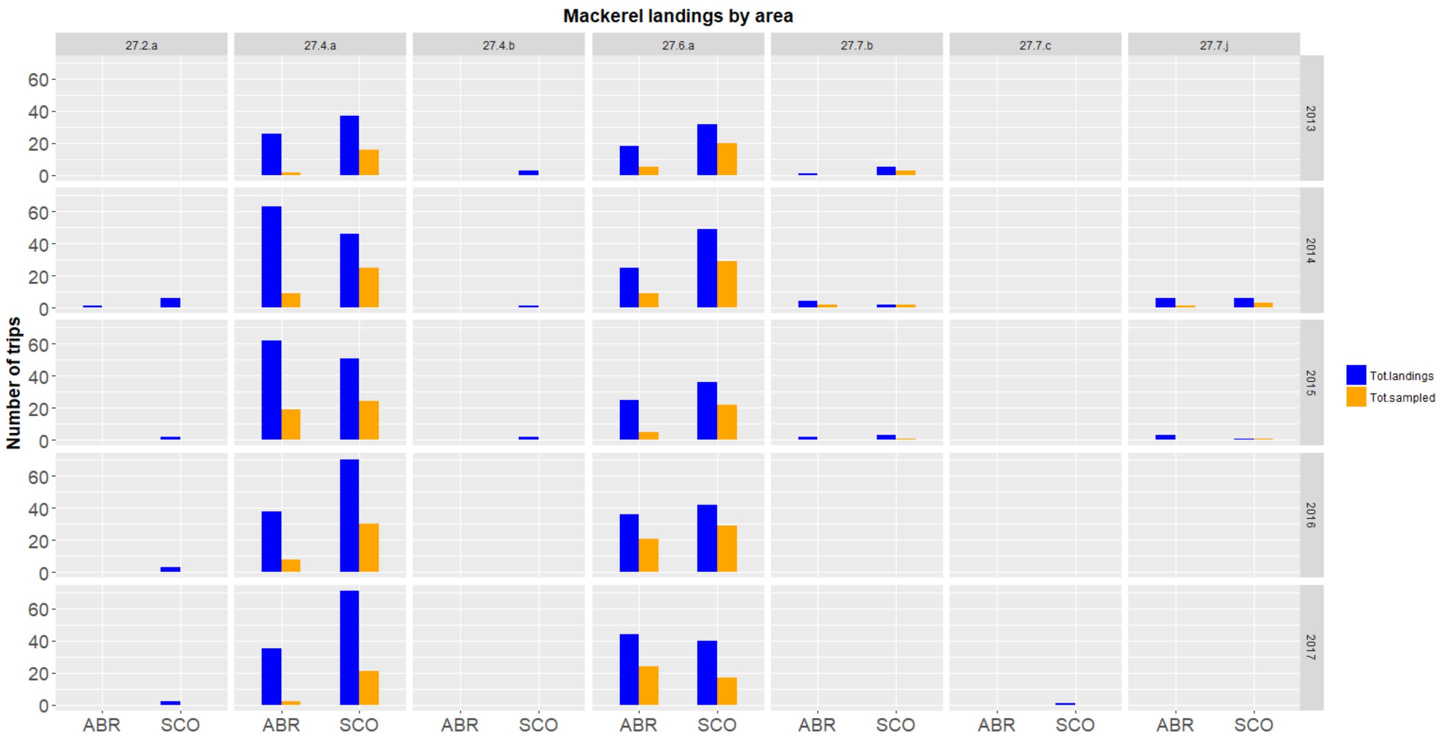

Figure 3.2. Mackerel total number of landings (Trips) (blue) and number of trips sampled (orange) by ICES statistical areas (columns) and years (rows) in Scotland (SCO) and abroad (ABR).

Table 3.2. Number of Scottish vessels landing mackerel by years and ICES areas and number of vessels that had samples taken from them**.** Numbers obtained from MSS sampling data.

Year	Area	Number of vessels with landings from this area	Numbers of vessels sampled	% of vessels sampled
2013	**4.a**	17	6	35
	4.b	2	0	0
	6.a	17	10	59
	7.b	6	3	50
2014	**2.a**	5	0	0
	4.a	18	10	56
	4.b	1	0	0
	6.a	18	8	44
	7.b	6	2	33
	7.j	10	3	30
2015	**2.a**	1	0	0
	4.a	18	10	56
	4.b	2	0	0
	6.a	18	9	50
	7.b	5	1	20
	7.j	4	1	25
2016	**2.a**	1	0	0
	4.a	21	14	67
	6.a	18	12	67
2017	**2.a**	2	0	0
	4.a	19	12	63
	6.a	20	14	70
	7.c	1	0	0

Sampling information content

Mackerel schools tend to be sorted by size and highly aggregated in space and time; these features help fishermen to try and target catches of certain sized fish. This can make the determination of growth rates from commercial catches a challenging task because of the low variability in size ranges of individuals comprising catches (ICES, 2005; Skagen, 1989). And even more so if few trips are sampled. The assumption used to raise samples to be representative of large areas is something that fishermen find difficult to digest because their impression is that there's a lot of spatial and temporal diversity in their catches. The current lack of haul-level sampling means it's not possible to quantify this diversity and determine its utility in assessing stock status.

During pelagic fishing operations, hundreds of individual fish are weighed during every landing. These are used to determine the proportion of the catch in different size grade categories and is sent to prospective buyers. Although these data are collected similarly by all pelagic vessels, there is no standardized protocol or systematic approach to storing it. Other than the average gram weight, it is almost never kept. Furthermore, while fish length is key piece of information collected by scientists during market sampling, it is never recorded by the industry, despite its potential relevance to quantifying the variability in catches and determining changes in growth and fish condition. Establishing a protocol to collect individual weight and length data could yield a significant increase of biological information resolved to the lat and long of every catch, with applications in stock assessment science, management and business marketing. For example, condition indices require both length and weight so that "plumpness", or girth, at a given length can be assumed to indicate fish health.

With regard to scientific applications, a statistical assessment of the information value of additional sampling will be important to determining its utility. A good measure of the precision and variability of size distributions between hauls is the effective sample size (Chih, 2010; Faes et al., 2009; Lehtonen & Pahkinen, 2004). Effective sample size is defined as the "sample size one would need in an independent sample to equal the amount of information in the actual correlated sample" (Faes et al., 2009) . Previous analysis of haul data collected by the Norwegian self-sampling reference fleet, reported very low effective sample sizes for mackerel, North Sea herring and Norwegian herring, which indicates there is less information in the sample than indicated by the total number of fish measured (Michael Pennington & Helle, 2011). Thus, from a statistical point of view, precision and efficiency in the sampling design is achieved by sampling as many primary units as possible, in this case fishing vessels, rather than in large sample sizes from every vessel. This kind of statistical assessment of the value of increased sampling should have an important bearing on the appropriate design of self-sampling, and/or the way that data is utilized.

3.2 Herring (North Sea and West coast).

Sampling coverage

Herring landings of Scottish vessels come mainly from ICES areas 4.a (Figure 2.1.4), although prior to 2015, 6.a was an area of an MSC certified fishery until doubts over stock identification undermined the stock assessment and led to advice for zero TAC.[4]

Sampling of landings of North Sea herring to Scottish ports has historically been high, covering 96% of the Scottish catch in 2016. Total coverage for all countries was 89% in 2016. In terms of the number of individual trips landing to Scottish ports, sampling has typically been around 55% (Figure 3.3) but declined in 2016 and again in 2017 to less than <30%. This is because, while there were more trips during these years, the number of trips sampled did not increase. No samples are reported for landings abroad. (Figure 3.3 and 3.4). With increases in volume landed in these years, herring sampling is not

[4] Since 2016, the pelagic industry have been actively engaged in scientific survey work to gather the information required to address issues with the assessment of stocks in 6aN and 6aS,7bc. (see ICES 2017 and Mackinson et al. 2018)

achieving the agreed sampling level established at the DCF (European Commission, 2008a, 2008f, 2008d) of at least one sample per 1000t of catch (ICES, 2017e).

However, ICES Herring Assessment Working Group (HAWG) 2017 (ICES, 2017e) reports that to address issues of uncertainty in the biological data, in the recent past there has been a significant increase in the number of individuals aged. In contrast, length measurements of individuals were reduced by approx. 30% in 2016.

Sampling coverage at the vessel level shows that approximately 50% of the vessels landings from each area were sampled in the past 5 years, with a considerable increase up to 72% of the vessels in the past year (Table 3.3).

Sampling information content

For the same reasons given as for mackerel, the method of raising of samples does not (from the industry perspective) account for the diversity they see in catches and is not well justified, even if statistically it makes sense.

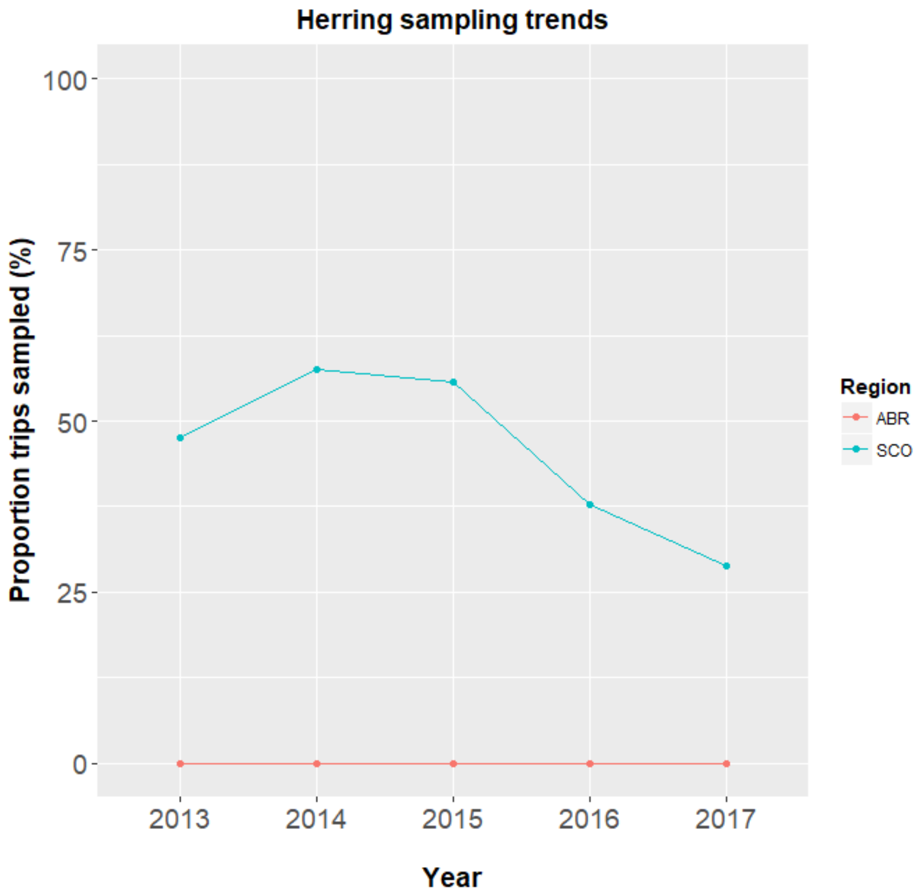

Figure 3.3. Proportion of herring landings sampled in Scotland (SCO) and abroad (ABR) from 2013-2017.

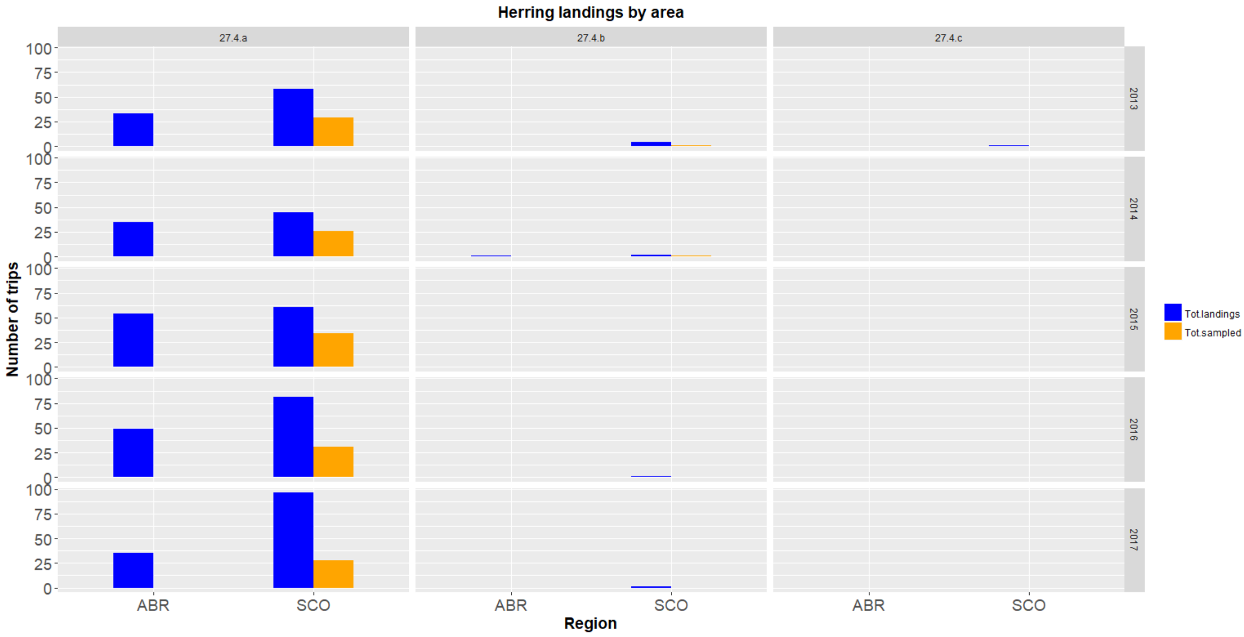

Figure 3.4. Total number of landings (Trips) (blue) and number of trips sampled (orange) of herring by ICES statistical areas (columns) and years (rows) in Scotland (SCO) and abroad (ABR)

Table 3.3. Number of Scottish vessels landing North Sea herring by years and ICES areas and number of vessels that had samples taken from them

Year	Area	Number of vessels with landings from this area	Numbers of vessels sampled	% of vessels sampled
2013	**4.a**	17	9	53
	4.b	3	1	33
	4.c	1	0	0
2014	**4.a**	18	9	50
	4.b	2	1	50
2015	**4.a**	18	10	56
2016	**4.a**	19	8	42
	4.b	1	0	0
2017	**4.a**	18	13	72
	4.b	1	0	0

3.3 Blue whiting

Sampling coverage

Landings of blue whiting by Scottish vessels have significantly increased over the past three years, reaching almost 18% of the EU quota share of the total TAC (~36 600 t) in 2016 (Table 2.1.1, Figure 2.1.5). ICES areas 6.a and 7.c accounted for most of the landings from Scottish vessels since 2013, with a great proportion of landings occurring abroad, mainly Ireland. Sampling intensity at trip level shows great variability (Figure 3.5). The proportion of trips sampled in Ireland prior to 2017 is unknown, since landings from Scottish vessels in Ireland are reported only as UK vessels, and thus impossible to identify. In 2017, however, MSS requested and funded samples to be taken by Irish authorities.

Nevertheless, the current sampling scheme shows important and large gaps for the Scottish fleet, with areas of major catches not sampled (e.g. 6.a in 2017) (Figure 3.5), and inconsistencies in the vessel coverage (50% of vessels sampled in 2017, 16% in 2016) (Table 3.4). Even though Scottish catches are only a small part of the total TAC (6%), compared to the principle fisheries from Norway, Faroe Islands, there are clear opportunities to contribute data relevant to stock assessment and management for a species/ fishery of increasing national importance.

In 2014, the ICES Stock Identification Methods Working Group (SIMWG) (ICES, 2016) concluded that the perception of blue whiting in the NE Atlantic as a single-stock unit is not supported by the best available science, but rather suggested the presence of two separate units. However, there is currently no information available that can be used as the basis for generating advice on the status of the individual stocks. It identified clearly the need for more information regarding the population structure. No marine laboratory is currently undertaking such work (Ciaran O'Donnell pers. comm).

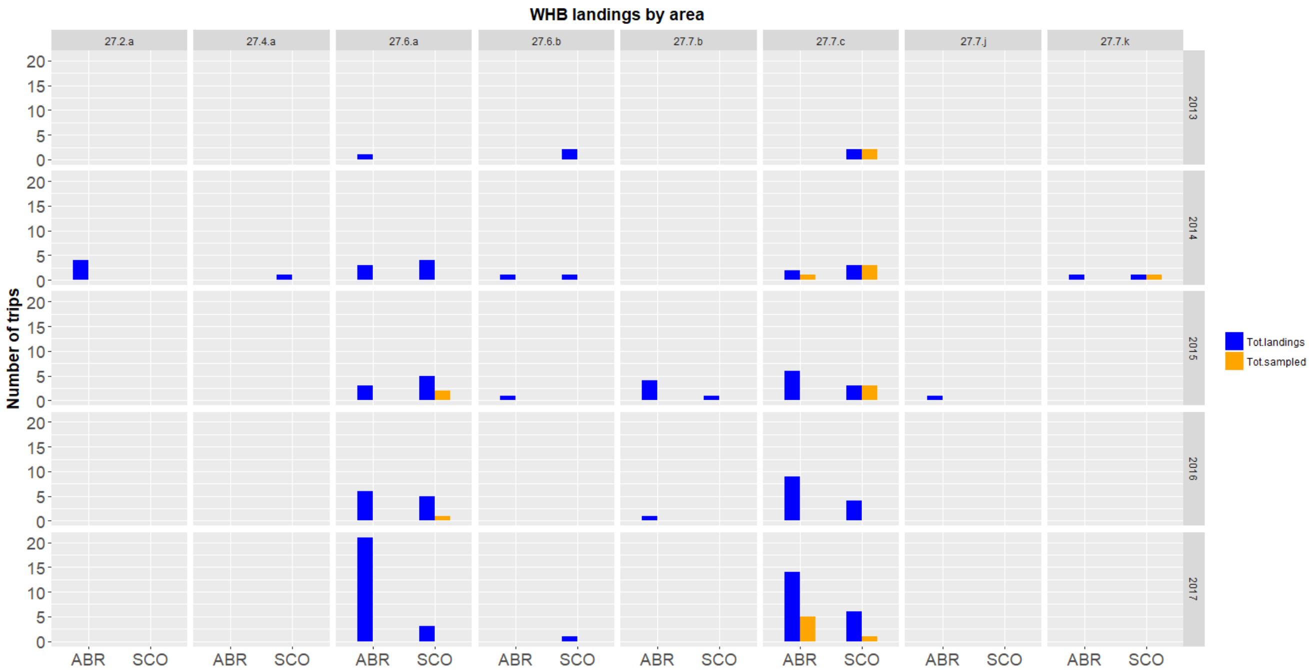

Figure 3.5. Total number of landings (Trips) (blue) and number of trips sampled (orange) of blue whiting by ICES statistical areas (columns) and years (rows) in Scotland (SCO) and abroad (ABR).

Table 3.4. Number of Scottish vessels landing blue whiting by years and ICES areas and number of vessels that had samples taken from them.

Year	Area	Number of vessels with landings from this area	Numbers of vessels sampled	% of vessels sampled
2013	**6.a**	1	0	0
	6.b	1	0	0
	7.b	1	1	100
2014	**2.a**	4	0	0
	4.a	1	0	0
	6.a	4	0	0
	6.b	2	0	0
	7.c	3	3	100
	7.k	2	1	500
2015	**6.a**	4	1	25
	6.b	1	0	0
	7.b	4	0	0
	7.c	5	3	60
	7.j	1	0	0
2016	**6.a**	6	1	17
	7.b	1	0	0
	7.c	7	0	0
2017	**6.a**	8	0	0
	6.b	1	0	0
	7.c	8	4	50

4 Methods and tools

4.1 Data collection and quality assurance

Self-sampling ought to be relatively straightforward on Scottish pelagic vessels because normally they have an appropriate workspace, a person tasked with measuring fish weights, and sufficient time between hauls to undertake more detailed sampling.

Given that sampling individual fish weights is a routine part of work, making the step to take scientific samples for length, weight and possibly other variables is not a large imposition, so long as four conditions can be met.

First is that both the skippers and persons undertaking the work are willing and know why it's important to take scientific samples. This is often generally the hardest part.

Second is that they need to know how to do it. Protocols need to be operationally workable, clear and robust, so that data is collected correctly. In collaboration with Marine Scotland, sampling protocols for mackerel, herring and blue whiting have already been developed during this project (Appendix 2).

Third is having the right tools to do the job. Initially, this means equipping pelagic vessels with measuring boards and robust templates for recording data, both paper and electronic versions. Simple things like printing length-weight recording sheets on waterproof paper and providing robust data entry sheets with automatic formatting and data validation tools are important in making the work efficient and minimizing chances for translation errors. The preferred route is that the individuals who do the sampling should also enter the data on to spreadsheets. This enables a personal level of scrutiny and control that cannot be guaranteed when someone else is left to interpret and enter data that another person has recorded.

Over the longer term, developing automated tools that make data capture and storage efficient will be important. The approach here is to work with the existing (and familiar) systems used on board and then bolt on additional capabilities (see section 4.2).

Fourth is getting the right kind of feedback to both skippers and the crew involved in sampling. Feedback on sampling performance and quality is needed, and also on the results themselves. As data 'owners', vessels should have their data returned in a format that is accessible to them. Seeing and understanding the value in the data they have collected is critically important to sustain sampling efforts over the long-term.

When sampling every landing (rather than every individual haul) would be an appropriate way to gather data for a particular application, self-sampling by factories could be effective and efficient. Conversations with all the pelagic factories undertaken during this project show that they are willing and interested to engage with such work. Site visits reveal that they are more than capable to undertake such work because they have dedicated quality control personnel who are experienced in sampling methodology and working with specific protocols that cover a range of product quality testing. In every case, information is recorded and stored in standard formats following established procedures. Conversations with the factories have already led to the initiation of novel PhD, which will utilise factory data on fish fats to examine changes in productively of the marine environment (Appendix 3).

Marine Scotland Science currently undertakes pelagic sampling at factories at the point of landing before the fish go through the grading machine, the so-called 'ocean run'. They sample lengths and collect 3 otoliths from every length class, which amounts to roughly 100-130 measured fish and otoliths from 30-50 fish per sample. With the exception of the Lunar factories, all factories also sample the ocean run. The difference is that they only measure weight, albeit for thousands to 10s thousands of fish for every landing. Engaging factories in additional length sampling, and possibly also removing otoliths, would require only minor adjustments to their existing operational processes and amount to very little additional effort compared to that already given to sampling. The benefit of undertaking a trial of this kind would be in being able to evaluate any possible data biases arising from existing scientific sampling methods.

Although it has been used a compliance tool, remote electronic monitoring (REM) has the potential to provide industry data for scientific purposes in future. It provides video footage, which is processed by trained analysts or possibly through specialised image recognition software, to collect data on the numbers, length and species of fish that are caught and retained by fishing vessels. Ongoing research is exploring the potential of REM data as part of a fisheries management strategy compared to traditional sources of industry data, such as on-board observers. If REM could be automated then routine use of REM could make important contributions to a fully documented fisheries.

4.2 Data storage, handling and management

Establishing new streams of routinely collected data presumes that there is an electronic repository for receiving, storing and accessing those data and sufficient human resources for the long-term management and analysis of the data. Since 2000, an EU framework (Data Collection Framework (DCF)) has been in place for the collection and management of standard fisheries data. Under this framework, EU Member States (MS) collect, manage and make available a wide range of fisheries data needed for scientific advice. The data are collected by national programmes in which the MS indicate which data are collected, the resources they allocate for the collection and how data is collected. MS report annually on the implementation of their national programmes to the Scientific, Technical and Economic Committee for Fisheries (STECF). Some types of data are publicly accessible via data portals. For example, Datras is a data portal maintained by ICES (http://www.ices.dk/marine-data/data-portals/Pages/DATRAS.aspx) which includes biological and catch data collected during research vessel surveys of European regional seas. In addition to their application in stock assessment, these data are widely used by university-based researchers to address a diverse range of ecological questions.

When the pelagic industry starts self-sampling, a considerable amount of data will be generated. Therefore, effective mechanisms for recording, storing, quality control and accessing data need to be developed. Developing automated tools that make data capture and recording efficient will be important to ensure self-sampling is feasible and sustainable. Where possible, the approach should be to work with the existing (and familiar) systems used on board and then to bolt-on additional capabilities. Possible solutions identified during this project include integration of weight data from Marel scales, length data from Zebra-tech electronic measuring boards and data capture and storage with eCatch - a system used by many vessels as their electronic logbook system.

Regarding long-term storage and access, a preferred option is to collect and format data so that it is compatible for storage within existing established systems used by Marine Scotland Science to provide information to the Marine Management Organisation (MMO) under the DCF, or directly to ICES. Use of such established channels for data is convenient and improves chances of uptake in government assessment. However, these databases are often inaccessible to scientists and other interested users outside government (universities, eNGOs). Independent research organisations that have interests in improving public access to marine data, e.g. Marine Alliance for Science and Technology

Scotland (MASTS), could be interested in hosting data hubs for the fishing industry and other sources of marine data. These options for archiving data would need to be explored once data begins to be generated. Whichever data hub is most appropriate, any data storage and sharing agreements should comply with a Data Policy (see below).

In addition to defining how the data will be handled post-collection, the pelagic industry needs to consider their commitment to providing essential internal support for analysis of the data they are generating. Marine Scotland Science has limited resources for investigating the information content of new data streams which are distinct from data that supplement existing data they collect and analyse. It is likely that industry will be responsible for demonstrating the utility for management. Having in-house scientific expertise is useful in this regard. There is also the potential for research partnerships with universities who are intrinsically interested in mining data. Student research projects are an economical means of identifying suitable statistical methods and applications of the data (c.f. Appendix 3).

As the data that are generated by a self-sampling programme fall outside the routine data regulated by the DCF there is considerable scope for developing a bespoke approach that suits Scottish fisheries. In this respect, it is timely that the EU has agreed to provide greater flexibility for end-users to define the details of data collection from 2017, which provides a route through which industry self-sampling data could be included in assessments and policy advice.

4.3 Data policy

Industry data represents a unique source of information because of the high resolution in time and space. The Scottish Pelagic Fishermen's Association wants to be a leader in provision of marine data from the fishing industry, demonstrating best practices for data access and use. As general rule, the SPFA aspires to take an open and transparent approach, which would need to be described in a Data Policy that covers conditions for:

- Submission and quality assurance
- Access arrangements
- Use
- Anonymisation
- Acknowledgements
- Sharing

As a starting point, the SPFA would look to the ICES data policy as its guidance on its policy.

http://www.ices.dk/marine-data/guidelines-and-policy/Pages/ICES-data-policy.aspx

5 Making the data count in the scientific arena

5.1 Ensuring utility – fit for purpose

The crux of making industry data initiatives have value is matching what is needed with the provision of relevant high-quality data. Demonstrable quality standards are important to having data accepted in any scientific arena, so both the methods used in self-sampling and the data arising from self-sampling need to meet accepted standards. Where standards and protocols relevant to a particular application exist already, these should be adopted, and adapted to meet operational requirements. In some circumstances, such standards don't exist and it will be necessary to co-construct and agree them with relevant authorities before data collection begins. This will provide the best chance that any data is acceptable when subject to expert review or specific audit.

In the beginning of a self-sampling programme, two 'institutional bars' need to be considered because they provide the conditions required to frame the data collection and justify its use. The first is the 'Regulation (EU) 2017/1004 of the European Parliament and of the Council of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008 (OJ L 157, 20.6.2017, p. 1)'

> *Article 2. The data referred to in point (a) of paragraph 1 shall include:*
>
> *(a) biological data on all stocks caught or by-caught in Union commercial and, where appropriate, recreational fisheries in and outside Union waters, including eels and salmon in relevant inland waters, as well as other diadromous fish species of commercial interest, to enable an ecosystem-based approach to fisheries management and conservation as necessary for the operation of the common fisheries policy;*
>
> *(b) data to assess the impact of Union fisheries on the marine ecosystem in and outside Union waters, including data on by-catch of non-target species, in particular species protected under Union or international law, data on impacts of fisheries on marine habitats, including vulnerable marine areas, and data on impacts of fisheries on food webs;*
>
> *(c) data on the activity of Union fishing vessels in and outside Union waters, including levels of fishing, and on effort and capacity of the Union fleet;*
>
> *(d) socioeconomic data on fisheries to enable the socioeconomic performance of the Union fisheries sector to be assessed;*
>
> *(e) socioeconomic data and sustainability data on marine aquaculture to enable the socioeconomic performance and the sustainability of the Union aquaculture sector, including its environmental impact, to be assessed;*

(f) socioeconomic data on the fish processing sector to enable the socioeconomic performance of that sector to be assessed.

Member States should determine the way they collect data, but in order to be able to combine data on a regional level in a meaningful way, minimum requirements for data quality, coverage and compatibility should be agreed by Member States at regional level, taking into account the fact that in some regions basins are managed jointly with third countries. When there is general agreement on the methods at regional level, regional coordination groups should, on the basis of that agreement, submit a draft regional work plan for approval by the Commission.

The second institutional bar is ICES technical guidelines '12.5 3 Criteria for the use of data in ICES advisory work' published in December 2016, which asks for anyone intending to collect data suitable for use as a basis for ICES advice to inform ICES. In particular, the criteria defined in the guidelines would require the industry (SPFA in this case) to:

1) Advise that unbiased access to and use of the full data set for analysis in support of scientific advice will be given to relevant persons.
2) Request that ICES informs us as to the expert group and persons with whom a prior written agreement should be made regarding the resolution and associated information of the data to be collected.

5.2 The data 'carrier'

The collection of data is not an end in itself. To be made useable and useful, the data and results of analyses need to be conveyed in an acceptable scientific format (see Box 4 in Mackinson et al. 2017) to the relevant institutions that serve to (i) verify and give credibility to the data through their quality control processes, (ii) apply the data in making decisions and (iii) represent end users. To ensure that the information arrives at a time that it can be used, the schedules of the work groups need to be considered.

To 'carry' the data on its journey through the system, someone acting as the data steward needs to be involved in various international scientific working groups to present the information and address any questions relating to methods, interpretation and data quality assurance. Thus, a clear chain of custody needs to be defined.

Box 2. How data from industry landings is used for stock assessment.

'Market sampling' is the beginning of the process to produce estimates of catch numbers-at-age that feed into the ICES stock assessments working groups. Throughout the year, landings of Scottish vessels are sampled regularly by staff from MSS. Information collected includes length and age of commercial species, and details of the landings. Age of the fish is determined by reading growth rings on otoliths. Otoliths are calcium carbonate structures founds in the head of the fish. The growth rings consist of white and dark pairs of layers, corresponding to winter and summer growth. If the age of a large number of individuals is determined, the age structure of a population can be later estimated.

Depending on the species, the process used to obtain the samples can significantly differ. In pelagic landings, catch is directly pumped towards the factories where the fish is processed and then transported to buyers. Prior to the fish entering the grading and processing machinery samplers take a full basket of fish at random. Demersal species, on the other hand, are landed directly into the market where auctions take place before the fish is sold and processed. For these species, sampling usually takes place before the auction.

Mackerel samples tend to be between 35-45kg while herring has lower sample weights between 20-35kg; approximately 80-120 individual in both cases. If for different reasons, samplers have not arrived at harbour once all the catch has been sent to the factory, they usually contact pelagic factories in order to keep a basket of fish.

Commercial catch data from logbooks and market samples are collected and stored by national authorities following the specifications defined in the Data Collection Framework (for EU countries). Prior to the annual ICES assessment working groups for each stock, national data submitters are responsible for delivering commercial catch data and associated sampling details to the stock coordinator. This information is aggregated by ICES subarea and quarters, using an Excel spreadsheet known as the ‘exchange format’. This spreadsheet can also include information on misreported catches, unallocated catches and discards from nationally or industry managed programmes. Upon completion of error checking, a major task requires the allocation of samples of catch numbers, mean length and mean weight-at-age to the un-sampled catches. The stock coordinator will choose appropriate samples (and their relative weightings) on the basis of fleet type, quarter and geographic area. If an exact match is not available, the search will move to a neighbouring area if the fishery extends to this area in the same quarter. More than one sample may be allocated to an un-sampled catch; in this case a straight mean or weighted mean of the observations may be used. If there are no samples available, the search will move to the closest non-adjacent area by gear (fleet) and quarter. This process is called raising the catch and is used to generate the catch numbers-at-age table and weight-at-age (in the catch) used in the stock assessment.

Given the high level of aggregation of the pelagic fishery within an ICES area during the same quarter , and the similarities between the vessels and gears employed, sample raising of the catch is considered be a reasonable assumption for the pelagic stocks. Once the samples have been assigned, the stock coordinator will produce a vector of catch numbers, weights and lengths in addition to the total catch. Since 2007, all catch data has been stored and processed using a web-based data portal known as InterCatch which is hosted by ICES and has the advantage of acting as a central repository for the data.

The information required to carry out stock assessment currently come from three different sources. Fisheries-dependent or commercial data includes market sampling, discard observer programmes and electronic logbooks while fisheries-independent data come from scientific surveys. Figure B2 shows a general overview of the process to combine the different types of data used to develop stock assessment models with its main sources of errors.

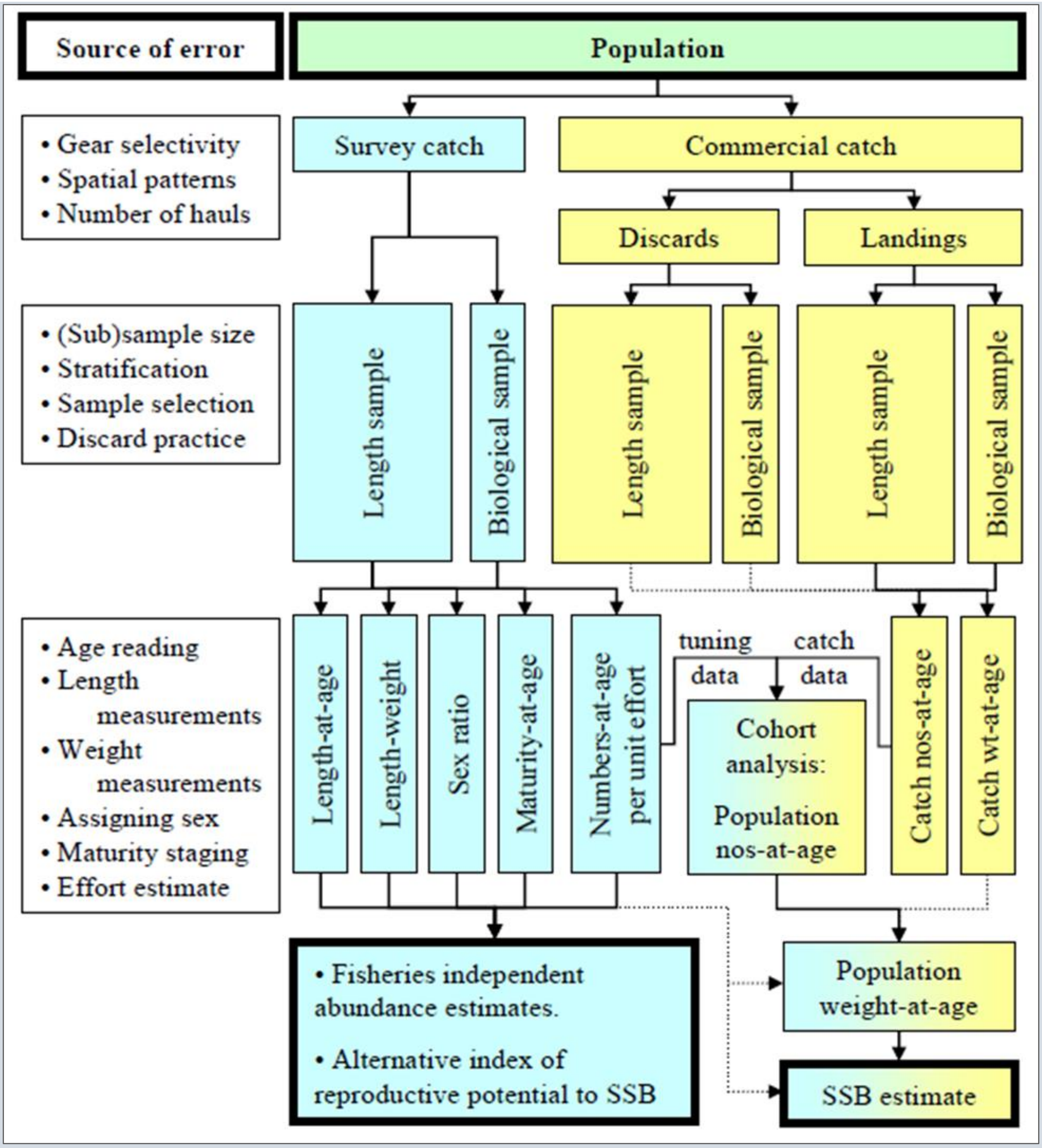

Figure B2. Diagram of the various steps involved in data collection and analysis of fisheries data and the sources of error at each step of the process. Blue cells signify survey data, yellow cells refer to commercial data (from ICES WKACCU, 2008)

Discard observer programmes provide information about those fish that are caught but never reach the market. Reasons to practice discards vary depending on the fishery, but include compliance with quota limits in mixed fisheries scenarios, limited commercial value of the catch or because the catch is below the legal minimum landing size (MLS). Since the implementation of the Landing Obligation (LO) by 2019 all quota species have to be landed including undersized fish. To reflect this change in the legislation the concept of MLS is obsolete and the new term Minimum Conservation Reference Size (MCRS) has been introduced.

Marine Scotland Science has been collecting data on discards since 1975 and provide discard information to ICES stock assessment Working Groups each year. Until 2014, information was provided for the top 8 demersal species; cod, haddock, whiting, saithe, monkfish, megrim and hake. Autonomously from this programme, an Independent On-board Observer Scheme (IOOS) run by Scottish Fishermen's Federation (SFF) Services, the wholly owned subsidiary of SFF and funded by the Scottish Government and European Maritime and Fisheries Fund collected discard and landing information from Scottish vessels. In 2013 the FMAC (Fisheries Management and Conservation Group) agreed that MSS and (SFF) should operate a joint Observer Sampling Scheme (OSS) to make better use of total observer resource. The joint scheme, overseen by MSS, is intended to provide:

- A single, definitive source of Scottish discard data collected (including ~40 species), stored and analysed in a unified way
- Statistically robust estimates of catch and discards for all required purposes (ICES and reporting to Commission)
- An increased number of sampling trips each year to provide greater coverage of the fleet
- A reduction in some of the variance associated with discard estimation
- More efficient utilisation of the resource and greater acceptance by all stakeholders that 'best possible' use is being made of available data

Approximately 200 trips a year are sampled, under this scheme. The length of each trip varies from two-three days for the inshore trips to 10-11 for the offshore ones. A common sampling protocol by onboard scientific observers is conducted in both programs. The MSS and SFF programs select vessels (all whitefish demersal and *Nephrops*) to carry observers using a stratified random sampling design by area, gear and quarter within each year. Both schemes depend on the voluntary cooperation of skippers, although access to observers is usually granted. For each haul the bulk of the catch is estimated and, based on the landings quantity, it is split into discards and landings. A subsample of the discard is taken (as randomly as possible) to be measured. A ratio is then available to raise the sample composition at haul level. Species are sorted and measured at the nearest cm. Quantity at length is then converted in weight using length/weight relationships. For the "major species" otoliths are collected to cover every cm in the length distribution over the whole trip. If it is a *Nephrops* trip/haul, a further split in males, females and berried is applied before measuring the length. Tailed prawns are measured considering their width which will then be converted into length. Other information recorded includes haul location (lat/long) and duration of the trawl, gear and depth.

Discard observer programme also provides data on landed species in terms of:

- Length distribution of landed cod, haddock, saithe and whiting at trip level
- Quantities of all the species landed with details at category level
- Quantities and length distribution for Below Minimum Size (what previously would have been discarded and it is now landed under the MCRS).
- In the specific case of Rockall Haddock, one otolith per cm for the marketable fish is collected.

Discard information, when available, is then combined with the market sampling data prior to the annual ICES assessment working groups, to obtain estimates of the fishing pressure at population level. The improved coverage of the fleet from SFF contributes to a more robust dataset which can be used within the evolving ICES framework; an additional valuable input is the provision of improved information on data-deficient stocks aiming to avoid the automatic reductions in TAC.

6 Resources

6.1 Effort and funding available to support self-sampling

Discussions with skippers and crew during meetings in Fraserburgh (11 July 2018) and Lerwick (17 July 2018) suggest that so long as sampling procedures can be adapted to fit in with the fishing process, the effort required to collect data from each haul is not expected to significantly affect normal operations on board.

The cost of time associated with collecting data at sea or at factories would be absorbed in to the daily operations of vessels and factories. Similarly, the industry through the SPFA would bear the costs for oversight of a self-sampling programme, at least to the extent that such a task is manageable for the intended purpose.

Additional cost and effort are expected to be necessary to provide more intense support during the start-up and testing stages, when evaluations of processes and data quality are required, and for day to day management of the programme. Furthermore, should the analysis of samples require specific dedicated skills such as age-reading of otoliths, then additional costs would be expected. Options for funding for these requirements include:

1) Accessing scientific quota to support self-sampling, where objectives are co-designed with Marine Scotland. During this project a discussion document on opportunities for utilisation of scientific quota (Appendix 4) was discussed at a Pelagic Strategy Review meeting with Marine Scotland on the 12 July 2018.
2) An industry levy to support industry-science initiatives, where the levy would be proportional to annual quotas or fixed quota allocations.
3) Partnerships in projects funded through applications for grants (such as Fisheries Innovation Scotland, EMFF, Horizon 2020, Student projects). However, these are unstable short-term solutions that are not well suited to a sustained a data collection programme.

6.2 Skills and Training

During delivery, training on sampling methodology will need to take place to ensure that the team have the skills and understanding necessary to do the job. It's best if the training opportunities are made as realistic as possible, so preferably on board a vessel or at a factory. Both the skippers and people doing the sampling on deck need to and know why it's important to take scientific samples, as well as how to do it.

Regardless of the survey approach undertaken, it's good practice for a scientist to go aboard to see how the self-sampling is working and discuss any improvements that might be necessary. During start-up, inevitably there will be a lot of questions and a need to scrutinise the quality of the data to see to check that procedures are being followed correctly.

Training on data recording and data entry spreadsheets will also be required.

7 Architecture of a Scottish pelagic self-sampling programme

A general architecture for a Pelagic self-sampling programme is show in Figure 7.1, with an applied example for mackerel in Figure 7.2. It synthesises considerations discussed in previous sections and also draws upon the attributes of success from other relevant self-sampling schemes, which are reviewed in section 1.5.

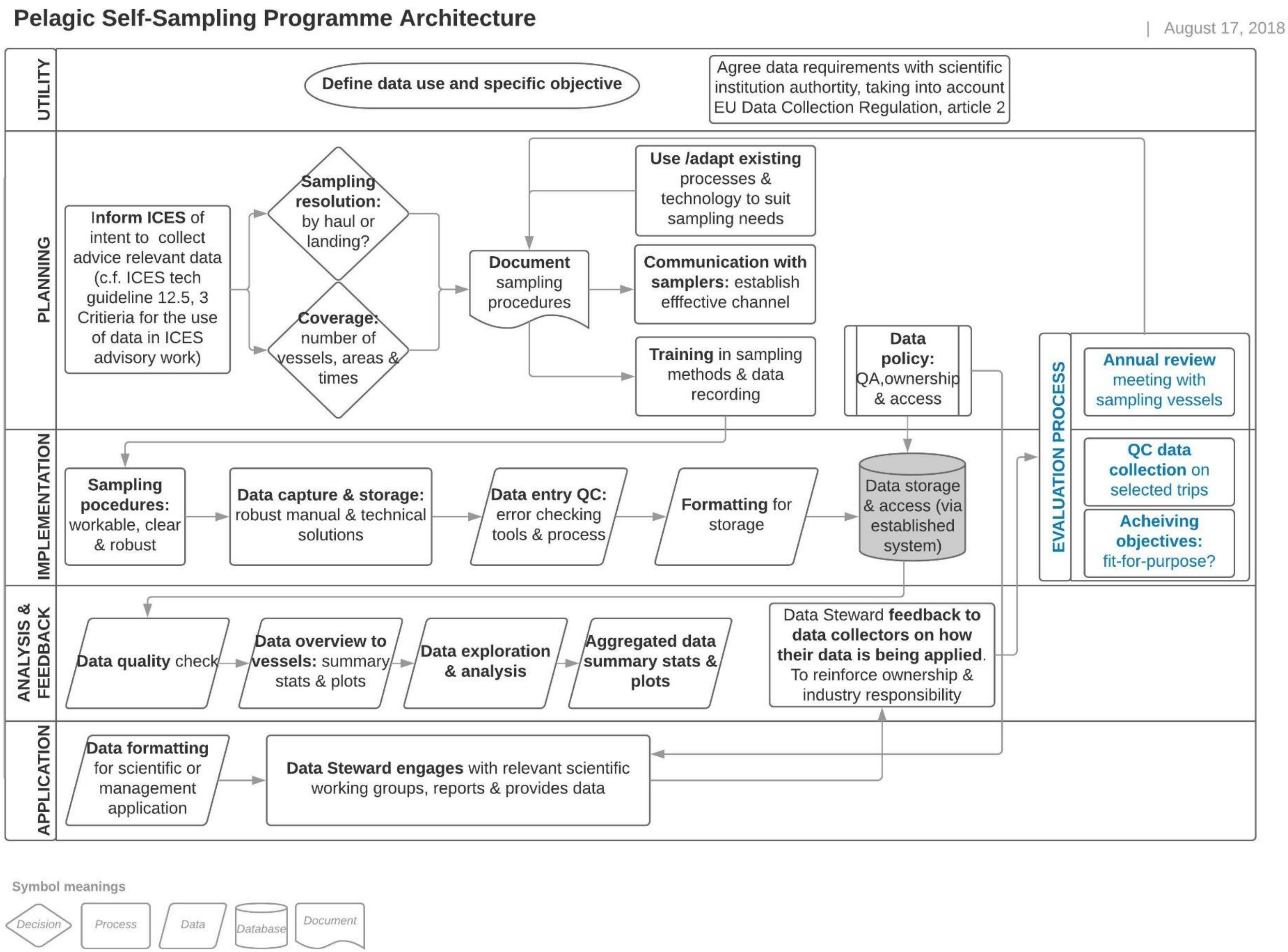

Figure 7.1. Generalized architecture of a pelagic self-sampling programme

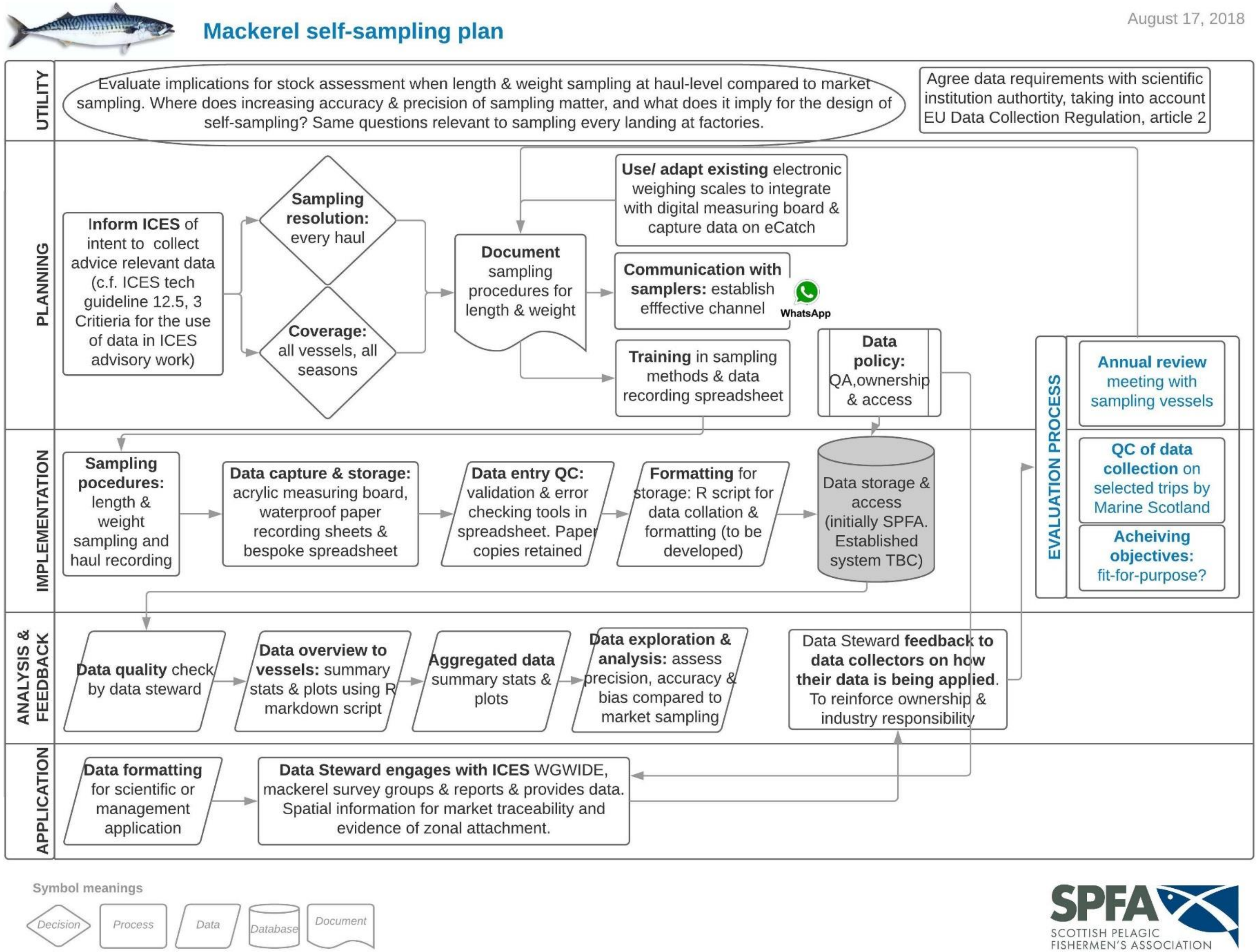

Figure 7.2. Plan for mackerel self-sampling work based on the general architecture in Figure 7.1

8 Potential for self-sampling in other Scottish fishing sectors

In addition to the pelagic sector, three other sectors constitute Scottish fisheries: demersal whitefish, *Nephrops* & mixed demersal, and shellfish. As with the pelagic sector, vessels with an overall length >12m have a statutory requirement to report their landings electronically[5], which are routinely sampled at the market by Marine Scotland Science. Vessels under 12m are also required to report their landings (using a FISH1 form) and are sampled at the market. Information from the discard components of the catch are collected by on-board observers in a programme run by Scottish Fishermen's Federation (SFF) and Marine Scotland Science. Data collected in both programmes provide the biological information used in stock assessment. The similarities in information requirements make it worthwhile considering how aspects of a plan for self-sampling in the pelagic sector may be relevant to needs in the demersal and *Nephrops* sectors.

Most Scottish shellfish fisheries are typified by vessels <12m operating inshore and not covered under the DCF, which significantly affects the availability of data useful for science. In particular, a lack of effort data and abundance estimates for the majority of lobster and crab stocks is a major concern. Because shellfish and their fisheries are very different from pelagic and demersal sectors they are not considered further here, and readers are referred to Little et al., 2015 and the Scottish Inshore Fisheries Integrated Data System (SIFIDS) project[6], led by the University of St. Andrews for detailed information.

8.1 Description of demersal and *Nephrops* fishing sectors

The fleet segments within these two sectors are typically classified in terms of their targeted stocks, gears, fishing grounds and seasons. Demersal trawlers (single and paired) and seine netters target haddock (*Melanogrammus aeglefinus*) and associated

[5] Vessels with overall length of 12m or longer are obliged to record and report their fishing activities to national authorities using two main systems of communication, Vessel Monitoring Systems (VMS) (Scottish government, 2018a) (European Commission, 2003; Scottish Government, 2018; Scottish Statutory Instruments, 2004) and Electronic Logbooks Software Systems (ELSS) (European Commission, 2006, 2008e, 2008c, 2009, 2010; Scottish Statutory Instruments, 2010).

[6] SIFIDS is undertaking a review and evaluation of current stock assessment methodologies within the context of Scottish inshore fisheries, quantifying the risks or uncertainties associated with each method. Based on a range of potential management goals, SIFIDS will evaluate the development of an optimised data collection and stock assessment strategy for inshore shellfish. https://www.masts.ac.uk/research/emff-sifids-project/

species such as cod (*Gadus morhua*), monkfish (*Lophius piscatorius* and *L. budegassa*), hake (*Merluccius merluccius*), saithe (*Polachius virens*) and whiting (*Merlangius merlangus*) (Scottish Government, 2017). The *Nephrops* fleet is composed of single and twin rig trawlers, with a distinction between inshore fleet and the offshore boats, which usually have a split quota between *Nephrops* and whitefish species. In terms of value, the *Nephrops* sector represents 14% of the total landed value by the Scottish fishing industry (including pelagic species) while whitefish species account for 31% of the total landed value.

A major change in fisheries management was introduced in the 2014 revised CFP. It specifies that all catches of species under international quota management should be landed and counted against quota, thus prohibiting discarding practices of commercial species (European Commission, 2015). The EU Landing Obligation (LO), also named the discard ban, has been implemented in different phases since 2015, and will affect all TAC species by 2019 (Needle et al., 2015). In the North Sea, the LO is applied according to the different metiers and gear types, while the West of Scotland is based on catch composition rules (MSS, 2014). For 2018, member states defined which species should be landed in the North Sea and North Western waters.

8.2 What are the priority science information needs in the demersal and *Nephrops* sectors?

The size and diversity of the fleet, the nature of mixed fisheries and the challenges this brings makes identifying the opportunities and priorities for industry data collection in the demersal and *Nephrops* sectors considerably more complex than in the pelagic sector. This section draws upon the expert knowledge of Scottish Fishermen's Federation, SWFPA and Marine Scotland Science to illuminate the main opportunities and is intended only as foundation to support more focussed discussion on how an industry self-sampling programme constructed with scientific survey design principles might be used to address specific issues.

Practical implementation of the LO and addressing its implications for the data needed to assess stocks and to develop workable management tactics is the priority for the demersal and *Nephrops* sector. The LO presents two particular problems for fisheries (and individual vessels): (1) closure by choke species. Species whose quota is low relative to its proportion in the catch, may have their quota exhausted quickly, which results in fishing having to stop. This may lead to underutilization of other quotas, and in extreme cases, to some fleets going out of business due to economical unviability. (2) Under the LO, the concept of Minimum Landings Sizes is no longer applicable, so fish of all sizes have to brought ashore and counted against quota. Any fish under the Minimum Conservation Reference Size (MCRS) cannot be sold for human consumption, which results in low sale value or the need to dispose them as 'waste'. A particular problem is the lack of suitable fish processing facilities with costly transport requirements from remote Scottish harbours for any fish not destined for human consumption.

The paradox of the LO is that implies there is no longer a need for discard observation programmes aimed at assessing discarding rates of target (TAC) stocks. These programmes have provided information necessary for stock assessments to estimate the total mortality on each species, and thus estimate sustainable fishing reference points. With the LO, the need for quantifying bycatch and discard may be eliminated because in theory the landing obligation negates the need for observers to assess discarding. But the practice itself may not end, leading to scientific assessments becoming blind when they were previously at least partially sighted. The consequence for management advice is greater uncertainty.

Returning to the two problems specified above. The first requires solutions for avoiding catching choke species and matching fishery quotas more in line with the proportions of species caught, such as further mechanisms for trading quota, or perhaps – more fundamentally – a revision of the relative stability keys in a post-Brexit scenario. The second requires solutions to avoid undersized fish, such as improvements in selectivity. Finding these solutions requires access to the information necessary to accurately diagnose and evaluate the problems. One way to achieve this would be for fishermen to be obliged to provide accurate reporting of their full catch (by means such as observers, self-sampling and with the aid of remote technologies) in return for temporary exemption from the LO. This way, the details of the effect of the LO could be evaluated and appropriate solutions considered. It would also give opportunities to provide much needed data on data poor species, including non-TAC stocks.

Other important issues for the demersal sector but presently taking a back seat because of the focus on the LO include:

- Lack of basic biological information on length, weight, age, and maturity necessary to assess abundance and fishing mortality (e.g. lemon sole, tusk).
- Stock distribution, identity and management boundaries.
- Mortality from by-catch of non-target stocks (e.g. flounder, gurnards).
- Understanding the combined effects of environment and fishing on stock productivity and changes in distribution (e.g. whiting on west coast where despite low fishing mortality, stocks have not recovered).

Within the demersal sector, several species of commercial interest for the Scottish fishing industry are classified as Data Limited Stocks (see Table 8.1). For some stocks such as lemon sole or tusk, there is only limited data on length and age (ICES, 2017g, 2017l), which restricts the development of full analytical assessments and leads to uncertainty about the status of the stock. Two *Nephrops* Functional Units (FU) (10 & 34) targeted by Scottish vessels present low levels of market sampling and discards, with gaps in some quarters, which increases the potential for biases in the results (ICES, 2017i). This may require more thinking about how the sampling is best designed to provide information where it is needed.

In some cases, such as saithe, and plaice for example, there is a lack of scientific survey information on younger age classes that could be used to provide estimates of future recruitment and stock size (ICES, 2017a, 2017j). In the case of anglerfish, the SCO-AMISS-IV-VI survey does not cover divisions 3.a, 4.b, and 4.c which collectively account for approximately 9% of landings in the North Sea and Skagerrak (ICES, 2017a). It is not known to what extent this omission affects the quality of the assessment, but these kinds of obvious uncertainties lead to a lack of confidence from industry in the ability of scientific surveys to represent changes in stocks.

As is the case for the pelagic species, engagement of the demersal industry in self-sampling schemes could help to address survey issues by providing information to aid planning, and as alternative indices of the stock trends, which could be used to help interpret, validate and make decisions about the appropriate use of scientific survey data in assessment models. Similarly, routine industry sampling of lengths and weights, and possibly fat content too, can provide detailed information on changes in fish growth and its relationship to stock size and environmental changes. However, given that fleets from other countries may have a large impact on the exploitation of demersal stocks, consideration needs to be given to the value of the information that self-sampling in the Scottish fleet alone may contribute.

The issue of how to define biologically relevant stock units remains a problem. Stock identity is particularly relevant for whiting and cod in the North Sea. ICES WKROUND 2013 (ICES, 2013) evaluated the available evidence on whiting structure and produced an area-specific survey-based analysis to determine whether estimated time-series of biomass and mortality were correlated between different areas. Although the northern North Sea appeared to be linked with the areas immediately to the south and with no others, the analysis was not sufficiently conclusive. While spatially discrete nursery grounds exist and are visible in surveys (age 0, Q3 survey; Figure 23.1.8), the distinction becomes less clear for older ages. There is some evidence for north–south split in the North Sea, and some evidence for links between Divisions 4.a and 6.a (Barrios et al., 2017; Holmes et al., 2014). The presence of different cod subpopulations in the North Sea has long been acknowledged (ICES, 2011, 2017c, 2017k). Potential differences in fishing mortality across these subpopulations threatens the sustainable exploitation of the stock as a whole (ICES, 2017c; Svedäng et al., 2010). In both species, full stock determination is hindered by data availability. WGNSSK (ICES, 2017 l) recommends, that the stock identity should be reviewed in the future when firm evidence become available and data can be provided at the appropriate spatial scale. Engaging the industry in the collection of genetic data through self-sampling schemes may tackle these limitations. The industry has already expressed its interest to participate in data collection that may be relevant to a benchmark assessment for cod.

Beyond observations on stocks caught during fishing operations, the utility of ancillary information on status of non-quota species, environmental conditions, changes in fish distribution, occurrence of protected and threatened species all add value to the sheer effort of observations required to understand changes in marine ecosystems and make wise choices about utilization.

Table 8.1. ICES stocks classified as DLS. Ordered alphabetically with each category

Category 3	Anglerfish (*Lophius piscatorius* and *L. budegassa*) in subareas 4 and 6 and Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat)
	Black-mouth dogfish (*Galeus melastomus*) in subareas 6 and 7 (West of Scotland, southern Celtic Seas, and English Channel)
	Brill (*Scophthalmus rhombus*) in Subarea 4 and divisions 3.a and 7.d–e (North Sea, Skagerrak and Kattegat, English Channel)
	Cuckoo ray (*Leucoraja naevus*) in Subarea 4 and Division 3.a (North Sea, Skagerrak and Kattegat)
	Dab (*Limanda limanda*) in Subarea 4 and Division 3.a (North Sea, Skagerrak and Kattegat)
	Flounder in Subarea 4 and Division 3.a (North Sea, Skagerrak and Kattegat)
	Grey gurnard (*Eutrigla gurnardus*) in Subarea 4 and divisions 7.d and 3.a (North Sea, eastern English Channel, Skagerrak and Kattegat)
	Greater-spotted dogfish (*Scyliorhinus stellaris*) in subareas 6 and 7 (West of Scotland, southern Celtic Sea, and the English Channel)
	Lemon sole (*Microstomus kitt*)) in Subarea 4 and divisions 3.a and 7.d (North Sea, Skagerrak and Kattegat, eastern English Channel)
	Lesser-spotted dogfish (*Scyliorhinus canicula*) in Subarea 4 and Divisions 3.a and 7.d (North Sea, Skagerrak and Kattegat, eastern English Channel)
	Lesser-spotted dogfish (*Scyliorhinus canicula*) in Subarea 6 and divisions 7.a-c and 7.e-j (West of Scotland, Irish Sea, southern Celtic Seas)
	Ling (*Molva molva*) in Subareas 6-9, 12, and 14, and Divisions 3.a and 4.a (Northeast Atlantic and Arctic Ocean)
	Megrim (*Lepidorhombus* spp.) in Division 6.b (Rockall)
	Plaice (*Pleuronectes platessa*) in Division 7.e (western English Channel)
	Plaice (*Pleuronectes platessa*) in divisions 7.f and 7.g (Bristol Channel, Celtic Sea)
	Plaice (*Pleuronectes platessa*) in divisions 7h–k (Celtic Sea South, southwest of Ireland)
	Starry ray (*Amblyraja radiata*) in Subareas 2 and 4, and Division 3.a (Norwegian Sea, North Sea, Skagerrak and Kattegat)

	Sole (*Solea solea*) in divisions 7.h–k (Celtic Sea South, southwest of Ireland) Spotted ray (*Raja montagui*) in Subarea 4 and Divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat, and eastern English Channel) Spotted ray (*Raja montagui*) in Subarea 6 and divisions 7.b and 7.j (West of Scotland, west and southwest of Ireland) Striped red mullet (*Mullus surmuletus*) in Subarea 4 and divisions 7.d and 3.a (North Sea, eastern English Channel, Skagerrak and Kattegat) Witch (*Glyptocephalus cynoglossus*) in Subarea 4 and divisions 3.a and 7.d (North Sea, Skagerrak and Kattegat, eastern English Channel) Thornback ray (*Raja clavata*) in Subarea 4 and in divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat, and eastern English Channel) Thornback ray (*Raja clavata*) in Subarea 6 (West of Scotland) Turbot (*Scophthalmus maximus*) in Subarea 4 (North Sea) Tusk (*Brosme brosme*) in Subareas 4 and 7-9, and Divisions 3.a, 5.b, 6.a, and 12.b (Northeast Atlantic) Whiting in Division 3.a (Skagerrak and Kattegat)
Category 4	Norway lobster (*Nephrops norvegicus*) in Division 4.a, Functional Unit 10 (northern North Sea, Noup) Norway lobster (*Nephrops norvegicus*) in Division 4.b, Functional Unit 34 (central North Sea, Devil's Hole) Pollack (*Pollachius pollachius*) in Subareas 6-7 (Celtic Seas and the English Channel)
Category 5	Blonde ray (*Raja brachyura*) in Subarea 6 and Division 4.a (North Sea and West of Scotland) Blue ling (*Molva dypterygia*) in Subareas 1, 2, 8, 9, and 12, and Divisions 3.a and 4.a (other areas) Norway lobster (*Nephrops norvegicus*) in Subarea 4, outside the functional units (North Sea) Norway lobster (*Nephrops norvegicus*) in Division 6.a, outside the functional units (West of Scotland) Pollack (*Pollachius pollachius*) in Subarea 4 and Division 3.a (North Sea, Skagerrak and Kattegat) Sandy ray (*Leucoraja circularis*) in subareas 6-7 (West of Scotland, southern Celtic Seas, English Channel) Shagreen ray (*Leucoraja fullonica*) in subareas 6-7 (West of Scotland, southern Celtic Seas, English Channel)

	Sprat (*Sprattus sprattus*) in Subarea 6 and divisions 7.a–c and 7.f–k (West of Scotland, southern Celtic Seas) Sprat (*Sprattus sprattus*) in divisions 7.d and 7.e (English Channel)
Category 6	Blackspot seabream (*Pagellus bogaraveo*) in subareas 6-8 (Celtic Seas, the English Channel, and Bay of Biscay) Cod (*Gadus morhua*) in Division 6.b (Rockall) Common skate (*Dipturus batis*-complex) in Subarea 4 and Division 3.a (North Sea, Skagerrak and Kattegat) Plaice (*Pleuronectes platessa*) in divisions 7.b–c (West of Ireland) Rays and skates (*Rajidae*) in Subarea 4 and in divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat, and eastern English Channel) Rays and skates (*Rajidae*) in Subarea 6 and divisions 7.a-c and 7.e-h (Rockall and West of Scotland, southern Celtic Seas, western English Channel) Roughsnout grenadier (*Trachyrincus scabrus*) in subareas 1-2, 4-8, 10, 12, 14 and Division 3a (Northeast Atlantic and Arctic Ocean) Roundnose grenadier (*Coryphaenoides rupestris*) in subareas 1, 2, 4, 8, and 9, Division 14.a, and in subdivisions 14.b.2 and 5.a.2 (Northeast Atlantic and Arctic Ocean) Sandeel (*Ammodytes* spp.) in Division 6.a (West of Scotland) Seabass (*Dicentrarchus labrax*) in divisions 6.a, 7.b, and 7.j (West of Scotland, West of Ireland, eastern part of southwest of Ireland) Sole (*Solea solea*) in divisions 7.b and 7.c (West of Ireland) Whiting (*Merlangius merlangus*) in Division 6.b (Rockall)

8.3 Appetite of the demersal industry to participate in voluntary data collection

Appetite to implement voluntary self-sampling schemes are likely to vary within the complex and diverse demersal and *Nephrops* sectors. Nevertheless, many of the reasons for industry wanting to engage in self-sampling data collection are shared with the pelagic sector; at the highest level, fishermen all agree on the long-term goal of securing access to good fishing opportunities for this and future generations. The basic approaches to industry data collection also remain the same (Mackinson et al. 2017), even if the specific data and management problems to be addressed differ.

From the SFF and SWFPA, the main drivers to start data collection through self-sampling programmes lies mainly within the mobile gear vessels, both the whitefish sector and the *Nephrops* trawlers. The main drivers identified include:

1. **Discard avoidance and mitigation.** Data to support discard mitigation measures and establish appropriate exemptions for high survivability species.
2. **Data limited stocks**. Basic biological sampling coverage increased on monkfish, cod in Rockall and ling in the west coast of Scotland and is willing to start self-sampling proposals.
3. **Stock identification.** Collection of genetic data that could aid in stock identity, specifically for species where TAC advice is zero catch. For example, as highlighted earlier, cod stocks in the North Sea and West of Scotland have a degree of mix that is not yet fully understood. The Scottish Fishing Industry are of the view that a wider understanding of composition of the West of Scotland stock could lead to more appropriate management decisions which would reflect the distribution and size of the component parts of the stock. Through work within the North West Waters Advisory Council, Industry have reiterated their willingness to engage in collection of genetic and biological data which will assist in filling the data gaps. Clearly, input from Member State Scientific Institutes is key to developing a work package that could be presented at a suitable time such as a Cod Benchmark.
4. **Demonstrating industry responsibility.** Engagement of the industry in data collection programmes is a step forward towards the responsible management of the stocks, which could promote the development of sustainability accreditations (MSC). For instance, lack of data for Protected Endangered and Threaten (PET) species, such as skates and rays, could be improved by industry data collection programmes

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Appendices

Appendix 1. Inventory of datasets collected by the industry

To assess the content and potential scientific applications of data already collected by the industry, an inventory of existing datasets was developed. All 23 vessels and 5 factories belonging to the Scottish pelagic sector were contacted either personally, by telephone call or by email and asked a series of questions regarding the methods used to collect data during fishing operations and landings.

Over the long history of some of these datasets, there have been changes in the way that information has been recorded. Three different systems are routinely used on pelagic vessels: paper diaries, plotter systems and Electronic Logbooks Software Systems (ELSS). Factories also record biological information as part of their processing and quality assurance protocols. Data collected by either skippers or factories was classified into six different groups according to the information recorded: a) Haul position and date (of either fish marks or hauls) b) Fishing activity (e.g. fishing track, gear setup, information on other vessels activities); c) Catch (in tonnes); d) Fish size (individual average weight of the haul in grams); e) Biology (e.g. fat content, sex, maturity) and f) Environment (e.g. temperature or bottom depth). Fishing vessels provide all data groups a-d and sometimes f, whereas factories provide data groups c-e. The data from fishing vessels and factories are described in greater detail in Sections A1.1 and A1.2, respectively.

Vessel data

Paper diaries

Dating back as early as the late 1970s, paper diaries or paper logbooks have been used by fishermen to record spatially resolved catch data for the purpose of documenting productive fishing grounds and developing insights into fishing opportunities based on seasonal conditions and past experiences. Most of the skippers (20 of 23 vessels, Figure A1.1) from the Scottish pelagic industry keep detailed diaries of their fishing operations. Twenty vessels keep a record of the total catch and the positions and date of the haul. Seventeen also include information about the average size of the fish from each haul (Figure A1.2). Less frequently recorded are environmental data (e.g. haul temperature, bottom depth) (four vessels) and information such as gear setup, description of the fishing track or weather conditions (five vessels) (Figure A1.2).

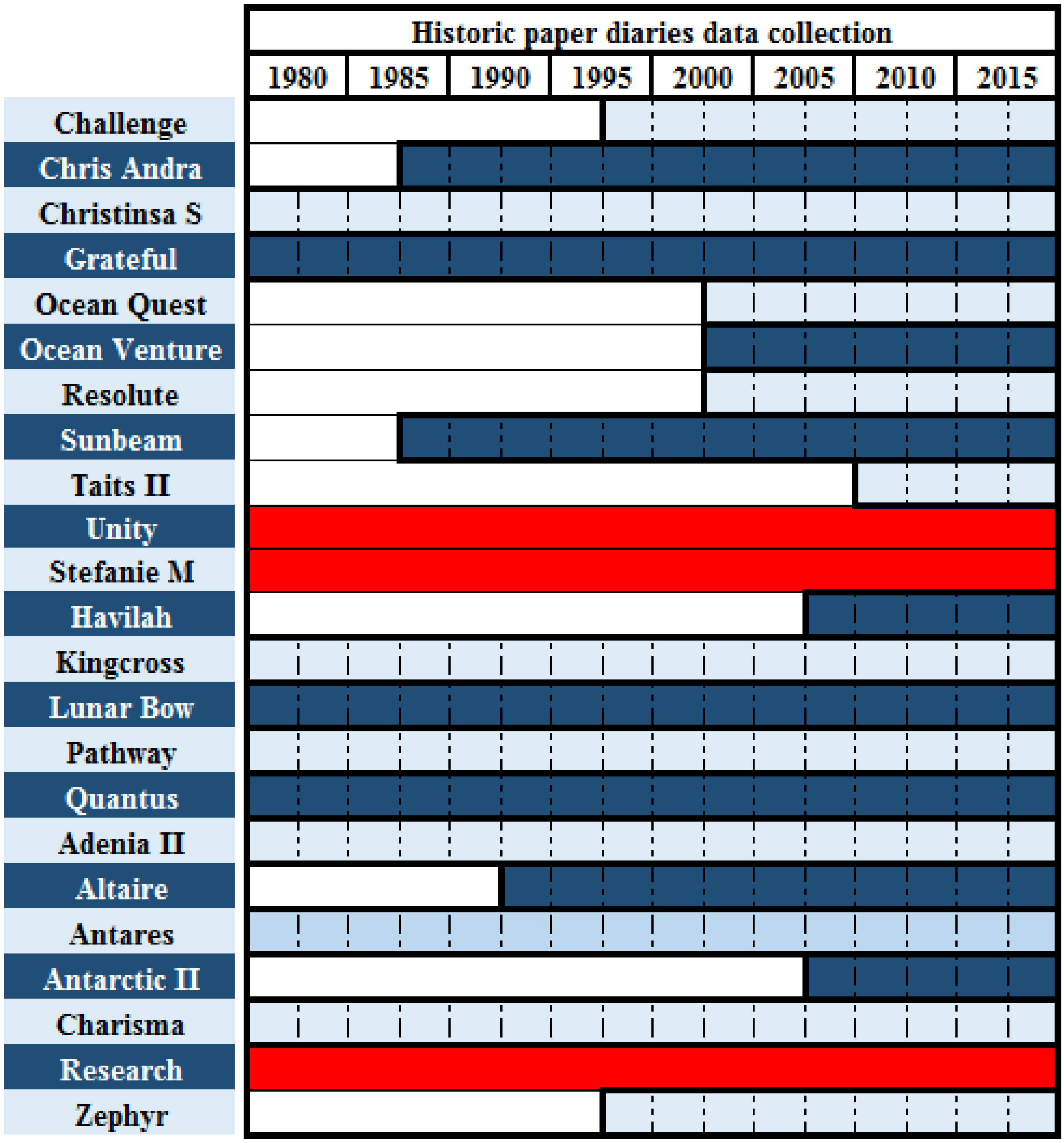

Figure A1.1. Timeline of paper diaries maintained by fishing vessel. Each box represents 2.5 years starting in 1980. Red lines indicate no information stored or intermittent data collection.

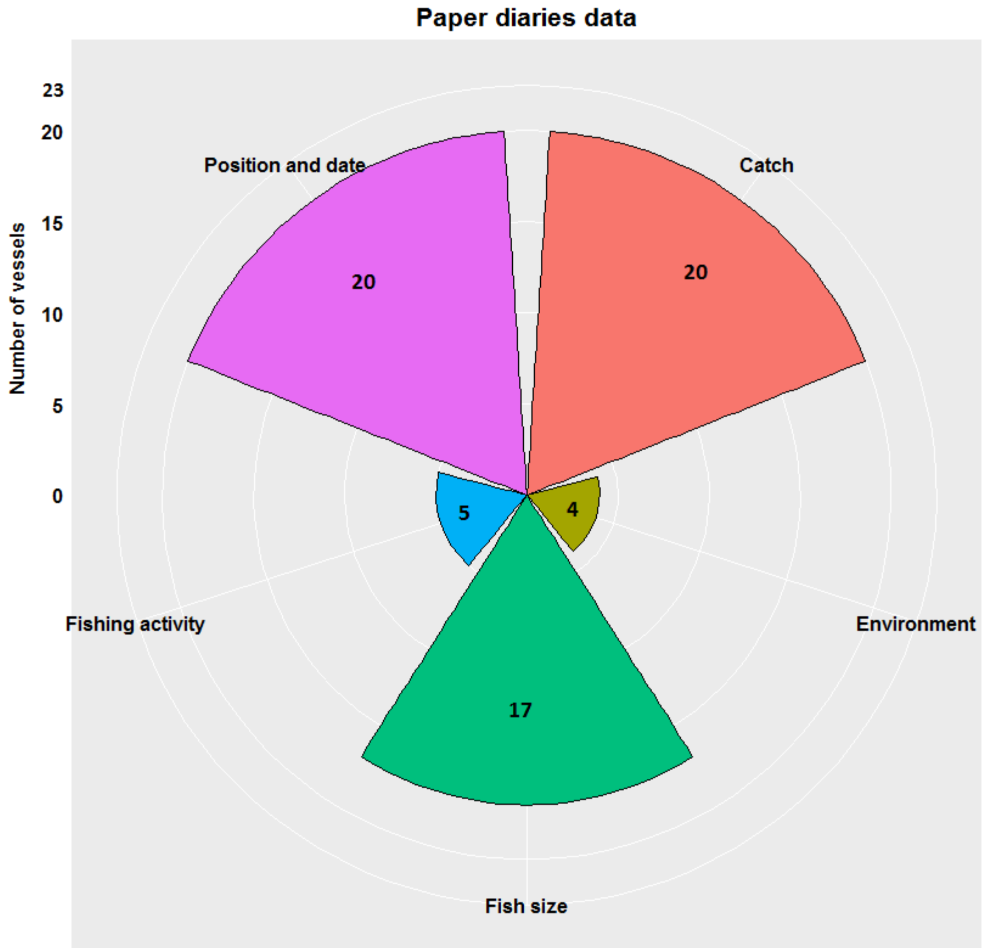

Figure A1.2. Radar plot of current types of data collected by the pelagic fishing vessels. Five categories of data on paper diaries: haul position and date, catch (tonnes in each haul), fish size (average individual fish size), fishing activity (fishing tracks) and environment (temperature, bottom depth). Numbers within each data type indicate the number of vessels that have historically collect that data on paper diaries.

Plotter devices

Electronic chart systems or 'plotters' are computer programs, originally designed for navigation but have evolved to integrate, display and store information from on-board systems such as echo sounders, radars or temperature sensors. On some fishing vessels, the plotter has become not only a useful navigation system, but also as an alternative to traditional paper diaries to store and access previous haul locations, fishing tracks and in some cases, more detailed data about the catch and size of the fish. The data extend back to around the early 2000's (Figure A1.3).

Figure A1.4a shows the wide variety of plotter providers, systems and models used by Scottish pelagic vessels. The most common are Sodena plotters (39% of pelagic vessels), followed by MAXSEA (34.8%) and OLEX (13%). The main types of data collected by these systems is shown in Figure A1.4b. Twenty pelagic vessels store haul position and date of the catch while just nine of them incorporate information about the total catch. Fishing activity (mainly the fishing tracks for each haul) is stored by eleven vessels. Average fish size is collected by six vessels. Pelagic boats tend to operate with multiple plotter systems as can be seen when the plotter devices are separated by harbour of origin (Figure A1.5). It's common practice to use different plotter systems to store different types of data according to the pros and cons of each system.

Detailed information about fishing activities, such as the fishing tracks, is often stored in the OLEX plotter system due to its capability to represent bottom topography in detail. Position, date and total catch are usually stored in an alternative system using event markers (e.g. MAXSEA and Sodena). Seapix is a newer tool with extensive capabilities whose potential is often not fully utilised. Users can enter and annotate 'Event marks', which consist of the date and time, lat/long and any comment input. These relatively small files can be exported from most systems and are sometimes loaded into alternative plotters. However, manufacturers tend to encrypt these files making them difficult to export in a format that can only be read, stored and handled in a simple spreadsheet form. Plotter systems also record vessel tracks, which comprise extremely large and extremely compressed computer files. Electronic engineer companies, like Echomaster Marine, Seafield Navigation, Woodsons, Furuno and Williamsons have experience in handling these files, so professional help would likely pay dividends. Naturally, there would be a cost associated with this.

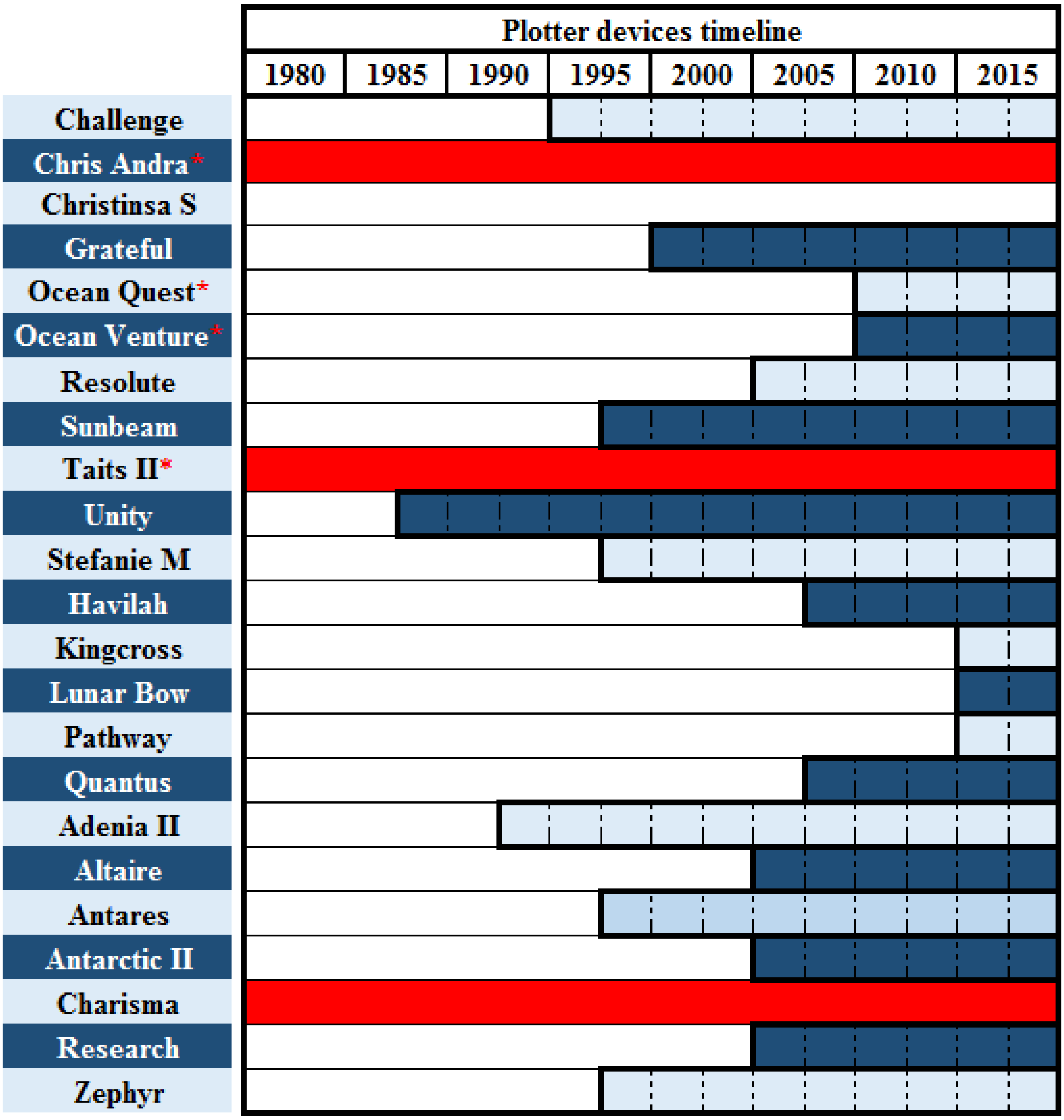

Figure A1.3. Timeline of plotter systems by vessel. Each box represents 2.5 years starting in 1980. In vessels where data was recorded in more than one system, starting date has been set to be the oldest plotter system. Red lines indicate no information stored or intermittent data collection. *Approximate starting date.

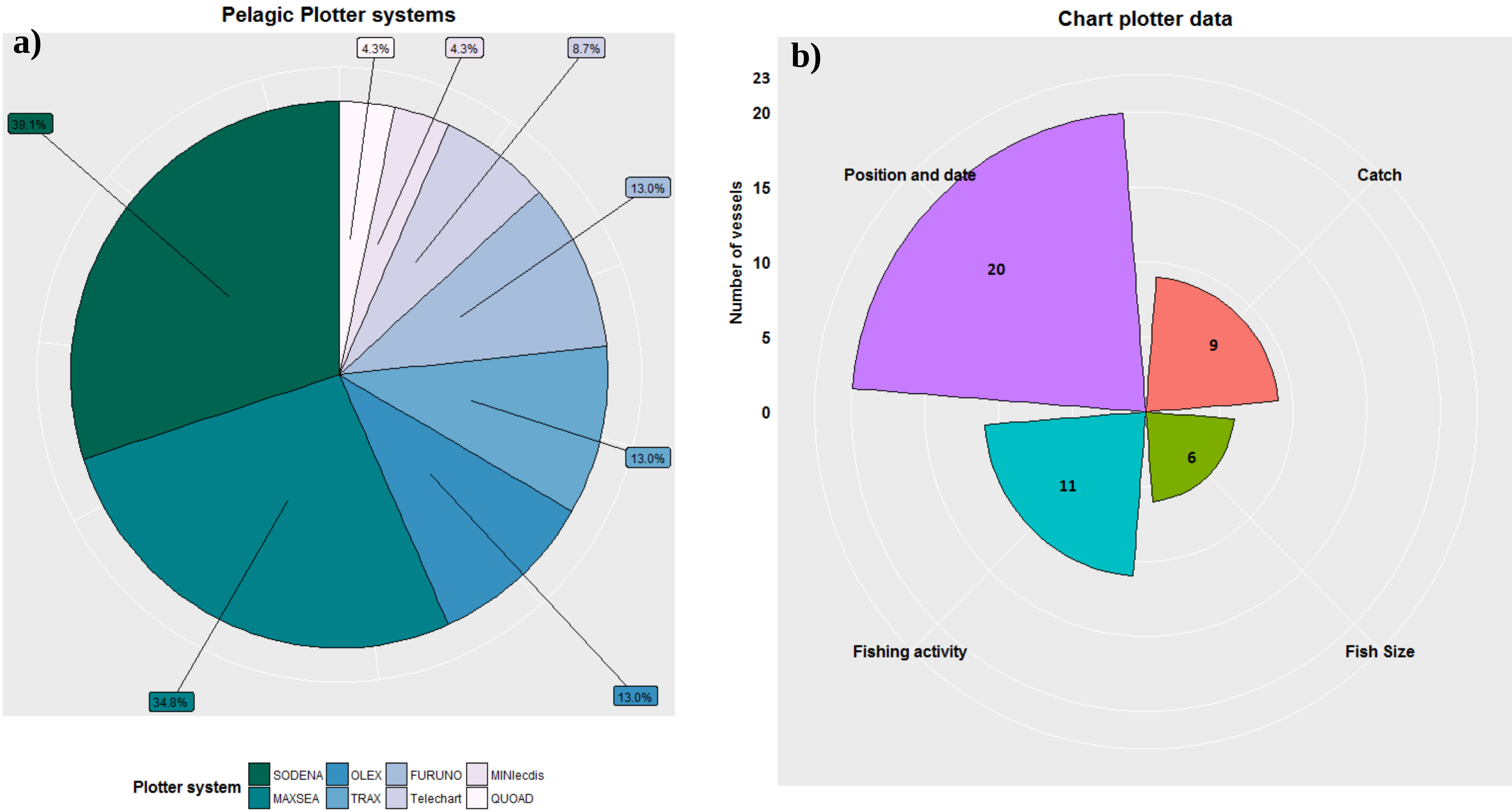

Figure A1.4. Description of a) plotter devices used by Scottish pelagic fishing vessels indicating the percentage of pelagic boats that have that plotter system expressed relative to the total size of the Scottish pelagic fleet (23 vessels) and b) data collected on these devices. Numbers within the plot indicate the number of pelagic vessels that collect each data type.

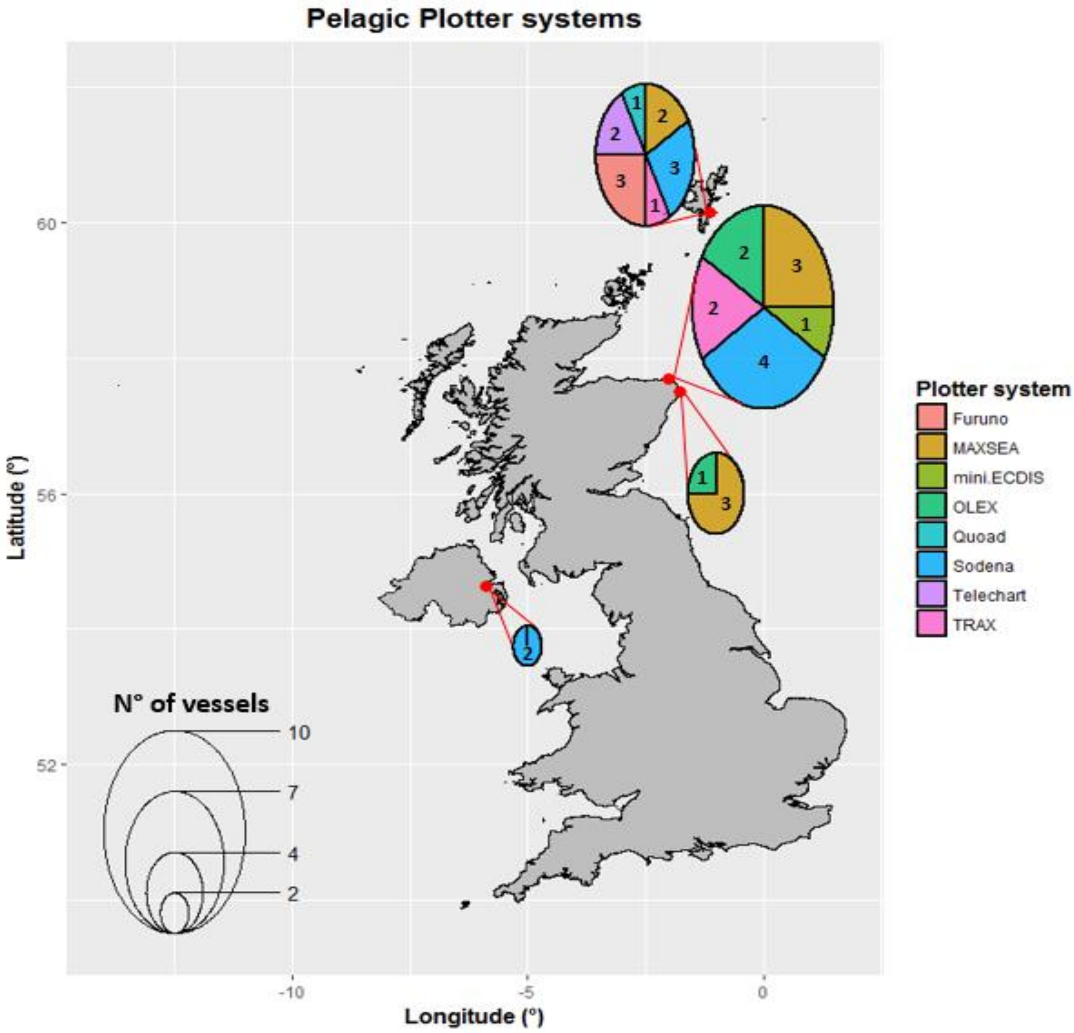

Figure A1.5. Plotter devices of pelagic fishing vessels by harbour of origin (Fraserburgh, Peterhead, Shetland and Northern Ireland). Numbers within the pie chart indicate the number of vessels using a particular plotter system. Size of the pie chart shows the relative fleet size for each harbour. Pelagic vessels often have more than one chart plotter device to collect data. Consequently, numbers within the pie do not have to sum the fleet size in each harbour.

During the project, one of the pelagic vessels shared the data stored from a MAXSEA plotter. Figures A1.5 and A1.6 show the density of herring and mackerel marks by years and months. Fish marks and hauls available in this dataset could be plotted at lat/long level but for visualization purposes we show them as number of marks per rectangles at defined resolutions (easily modifiable to finer scale resolutions). The limited number of years showed here for both species is explained by the fact that different plotter systems have been used during fishing operations. This highlights that considerable effort would be required to harmonize all the plotter devices both within and across vessels. This particular vessel rarely stores haul-specific information in its plotter system, but mostly in its paper diaries. As seen in Figure A1.6, certain positions or fish marks observed are not mackerel marks, but rather errors during the input of the information in the system, or a wrong labelling of the mark. However, these errors are easily identified and the information can be validated with skippers through the scrutiny of the plots. Once limitations like this are considered, these figures demonstrate the amount of information available.

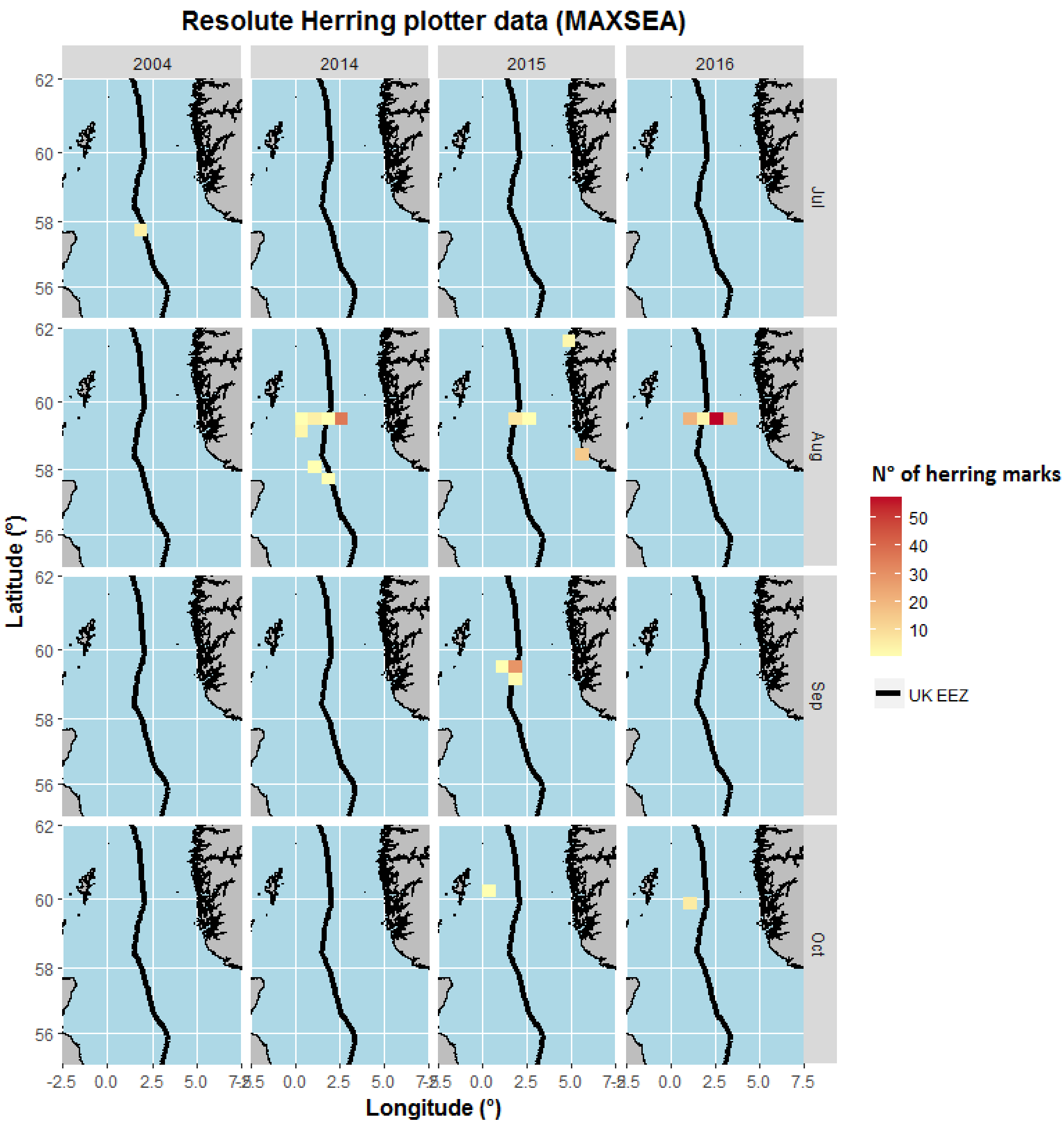

Figure A1.5. Density of herring marks as numbers per square (8.4x7 nm) available in the MAXSEA plotter system from the Scottish pelagic fishing vessel *Resolute*. Black continuous line shows the UK Exclusive Economic Zone.

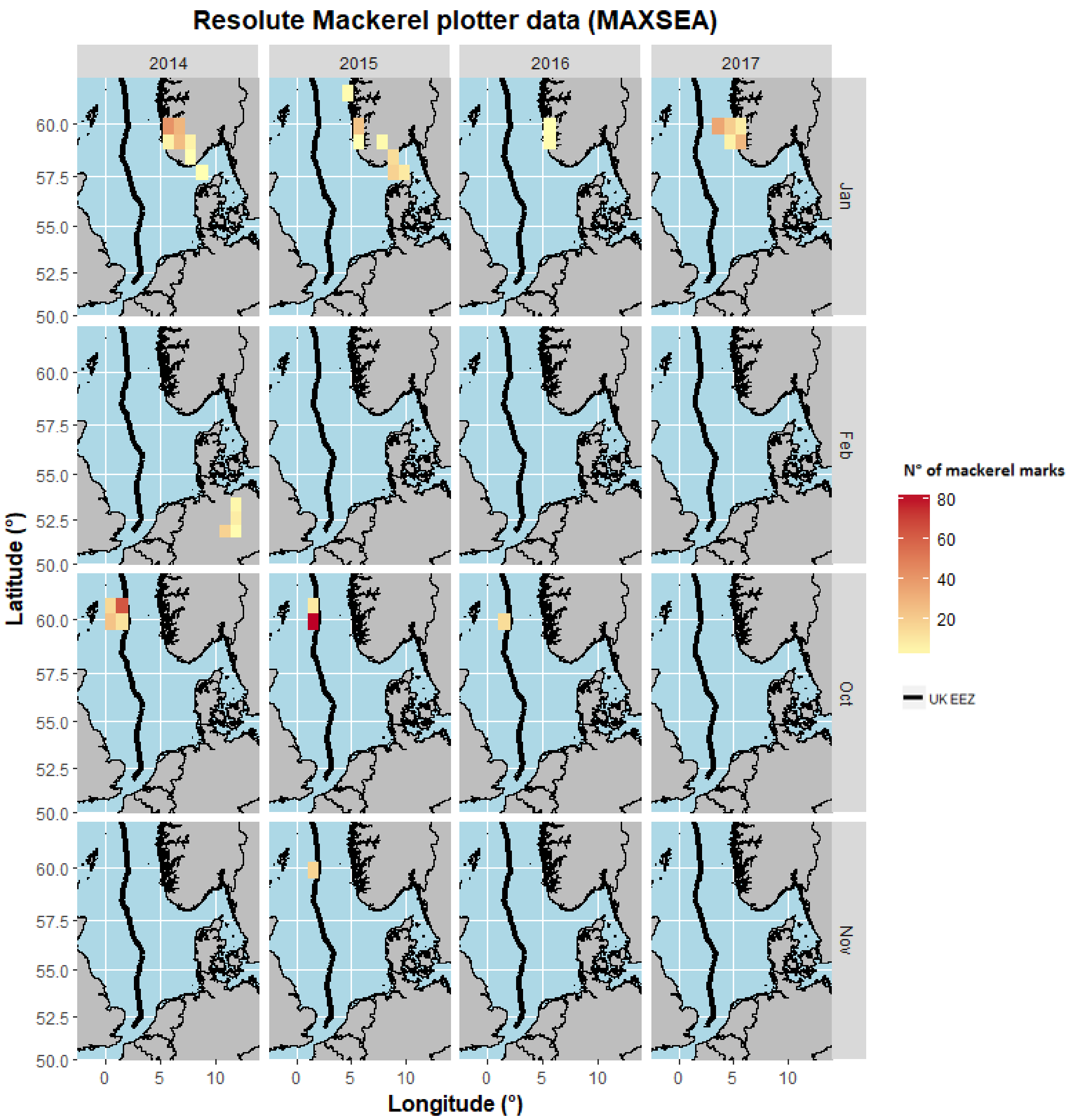

Figure A1.6. Density of mackerel marks as numbers per square (12x10.6 nm) available in the MAXSEA plotter system from the Scottish pelagic vessel Resolute. Black continuous line shows the UK Exclusive Economic Zone.

Electronic logbook

Electronic logbooks were introduced by the Sea Fishing (EU Recording and Reporting Requirements) (Scotland) Order 2010 (SSI 2010/334) as a system for electronically reporting fishing activity of Scottish vessels operating in UK, EU and third country waters. There are a wide range of providers of elogbooks with 4 different types used by pelagic vessels (eCatch, Olfish, OLRAC, Seatronics). The most common elogbook is the Dutch system, eCatch, with more than 45% of pelagic vessels (and probably more in the future) reporting fishing activities using this software (Figure A1.7).

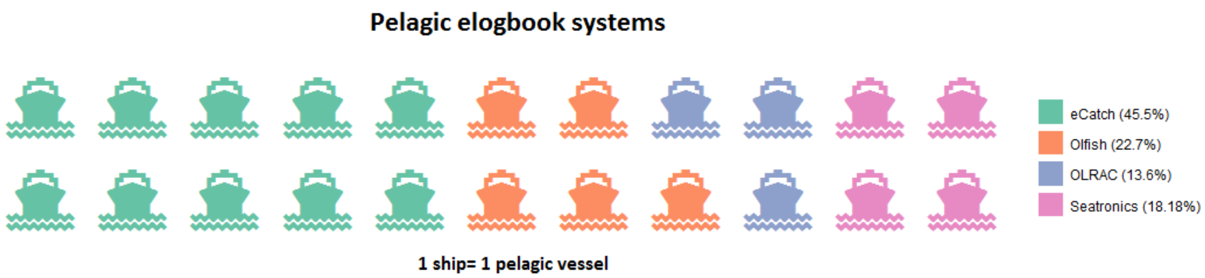

Figure A1.7. ELSS systems used by pelagic vessels. Each boat represents one pelagic boat. Information from one vessel not available.

Current reporting protocol obliges fishing masters to send the following information on a daily basis: gear used (its dimensions and mesh size), species caught in live weight, geographical area where fish is caught (at ICES statistical rectangle) and any discards by species above 50kg in total weight. Separate fishing reports must be submitted if fishing occurred in different ICES areas within the same day. In addition, vessels must provide information on departure from port, catch on entry and catch on exit from waters under special fishing regulations (e.g. cod recovery plan), western waters and foreign Economic Exclusive Zones (EEZ), end of fishing, return to port and landings. A full description of the reporting protocols and currently approved e-logbook systems in the UK can be found at (Marine Management Organisation, 2014; Scottish Governement, 2014)

In the UK the data from elogbook systems is systematically monitored, standardized and stored by the Marine management organization (MMO). Consequently, when considering analysis purposes in terms of its standardization, this centralised data source offers several advantages compared to diaries and plotters On the other hand, the key shortfall is that e-logbook data lack spatially resolved information at haul level, which can be an important limitation for certain studies. This information could be however obtained and linked from data belonging to the VMS.

Elogbook providers can sometimes offer a range of additional tailored services to support onboard data collection. A good example of this being the development by eCatch (www.e-catch.eu) of an app to collect production information on Freezer Trawlers and also to store data from biological sampling onboard. During this project, we have been in contact with eCatch about options for software to store and access data from self-sampling on board Scottish pelagic vessels.

Factory data

Five factories are responsible for processing pelagic landings in Scotland. All of them record the following data at trip level: landed weight, individual fish weight samples, fat content and food hygiene measures, such as histamines and Total Volatile Base Nitrogen (TVBN), which seafood processing companies are obliged under European legislation to test the content of these substances. Table A1.1 summarises the types of data available in each factory and specifies the protocols.

Different factories store data in different formats, but it is generally kept as spreadsheets or separate word documents for each landing. Since most factories keep information recorded on paper, the storage space creates a problem and often the information is discarded after about 5 years. Another reason for not keep the information is that after 2 years the factories will have sold all of the product relating to the sampling. Currently, the data is collected solely for marketing and sales objectives. Until now, its utility to science has not been considered. Nevertheless, two factories still keep older records as far as 1999 and 2005 (Table A1.1).

Factories also measure the weight of thousands of individual fish from every landing so that they can determine the price to pay vessels and grade the landing according to product sizes. With the exception of occasional length measurements for some blue whiting products, none of the factories routinely records lengths of individual fish.

The factories use similar methods to sample the landings as part of their quality control process. Methodologies to test histamine content and the permitted levels for each species are determined in European Commission, 2004, 2005a. TVBN specifications can be found in (European Commission, 2005b, 2008b). Analysing trends in histamine and TVBN content of Scottish pelagic products has not previously been attempted, but demonstrating the high standards for fish preservation and processing could potentially have interesting marketing prospects for the industry.

Determination of fat content is not a mandatory requirement but is collected to provide information required by customers. To determine fat content, three individuals from each size category are selected randomly and blended in a mixer, followed by heating in a microwave. Fish weight is measured before and after heating to calculate the percentage of water loss. The sum of water loss and fat content is estimated to be 80% of the fish weight, which agrees with previous studies that found a stable proportion of ~20% of protein and ash content thorough the year in pelagic species (Karakoltsidis et al., 1995; Suvanich et al., 2006). If fat content for each sample is within a 10% range, the sample is considered appropriate; otherwise, measurements are repeated for the outliers. With the exception of Pelagia (which uses FOSS (brand) machine) all other factories use this methodology to estimate the fat content of fish.

Scottish pelagic vessels are known to have almost negligible bycatch, with significant bycatch occurring only when hauls targeting herring or mackerel end up with a mixture of both species. Other species that appear in pelagic hauls, such as haddock and other demersals generally occur in such low numbers (measured in individuals) that they are not reported by factories. Several pelagic factories noted that quantifying the bycatch would be feasible.

Table A1.1. Scottish pelagic processing factories with datasets available, periods of time data has been collected, storing protocols and potential applications.

Factory name	Data collected	Dates available/ Storing format	Sampling process	Applications
Lunar Fraserburgh	-Fish weight -Fat Content -Histamines and TVBN -Taste -Pathogens	2014-present (excel/electronic)	Weights - after grading machine and QC box checks Fat – evaporation method	**Fish weight:** length-weight relationships for stock assessment
Lunar Peterhead	-Fish weight (after grading and box checks) -Fat Content -Histamines and TVBN -Taste -Pathogens	2005-present (excel/electronic)	Weights - after grading machine and QC box checks Fat – evaporation method	**Fat content:** proxy of stock wealth, environmental status and recruitment potential
Northbay Pelagic	-Fish weight (after grading and box checks) -Fat Content -Histamines and TVBN -Taste -Pathogens	2013-present Printed and attached to each landing. Electronic protocol through PDF documents being currently set	Weights – Ocean run, after grading machine and QC box checks Fat – evaporation method	**Histamines and TVBN:** index of freshness and improvement in preservation of the catch
Denholm Seafoods Ltd	-Fish weight (after grading and box checks) -Fat Content -Histamines and TVBN -Taste -Pathogens	1999 (2008 digital)-present Printed and attached to each landing	Weights – Ocean run, after grading machine and QC box checks Fat – evaporation method	**Bycatch:** estimates of bycatch can be included in stock assessment.
Pelagia (Shetland Catch Ltd.)	-Fish weight (after grading and box checks) -Fat Content (FOSS machine) -Histamines and TVBN -Taste -Pathogens	~2002-present Electronically through Word documents for each landing	Weights – Ocean run, after grading machine and QC box checks Fat – by machine measurement	

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European Commission. (2005a). Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:338:0001:0026:EN:PDF

European Commission. (2005b). Commission Regulation (EC) No 2074/2005 of 5 December 2005 laying down implementing measures for certain products under Regulation (EC) No 853/2004 of the European Parliament and of the Council and for the organisation of official controls under Regulatio. Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:338:0027:0059:EN:PDF

European Commission. (2008). Commission Regulation (EC) No 1022/2008 of 17 October 2008 amending Regulation (EC) No 2074/2005 as regards the total volatile basic nitrogen (TVB-N) limits. Retrieved from https://www.fsai.ie/uploadedFiles/Reg1022_2008.pdf

Karakoltsidis, P. A., Zotos, A., & Constantinides, S. M. (1995). Composition of the Commercially Important Mediterranean Finfish, Crustaceans, and Molluscs. *Journal of Food Composition and Analysis*, *8*(3), 258–273. https://doi.org/10.1006/JFCA.1995.1019

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Scottish Governement. (2014). On board Electronic Logbook Software Systems(ELSS) Approvals. Retrieved July 27, 2018, from https://www.gov.scot/Topics/marine/Compliance/ERS/approveduk

Suvanich, V., Ghaedian, R., Chanamai, R., Decker, E. A., & McClements, D. J. (2006). Prediction of Proximate Fish Composition from Ultrasonic Properties: Catfish, Cod, Flounder, Mackerel and Salmon. *Journal of Food Science*, *63*(6), 966–968. https://doi.org/10.1111/j.1365-2621.1998.tb15834.x

Appendix 2. Self-sampling protocol for mackerel

Mackerel weight and length sampling protocol

Why? Measuring both the weight and length of fish at the same time provides information on their growth that can be used in assessing the state of the stock.

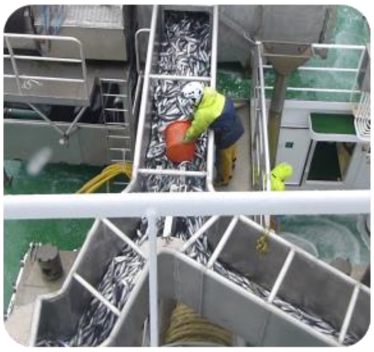
When? A sample of weight and length should be taken from every haul, and the details of the haul recorded so that the date and position can be linked to the sample details. A sheet for recording the haul data is provided.

What? The sample needs to be representative of overall catch, so the sample needs to be taken at different times during pumping. We will use the start, middle and end.

How?

1. During pumping, take half a basket of fish at the start, middle and end, and put them to one side until the fishing work is done. The order of the baskets doesn't matter because all the fish will be weighed and measured. The three baskets together should be around 40-45kg and provide a sample of around 100-130 fish.
2. Take each fish and measure its length (see diagram) to the nearest lowest cm (for example, if it is 37.7cm, write down 37 cm. If its 37.4 cm, write down 37), then measure its weight in grams.
3. Record the measurements of **all** the fish in the basket on the recording sheet provided. Use a separate sheet for each haul.
4. Enter the data from the paper copy into the spreadsheet sent to the skipper. The file is called 'Length-Weight Data Entry sheet_SPFA.xlsx'

Mackerel sample: take 1/2 basket at the start, middle and end of pumping



3 x 1/2 baskets (giving approx. 40-45kg = 100-130 fish)

For every fish in the basket, measure and record length to lowest cm, then weight in grams

Appendix 3. PhD proposal on pelagic fish fats: *What can the fat content in mackerel and herring reveal about the ecosystem functioning in the North Sea?*

Supervision

Academic supervisor 1. Dr C Tara Marshall

Institution and School: University of Aberdeen
School of Biological Sciences
Lab web site url: http://www.abdn.ac.uk/sbs/people/profiles/c.t.marshall
Track record: F. Sandison (Year 2), T. Busbridge (part-time Year 2), I. Indongesit (Year 2), J. Wouter (Year 1), H. Holah (part-time Year 1) and has had 9 PhD students complete their PhD degrees with 100% submission rate within 4 years of registration.

Industry partners/ co-supervisor 1. Dr Steven Mackinson

Institution: Chief Scientific Officer, Scottish Pelagic Fishermen's Association, Fraserburgh.
Website: http://www.scottishpelagic.co.uk/
Facebook: https://www.facebook.com/SPFAScience/
Track record: Kathryn Lees (PhD), Jeroen van der Kooij (PhD), Julio Araujo (PhD), Celina Wong (PhD), Carole White (PhD), Jennifer Shepperson (PhD candidate) Robin Boyd (PhD candidate), Mandy Bunk (Mphil). Various MSc projects.

Industry partners/ co-supervisor 2. Martin Pastoors

Institution: Chief Scientist, Pelagic Freezer Trawler Association, Netherlands.
Website: http://www.pelagicfish.eu/research

Matched Funding

Matched funding will come from the pelagic fishing industry. 25% from the Scottish Pelagic Fishermen's Association (http://www.scottishpelagic.co.uk/) and 25% from the Pelagic Freezer-trawler Association (http://www.pelagicfish.eu/).

Focus of studentship with respect to priority research areas

This proposal is directly relevant to several priority research areas identified in the SBS strategic plan (2015-2020) including food security, marine sciences, environmental dynamics and large scale ecological studies. It is well established that the high content of fat is indicative of good feeding (Yaragina & Marshall, 2000) and favourable environmental conditions (Sandeman et al., 2008). Using fat content as a direct measure of fish condition (Stevenson & Woods, 2006), the studentship will investigate how changes in the condition of pelagic fish (mackerel and herring) can be used as indicators of ecological change in the marine environment. With moves toward integrated assessment of marine ecosystems (ICES, 2017f; Ramírez-Monsalve et al., 2016), such bio-integrating metrics can provide timely indicators of the state of the marine environment in relation to, for example, the productivity and composition of zooplankton community, and the health (*sensu* energy reserves) of fish stocks (Golet et al., 2007). Mining archived data can also reveal historical trends, providing the opportunity to understand how changes in climate and ocean conditions are related to changes in marine food webs. Such knowledge is particularly relevant to improving predictions of marine ecosystem impacts due to climate change.

There are several reasons why the focus on pelagic fish make this project particularly relevant to understanding changes in the marine ecosystem and the consequences for society. First, pelagic fish play a central role in the transfer of energy from zooplankton to higher consumers, and due to their great abundance have a big impact on the dynamics of ecosystems (Pikitch et al., 2012; Smith et al., 2011). Second, pelagic fish are a mainstay in food provision and a key source of protein for people around the world. Third, in our regional seas, pelagic fish and the fisheries that depend upon them play a big part in the economy and in the fabric of marine communities.

Approach

The project will mine data on the direct measurement of fats in pelagic fish undertaken by the fishing industry, which is routinely collected but has never before been utilised for the purpose of research. These data are recorded and stored by fish factories and fishing companies and used primarily for quality control and marketing. Due to the systematic nature of the sampling as well as the temporal extent of the data the project has enormous potential to release the scientific value of this data particularly in the context of the Ecosystem Approach to Management (ICES, 2017f). It also has considerable potential to identify to future opportunities where the fishing industry and science can work in partnership to undertake applied research projects.

The student will be supervised by academics from the University of Aberdeen (and possibly) and an overseas research institute, with additional support coming from senior scientific personnel of the industry sponsors.

Outline of research plan

Chapter 1 [Review and Thesis]**. Fats as an ecosystem indicator: a review of what is known and what remains to be discovered.**

- Fats as a bio-integrator – what this means and why it has value as an indicator of changes in the ecosystem. What they have been used for and what they reveal.
- What questions remain unanswered? – these are the basis for this thesis
- How the thesis is organised

Chapter 2 [Approach and Data collection]. **Revealing the value of industry data: the benefits and challenges of working with industry**

- The approach – working closely with industry that have collected this data for marketing purposes, leaving the scientific value still to be mined and discovered
- Describes the methodological approach
- Describes the data collection process – accessing, formatting, access and use agreements.
- Identifies the challenges and systems for improving future data collection so that the data is accessible and useable.

Chapter 3 [Data handling and specific methods]. **Releasing the value of the data.**

- Methods for measuring fats. Describe them (Boiling method, FOSS machine, hand held fatometer, others?), discuss their strengths and weakness. Inter-comparison.
- Reconciling the methods. Standardising the data sets across methods so they can be combined and used as one. Validation of methods.

- Harmonising raw data to form one dataset for analysis. The outcome here is the data set.

Chapter 4 [Analysis]. **Patterns in the ocean.**

- Spatio- temporal patterns described
- Seasonal patterns
- What they tell us about the fish and the ecosystem

Chapter 5 [So what]. **Use and use-ability of industry data on fats**

- Interesting ecological patterns have been revealed, but
- Who wants to know this and what value is it to them?
- How can industry take a different look at and utilise the value of the information they have been collecting for a long time already.

Chapter 6 [Conclusion].

Skills

Three skill sets are necessary for the work: (1) People skills – working with industry and accessing industry data requires the ability to establish and maintain good working relationships. It requires, diplomacy, patience, acute awareness of sensitive issues and reliability. (2) Analytical skills – in particular the ability to collate, organise, manage and interrogate large data sets. Industry data will likely come in a variety of forms that will need to be collated, stored in a database and harmonised. Different methods used in the analysis of fats will need to be validated and standardised to make them comparable. Analysing the data will require statistical and data visualisation skills. If required, the student will take a statistics course and a course on the statistical programming language R in the first year. (3) Communication - a key component of the studentship will be feeding back results to industry, marine research institutes, and academia at conferences, industry events and through publishing in the peer-reviewed literature.

Knowledge about fish is not essential but will be developed through the project work. This project has additional scope for developing complementary analytical skills in other fields including GIS, data visualisation and stakeholder engagement.

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Appendix 4. Discussion document on the use of "Scientific Quota" to fund Fishery Science

Steven Mackinson
Scottish Pelagic Fishermen's Association
5 July 2018

Purpose

To open up a dialogue between the pelagic fishing industry, Marine Scotland and Defra on the utilisation of Scientific Quota to support industry participation in the collection of scientific data relevant to stock assessment and management of pelagic fisheries (and equally relevant to other fisheries).

Rationale

Reductions in government funding, pressures for greater efficiency, the demands for information needed to support an ecosystem approach to fisheries management, and the opportunities and challenges of Brexit, require innovative thinking about the efficient utilisation of available funding resources. One of those sources is Scientific Quota (SQ). This discussion document reviews the recent utilisation of SQ in Scotland and, as a means to facilitate discussion, looks at the approaches to its use by Scotland and other countries.

It provides an update to a document prepared by Bill Turrell in 2010 on "Use of Scientific Quota to fund Fisheries Science" (Annex 1), which considered only the principal whitefish and *Nephrops*. The 2010 document identified that in 2011 Scotland could have access to fish over and above its allocated quotas which could be used to fund science to an estimated value of £2.3m in the North Sea and £1.1m on the West Coast. It was therefore suggested to engage industry in discussions about how to make the use of SQ work in practice, and considered the role of the former Science Industry/ Science Partnership group (now channelled through Fisheries Innovation Scotland). In relation to process, it noted that if the UK and/or Scotland is to use SQ in a systematic way, a process should be agreed with the rest of the UK, and that an open, transparent and fair procurement policy using SQ to charter industry vessels would be necessary.

The increasing shift to partnership working is an important driver for this discussion document. Defra's recent White Paper on the future of fisheries states "*Our future vision is that industry should take a greater, shared responsibility for sustainably managing fisheries, while making a greater contribution towards the costs. This can include, for example, work to develop new management practices and contributing to fisheries science*". And further, "*We will consider allocating some new quota within the reserve through a tendering system to deliver sustainable fisheries, to promote the economic interests of coastal communities, to create opportunities for new entrants to the industry and to fund a world-class fisheries management system*".

Scope

The 2010 document focussed on the use of SQ to enable scientific work to be carried out using commercial fishing vessels. This discussion document goes further by considering the opportunities that SQ may present to foster a more systematic partnership working model for the collection of scientific data as well as support for the expertise to analyse the data and make use of the insights derived from analysis. This is consistent with approaches being adopted by other countries, which seek to mobilise SQ as a means to address scientific needs over and above routine work.

Interpretation of Scientific Quota

'Scientific Quota' (SQ) refers to provisions in COM (2018/0193) [7] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, (amending COUNCIL REGULATION (EC) No 1224/2009[8]) establishing a Community control system for ensuring compliance with the rules of the common fisheries policy. In this document, the revised Article 33, paragraph 6 states:

"Catches taken in the framework of scientific research which are marketed and sold including, where appropriate, those below the applicable minimum conservation reference size, shall be recorded by the Member States and the data on such catches shall be submitted to the Commission. They shall be counted against the quota applicable to the flag Member State insofar as they exceed 2 % of the quotas concerned. This paragraph shall not apply to catches taken during research surveys at sea as referred to in Article 5(1)(b) of Regulation (EU) 2017/1004[9] of the European Parliament and of the Council (*)".

The interpretation of Article 33(6), and hence how to deal with SQ, has recently created a lot of discussion, particularly in the Netherlands and Denmark.

In plain English, an interpretation of the text '*Catches taken in the framework of scientific research which are marketed and sold shall be recorded…and…shall be counted against the quota applicable to the flag Member State insofar as they exceed 2 % of the quotas concerned',* would be:

> While conducting scientific research activity, any fish marketed and sold that amount to more than 2% of the UK quota for that species must be recorded as catches against the quota of that species. ***Implying that***: while conducting scientific research activity, any fish marketed and sold, up to 2%, are not required to be recorded against quota. This 'less than or equal to 2%' part is what is commonly referred to as the 'Scientific Quota'. It is generally thought of as relating to catches made by commercial vessels undertaking scientific work, but actually the regulation does not specify the type of vessel.

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[7] Brussels, 30.5.2018 COM(2018) 368 final 2018/0193 (COD) Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Council Regulation (EC) No 1224/2009, and amending Council Regulations (EC) No 768/2005, (EC) No 1967/2006, (EC) No 1005/2008, and Regulation (EU) No 2016/1139 of the European Parliament and of the Council as regards fisheries control {SEC(2018) 267 final} - {SWD(2018) 279 final} - {SWD(2018) 280 final}

[8] COUNCIL REGULATION (EC) No 1224/2009, Article 33(6): Catches taken in the framework of scientific research which are marketed and sold shall be counted against the quota applicable to the flag Member State insofar as they exceed 2 % of the quotas concerned. Article 12(2) of Council Regulation (EC)No 199/2008 of 25 February 2008 establishing a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy(1) OJ L 60, 5.3.2008, p. 1. (1) shall not apply to scientific research voyages during which such catches are taken".

[9] Regulation (EU) 2017/1004 of the European Parliament and of the Council of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008 (OJ L 157, 20.6.2017, p. 1)

Three especially pertinent texts are:

(i) the definition of '*framework for scientific research'* – this could mean at sea scientific survey work or more loosely, anything regarded as scientific research, where the 'framework' could be objectives for research knowledge defined by, or endorsed by, a government research institute.

(ii) the catches being '*marketed and sold'* – this bit would seem to imply some particular significance to being sold, perhaps intended to related specifically to the act of commercial selling for profit. However, what is meant by marketing and sold could be open to a broad interpretation.

(iii) *'of the quotas concerned'* – which might be interpreted that the research should relate specifically to the species whose quota is concerned. Or, perhaps not at all, and interpreted instead as meaning that if under the auspices of scientific activity, more than 2% of the quota of species Y is caught then it needs to be counted against the quota of species Y, regardless whether the research is related to species Y.

The second part *'This paragraph shall not apply to catches taken during research surveys at sea as referred to in Article 5(1)(b) of Regulation (EU*) 2017/1004)' basically says that any catches taken during specified **mandatory research surveys** under the Union framework (Data Collection Framework) are not included in the accounting for catches against quota in this '*framework for scientific research'*.

The list of **mandatory surveys** that Marine Scotland Science (MSS) currently propose to carry out each year in its DCF work plan is:

IBTS North Sea Q1
IBTS West Coast Q1
MEGS (three in the relevant years)
HERAS (North Sea and WoS I)
IBTS North Sea Q3
IBTS West Coast Q4
2 Nephrops TV (would need to clarify Functional Units if necessary)
Blue whiting (but MSS only provides staff not RV vessels)

Additional **non-mandatory** surveys of MSS within DCF workplan are:

Scottish Anglerfish and Megrim Survey (SIAMISS)
Rockall haddock
Deepwater (biennial)
Sandeel

To summarise, the 'opportunities' that may be interpreted under Article 33 (6) are:

- The 'framework for scientific research' provides a very broad interpretation of what scientific activities could be considered as relevant. It does not specifically relate to sea-going surveys, and neither does it say how the research should be undertaken and by whom. It ought then to be sufficient to define that any activity is scientific research by linking it to specified research objectives.
- An open interpretation of 'the quota concerned' for the Member state would provide the opportunity to do research on important species or fisheries-related issues that are relevant to, but not necessarily focussed on, the species whose SQ is utilised to support research activities. There are examples of this already.

- The DCF establishes rules on the collection, management and use of biological, environmental, technical and socioeconomic data in the fisheries sector and does not require catches from scientific research voyages to be counted against national quota. It provides member states with the rules to provide a minimum level of data. It does not preclude using SQ to address CFP relevant issues (which is desirable) in ways that can be used to enhance and improve any deficiencies in the existing scientific data collection programme and to ensure the necessary scientific capacity to undertake such work.

The size of Scientific Quota available

The table below give an indication of the size of SQ available. For comparison, the science operating budget for Marine Scotland Science in 2017 was £16m[10], and over the course of its duration, the European Maritime and Fisheries Fund (EMFF) accounted for £30m of Marine Scotland's expenditure on science, data and compliance (from Marine Scotland 2020 budget review). *[NB Would be good to know value without compliance]*

Table A4.1. The tonnage and approximate value (based on 2017 prices) of Scientific Quota available to the UK and to Scotland. (see Table A4.2 for details).

	Scotland SQ (tonnes)			TOTAL value (£)			% of available SQ utilised		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
Mackerel (WS)	3,730	3,170	3,613	3,357,881	2,854,177	3,252,695	0%	37%	7%
Mackerel (NS)	28	24	28	25,549	21,954	24,809	0%	0%	0%
Herring (NS)	890	1,005	946	379,602	428,694	403,831	0%	0%	74%
Herring (WS)	206	-	38	87,766	-	16,131	0%	-	0%
Blue whiting	723	762	1,413	118,651	124,945	231,802	0%	0%	0%
Horse mackerel (WS)	63	81	62	45,055	57,603	44,115	0%	0%	0%
Horse mackerel (WS)	13	13	17	9,457	9,457	11,940	0%	0%	0%
Sprat (NS)	73	111	11	16,012	24,290	2,403	0%	0%	0%
Boarfish (WS)	71	46	29	15,443	9,971	6,380	0%	3%	0%
Cod (NS)	147	170	198	341,242	393,408	458,481	7%	61%	8%
Haddock (NS)	446	627	347	674,804	947,905	524,829	4%	0%	4%
Haddock (VIa)	56	78	41	84,901	117,328	62,089	0%	1%	37%
Haddock Vib)	32	38	57	47,648	57,504	85,694	0%	0%	0%

[10] Listed on Job advert for Director Marine Scotland Laboratory

Whiting (NS)	131	126	147	171,161	165,266	192,686	0%	3%	0%
Saithe (NS)	57	57	87	56,748	56,564	86,598	35%	12%	75%
Saithe (WS)	39	39	43	38,978	38,526	42,563	0%	8%	35%
Hake (NS)	8	9	10	17,261	18,915	21,260	146%	0%	30%
Hake (WS)	77	94	102	162,327	197,257	215,591	0%	0%	15%
Monkfish (NS)	121	145	174	334,926	401,902	482,291	12%	9%	69%
Monkfish (WS)	23	27	32	62,583	75,100	90,105	0%	0%	46%
Megrim (NS)	33	42	42	97,864	123,916	123,916	27%	2%	18%
Megrim (WS)	17	21	25	49,071	61,954	74,383	0%	0%	24%
Ling (NS)	31	38	45	52,436	62,901	75,442	33%	5%	17%
Ling (WS)	35	42	56	58,070	70,666	93,991	0%	5%	27%
Nephrops (NS)	214	164	240	739,052	567,343	829,760	5%	5%	3%
Nephrops (WS)	199	232	230	689,294	802,733	797,011	0%	0%	3%
Totals	**7,462**	**7,159**	**8,034**	**£ 7,733,782**	**£ 7,690,278**	**£ 8,250,796**	**1%**	**18%**	**16%**

Approaches to use of Scientific Quota

Some examples from different fishing nations, including Scotland, are briefly described below.

Marine Scotland

(information from Iain Gibb, Marine Scotland procurement).

Marine Scotland undertakes two main types of charter (of commercial vessels) where SQ is used to either supplement, or fully fund the required work. All quota allocations are confirmed prior to tender via the SG, MS Quota Management Unit in Edinburgh.

When engaging this approach for work undertaken on pelagic vessels, a single fishery is targeted for recovery of SQ at the first available landing to the vessel. This covers surveys such as mackerel egg and herring acoustic work in the first and second quarters of the year, where quota is taken in Q2/3. SQ is offered in exchange for a number of days survey time (maximum 'X' days depending on the daily rate of charter). Using the Public Contracts Scotland portal, the charter submits a tender bid (price) to undertake the survey. Bids are assessed with quality and financial (daily rate) criteria. Once the tender is awarded a derogation letter is issued to authorise the vessel to operate during the survey, and land from the first commercial landing for the species a volume of fish up to the specific capped value of the tender (at point of sale). Thus, the final amount of SQ allocated reflects the daily rate multiplied by the duration of survey. If the vessel lands more than the monetary value agreed, the excess must be covered by the vessels own quota allocation. Therefore bidding vessels must have sufficient quota in the relevant area. If the vessel lands less than the value agreed no additional compensation will be offered. A derogation is provided by Marine Scotland – Fisheries Policy Division to permit the vessel owners to land and sell legal sized fish, up to the agreed value, out-with quota restrictions (i.e. the landing will not count against vessels quota).

Mixed demersal fishery charters are not fully funded by the use of SQ, but instead land specific species (up to pre-arranged capped limits) which are sold at the end of survey period and are offset against the charter cost. These surveys go through the same tender and derogation process as described above. The list below is an example of the maximum capped limits for such a survey lasting 14 days. Any other species retained and sold goes against the vessels PO quota.

Species	Maximum Limit
Anglerfish (west Scotland)	10 tonnes
Haddock (west Scotland)	10 tonnes
Hake (west Scotland)	10 tonnes
Ling (west Scotland)	10 tonnes
Megrim (west Scotland)	4 tonnes
Nephrops (west Scotland)	5 tonnes
Plaice (west Scotland)	1 tonne
Pollack (west Scotland)	0.5 tonnes
Saithe (west Scotland)	10 tonnes
Blue ling (west Scotland)	5 tonnes
Tusk (west Scotland)	0.5 tonnes

An example of using SQ for one species to undertake research on another was the 2018 survey of salmon smolts, the charter for which was paid for using North Sea herring quota.

Defra

- In parallel to this document, recent discussions (25 June 2018 minutes) with Defra on industry engagement in science raised the issue of SQ as a funding mechanism. It was listed as a next step for Defra to look into the UK approach for coordinating additional quota for scientific purposes and how it's currently utilised.

Other countries approach to using SQ

Ireland: In 2017 and 2018, Horse Mackerel SQ was utilised to pay for chartering industry survey work on 6aS herring.

Netherlands: SQ in the Netherlands is generally utilized to compensate or fund vessels and vessel-time when those vessels are participating in a scientific research program. Sometimes, SQ is used in conjunction with national or European research projects where the SQ is specifically targeted at the vessel costs. In the Dutch pelagic industry, SQ is utilized to fund a comprehensive research program with several different elements (e.g. industry surveys, self-sampling, selectivity trials). In this case the SQ is allocated to the participating vessels and the vessel owners pay a 'rent' at an agreed price per species to the PFA with which research projects can be executed. Proposals for scientific research projects are made to the Ministry of LNV. Recent examples of SQ projects include the PFA self-sampling program, the 6a herring survey, the hake selection trials and the use of multi-frequency echosounders for species recognition. *(Pers., Comm. Pastoors, M. Pelagic Freezer Trawler Association)*

Denmark: After two years of discussion, and spurred by a desire to mobilise SQ more actively, Denmark has since 2018 adopted the same kind of approach as the Netherlands. In 2017, money from the sale of SQ was used to fund a fishing vessel participating in the international mackerel and horse mackerel egg survey. In 2018 SQ will be used to fund coverage of the North Sea basin as part of the international swept area survey for mackerel. It is also a goal that the SQ will be used to establish the capabilities at DTU-Aqua to undertake a Management Strategy Evaluation of North Sea herring. *(Pers., Comm. Sparrevohn, C. Danish Pelagic Producers Association).*

Norway: Having recently implemented a new mechanism to generate fisheries research funding, Norway has recently moved away from the use of SQ for specific applications. Instead, the SQ is allocated across the fleet as quota and a new Research Fee is applied as a levy on the first sale landings of fish from all boats. This is used to support relevant scientific research. In return, fishermen representatives have a seat on the planning group chaired by the Institute of Marine Research that defines objectives for research. Norway involves the industry quite closely in the collection of scientific data, in particular having a dedicated 'reference fleet' to take representative scientific samples. During this data collection process they have specific exemptions to ensure that fishing operations are representative of true activity. *(Notes from comments made by Director General, Vidal Landmark, during FIS conference, 10 July 2018)*

Faroes: Like Norway and Scotland, the Faroes aspires to have the best scientific information to support a world class fisheries management system. There has recently been a complete overhaul of the management system, not without controversy. A Resource Fee is levied on the industry, and it is expected that this will generate funds to support the management system. With regarding to industry involvement in delivery of scientific information, they see that there are many opportunities, as yet untapped. The technologies that vessels have will make it possible to collect relevant data on a daily basis. *(Notes from comments made by Fisheries Minister, Høgni Hoydal, during FIS conference, 10 July 2018)*

Identification of scientific information needs suitable for deploying SQ

Issue	Status
Discard ban implementation trials (e.g gear, timing etc. Example recent Shetland Fishermen's Org initiative)	SQ has been used in the past
Supplement traditional stock surveys (e.g. HERAS, mackerel egg) either to provide prior planning information and/or delivery of the scientific survey itself.	SQ has been used in the past
Haul-by-haul catch and biological data self-sampled on pelagic vessels, providing information relevant to assessment and management of mackerel, herring and blue whiting. SQ to pay for the additional costs of self-sampling such as the quality control and auditing of sampling methods, additional age reading, data storage (on existing systems) and formatting for use.	New opportunity
Acoustic surveys for abundance and distribution (processing and analysis resources)	New opportunity

Resource for Management Strategy Evaluations capabilities	New opportunity
Resource for Management and Rebuilding plan development	New opportunity

Table A4.2. Values and utilisation of Scientific Quota in Scotland [Information from Ross Parker, Marine Scotland].

2015	UK Quota (tonnes)	2% SQ	Scotland Share	Scotland SQ (t)	Price/tonne (£) 2017	Scot SQ Value (£)	Scot SQ landed	Quota left	% utilisation SQ
Mackerel (WS)	245,363	4,907	76%	3,730	900	3,357,881	0	3,730	0%
Mackerel (NS)	1,933	39	73%	28	900	25,549	0	28	0%
Herring (NS)	62,292	1,246	71%	890	427	379,602	0	890	0%
Herring (WS)	13,711	274	75%	206	427	87,766	0	206	0%
Blue whiting	39,065	781	93%	723	164	118,651	0	723	0%
Horse mackerel (WS)	7,829	157	40%	63	714	45,055	0	63	0%
Horse mackerel (WS)	1,314	26	50%	13	714	9,457	0	13	0%
Sprat (NS)	8,271	165	44%	73	219	16,012	0	73	0%
Boarfish (WS)	4,197	84	84%	71	219	15,443	0	71	0%
Cod (NS)	11,369	227	65%	147	2,320	341,242	10	137	7%
Haddock (NS)	28,576	572	78%	446	1,512	674,804	20	426	4%
Haddock (VIa)	3,532	71	80%	56	1,512	84,901	0	56	0%
Haddock Vib)	2,079	42	76%	32	1,512	47,648	0	32	0%
Whiting (NS)	8,739	175	75%	131	1,309	171,161	0	131	0%
Saithe (NS)	5,249	105	54%	57	994	56,748	20	37	35%
Saithe (WS)	3,022	60	65%	39	994	38,978	0	39	0%
Hake (NS)	574	11	71%	8	2,106	17,261	12	-4	146%
Hake (WS)	9,155	183	42%	77	2,106	162,327	0	77	0%
Monkfish (NS)	7,641	153	79%	121	2,778	334,926	15	106	12%
Monkfish (WS)	1,635	33	69%	23	2,778	62,583	0	23	0%
Megrim (NS)	2,006	40	83%	33	2,928	97,864	9	24	27%

Megrim (WS)	1,295	26	65%	17	2,928	49,071	0	17	0%
Ling (NS)	1,869	37	84%	31	1,668	52,436	11	21	33%
Ling (WS)	2,863	57	61%	35	1,668	58,070	0	35	0%
Nephrops (NS)	15,456	309	69%	214	3,460	739,052	10	204	5%
Nephrops (WS)	13,854	277	72%	199	3,460	689,294	0	199	0%
Totals	502,889	10,058		7,462	40,715	£ 7,733,782	107	7,356	1%
2016	**UK Quota (tonnes)**	**2% SQ**	**Scotland Share**	**Scotland SQ (t)**	**Price/tonne (£) 2017**	**Scot SQ Value (£)**	**Scotland SQ landed**	**Quota left**	**% utilisation on SQ**
Mackerel (WS)	208,557	4,171	76%	3,170	900	2,854,177	1159	2,011	37%
Mackerel (NS)	1,661	33	73%	24	900	21,954	0	24	0%
Herring (NS)	70,348	1,407	71%	1,005	427	428,694	0	1,005	0%
Herring (WS)	-	-	75%	-	427	-	0	-	#DIV/0!
Blue whiting	41,137	823	93%	762	164	124,945	0	762	0%
Horse mackerel (WS)	10,002	200	40%	81	714	57,603	0	81	0%
Horse mackerel (WS)	1,314	26	50%	13	714	9,457	0	13	0%
Sprat (NS)	12,547	251	44%	111	219	24,290	0	111	0%
Boarfish (WS)	2,710	54	84%	46	219	9,971	2	44	3%
Cod (NS)	13,107	262	65%	170	2,320	393,408	103	66	61%
Haddock (NS)	40,141	803	78%	627	1,512	947,905	3	625	0%
Haddock (VIa)	4,881	98	80%	78	1,512	117,328	1	77	1%
Haddock Vib)	2,509	50	76%	38	1,512	57,504	0	38	0%
Whiting (NS)	8,438	169	75%	126	1,309	165,266	4	122	3%
Saithe (NS)	5,232	105	54%	57	994	56,564	7	50	12%
Saithe (WS)	2,987	60	65%	39	994	38,526	3	36	8%
Hake (NS)	629	13	71%	9	2,106	18,915	0	9	0%
Hake (WS)	11,125	223	42%	94	2,106	197,257	0	94	0%
Monkfish (NS)	9,169	183	79%	145	2,778	401,902	14	131	9%
Monkfish (WS)	1,962	39	69%	27	2,778	75,100	0	27	0%

Megrim (NS)	2,540	51	83%	42	2,928	123,916	1	42	2%
Megrim (WS)	1,635	33	65%	21	2,928	61,954	0	21	0%
Ling (NS)	2,242	45	84%	38	1,668	62,901	2	36	5%
Ling (WS)	3,484	70	61%	42	1,668	70,666	2	40	5%
Nephrops (NS)	11,865	237	69%	164	3,460	567,343	8	156	5%
Nephrops (WS)	16,134	323	72%	232	3,460	802,733	0	232	0%
Totals	486,356	9,727		7,159	40,715	7,690,278	1,308	5,852	18%
2017	**UK Quota (tonnes)**	**2% SQ**	**Scotland Share**	**Scotland SQ (t)**	**Price/tonne (£) 2017**	**Scot SQ Value (£)**	**Scotland SQ landed**	**Quota left**	**% utilisation SQ**
Mackerel (WS)	237,677	4,754	76%	3,613	900	3,252,695	238	3,375	7%
Mackerel (NS)	1,877	38	73%	28	900	24,809	0	28	0%
Herring (NS)	66,268	1,325	71%	946	427	403,831	700	246	74%
Herring (WS)	2,520	50	75%	38	427	16,131	0	38	0%
Blue whiting	76,319	1,526	93%	1,413	164	231,802	0	1,413	0%
Horse mackerel (WS)	7,660	153	40%	62	714	44,115	0	62	0%
Horse mackerel (WS)	1,659	33	50%	17	714	11,940	0	17	0%
Sprat (NS)	1,241	25	44%	11	219	2,403	0	11	0%
Boarfish (WS)	1,734	35	84%	29	219	6,380	0	29	0%
Cod (NS)	15,275	306	65%	198	2,320	458,481	15	183	8%
Haddock (NS)	22,225	445	78%	347	1,512	524,829	15	332	4%
Haddock (VIa)	2,583	52	80%	41	1,512	62,089	15	26	37%
Haddock Vib)	3,739	75	76%	57	1,512	85,694	0	57	0%
Whiting (NS)	9,838	197	75%	147	1,309	192,686	0	147	0%
Saithe (NS)	8,010	160	54%	87	994	86,598	65	22	75%
Saithe (WS)	3,300	66	65%	43	994	42,563	15	28	35%
Hake (NS)	707	14	71%	10	2,106	21,260	3	7	30%
Hake (WS)	12,159	243	42%	102	2,106	215,591	15	87	15%
Monkfish (NS)	11,003	220	79%	174	2,778	482,291	120	54	69%

Monkfish (WS)	2,354	47	69%	32	2,778	90,105	15	17	46%
Megrim (NS)	2,540	51	83%	42	2,928	123,916	8	35	18%
Megrim (WS)	1,963	39	65%	25	2,928	74,383	6	19	24%
Ling (NS)	2,689	54	84%	45	1,668	75,442	8	38	17%
Ling (WS)	4,634	93	61%	56	1,668	93,991	15	41	27%
Nephrops (NS)	17,353	347	69%	240	3,460	829,760	8	232	3%
Nephrops (WS)	16,019	320	72%	230	3,460	797,011	8	223	3%
Totals	**533,346**	**10,667**		**8,034**	**40,715**	**£ 8,250,796**	**1,267**	**6,767**	**16%**

Scottish Charity Number SC045119

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