The fishPi[2] Project
Regional co-operation in fisheries data collection

STRENGTHENING REGIONAL CO-ORDINATION IN FISHERIES DATA COLLECTION

The fishPi[2] Project

Summary Report Annexes

MARE/2016/22

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Annexes to the main fishPi[2] Summary Report

Contents

Glossary

Acronym	Full Wording
AIS	Automatic Identification System
CCTV	Closed Circuit Television
CFP	Common Fisheries Policy
CLEF RDB	Core Library for Ecosystem and Fisheries Regional Data Base
COI	Country of interest
EM	Electronic Monitoring
ERS	Electronic Recording and Reporting Systems
EU	European Union
EU-MAP	European Union Multi-Annual Plan
FAO	Food and Agriculture Organization of the United Nations
FOI	Fish species of interest
FU	Nephrops Functional Unit
GNSS	Global Navigation Satellite System
GPS	Global Position System
GT	Gross Tonnage
IBTS	International Bottom Trawl Surveys
ICES	International Council of the Exploration of the Sea
IESSN	International Ecosystem Summer Surveys in the Nordic Seas
IFCA	Inshore Fisheries and Conservation Authorities
IRCS	International Radio Call Sign
ISSCAAP	International Standard Statistical Classification of Aquatic Animals and Plants
kg	kilogram
LSF	Large Scale Fisheries
MB	Megabyte
MMO	Marine Management Organization
MRF	Marine Recreational Fisheries
MS	Member State

MSAR	Monthly Shellfish Activity Returns
MSE	Management Startegy Evaluation
NA	North Atlantic
NC	National Correspondent
NSEA	North Sea and Eastern Arctic
NWP	National Work Programmes
PETS	Protected Endangered and Threatened Species
PGCCDBS	Planning Group on Commercial Catches, Discards and Biological Sampling
PGDATA	Planning Group on Data Needs for Assessment and Advice
PSU	Primary Sampling Unit
R	Free software for statistical analysis
RCG	Regional Coordination Groups
RCG	Regional coordination group
RDBES	Regional Data Base Estimation System
RDBES	Regional DataBase and Estimation System
RSE	Relative standard error
SC RDB	Steering Committee of the Regional Data Base
SRS	Simple random sampling
SSF	Small scale fishereis
SSU	Secondary Sampling Unit
STECF	Scientific Technical and Economic Committee for Fisheries
STECF EWG	Scientific Technical and Economic Committee for Fisheries Expert Working Group
SWOT	Stregnth Weakness Opportunities Threats
UK	United Kingdom
UN	United Nations
UN/LOCODE	United Nations location code
VMS	Vessel Monitoring System
WGBFAS	ICES Baltic Fisheries Assessment Working Group
WGCATCH	ICES Working Group on Commercial Catches
WGECO	ICES Working Group on Ecosystem Effects of Fishing

WGMIXFISH	ICES Working Group on Mixed Fsiheries Advice
WGNSSK	ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak
WGRFS	ICES Working Group on Recreational Fisheries Surveys
WGSAM	ICES Working Group on Multispecies Assessment Methods
WKMERGE	ICES Workshop on methods for merging metiers for fishery based sampling
WKPICS	ICES Workshop on Practical Implementation of Statistical Sound Catch Sampling Programs
WKPRECISE,	ICES Workshop on methods to evaluate and estimate the precision of fisheries data used for assessment
WKTARGET	ICES/Probyfish Workshop on identification of target and bycatch
WoRMS	World Register of Marine Species
WP	Work Package

Annex 1

Annex 1.1 Tasks and objectives for the RCGs, present situation and desired future – outcome of brainstorming exercise.

The face-to-face meeting began with a brainstorming exercise aiming to identify and analyse the possible objectives and tasks for the RCG. We then discussed how well these tasks and objectives are fulfilled today, the desired future situation, needs and actions allowing us to move towards the desired future situation and obstacles to overcome. The purpose of the exercise was to use the outcome of this discussion when identifying prerequisites for RCG work.

The objectives identified include development and establishment of regional workplans and regional sampling plans, end-user driven data collection and transparent quality assurance and assessment of collected data. There is a substantial array tasks to fulfill these objectives. RCG work can be seen as a large jigsaw puzzle with a lot of pieces that need to be developed to fit into the large picture. This require a government structure were one group (the RCG meeting) have a clear objective to focus on the large picture and make sure that the pieces fit while other groups (subgroups) are responsible for the detailed development. Identified obstacles are largely related to commitment from the institutes, resources and time. Work is presently dependent on personal commitments and interests from some experts. A key question then becomes how we can make RCG work more attractive and career promoting for individuals and institutes. FishPi2 WP1 have consider this question in the proposals for prerequisites for effective RCG work.

A table with the full result from the brainstorming exercise is presented in table 1. The list should however not be seen as an exhaustive overview of objectives and tasks for the RCGs as this wasn´t the main purpose of the exercise.

Table 1. FishPi2 WP1. Outcome of brainstorming exercise. Tasks and objectives for the RCGs, present situation and desired future.

Output of brainstorming exercise - Regional Work Plan							
Primary objective	**Secondary objective / Task**	**Whats needed**	**Current situation**	**Desired future**	**Actions**	**Obstacles**	**Who is working on it**
Regional work plan (RWP)	Overall agreement of the general architecture of a RWP Shared and agreed documentation	Argumentation on pros and cons, and gains expected by participants,	Scattered information	Clear documentation (e.g. publication)	Identification of building blocks in a RWP, identify what a RWP look like	resources & time	RCGs
Regional work plan (RWP)	All MS committed	Commitment, effort and cooperation Define time frame for the implementation	RCG but with limited commitment, only few countries participate, heavily dependent on personal commitments and interests	Formal commitment to work by claiming our role based on impact/importance for DCF (inter)nationally, each MS should describe in their WP what they are doing	Improve visibility, show impact, claim spot, more efficient setup reducing meetings (combine!); section in the WP needs to be included (refer to commitment, resources, actions)	Resources and time commitment at institutes, how to show impact, too many meetings already while RCGs should have priority	fishPi2 WP1, RCGs
Regional work plan (RWP)	Strengthen process for decision making in the RCGs	The RCGs need to have a better decision making process	RCG but not fully working	Effective forum for decisions	Suggestions for decisions to be presented within the right fora, with the appropriate people involved, arrange appropriate mandates in each MS	National legislation/procedures	RCGs
Regional work plan (RWP)	Agreement on selection of fisheries/variables to be included Documentation on arguments for a specific RSP	Criteria used to define the fisheries/element chosen Gains expected		Clear documentation (e.g. publication)		national needs and dependency, national practicalities	fishPI2 WP2 and 3

Regional work plan (RWP)	End-user interaction and inputs	End-users to be more active in the process, including needs in terms of quality	End-user express needs mainly through data calls. Limited guidance on quality needed.	End-user to express more clear needs, incl quality and also when they do not need data. End-users are able to prioritize between needs.	Finalize development of RDBES. Support end-user by providing information on data collected incl quality	Funds for development of RDBES unsure. End-user unwilling to say when they don't need data	RCG subgroup on end-user needs, RDBSC, ICES Data Centre

Output of brainstorming exercise - Regional Sampling Plan

Primary objective	**Secondary objective / Task**	**Whats needed**	**Current situation**	**Desired future**	**Actions**	**Obstacles**	**Who is working on it**
Regional sampling plan (RSP)	Willingness to move towards regional sampling plans	All MS willing to participate	Some MS do not change anything	All MS are open to changes		MS	
Regional sampling plans (RSPs)	Set up structures and tools for establishing regional sampling plans	Common understanding on what a RSP is, tools & methods to set up RSP	Partly unclear and scattered, some RCM/RCG initiatives incl. RDB, projectbased fishPi, fishPi2	Clear picture on RSPs, working tools & methods	Agreement on the structure of RSPs, take all past experience and developments into account and make them work	Different views on the nature of a RSP, tools too complicated or non-practicle; methods not easy to implement	fishPi and fishPi2, subgroups within RCGs
Regional sampling plans (RSPs)	Sampling plans covering entire regions incl non-EU countries	cooperation with 3th countries	very limited	full cooperation	have (draft) regional plan identifying needs for cooperation	lack of willingness to cooperate with EU	?
Regional sampling plans (RSPs)	Development (sampling design) Identification of core elements		Theoretical Project based	Practical Implementable	Start the work on a practical case using all available knowledge	Feeling that not all MS is needed ; Coordination of effort (putting the right people together); Not knowing where to start ; Linkages of the different components	fishPI2 WP2 and 3 , subgroups in RCGs
Regional sampling plans (RSPs)	implementation of statistical sound sampling	Implement in all countries	implemented in some countries/sampling schemes		All countries to implement statistically sound sampling. Decision making :)	national needs and dependency, national practicalities preventing implementation of common methods, MS unwilling to change	ICES WGCATCH (methodologies), Decisions ?

Regional sampling plans (RSPs)	Implementation - Practical implications - cost sharing	Cost sharing Exchange of staff Staff and cost effort (+/-)	Largely unknown how MS can share responsibilities and costs in the context of EMFF administration	Possibility to fund tools regional activities and tools		Funds through EMFF are managed nationally, long standing problem to fund regional initiatives, MS would like to keep their budgets	fishPi2 WP3 (methodologies), connections to EHFF ?

Output of brainstorming exercise - Regional Sampling Plan continued

Primary objective	Secondary objective / Task	Whats needed	Current situation	Desired future	Actions	Obstacles	Who is working on it
Regional sampling plans (RSPs)	Implementation - Legal implications	Shared responsibilities. Clear documentation on what happen if one MS do not do their part of the RSP	Largely unknown how MS can share responsibilities and costs in the context of EMFF administration			Who is responsible for data failures?	?
Regional sampling plans (RSPs)	Agreement on references	Agreed and shared references on all elements of data collection, mainly all fields of the RDB	Scattered , managed by RDB developers	Open process Agreed and shared references Easily accessible	Test		SCRDB, RCGs, fishPi, fishPi2
Regional sampling plans (RSPs)	Agreement on methodologies	Commom methodologies	under development	agreed methodologies based on end user needs	define end users quality criteria and needs	national needs and dependency, national practicalities preventing implementation of common methods	RCGs, ICES SGPIDS, WKPICS, WGCATCH (methodologies), agreement ?
Regional sampling plans (RSPs)	Agreement on estimation procedures		Mostly national procedures	Estimation libraries up and running			ICES WGCATCH, institutes (methodologies), agreement ?
Regional sampling plans (RSPs)	Regional database with transparent regional estimation procedures (RDBES) up and running. All MS use the system	faster development of RDBES	national data in national databases and Intercatch, slow development, unknown data quality,	Put it to use for coordination and dissemination, RDBES for transparent data processing / estimation and quality assurance	Make RDBES development a high priority, Development and maintenance, Complete tools for regional coordination	resources/time, MS and EC, fear of misuse	ICES DataCentre, SCRDB

Output of brainstorming exercise - Regional Sampling Plan continued							
Primary objective	**Secondary objective / Task**	**Whats needed**	**Current situation**	**Desired future**	**Actions**	**Obstacles**	**Who is working on it**
Regional sampling plans (RSPs)	Help desk on field implementation	Good practice and guidelines agreed; RCG subgroup acting as respondents; FAQ	scatted, no subgroup on practical implementation exists	Clear documentation (e.g. publication), visible FAQ			?
Regional sampling plans (RSPs)	set up a review and monitoring process for RSPs	develop criteria for review of RSPs	no RSP	review criteria for RSPs	agree on review criteria for RSPs	no RSP	
Regional sampling plans (RSPs)	set up a review and monitoring process for RSPs	set up monitoring process (timelines, steps...)	no RSP	agreed structure for monitoring process	agree on steps & timelines for monitoring process	no RSP	
Regional sampling plans (RSPs)	Incorporation of sampling related to "impact of fishing on ecosystem" into regional sampling plans	Identify enduser needs	Not a priority in RCGs, less interaction with ICES than on stock assessment	Higher priority in RCGs, understanding on requirements	coordinated sampling effort, responding to end-user needs, incorporated into regional sampling plan	End-user needs channel through different routes	fishPi2, ICES WKPETSAMP, agreements ?
Regional sampling plans (RSPs)	Motivation of appropriate experts	Different streamline of attendance Create awareness at national level	People not motivated	Annual meeting bringing all together (ideal RCG) + intersession working like a WS	Take decision on working procedure in RCG and sub-groups	People's mind	

Output of brainstorming exercise - Data Quality							
Primary objective	**Secondary objective / Task**	**Whats needed**	**Current situation**	**Desired future**	**Actions**	**Obstacles**	**Who is working on it**
Improve the quality of data and estimates	Quality assured data	Further development of RDB with QA'ed data - independently assured (?)	National aggregated data with ambiguous but self assured quality	RDBES holding Quality assured data with reference to National Sampling Schemes,	Make RDBES development a high priority, Development and maintenance, Complete tools for regional coordination	resources/time, MS and EC, fear of misuse	ICES Data Centre, SCRDB, RCG subgroups
Improve the quality of data and estimates	Documentation of the sampling schemes themselves	Best-practices need to be developed. MS need to document their sampling schemes	Scattered information primarily in national workplans	Clear documentation (e.g. publication), RCG website with links to National websites and documentation	Develop best practices		ICES WGCATCH, PGDATA, RCG subgroup
Improve the quality of data and estimates	Quality assured estimation procedures	Further development of RDB with transparent estimation procedures (RDBES)	National aggregated data with ambiguous but self assured quality	Data put in the RDB and processed transparently through tools in RDBES	Resources for development of RDBES	resources/time, MS and EC, fear of misuse	ICES Data Centre, SCRDB, RCG subgroups
Improve the quality of data and estimates	Establishment of Regional Work Plans	Agreed RWPs	National work plans	Commitment; Achievement and a product RCGs can sell!	Resources; Time; Comittment	You wouldn't or couldn't assess the collective quality and impact on assessments. Or be able to consider optimising sampling plans at a regional level	RCGs
Improve the quality of data and estimates	Effective use of expertise	Improved cooperation	RCGs, national schemes and dependence on EU tenders	Maintain but improve cooperation	More commitments and willingness to share. Develop areas and building blocks where we can cooperate more and demonstrate that cooperation.	Resources; Time; Commitment; Concerns about national impact on resources	RCGs
Improve the quality of data and estimates	Effective use of expertise	Improved use of expertise	Available regionally but not necessarily at a national level. Reliant on ICES	More effective experts. Effective experts who can excite new blood and initiatives.	Sell the opportunities and ensure commitment from all MS. Develop the expertise to assure quality. RCGs provide the focus and direction	Resources; Time; Comittment	

Improve the quality of data and estimates	Improved Awareness of Quality		End users not aware of the quality of estimates they are getting. They do in most cases appear happy with what they get anyhow.	End users are aware of the quality and use it in the input to the assessments. Data carries an RCG 'kite' mark	Improve communication. Stock data summaries. Feed into stock report. Data inventories and quality indicators. Publishing data inventories. Refer to PGDATA guidance.	Resources; Time; Comittment	End-user subgroup, Liason Meeting, Other end-user communications

Annex 1.2 Intersessional subgroups – suggestion for robust structure and more formalized working procedures.

A substantial part of the work carried out in the RCGs need to be done between meetings in intersessional subgroups. The subgroups are initiated by the RCG meeting and are sometimes more or less coordinated between RCG NA, RCG NS&EA and RCG Baltic. Effective RCG work is thereby largely dependent on effective work in the subgroups. FishPi2 WP1 spent time analyzing the present challenges and propose a robust structure in the set-up of the subgroups as well as more formalized working procedures.

Key challenges for effective subgroup work

Member States and Institutes need to prioritize regional work and the right experts need to be attracted.

The written consultation process in fishPi (MARE/2014/19) showed that there is a strong agreement between Member States on the objectives of the RCGs. MS do further consider that they have expertise to fulfill the tasks needed to meet the objectives of the RCGs and are in many cases willing to prioritize regional work. In reality might, however, the RCG work compete with other obligations (and science) at the institutes that might be more career promoting. A key point is thereby to make the RCG work more rewarding for institutes and experts. There are no comprehensive solutions to this problem but the main point is that expert and institutes need to be recognized for the work they carry out. A starting point is to have authors on reports that the subgroups produce. There is no point with authors if only RCG members sees the reports so they need to be made publically available. This require a dedicated website[1] were the reports from meetings and subgroups can be published.

Intersessional subgroup work is complex management of time and resources across an array of individuals and institutes.

It is important to realize that intersessional subgroup work is complex management of time and resources across an array of individuals and institutes. This is a challenge it its own. It is further so far usually individuals, not institutes, that take on tasks in the RCGs. This might end up in situations where it, on the individual level, is difficult to prioritize the regional tasks if there are time constrains and if

[1] There is already a website dedicated to Data Collection and the RCG, hosted and maintained by JRC, but it is desirable to have an independent one, more easily modifiable by RCG participants and that can reach a broader public. https://datacollection.jrc.ec.europa.eu/docs/advisory-bodies

national tasks are better known at the institutes. This may slow down the progress in the intersessional groups, in particular if different experts can prioritize RCG work at different times. Intersessional RCG work thereby need to be better planned and institutes/MS (in contrast to individuals) need to make resources available in accordance with the plan to improve the situation. This require more formalized working procedures as institutes need to know what they sign up for. Subgroups also need to be set up with a multiannual perspective (in contrast to *ad-hoc* based) as it takes time for group to find its working procedures. Subgroups that are more permanent might also imply that it is easier for institutes to utilize personnel resources that do not participate in the RCG meetings for intersessional work. The subgroups should, were possible, be pan-regional for the RCG NS&EA, RCG NA and RCG Baltic, and others if needed, to avoid scattering of expertise.

Set-up of subgroups and suggestion for subgroups

The RCG NS&EA, RCG NA and RCG Baltic need to identify the intersessional subgroups required for their tasks. The topic for the different subgroups is suggested to be broad. This means that specific tasks identified by the RCGs, as far as possible, can be assigned to an already existing subgroup instead of a continuous initiation of new subgroups. FishPi2 WP1 produced a suggestion for the establishment of seven subgroups. This suggestion was discussed with the RCGs in their 2018 meetings. The RCGs largely agreed with the suggestion but extended the list with two more groups, separated one into four task areas and put one on hold.

Suggested subgroups:

1. Subgroup on implication of management measures on data collection
2. Subgroup on effective interaction between end-users and RCGs
3. Subgroup on data analysis to support RCG work (divided into four by the RCGs)
    a) Regional overviews of fisheries and sampling
    b) Development of codes and tools to support harmonization in reporting to COM, across MS
    c) Métier issues – harmonization of assignment of métiers and transversal variables
    d) Facilitation of quality assurance of data and sampling programmes
4. Subgroup on design and implementation of regional sampling plans
5. Subgroup on surveys (put on hold by RCGs)
6. Subgroup on diadromous species
7. Subgroup on regional database
8. Subgroup on development of Draft Regional work plan (added by RCGs)
9. Subgroup on revision of EUMAP (added by RCGs)

Working procedures for subgroups

1. The RCG meetings assign chairs for the different subgroups.
2. Tasks are allocated to the subgroup during the different RCG meetings. When doing so the RCG meetings need to be clear on what they expect from the subgroups and how the outcome shall be used. The tasks and output from the subgroup fall into 2 main types of work i) Tasks for internal RCG work (analysis of different topics to be used as basis for discussions,

development of tools etc) or ii) Preparatory work for decision making, including input for regional workplans.

3. Resources (persons) are allocated to the subgroup by the RCG meetings. The chair of the RCG contacts the institutes/MS to make sure that participation is sanctioned and that the institute/MS take responsibility of the task.

4. The first task for the chair(s) of a subgroup is to match the tasks with the resources available and to make a workplan/ road-map, including milestones and timeline, for the year. It is important that the work given to the subgroup is doable given the amount of resources. If tasks are too excessive, the chair can bring it to the liaison meeting for prioritization. The workplan / road-map shall be communicated to the chair(s) of the RCG and to the institutes. The workplan /road-map shall also be accessible for all members of the RCGs (published on SharePoint or website).

5. The chair(s) of the subgroup shall stay in contact with the chairs of the RCG and report on progress, unforeseen obstacles, delays etc

6. The subgroup shall, each year, prepare a short report. The report should be structured in a way so it is clear what the objective of each output is. The participants in writing the report shall be authors. The report need to be completed one month before the RCG meeting. The report shall be made public as a standalone document (website) after it has been reviewed by the RCG.

Annex 1.3 Establishment of RCG Secretariat

The RCGs are the main hub for regional coordination and cooperation within the different regions. The RCGs are presently lead by chairperson (s) that, according to the established Rules and Procedures for the RCG, have extensive tasks. These tasks include planning for the meeting (venue, participants, terms of reference, agenda), reporting from the meeting and keep track of work going on between meetings. Chairs are elected for 2 years. The RCGs have repeatedly suggested the establishment of a secretariat to support the chairs and to add continuity in the working procedures when chairs are changing. Such a function would also help to keep a more continuous process towards a regionalization and would assure a more stable quality standard of the work independent of chair.

The need for a secretariat is also more imminent if the bulk of the work in the RCGs primarily, as suggested by fishPi2 WP1, is carried out in sub-groups working intersessionally between meetings. This require constant follow ups by the chairs to assure work is on track.

A secretariat can have many functions. The particular needs for the RCGs were discussed within fishPi2 WP1 were several present and former chairs of RCGs are members of the core team. The core team concluded that the desired role for the secretariat would be administrative (in contrast of scientific/strategic), at least for the short and medium term.

A secretariat could provide support to one or several RCGs.

The main desired tasks for a secretariat is described below

Tasks for the secretariat

Support the chairs to set up and run the RCG meeting(s)

- Venue - support chairs to provide details of accommodation, travel and other organizational information relevant for the meeting in accordance with the rules of procedures.
- Participants – support chairs with updated participant lists (including mailing lists), lists of NCs, make sure participants are nominated in accordance with the rules and procedures
- Observers – support chairs to, if needed, invite observers to the meeting and make sure that the procedure follows the rules and procedures
- Agenda – support chairs to set up agenda and make sure the agenda is sent to participants in accordance with rules and procedures
- Documents - Keep track of documents for the RCGs and make them available for the participants in accordance with the rules and procedures
- Some rapporteur tasks during the meeting

Support the chairs to report from RCG meeting(s)

- Support chairs in tracking and coordinating recommendations and agreements

- Finalizing draft report - support chairs to “hunt” contributions to the report from participants
- Format report
- Support chair to finalize the report in accordance with the rules and procedures

Support the chairs to organize and monitor intersessional subgroup work

- Organize and update lists, including contact information, on participants in the different intersessional sub-groups.
- Keep track on sub group work, make sure that work plans for the sub-groups are produced, milestones reported and that results are delivered in time for the RCG meetings.
- Support, if needed, sub-group chairs

Maintain the website

- Be responsible for updating the webpage, make sure it is updated with all latest reports, annexes, documents, protocols, guidelines, tools etc.

Costs for the secretariat

Fishpi2 discussed staff level required to fulfil the desired tasks and elaborated on the total costs for the service carried out by the secretariat. There are many assumptions in the presented costs and the figures should be seen as a starting point for a discussion. The detailed estimated costings are based on the provision of Secretariat Services to two RCCGs (Baltic and NSEA+NA) each holding a five day meeting and a two day meeting. The level of Secretariat support for intersessional subgroup working will need to be carefully considered as this will add to the overall costs in both staff time and travel and subsistence costs. For the purposes of illustration 3 days staff time per subgroup per year has been allocated. There are in total 14 subgroups. There may be additional staff time and other costs associated with setting up the Secretariat that would only be incurred during the first year of operation.

In the example we have included 2 levels of staff and identified their skills and experiences.

RCG Co-ordinator - An individual with experience in the provision of Secretariat support for international organisations. Preferably with an interest in and with some experience of fisheries (in Europe). Understands the roles and responsibilities of the RCGs. Politically astute, capable of working independently and internationally. Able to represent the RCG's in an outward facing role with relevant stakeholders. Good strategic thinker. Able to update website content using standard software. Possibly a full time role.

RCG Administrator - Familiar with and capable of efficient delivery of administrative services. Able to work remotely and requiring minimum supervision. Work must be accurate, timely and thoughtful.

Must be consciences and capable of responding quickly and prioritizing tasks. Likely to be a part time role - 30%.

The detailed costs (time and euro) is outlined in table 1. Note that this is an example as a basis for future discussion. A budget of approximately €100 000- 120 000 would probably be sufficient to cover the needs for two RCCGs (Baltic and NSEA+NA) including support for subgroup work. Several models for how the costs should be split could be considered. These include flat rates across MS or rates based on shares in the fisheries. It also need to be examined if the Commission can pay part (or all) costs of the costs.

Secretariaty Roles and Tasks Description	Resource (Days)		Resource (Cost)				
	Co-ordinator	Administrator	Co-ordinator	Administrator	Travel	Subsistence	Expenses
Support the Chairs in setting up and running RCG meeting(s)							
Venue *- support Chairs by provide details of accommodation, travel and other organizational information relevant for the meeting in accordance with the rules and procedures.*	***0,75***	***7,05***	€ 300	€ 2 820			
Participants *– support Chairs with updated participant lists (including mailing lists), lists of NCs, make sure participants are nominated in accordance with the rules and procedures*	***2,15***	***1,9***	€ 860	€ 760			
Observers *– support Chairs, if needed, in inviting observers to meetings and ensure conformation with rules and procedures*	***0,15***	***0,2***	€ 60	€ 80			
Agenda *– support Chairs in set up agendas and make sure the agenda is sent to participants in accordance with rules and procedures*	***11***	***5,1***	€ 4 400	€ 2 040			
Documents *- Keep track of documents for the RCGs and make them available for the participants in accordance with the rules and procedures*	***4,5***	***2,25***	€ 1 800	€ 900			
Act as rapporteur during RCG meetings	***14***	***2***	€ 5 600	€ 800	€ 1 000	€ 2 000	
Support Chairs in reporting RCG meetings	***20,25***	***2,95***	€ 8 100	€ 1 180			
Support Chairs in tracking and coordinating recommendations and agreements	***5***	***2,25***	€ 2 000	€ 900			
Support the Chairs in organising and monitoring intersessional subgroup work	**100,1**	**20**	€ 40 040	€ 8 000	€ 1 500	€ 1 500	
Maintain the website (and help to establish it)	13	4	€ 5 200	€ 720			€ 22 000
RCG Updates and breifings for stakeholders	4	0,25	€ 1 600	€ 45			
RCG Outreach and Representation	4	0,11	€ 1 600	€ 20			€ 1 000
Finance	3,1	2,35	€ 1 240	€ 423			
Risk Register	0,25	0,01	€ 100	€ 2			
Subject to financial model to support Secretariat							
Contractual Arrangements	3,5	3	€ 1 400	€ 540			
Total for 1 RCG per year	**185,75**	**46,37**	**€ 74 300**	**€ 8 347**	**€ 2 500**	**€ 3 500**	**€ 23 000**
Total for 2 RCGs per year (assuming pan-regional subgroups)	**271,4**	**72,74**	**€ 108 560**	**€ 8 693**			
Proportion of FTE (based on 220 days P/A)	**1,23**	**0,33**					

Table 1. Example of budget for Secretariat Service for RCGs

Annex 1.4 Establishment of RCG Website

The RCGs are established to support collaboration and cooperation between Member States. They have important tasks including "developing and implementing procedures, methods, quality assurance and quality control for collecting and processing data with a view to enabling the reliability of scientific advice to be further improved" and preparation of regional workplans ((EC) 2017/1004). The RCGs are further expected coordinated with third countries and to interact with end-users of scientific data.

MS have, in RCGs and their predecessors the RCMs, over the years developed a high degree of coordination (see fishPi (MARE/2014/19)). The problem is that the work done by the RCGs are invisible for most people not directly involved. To some extent this due to how the RCGs are reporting but also to the fact that the reports are hard to find for stakeholders outside the "DCF machinery". The result is that outcome of the work done in the RCGs is more or less limited to participants in the RCGs, which in the long run may hamper regional cooperation and end-user interaction.

The RCGs have recommended the development of a dedicated RCG website. RCG reports are presently published at the JRC website but they do not reach a wide audience. One reason could be that the reports are long and cover an array of topics, which vary year from year. For people not attend the meetings is it simply difficult to know if the content of the reports are of interest or not. Another reason might be that it might not be obvious for people outside the "DCF world" were to look for the information. FishPi2 WP1 concludes that improved outreach is a key aspect for future RCG work. A website dedicated to the RCGs is needed if outcomes from the RCGs shall reach a wider audience.

FishPi2 WP1 discussed to whom the website should be targeted, if a webpage overlaps with the present SharePoint system (hosted by ICES) and what type of information that should be present on the webpage.

The discussion is summarized below.

- The SharePoint system should be kept and used, for working material, preparations for meetings and intersessional sub-group work.
- The website shall contain all finished work, which mean that all pages shall have open access.
- The targeted audience is, at least for the short and medium term, people with a prior interest and knowledge in fisheries eg end-users, managers, NGOs,…
- The website could serve several, or all, RCGs
- The webpage should be nice, logic and easy to navigate within. It should be updated on a regular basis (responsibility of secretariat). We shall avoid publish the same thing twice. If, for example, agreed reference lists are published elsewhere the website shall contain links.
- The RCG chairs should act as editing committee
- The website should consist of the following sections (at least)

A. description of the RCGs; role and tasks in data collection process, rules and procedures, participants and observers in meetings, procedures for observers, contact details to chairs and secretariat

B. B) work done by the RCGs, regional workplan, reports, standalone annexes, sub-group reports, agreed workplans for sub-groups, recommendations and agreements, agreed guidelines, best practices and protocols, reference lists

C. C) Data products from the RDB (developed by RCG sub-group), Overviews of regional fisheries and sampling. Link to ICES and regional database page. Link to github

D. D) Gateway to other websites of relevance for implementing DCF (ICES, MS DCF websites), COM, STECF etc

Annex 2

Annex 2.1 Celtic Sea fisheries

The tools developed in WP2 were also applied to the Celtic Sea (ICES areas 7b-k) in order to explore which stocks or fisheries present a wide scope for regional sampling. Suitable stocks should be:

- Caught by more than two countries (otherwise a bi-lateral sampling programme would suffice)
- The catches should not be dominated by a single country (otherwise the benefit from regional coordination is small)
- The landings should be of significant value (the cost of implementing a regional sampling programme should be small, compared to the value of the stock).

The logbook dataset included all the main countries fishing in the Celtic Sea. The dataset was reduced to the stocks for which at least 50% of the landings (in 2015 and 2016 combined) were taken from areas 7b-k.

In order to explore how evenly the landings are distributed between the countries, a number of statistics were calculated: the Shannon diversity index; the Simpson diversity index; the evenness index; the maximum proportion of the landings taken by any country; and the number of countries with landings of the stock. Figure 1 shows that the indices were highly correlated. The choice of which measure of evenness will be used in the analysis is therefore largely irrelevant.

A comparison between the 2015 and 2016 data indicated that the measures of evenness are quite consistent between these years (data not shown). This is not surprising considering the quota are allocated according the principles of relative stability between years.

Figure 2 shows that stocks like Celtic Sea/Biscay anglerfish and megrim, Celtic Sea whiting and pilchard and pollack in 6,7 are fished by 6 or more countries, none of which has more than a 60% share of the landings. These stocks are also of considerable commercial value. Celtic Sea cod and haddock and FU2021 *Nephrops* are also commercially important species caught by 5 or more countries but one of those strongly dominates the landings. There are a number of ray species in the Celtic Sea as well as plaice and sole stocks that are caught by 4 or more countries without being dominated by one of them; however these are relatively small stocks.

A different way of looking at the distribution of the landings is presented in Figure 3. Anglerfish (mon.27.78ab) appears to be a good candidate stock; even though France takes 60% of the landings, Ireland, the UK and Spain also have significant landings. Anglerfish are caught in a mixed fishery, mainly with megrim (Figure 4). Megrim (meg.27.7b-k8abd) also appears to be a good candidate stock for regional sampling; the landings are quite evenly distributed over Ireland, the UK, France and Spain. Even though megrim and anglerfish are often caught together, there is no uniform megrim/anglerfish fishery. The highest catch rates for megrim are on the continental shelf while anglerfish are relatively more abundant along the shelf edge. Additionally, both species are landed as a by-catch in fisheries targeting other species. A regional sampling plan would likely have to be extended to all the (main) stocks caught in the demersal fisheries in the Celtic Sea.

Pilchard (pil.27.7) landings are mostly taken by the UK and France but the Netherlands and Denmark also have significant landings (Figure 3). Pilchard are mainly taken in targeted fisheries (Figure 5); landed by-catches in other fisheries are relatively minor, therefore a dedicated regional sampling plan for this stock might be appropriate.

Celtic Sea herring (her.irls), boarfish (boc.27.6-8) and cuttlefish (ctl.27.7de) are mostly taken by a single country (Figure 3) and therefore would not be suitable candidates for a regional sampling plan.

Celtic Sea whiting (whg.27.7bce-k) are mainly landed by two countries (Ireland and France; Figure 3). Fisheries for cod, haddock and whiting in the Celtic Sea are often considered to be a more or less distinct metier; however Figure 6 shows that these stocks are caught in a broader mix with anglerfish, megrim, hake, Nephrops and others. It is probably not practical to develop a regional sampling plan for any specific demersal stocks in the Celtic Sea; they will need to be considered together due to the highly mixed nature of the fisheries.

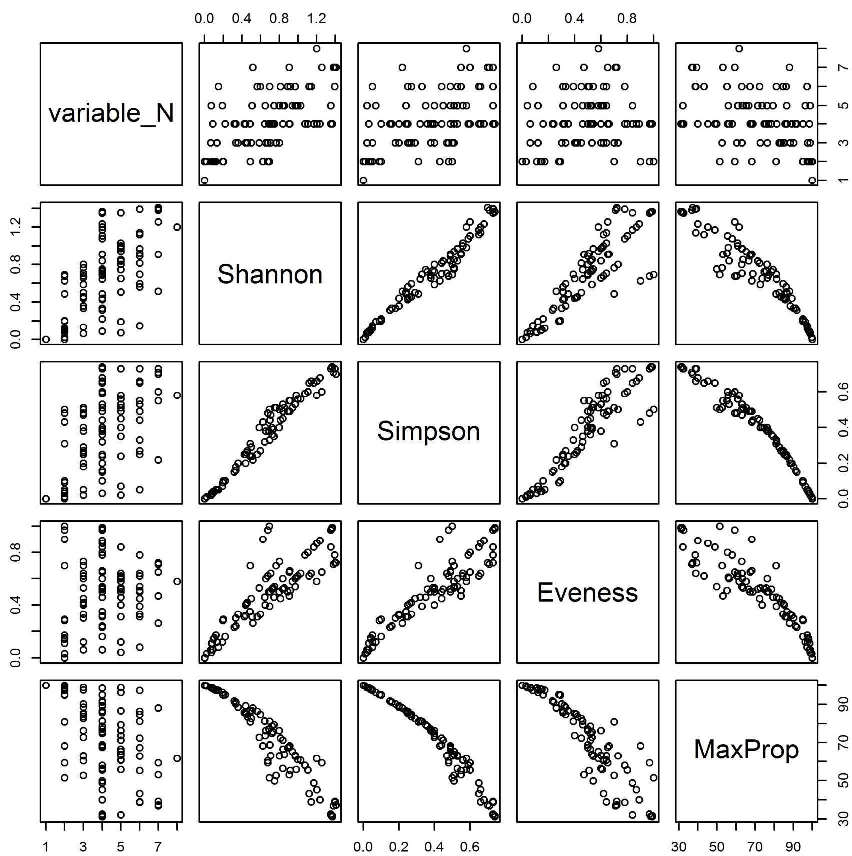


Figure 1. Correlation between the various indices of evenness or diversity. Each point is a stock. Stocks with low diversity or evenness are dominates by a single or a small number of countries.

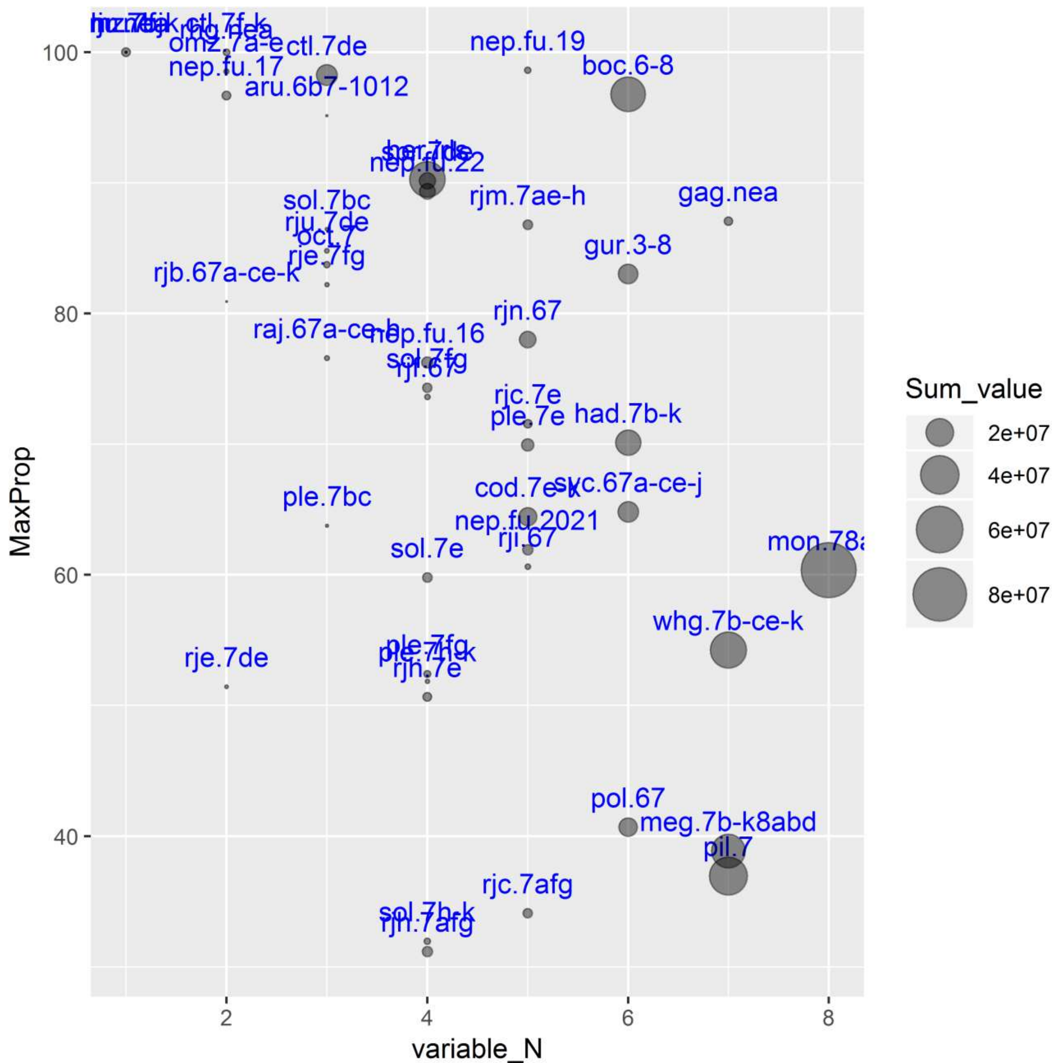


Figure 2. The number of countries with landings of each stock (variable_N) versus the maximum proportion of the landings by any of these countries. The size of the bubbles corresponds to the landings (in kg, 2015 and 2016 combined). The labels are the ICES stock codes.

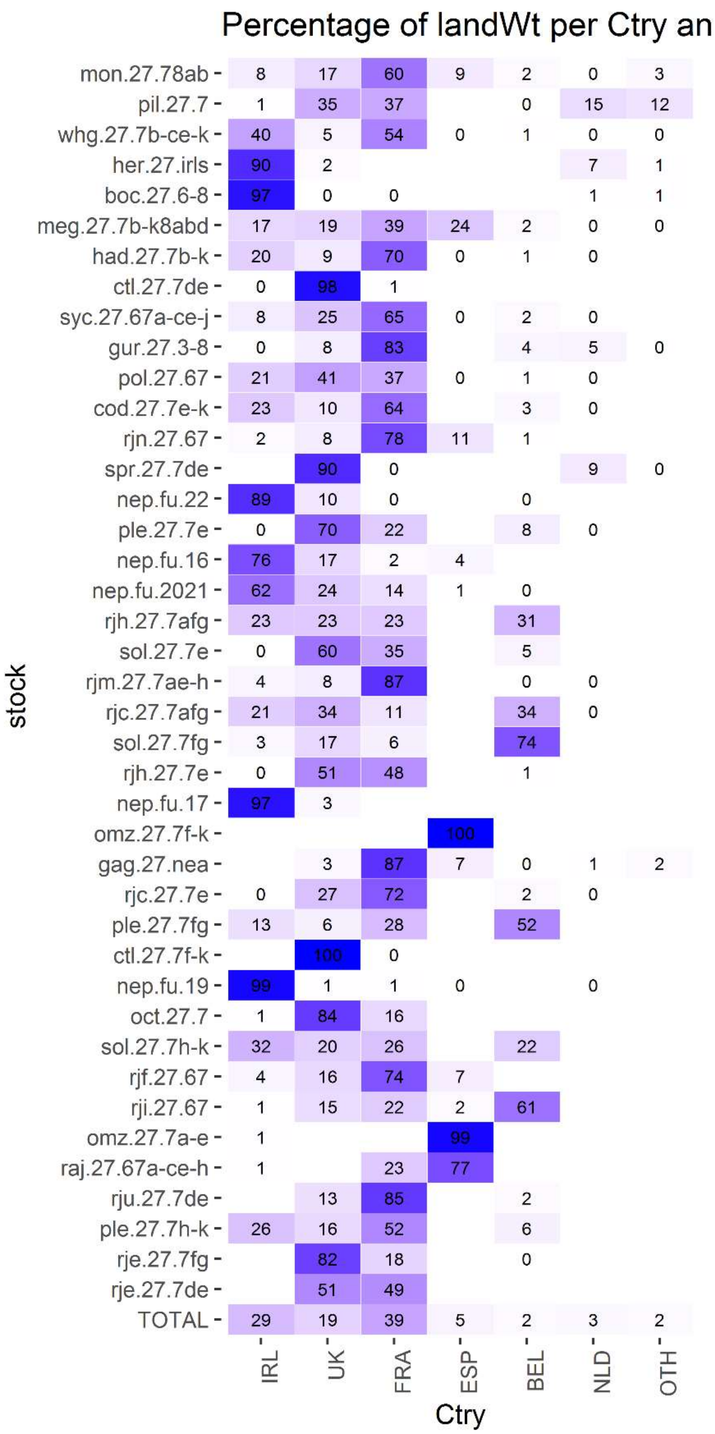


Figure 3. Percentage of the landings by country and stock (2015 and 16 data combined). The stocks are ordered from top to bottom in ascending order of the total landings.

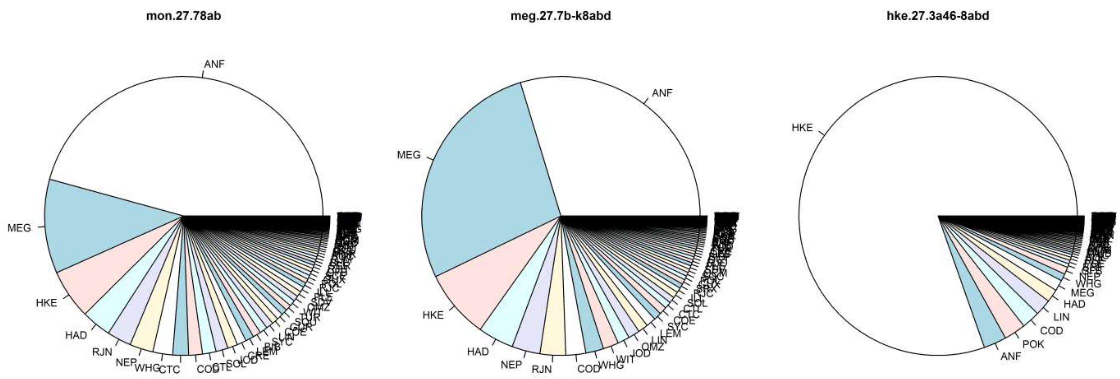


Figure 4. The species composition in the landings of anglerfish, megrim and hake. For each fishing trip the landings of each species were weighted by its landings of the stock in question. The left plot shows that anglerfish are mainly landed with other anglerfish but also with megrim, hake, haddock, rays, Nephrops, whiting and a large number of other species. The middle plot shows that most megrim landings come from trips that also landed a lot of anglerfish. Other by-catches are hake, haddock Nephrops, rays, cod and many others. The left plot shows the species composition of hake landings (not included in the previous analysis because less than 50% of the landings originate from the Celtic Sea but often associated with anglerfish and megrim). Most hake landings come from a highly targeted fishery and therefore do not need to be considered in relation to the mixed fishery for anglerfish and megrim.

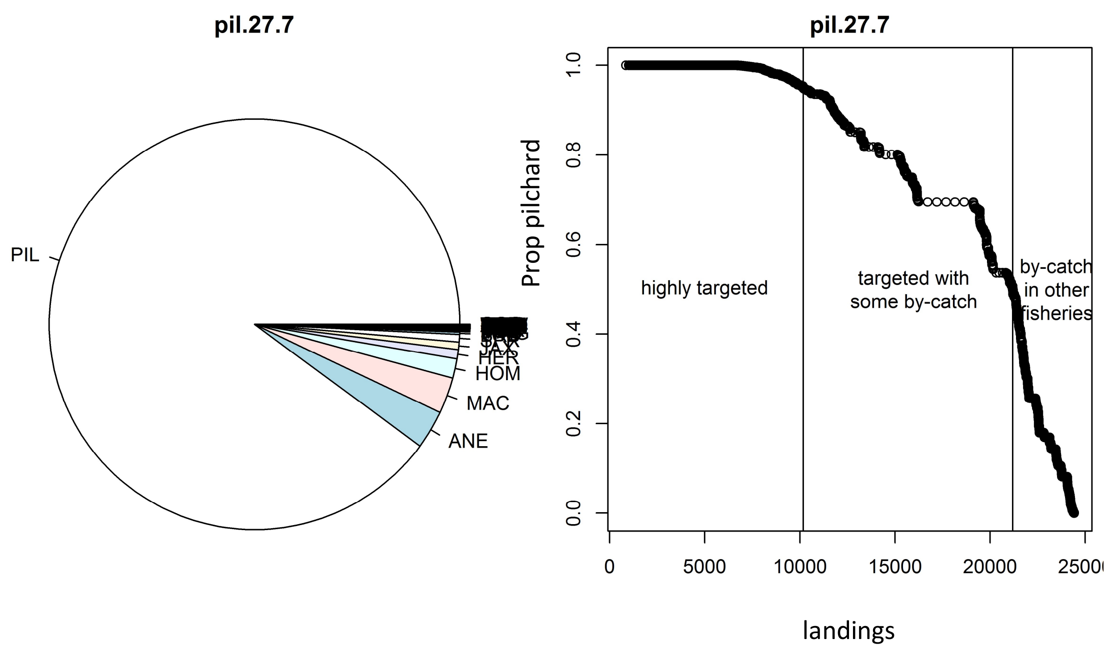


Figure 5. Left: the species composition in the landings of pilchard; for each trip the landings of each species were weighted by the landings of pilchard. The pie plot shows that pilchards are highly targeted. Some by-catches occur of anchovy, mackerel, horse mackerel (or pilchards are caught as a by-catch in the fisheries for these species). Right: the proportion of pilchard in the landings of each

trip plotted against the cumulative landings of pilchard. Around 40% of the landings come from a highly targeted fishery; another 40% of the landings come from fisheries with a small amount of landed by-catch. The remainder of the landings result from a by-catch in other fisheries.

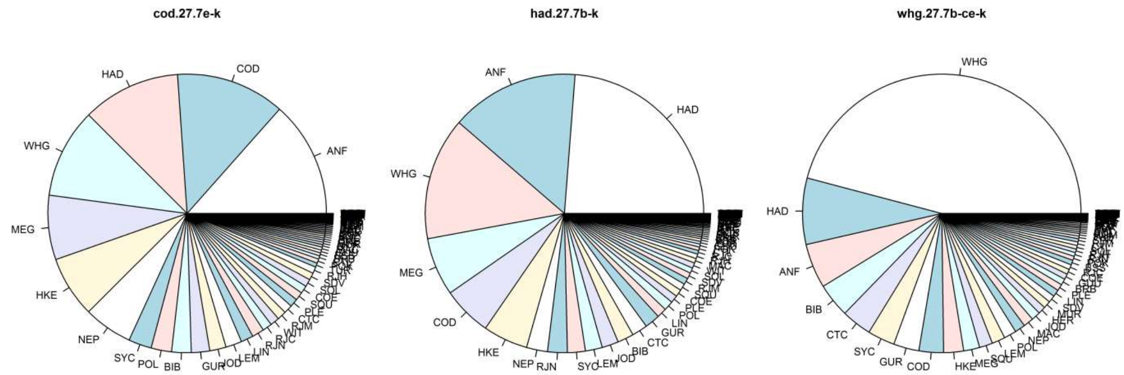


Figure 6. The species composition in the landings of Celtic Sea cod, haddock and whiting. For each fishing trip the landings of each species were weighted by the landings of the stock in question. The left plot shows that cod are landed in a very highly mixed fishery with anglerfish, haddock, whiting, megrim hake, Nephrops and many others. The middle plot shows that haddock are caught in a very similar mixed fishery. The left plot shows that much of the whiting landings result from a targeted fishery, but they are also caught with haddock, anglerfish, bib, cuttlefish, dogfish and many other species.

Annex 2.2 North Sea demersal fisheries

To provide an assessment of the suitability of the North Sea demersal fisheries for regional sampling, the first step is to examine the fishing activity of the region. To create a suitable dataset, a data call was issued to all member states requesting official logbook and sales notes on the total fishing activity for the area of study for 2015 and 2016. From these data, a comprehensive overview of the North Sea landings by all nations, into all nations, can be made.

The resulting data set included all fishing trips with some component of their landings from the "wider North Sea", defined in terms of ICES divisions (27.3.a, 27.4.a, 27.4.b, 27.4.c, 27.7.d). Although this included fishing from areas outwith the defined area of interest, it ensured all relevant fishing activity was included in the study.

Categorising all landings into taxonomic groups (using ISSCAAP[2] codes) shows the largest groups, by landed weight are pelagic, demersal and crustacean (Table 1). Each fishing trip was also categorised by main taxonomic group, the group with the greatest total landed weight determined the 'main' taxonomic group for that trip. This allows the extent to which fishing trip groups land the species of the same taxonomic group to be summarised, for example the trips targeting demersal species land 319,423 tonnes (94%) demersal species, while also landing species from other taxonomic groups (Table 1).

Table 1. Landed tonnages from 2015 North Sea fishing trips classified by taxonomic group. Fishing trips are allocated a 'main' taxonomic group, assigned by selecting the group with the highest total landed weight. Fishing trips are then grouped according to their main taxonomic focus and the total landed tonnage of each taxonomic group is shown.

		Fishing trip by main taxonomic group.								
		pelagic	demersal	crustacea	mollusca	elasmobranchs	cephalopod	diadromous	freshwater	Total
Species taxonomic group	pelagic	1124593	2615	112	10	164	177	0	0	1127671
	demersal	4023	319423	3955	269	1535	859	1	0	330065
	crustacea	75	5326	93974	131	46	16	1	1	99570
	mollusca	7	591	50	74046	13	21	0	0	74728
	elasmobranchs	261	5267	107	53	3226	206	0	0	9120
	cephalopod	322	5215	82	115	216	2708	0	0	8658
	diadromous	10	47	12	6	2	0	35	0	112
	freshwater	0	1	1	0	0	0	0	26	28
	benthos	0	0	0	0	0	0	0	0	0
	Total	1129291	338485	98293	74630	5202	3987	37	27	1649952
	Nunmber of trips	12473	97668	112429	38383	5956	4209	627	58	271803

To explore suitable regional fisheries, an assessment of the landings focussed in on the demersal fish species of interest (FOI), which includes plaice, saithe, cod, haddock, common sole, whiting, hake, monkfish, turbot, tub gurnard, common dab, surmullet, lemon sole, ling, brill, flounder, grey gurnard, pollack and witch, from the wider North Sea area from a single year (2015). The analytical tools developed as part of WP2 were used to make this assessment.

a. Nations

[2] International Standard Statistical Classification of Aquatic Animals and Plants

The main eight nations with landings from the wider North Sea are Belgium, Germany, Denmark, France, England, Scotland, the Netherlands and Sweden. Figure 1 shows the originating ICES division and the flag country of the vessels for these landings. It is evident each division is fished by several countries and that vessels from multiple nations land into each country (Table 2 and Fig. 2).

Table 2. Landed weight (tonnes) into each country, by vessel flag country.

	VESSEL FLAG COUNTRY							
LAND COUNTRY	**BEL**	**DEU**	**DNK**	**ENG**	**FRA**	**NLD**	**SCT**	**SWE**
BEL	5346	66		8		340		
DEU		1825	165					
DNK	3637	20223	47866	3807	4154	1119	962	1926
FRA	1276			1367	17382	2824		
GBE	527		353	4266	19	149	276	
GBS		488	7	11752	5194		59628	
NLD	3543	17472	334	13636	63	48946	3239	
SWE			109					1566

b. Species

Most FOI species are landed into multiple nations (Fig. 3) by vessels with various flag countries. There are some exceptions to this, e.g. ANF (monkfish) and FLE (flounder), where the majority of landings are into a single nation. Similarly SOL (common sole) and TUR (turbot) are mostly landed into a single nation, although in these cases a high percentage of the vessels landing these species are foreign. Figure 4 shows the relative catch of each of the FOI species from each fishing area for each nation.

Considering stocks instead of species, Figure 5 shows the relative proportion by landed weight for each stock from each ICES division (or subdivision). The North Sea dominates stocks covering the whole of the wider North Sea, accounting for 85% of the landed weight of these stocks, on average, whilst the Skagerrak and Kattegat and Eastern Channel still have a substantial contribution to these stocks, around 14% on average. The commercial important stocks (corresponding, in the main, to the species of interest mentioned earlier) are mostly landed by more than one country with no country dominating the landings (Fig. 6).

c. Metiers

A large number of metiers are used within the wider North Sea area, with different metiers in use by different countries, as shown in Figure 7. In this analysis, otter trawl gears (OTB, PTB, OTT) have been combined into a single gear code (OTC), and this results in 153 metiers. Each species is fished by multiple metiers, and there is little consistency in the use of metiers by each nation state for each of species (Fig. 8).

d. Clustering ICES rectangles

The fisheries within the wider North Sea are complex in that many species are landed by many nations using a wide range of gear types, within areas with non-biologically defined boundaries.

One way to try to identify patterns within the landings data, that do not meet pre-defined boundaries, is to use cluster analysis. Cluster analysis groups together units based on their similar composition. To identify the fishing areas within the wider North Sea from which a similar composition of FOI species are landed, a cluster analysis can be applied to ICES statistical rectangles.

This analysis shows that the rectangles of the wider North Sea are optimally clustered into seven groups which share a relatively similar composition of FOI species (Fig 9). This process is a way of identifying biologically driven geographic areas within the wider North Sea.

e. Summary

In summary, the demersal stocks in the wider North Sea are fished by fleets from several nations, and are landed into more than one nation (Table 2, Fig 2). The landings of most commercially important stocks are not dominated by a single nation but shared between nations (Figs 4 and 6). Similarly, the stocks are shared between areas (Fig 5). Many species are landed together, being caught in geographically similar clusters (Fig 9) and by several nations (Table 1, Fig 3) using a variety of metiers (Figs 7 and 8). Therefore demersal stocks in the wider North Sea need to be considered together and demersal fisheries in the North Sea are suitable for a regional sampling design.

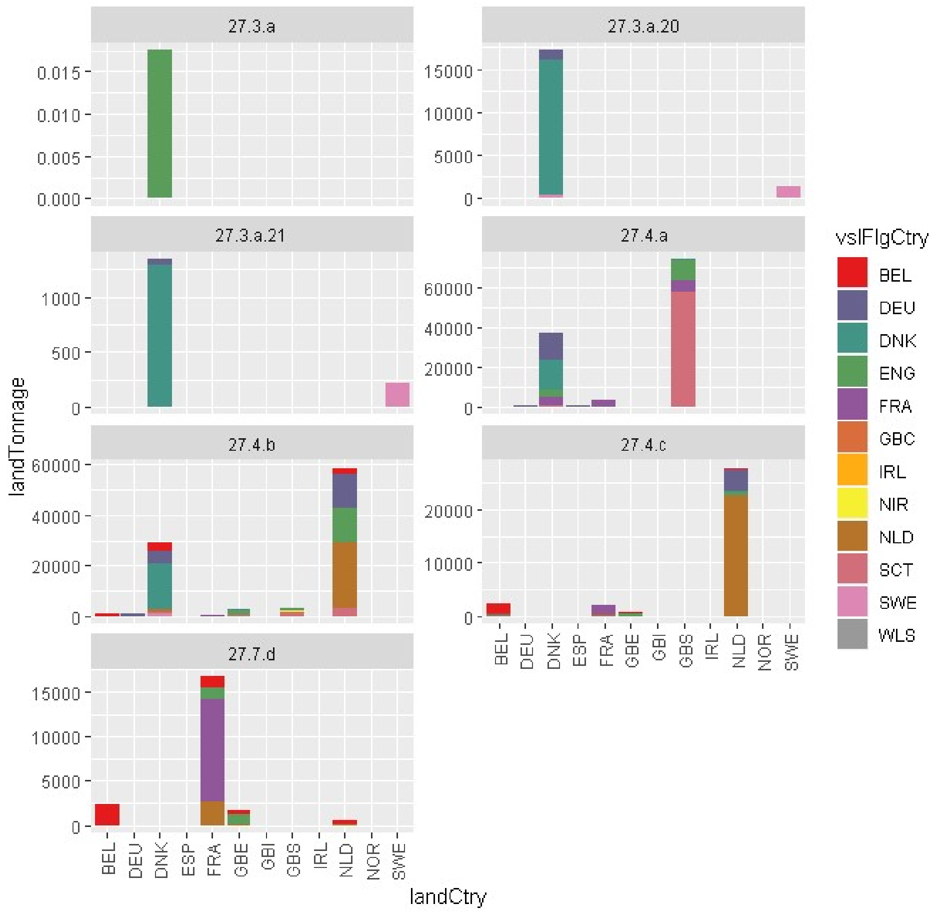


Figure 1. Barplot (generated from FishPi2WP2 function: plot_stock_data) of landed weight (tonnes) of fish species of interest (FOI) by landing country and vessel flag country, for each area.

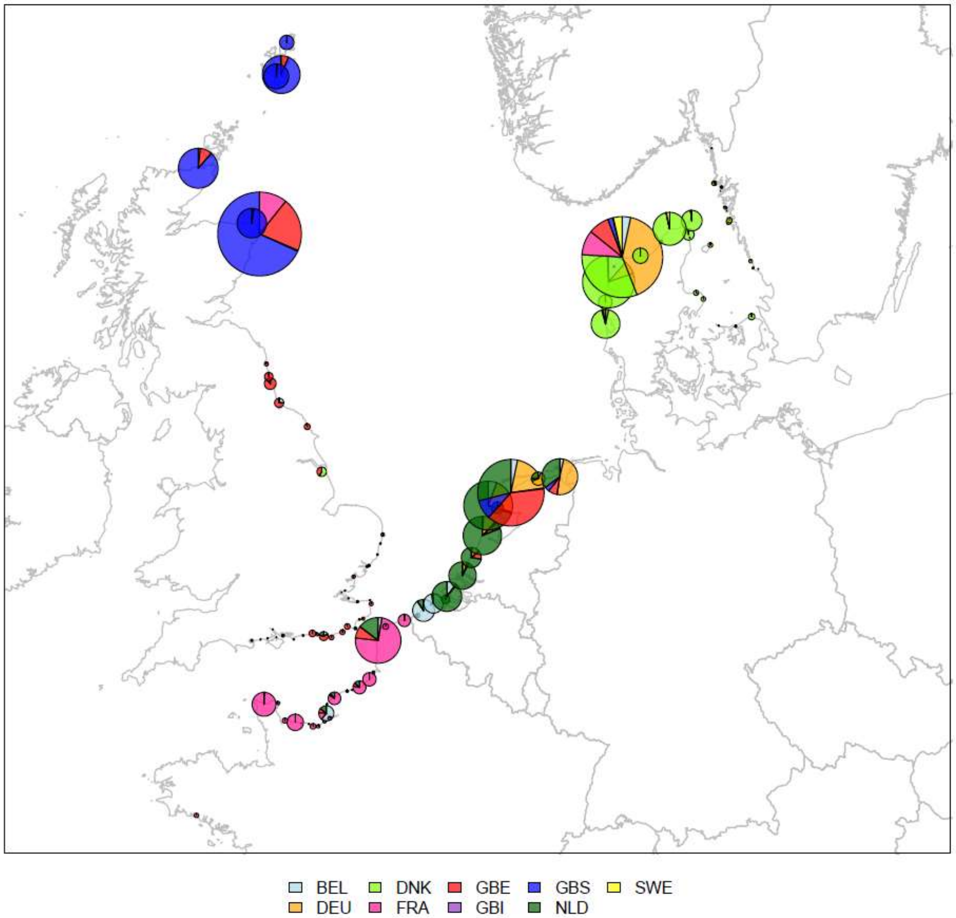


Figure 2. Pie-charts (generated from FishPi2WP2 function: portPie) of landed weight (tonnes) of demersal by vessel flag country, shown at the locations of the major ports.

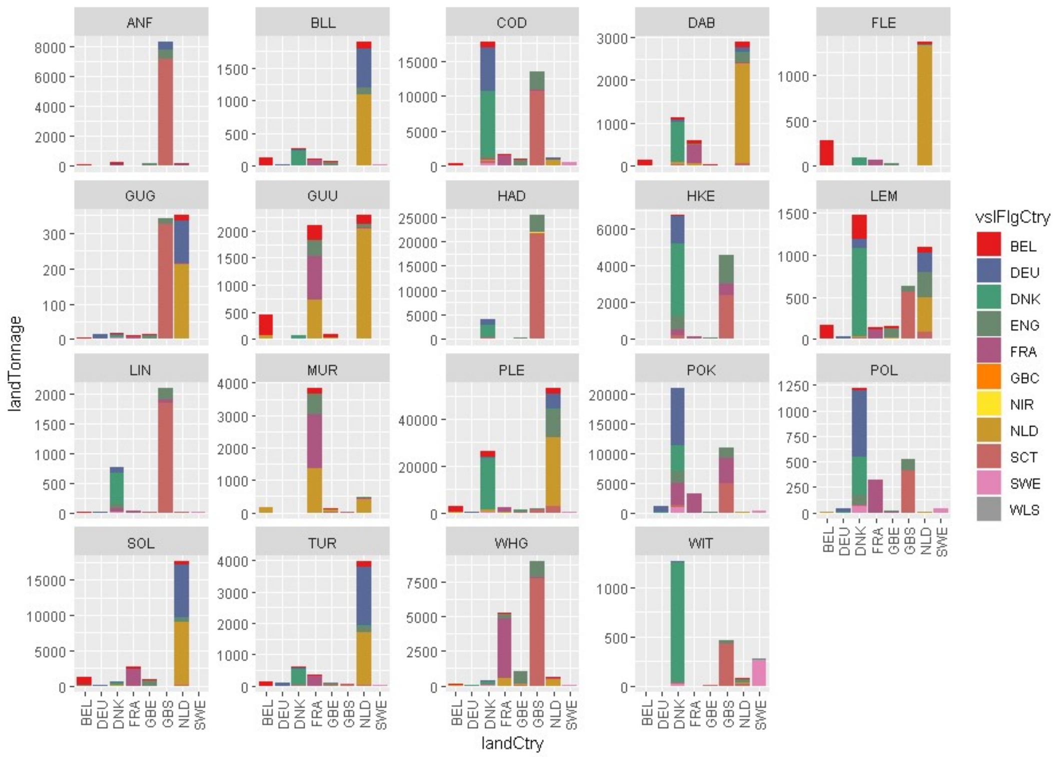


Figure 3. Barplot (generated from FishPi2WP2 function: plot_stock_data) of landed weight (tonnes) of fish species of interest (FOI) by landing country and vessel flag country, for each FOI species.

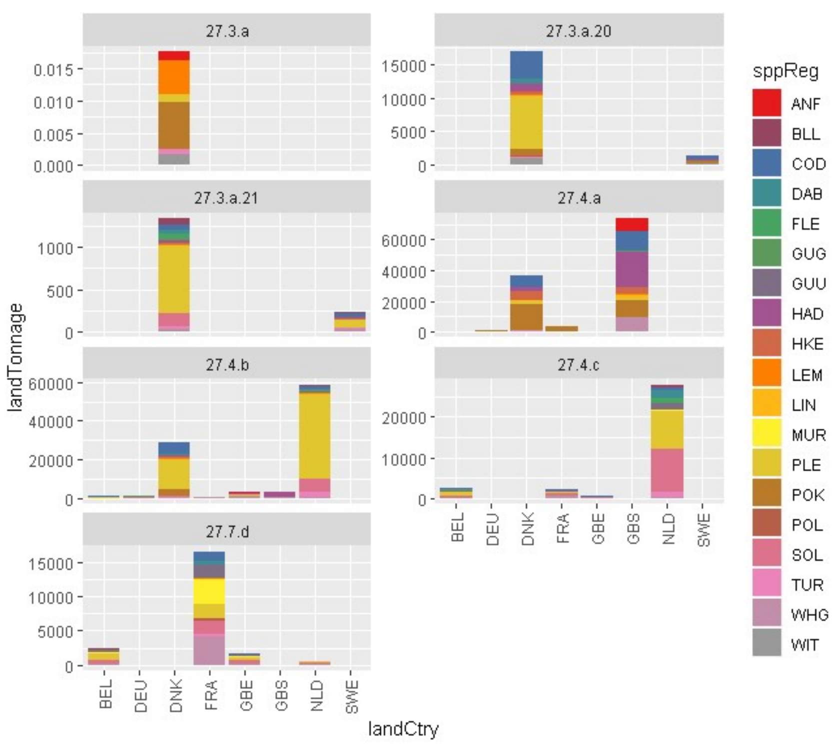


Figure 4. Barplot (generated from FishPi2WP2 function: plot_stock_data) of landed weight (tonnes) of fish species of interest (FOI) by landing country and FOI species, for each area.

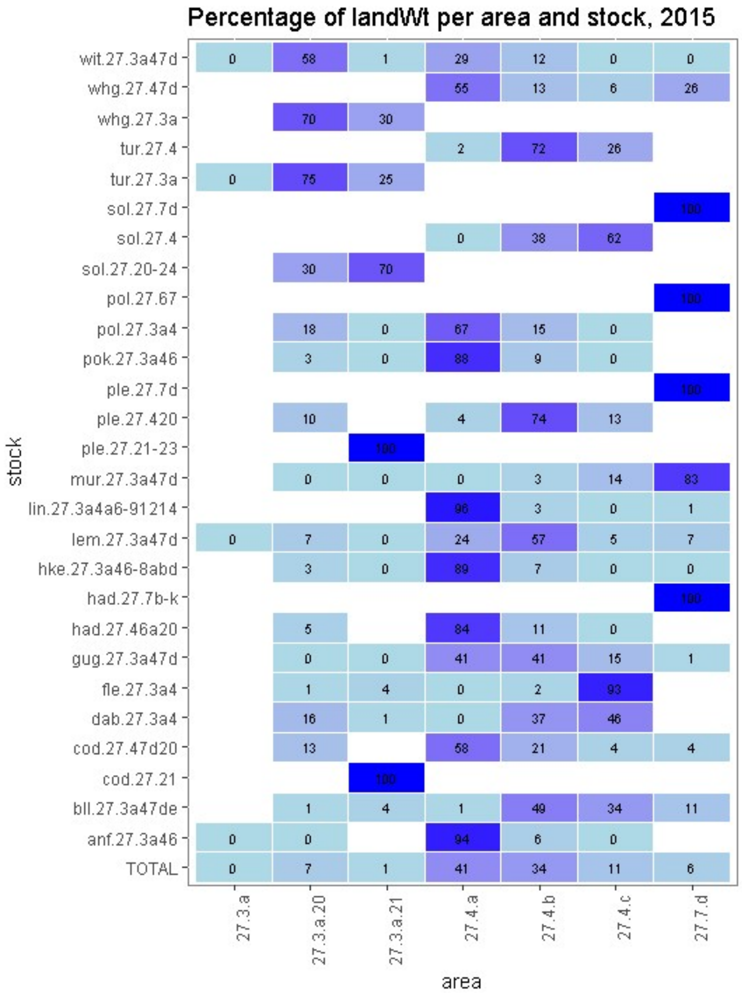


Figure 5. Image (generated from FishPi2WP2 function: heatmap) of percentage by landed weight of each stock in each ICES division (or subdivision). ICES naming conventions have been used to identify stocks. Divisions with higher percentages of that stock are coloured darker blue.

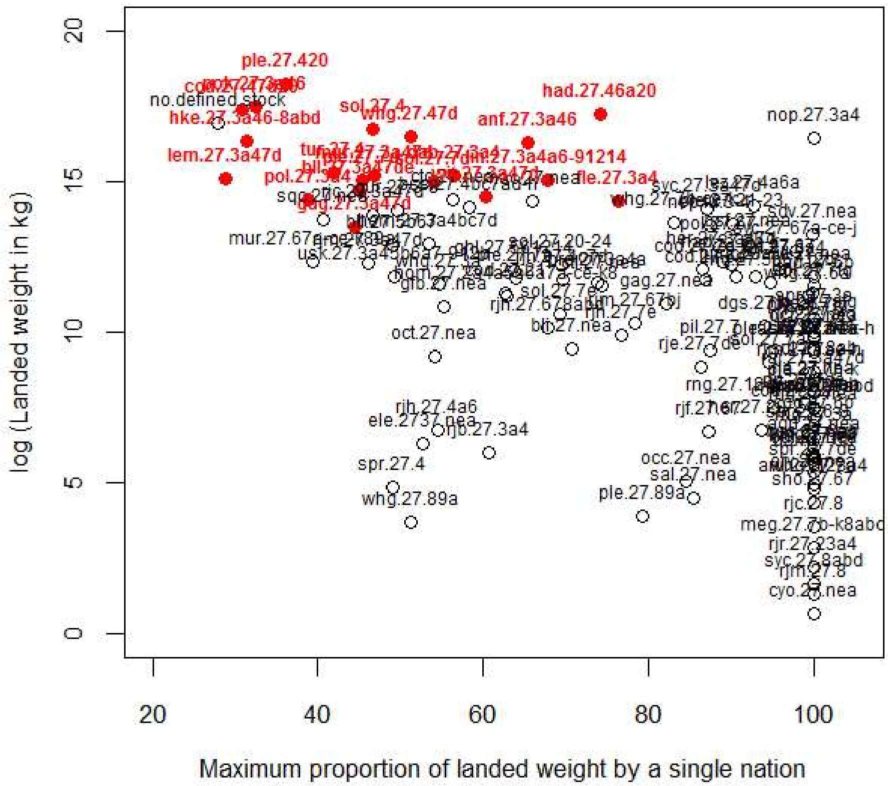


Figure 6. The importance of stocks landed from vessels fishing in the wider North Sea in 2015 (generated from FishPi2WP2 functions). This is represented by the log of the total annual landed weight for all countries versus the maximum percentage of this landed weight by a single nation. ICES naming conventions have been used to identify stocks. Stocks coloured red correspond to stocks for the fish of interest.

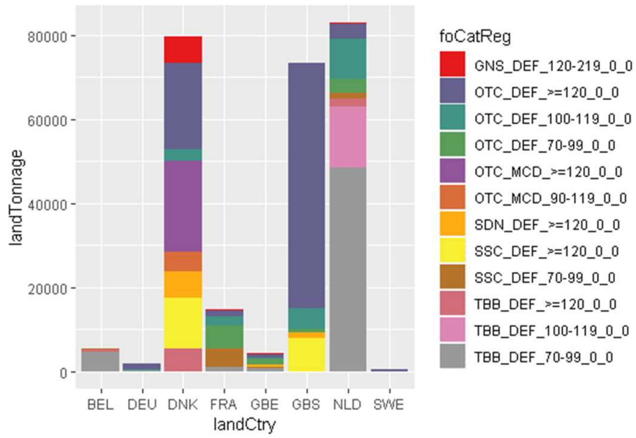


Figure 7. Barplot (generated from FishPi2WP2 function: plot_stock_data) of the top 12 metiers used by the main eight landing countries.

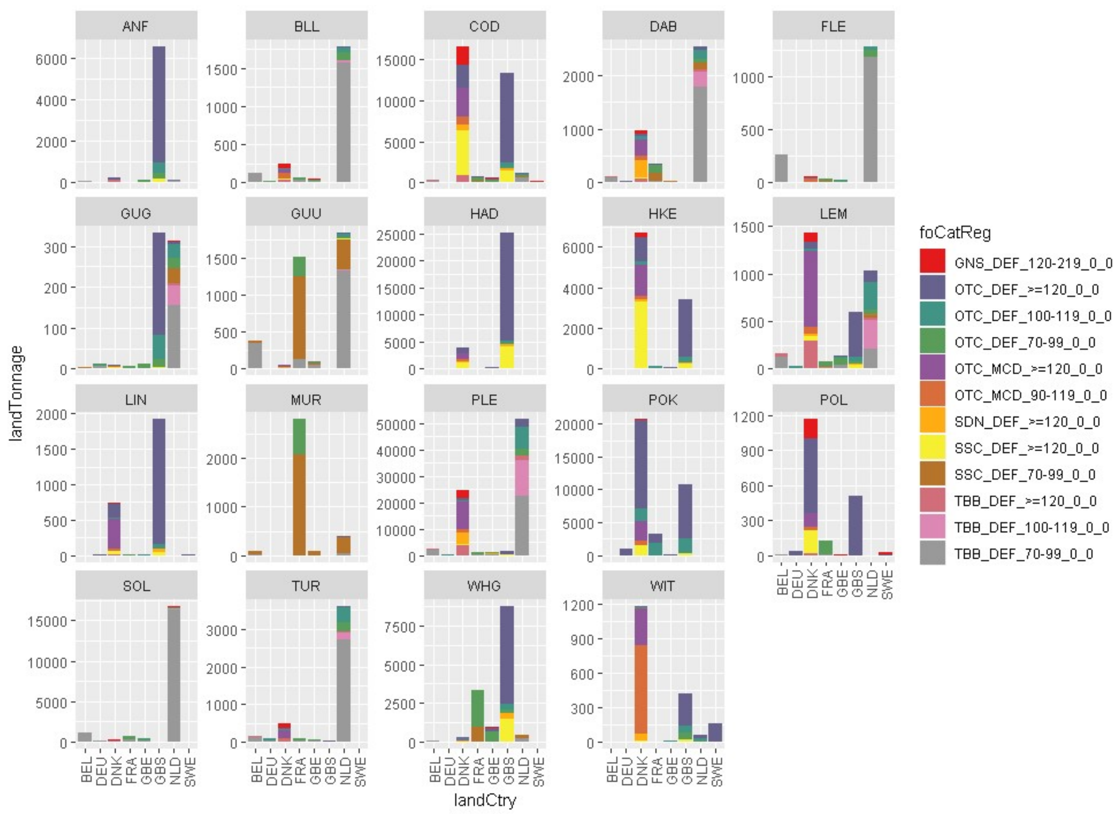


Figure 8. Barplot (generated from FishPi2WP2 function: plot_stock_data) of the top 12 metiers used to land each fish species of interest into the main eight landing countries.

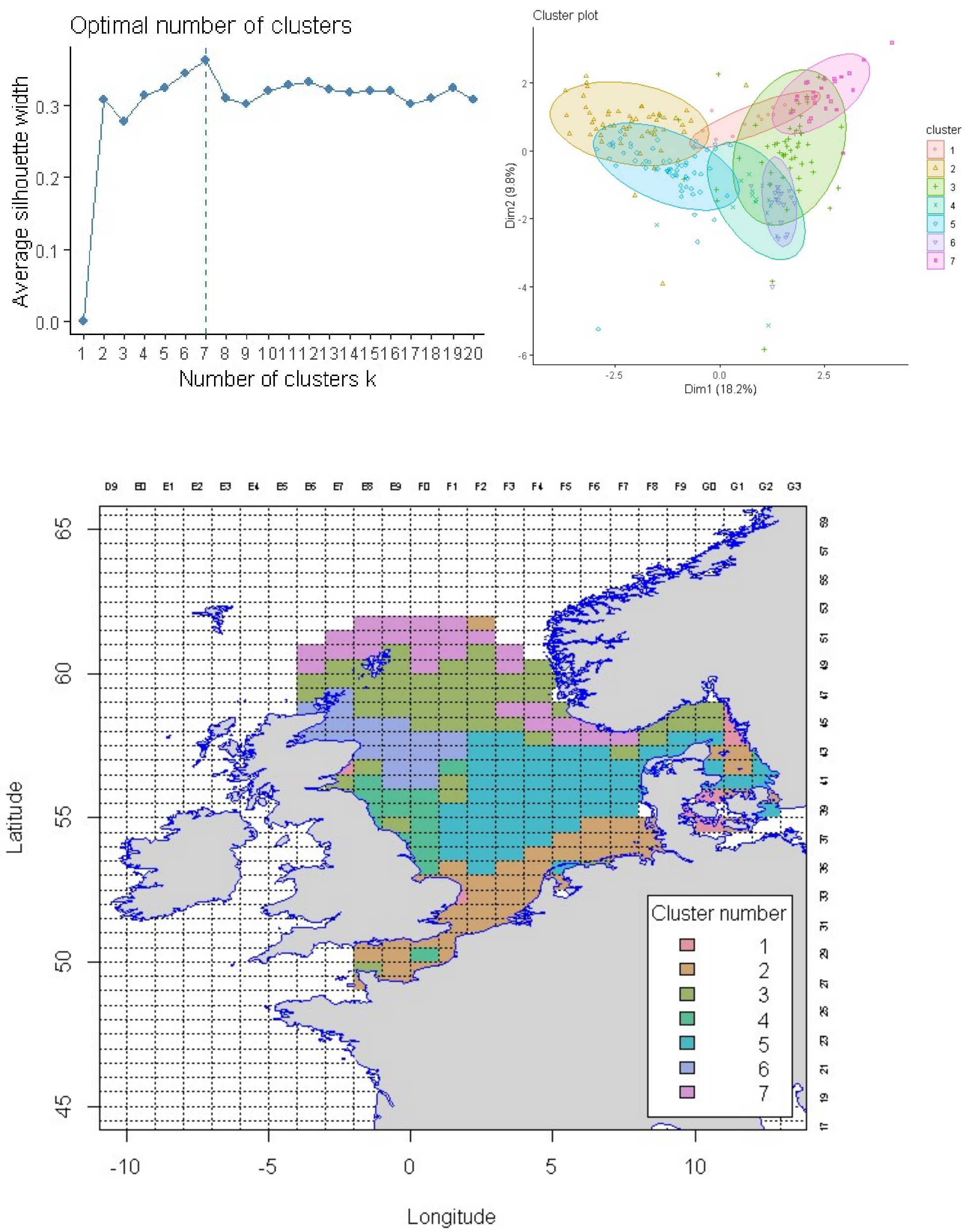


Figure 9. Cluster analysis (generated from FishPi2WP2 functions) results of the ICES statistical rectangles, based on the composition of fish species of interest (FOI). The optimal number of clusters is seven (top left panel), which are represented in ordination space where similar rectangles are plotted close together and dissimilar rectangles are placed further apart, with coloured ellipses identifying the clustered groups (top right panel). The geographic distribution of the clusters is shown in the bottom panel.

Annex 2.3 Iberian Case study: Fishery description

Introduction

Iberian Case Study

The Iberian case study is focused in the design of a draft on-shore regional plan for the trawl fishery in Iberian waters.

This comprises the activity of four metiers level 5 (Table 1)[3] operating in two ICES subareas (27.9 and 27.8c). Catches performed in these subareas are made by almost exclusively by Portuguese and Spanish vessels, with less than 0.5% made by French vessels. Therefore, this study is focused in establishment of a regional plan for the Spanish and Portuguese trawl fleets.

The selected trawl fishery fits in the criteria to select fisheries suitable for a regional sampling plan:

- The catches of target stocks are shared by several countries (here Portugal and Spain).
- The fishery is multispecific, with a large amount of species caught together.
- The fishery targets commercially important species.

This case study represents a good opportunity to develop and theoretically test a methodology to define regional sampling plans, especially since only two countries are involved in the fishery.

The Spanish activity in the Southern part of the Division 27.9.a (9aS) is excluded from the study as it's exclusively a Spanish activity and it is sampled completely within the Spanish on-board sampling programme. Hereafter in this document Iberian waters refers to 27.9a (except 9aS) and 27.8c.

Table 1 Metier description

Metier	Description	Main landed species
OTB_DEF	demersal finfish fishery; Portugal and Spain	Blue whiting (*Micromesistius poutassou*), horse mackerel (*Trachurus trachurus*), European hake (*Merluccius merluccius*), chub mackerel (*Scomber colias*), blue jack mackerel (*Trachurus picturatus*), Atlantic mackerel (*Scomber scombrus*)
PTB_MPD	mixed pelagic and demersal; only Spain	*Blue whiting (Micromesistius poutassou), European hake (Merluccius merluccius), Atlantic mackerel (Scomber scombrus)*
OTB_MPD	mixed pelagic and demersal; only Spain	*Horse mackerel (Trachurus trachurus), Atlantic mackerel (Scomber scombrus)*
OTB_CRU		

[3] There are 4 metiers level 5 with activity in the area comprised in this case study: OTB_CRU, OTB_DEF, OTB_MPD and PTB_MPD (**Error! Reference source not found.**5). Each of them corresponds to one metier level 6, except from OTB_CRU, which includes OTB_CRU>=55_0_0 and OTB_CRU>=70_0_0. Therefore in the summary report it is mentioned 5 metiers level 6.

	crustacean fishery; only Portugal	*Deepwater rose shrimp (Parapenaeus longirostris), blue whiting (Micromesistius poutassou), European hake (Merluccius merluccius)*

Fisheries description based on fishPi² data

This section presents a data exploration and fishery description of the dataset used the Iberian case study, which is a necessary step to identify key variables and factors potentially affecting the simulation and the results obtained.

Member States involved in the project and specifically in this case study, received a data call of the FishPi2 project over the period 2015-2016. The requested data corresponded to official logbooks and sale notes of the total fishing activity developed by each country in the study area.

Every variable showed here is analysed based on two aspects: a) landings (tonnes) and b) fishing effort (number of trips). In most figures, the mean of 2015-2016 data is used.

Vessel flag country

Spain and Portugal are the two countries with trawling activity in Iberian waters with around 53,000 tons and 31,000 tons by year respectively. Spain accounts for the 63.2% of the catches (Figure 1) and a higher percentage of the number of trips.

As a note, French dataset was submitted late and didn't allow a correct merge with the Spanish and Portuguese dataset. Nonetheless, it was determined that the activity of France vessels in the Iberian area was negligible, therefore French data was not used in subsequent analysis.

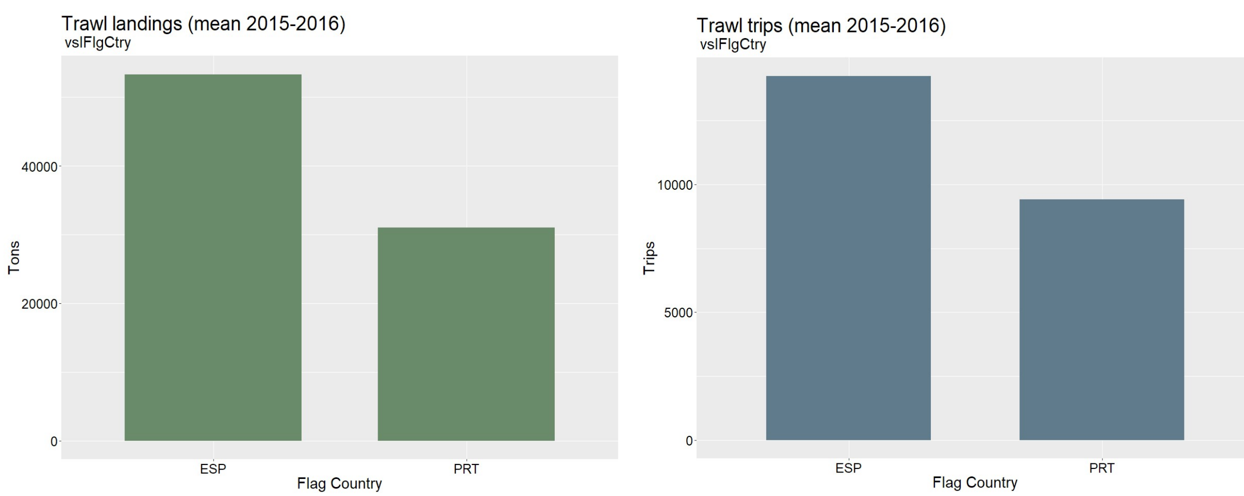


Figure 1. Total trawl landings (mean 2015-2016 and Number of trips (mean 2015-2016) by flag country. Trawlers in Iberian waters (27.8.c. and 27.9.a).

Whereas landings in Portuguese ports are made exclusively by Portuguese vessels, landings in Spanish ports are vastly dominated by Spanish vessels but with some trips by Portuguese vessels (Figure 2)

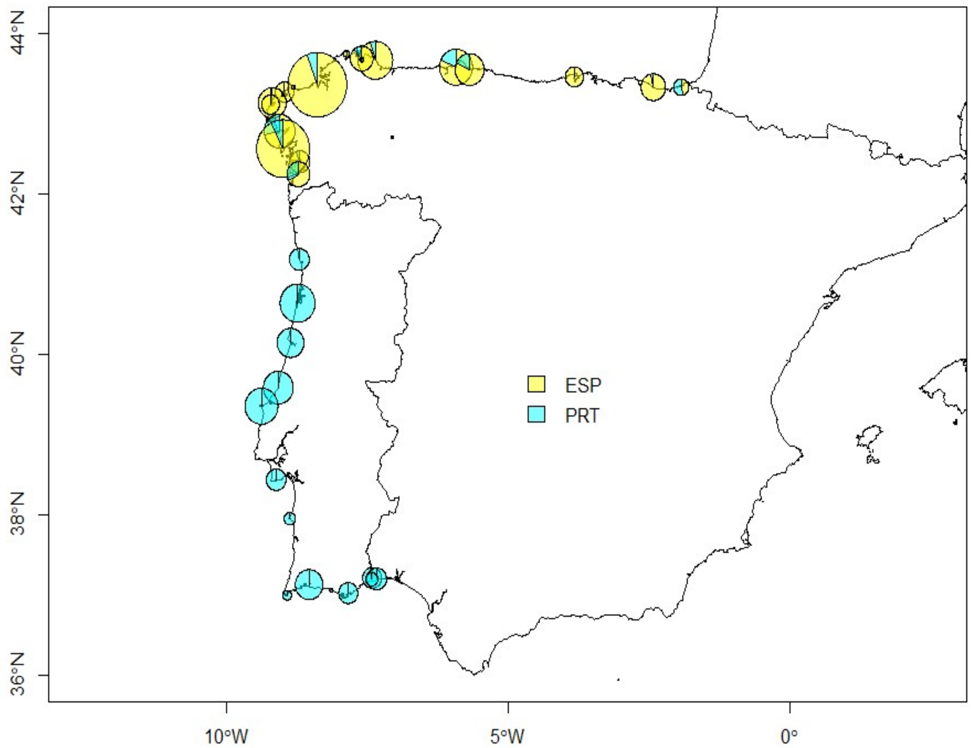


Figure 2. Number of trips (proportional size) per flag country and port (mean 2015-2016). Trawlers in Iberian waters (27.8.c. and 27.9.a).

Fleet: Vessel length

175 trawlers operated in Iberian waters (except 9aS) during 2015-2016. The fleet mostly included industrial vessels over 24m length overall (Figure 3) which account for most of the landed weight (96.7%) and trips (Figure 4). Both fleets also had a small number of vessels between 18-24m and the Portuguese fleet also had some vessels 0-10m, 10-12m and 12-18m.

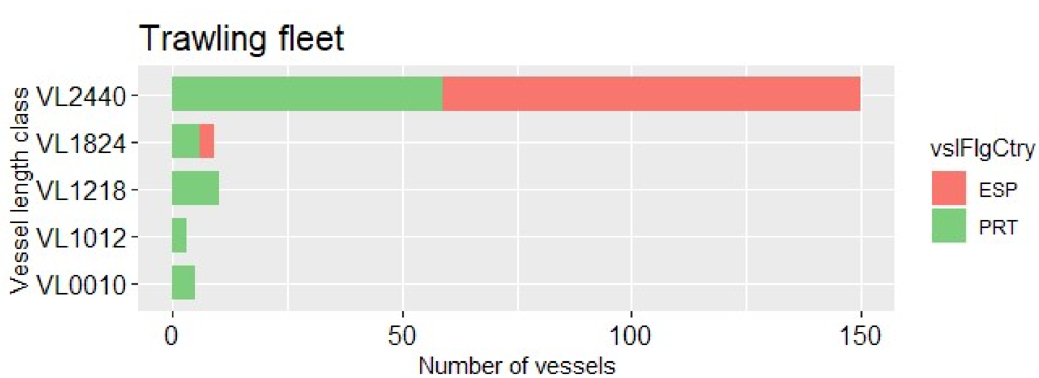


Figure 3. Number of vessels by length overall class. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

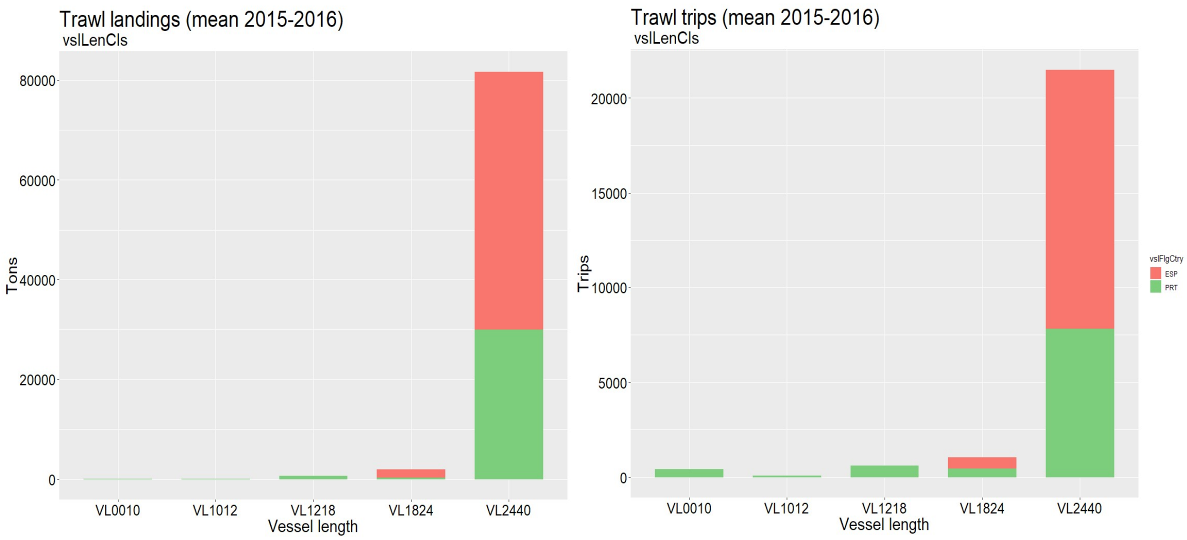


Figure 4. Total landings and Number of trip by length class. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

Fleet: Métier level 5 & Métier level 6

There are four metiers level 5 with activity in the area comprised in this case study: OTB_CRU, OTB_DEF, OTB_MPD and PTB_MPD (Figure 5). Each corresponds to one metier level 6, except for OTB_CRU, which includes OTB_CRU>=55_0_0 and OTB_CRU>=70_0_0.

There are five metiers level 6 with activity in the area comprised in this case study (Figure 6). OTB_DEF_>=55_0_0 and PTB_MPD_>=55_0_0 (the latter exclusively used by Spanish vessels) account for the 80.1% of the landings.

All Portuguese landings are performed by the OTB fleet, mainly by the metier OTB_DEF_>=55_0_0 (94.6%) which also largely dominates in number of trips. Spanish landings (and even number of trips) are more homogeneously distributed among the three metiers.

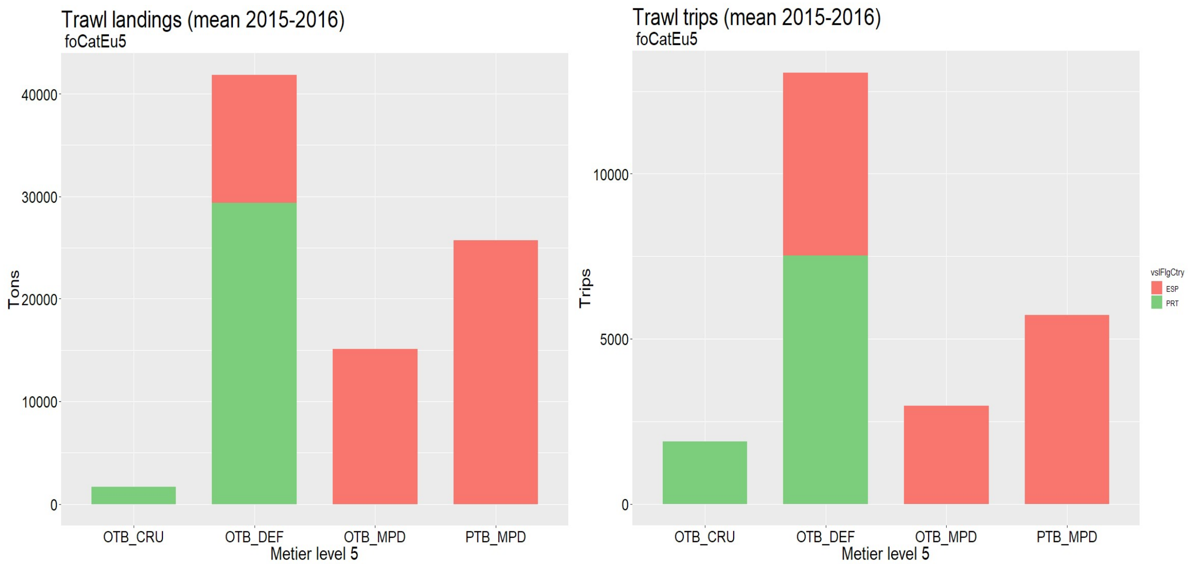


Figure 5. Landings (mean 2015 – 2016) and Number of trips by metier level 5 (mean 2015 - 2016). Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

Table 2. Landings by métier level 6. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

foCatEu6	landings	per_land	cum_per_land	n_trips	rank_trips
OTB_DEF_>=55_0_0	83676,0	49,59	49,59	26132	1
PTB_MPD_>=55_0_0	51504,1	30,52	80,12	11440	2
OTB_MPD_>=55_0_0	30205,5	17,90	98,02	5957	3
OTB_CRU_>=55_0_0	2445,3	1,45	99,47	3435	4
OTB_CRU_>=70_0_0	900,8	0,53	100,00	333	5

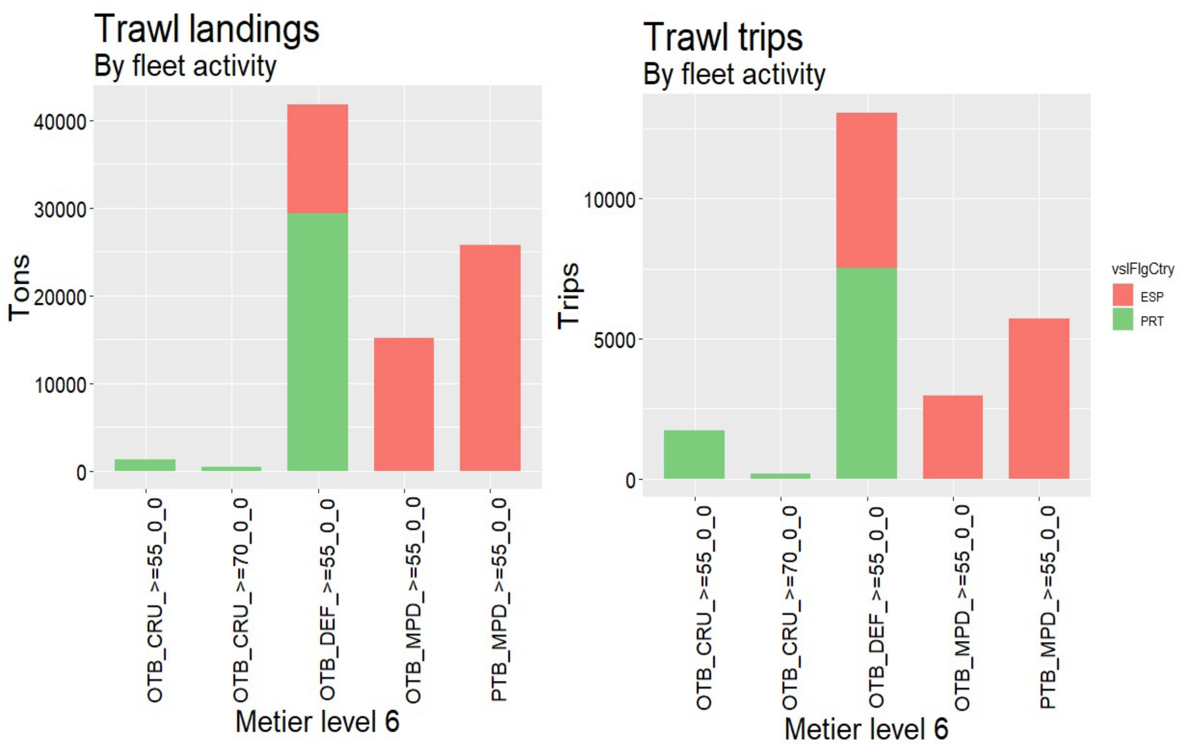


Figure 6. Landings (mean 2015-2016) and Number of trips (mean 2015-2016) by metier level 6. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

Geographical area: Division

In Iberian waters (ICES Divisions 27.9.a except 9.aS, and 27.8.c) the trawl fleet exerts an important activity in the two divisions: 27.8.c dominates landings in weight with around 46.000 tons/year (55.0 %) whereas the 27.9.a (except 9.aS) dominates in number of trips with circa 13.000 trips (Figure 7).

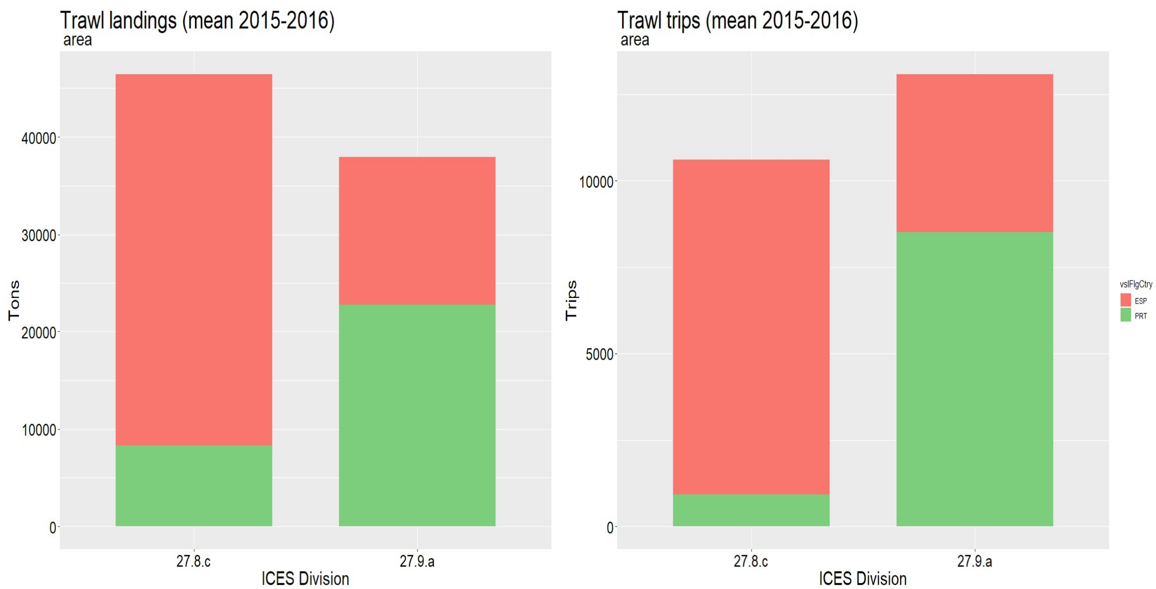


Figure 7. Landings (mean 2015-2016) and Number of trips (mean 2015-2016) by ICES division. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

Geographical area: Subdivision

Subdivisions of ICES Division in the Iberian region (Table 3) represent national fragmentations commonly used by Spain and Portugal for sampling, compilation and provision of fisheries data. This work could represent an opportunity to make a common exercise with these Iberian subareas to test if it would improve current situation or follow broader guidelines and avoid the risk of over stratification.

Landings are higher in subarea 8cW (34.7% of landings) followed by 8cE and 9aN (Figure 8).

According to the logbook data, some trips were assigned to the islands areas (CAN, AZR, MAD, corresponding to the Canary Islands, Azores and Madeira) which are likely errors.

Table 3. Iberian subdivisions.

Areas	Country	Description
8cE	ESP	ICES Division 27.8.c corresponding to Asturias, Cantabrian and Basque Country waters
8cW	ESP	ICES Division 27.8.c corresponding to Galician waters
9aN	ESP	ICES Division 27.9.a corresponding to Galician waters
9aPN	PRT	ICES Division 27.9.a corresponding to Northern Portuguese waters

9aPC	PRT	ICES Division 27.9.a corresponding to Central Portuguese waters
9aPS	PRT	ICES Division 27.9.a corresponding to Southern Portuguese waters
9aS	ESP	ICES Division 27.9.a corresponding to Andalusian waters

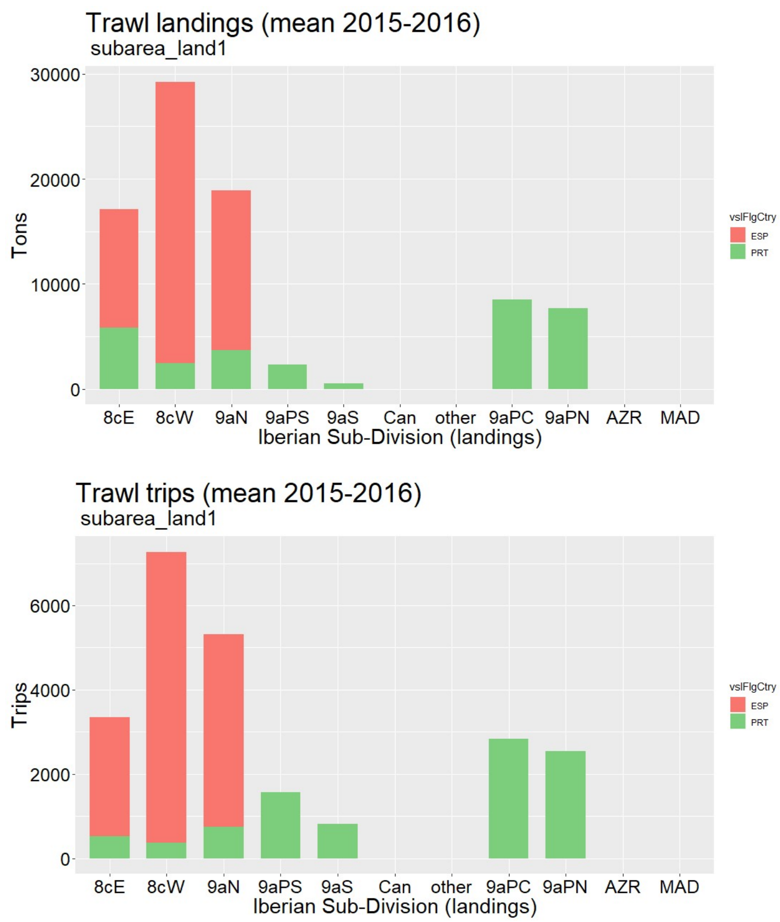
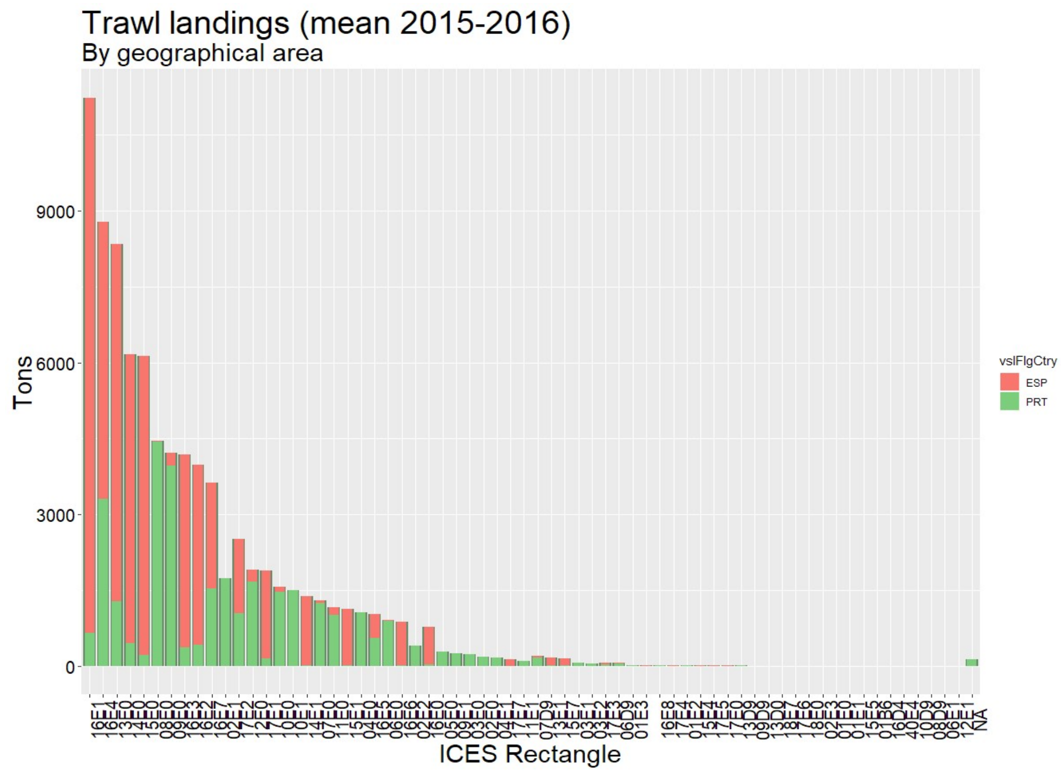


Figure 8. Landings and number of trips per subdivision (mean 2015-2016). Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

Geographical area: Rectangle

Considering landings by ICES rectangles, 90% of landed weight was concentrated in 19 out of a total 66 ICES rectangles. The top three rectangles (16E1, 16E4 and 13E0) accounted for the 33.6% of landed weight, with two of these (16E1, 13E0) also in the top three of the number of trips.



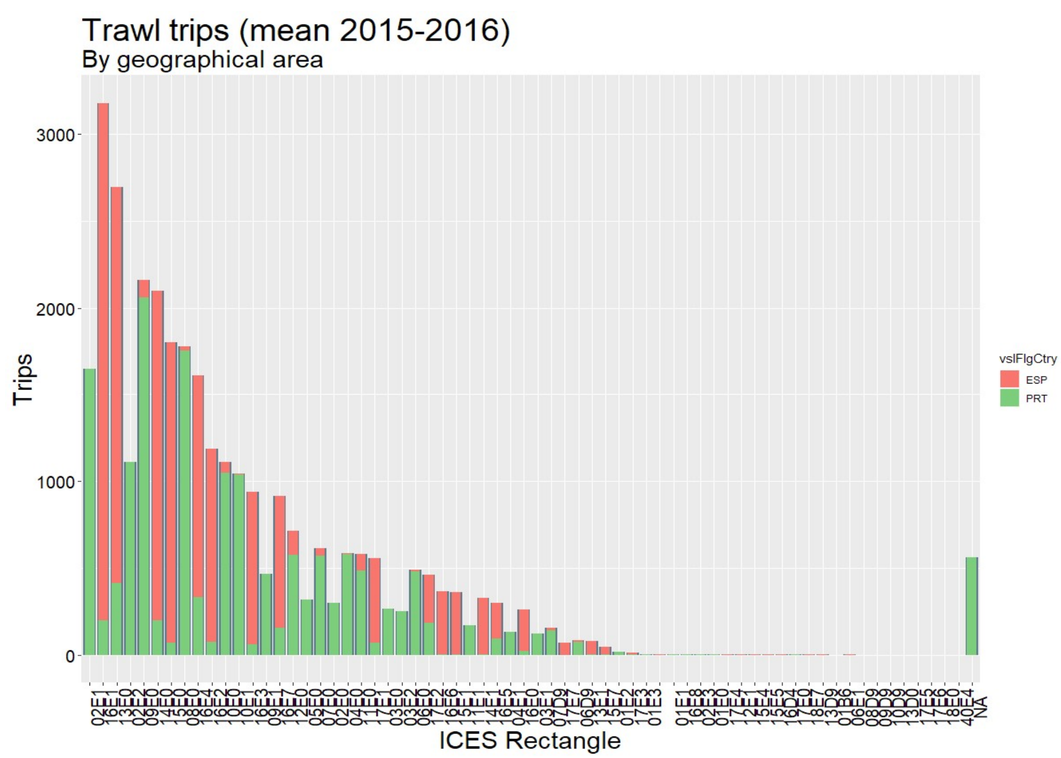


Figure 9. Landings and number of trips by statistical rectangle (mean 2015 and 2016). Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

Quarter

Landed weight showed a seasonal variation, namely higher during the first and second quarters (Figure 10). Meanwhile, fishing effort is more evenly distributed among quarters, slightly higher in the second quarter and slightly lower reduction in the fourth quarter (Figure 18).

All metiers level 6 followed this seasonal trend in landed weight, with the highest catches in first and second quarters, with the exception of OTB_CRU (which have fishing closures in the first quarter) (Figure 11).

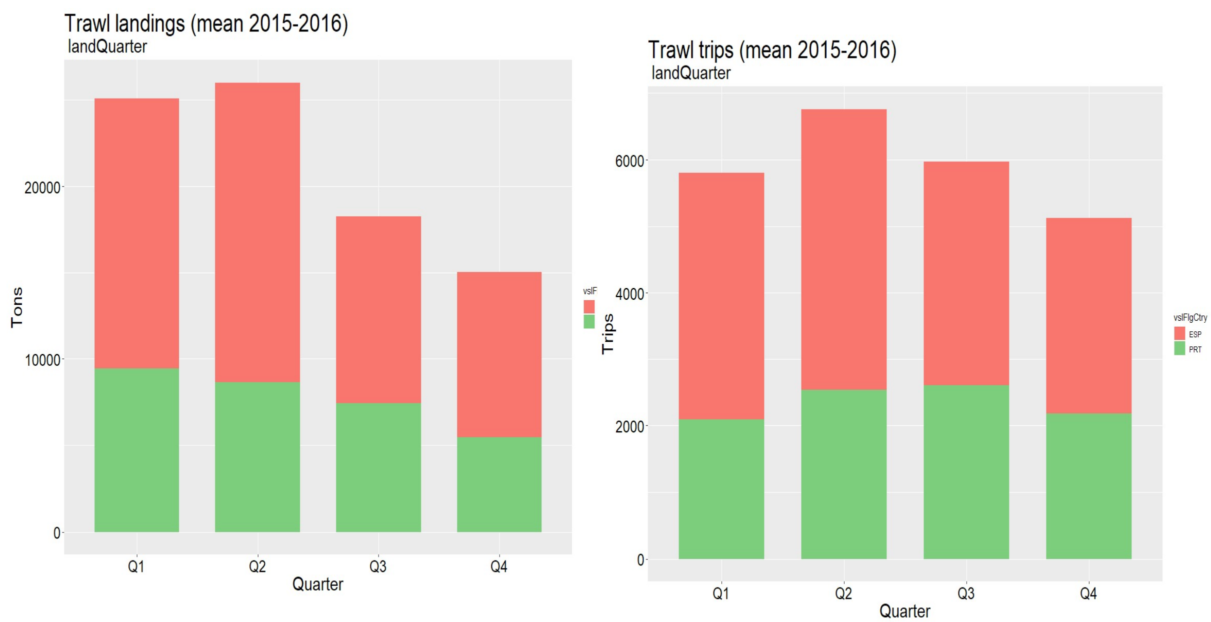


Figure 10. Landings (mean 2015-2016) and Number of trips by quarter (mean 2015-2016). Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS)

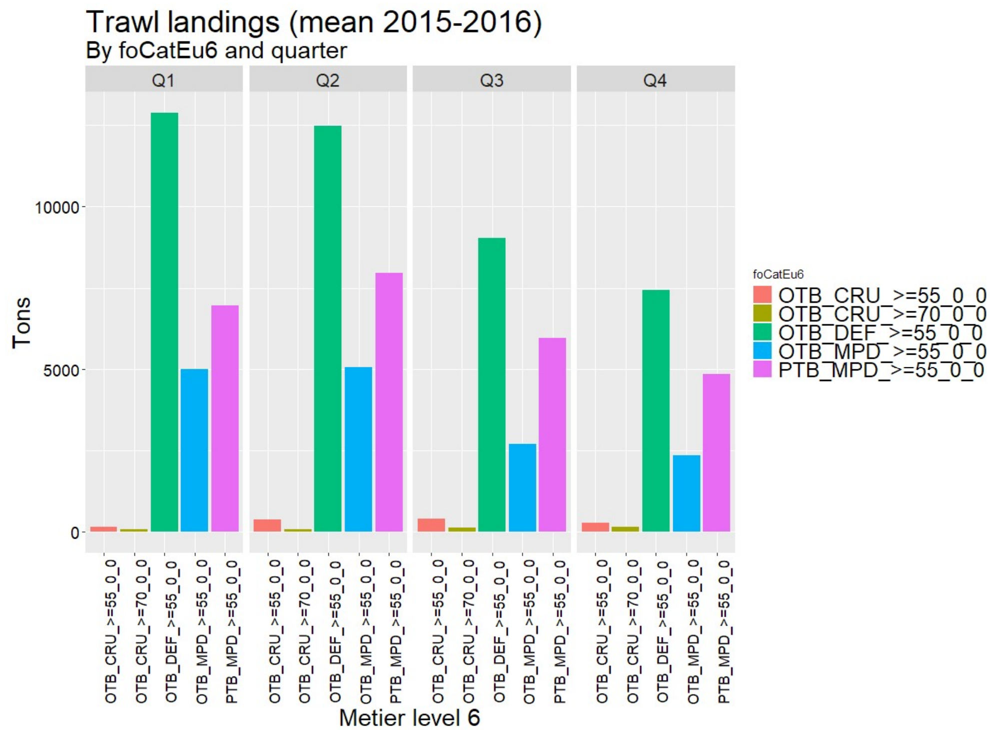


Figure 11. Landings by metier level 6 and quarter. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

Species

Four species accounted for 86.7% of the landings (blue whiting, horse mackerel/blue jack mackerel, mackerel and hake). Among all species, 13 had more than 700 tons contributing to 95.0% of total cumulative landed weight.

The eight species/groups of species selected for the Iberian case study account for the 89.3% of the landings. These are: blue whiting (WHB), horse mackerel/blue jack mackerel (JAX), mackerel (MAC), hake (JKE), megrims (LEZ), monkfish (ANF), Norway lobster (NEP) and shrimps (DPS).

Table 4. Landings per species (2015-2016). Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

sppFAO	landings	per_land	cum_per_land	n_trips	rank_trips
WHB	56007,3	33,2	33,2	21093	3
JAX	49408,1	29,3	62,5	26733	2
MAC	31631,6	18,7	81,2	10853	7
HKE	9237,7	5,5	86,7	32983	1
OMZ	3439,1	2,0	88,7	11994	6
BOG	2049,5	1,2	89,9	3243	29
LEZ	1943,1	1,2	91,1	14034	4
ANF	1806,5	1,1	92,2	13460	5
VMA	1345,1	0,8	93,0	4432	19
BIB	1053,5	0,6	93,6	6751	9
XOD	865,9	0,5	94,1	4326	21
OCM	773,2	0,5	94,6	5677	13
RJC	763,0	0,5	95,0	6506	10
SYC	635,9	0,4	95,4	4508	18
SBA	613,5	0,4	95,8	6233	12
OCC	600,3	0,4	96,1	6336	11
GUX	435,8	0,3	96,4	4205	22
NEP	421,0	0,2	96,6	3966	23
DPS	366,0	0,2	96,8	2930	31

Landings per species, landing port and metier level 5

Considering the species of interest in the case study, species composition of landings varied largely among ports, which may have relevant implications in terms of sampling design (Figures 12 and 13 - these figures included the 36 ports that account for 99.9% of total landings).

Portuguese ports are dominated mainly by JAX landings (except for PTOLH (Olhão), PTSAG (Sagres) and PTVRE (Vila Real de Santo António) where crustacean landings are dominant/important). Spanish ports however, are more heterogeneous in terms of species composition, according to the target species of the different metiers operating in the area but with half the ports dominated by blue whiting (WHB) and several dominated especially by Atlantic mackerel (MAC) or horse mackerel/blue jack mackerel (JAX). In addition, the most important metier level 5 in terms of landed weight overall (OTB_DEF) dominated most ports (Figure 14). Moreover, some Spanish ports (ESCED (Cedeira), ESCIO (Cillero), ESCNO (Cariño), ESIAS (Camariñas), ESLAX (Lage), ESLCG (A Coruña)) were especially relevant for PTB_MPD that landed mostly blue whiting (WHB). And meanwhile, some Portuguese ports (and one Spanish port ESAYA (Ayamonte)) were important for OTB_CRU, with Norway lobster (NEP) and shrimps (DPS) especially landed in some of these Portuguese ports (PTOLH (Olhão), PTSAG (Sagres)) and blue whiting especially landed in others (PTSIE (Sines), PTVRE (Vila Real de Santo António)).

Figure 12. Landings per port and species (in each port the area dedicated to each species is proportional to the landings within that port). Includes only the species of interest in the case study. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

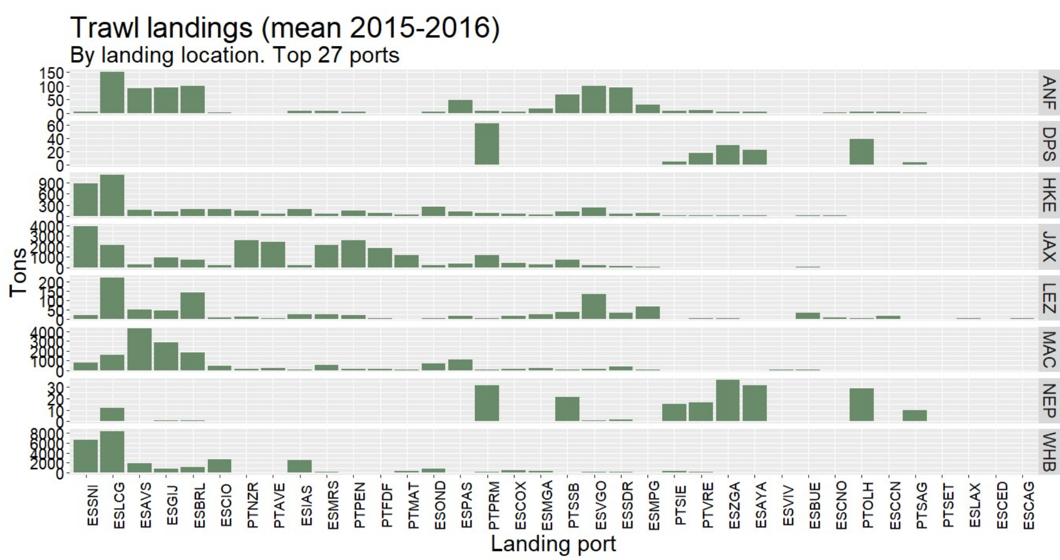


Figure 13. Landings per port and species. Includes only the species of interest in the case study. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

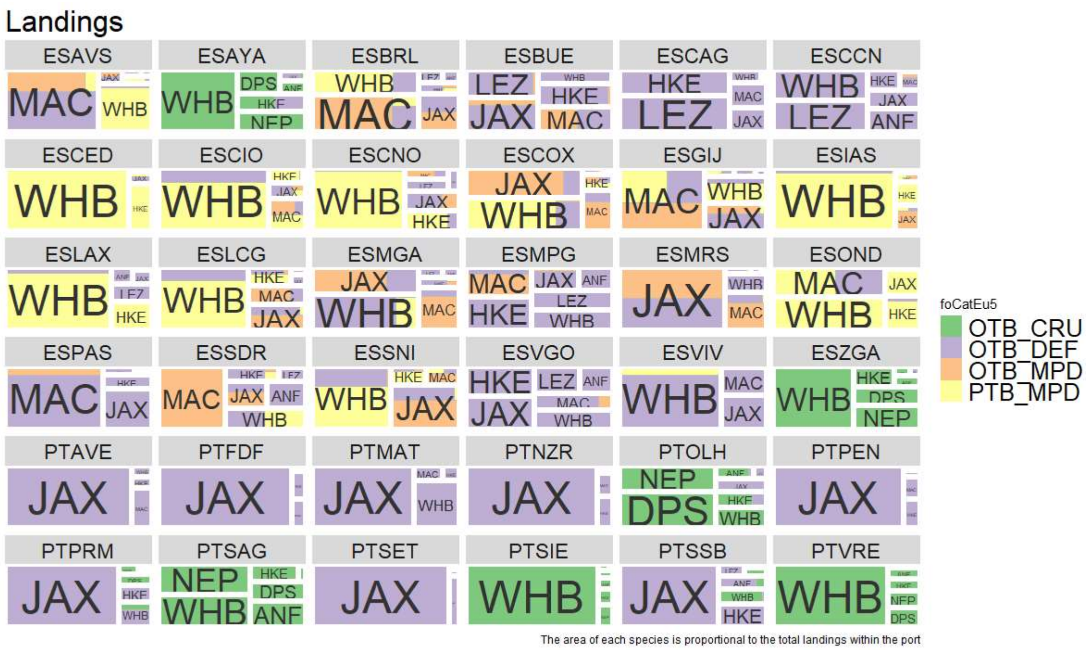


Figure 14. Landings per port, species and metier level 5 (in each port the area dedicated to each species is proportional to the landings within that port). Includes only the species of interest in the case study. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

Landings per species, quarter and metier level 5

Considering the species of interest in the case study, some showed similar landing trends throughout the year such as hake (HKE), megrims (LEZ) and anglerfish (ANF), whereas other species showed some fluctuation (JAX, WHB), and especially one species (mackerel - MAC) presented a highly marked seasonality concentrating landings in the first two quarters.

The dominant metier level 5 (OTB_DEF) dominated landings of several species of interest (ANF, JAX, LEZ) and was important for landings of other species that were mostly landed by PTB_MPD (HKE, WHB) or OTB_MPD (MAC), whereas crustaceans were mostly landed by OTB_CRU. This was observed throughout the year without relevant variation.

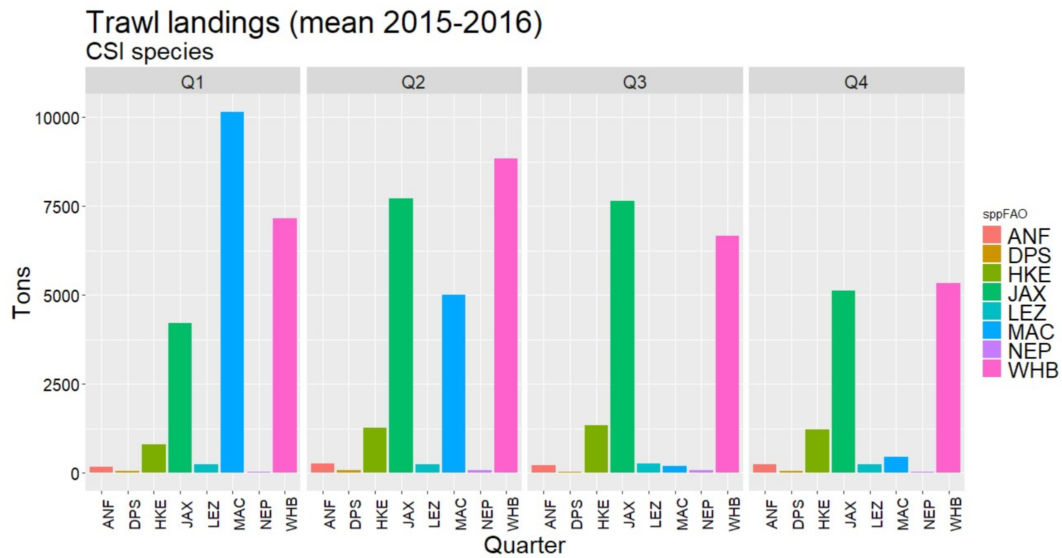


Figure 15. Landings per species and quarter. Includes only the species of interest in the case study. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

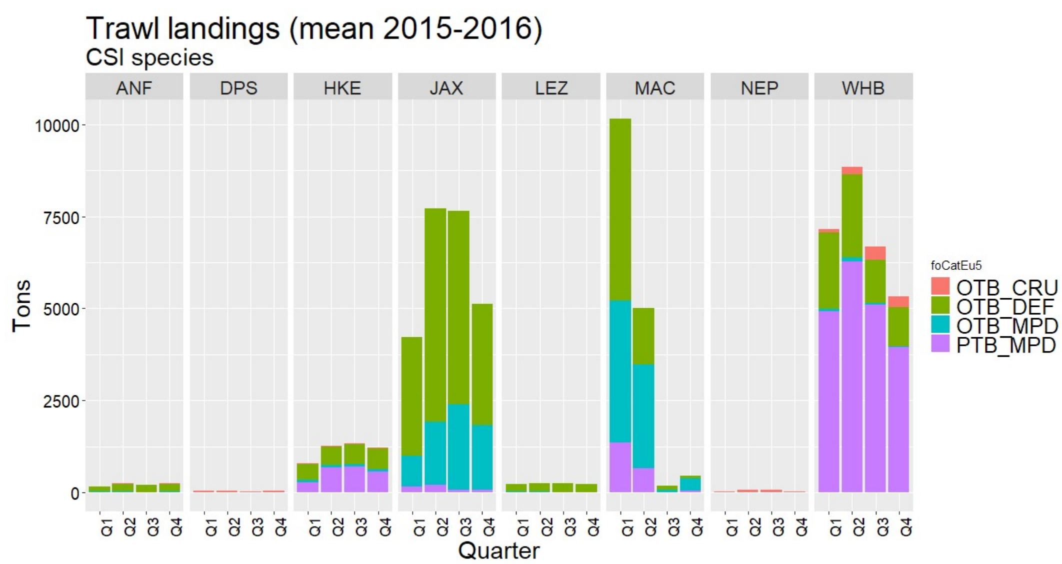


Figure 16. Landings by species quarter and metier. Includes only the species of interest in the case study. Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS).

Landing country

Trawlers in Iberian waters (27.8.c. and 27.9.a except 9aS) mostly land in Spanish ports (78.1%). This represents the totality of landings by Spanish vessels (except for 1 trip) and also an important contribution by Portuguese vessels (that land 40.3% of their catches in Spanish ports).

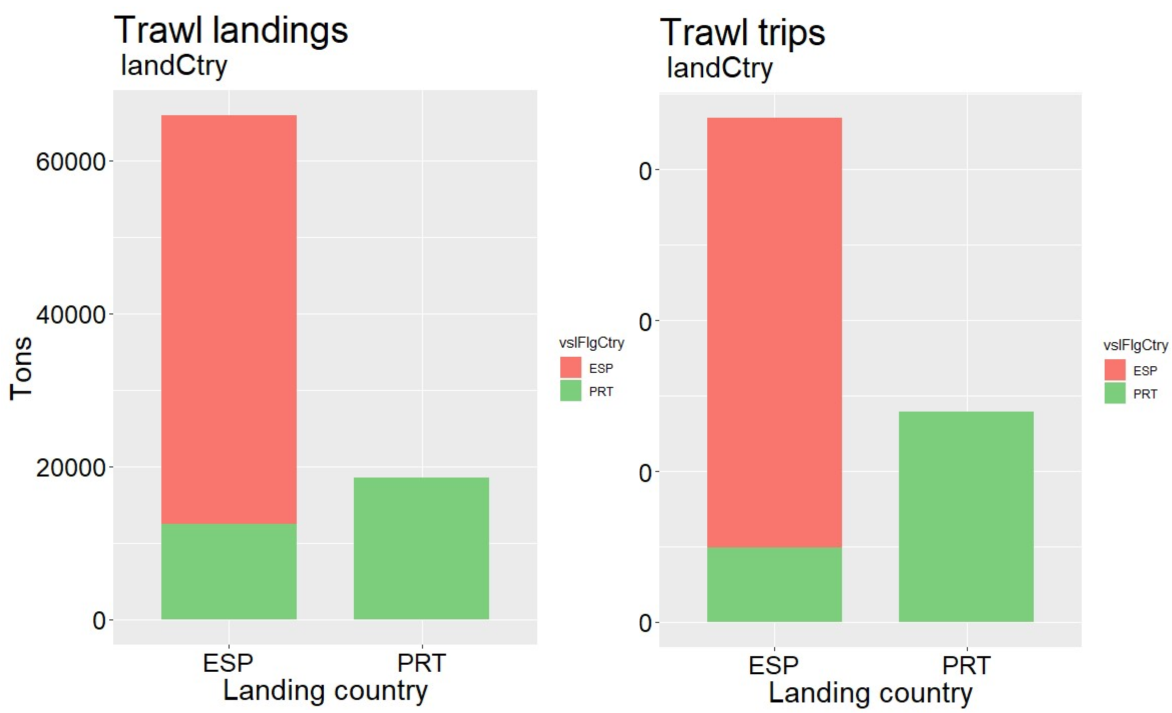


Figure 17. Landings (mean 2015-2016) and Number of trips by landing country (mean 2015-2016). Trawlers in Iberian waters (27.8.c. and 27.9.a).

Access to the landings in the landing port may not be possible when landings are transported directly for sale in other locations in the same or different country. Thus, “sell port” would be needed to determine where the fish is accessible for sampling purposes. But for this case study, landing port and sampling port were considered the same as no further analysis could be done based on the available data.

Sampling institute

The study area in the Iberian case study is sampled by three institutes: IEO, IPMA and AZTI.

Two institutes deal with the fisheries sampling in Spain depending on the region: AZTI samples the Basque Country (corresponding to the Eastern part of the Bay of Biscay), while the IEO sample from Cadiz to Cantabria regions. IEO covers the 73.5% of the landings, followed by IPMA with 21.9% and AZTI with a 4.6%.

Portuguese vessels landed in Portuguese and Spanish ports (especially ports covered by IEO but also ports covered by AZTI), whereas almost no Spanish vessels landed in Portugal (only 1 trip).

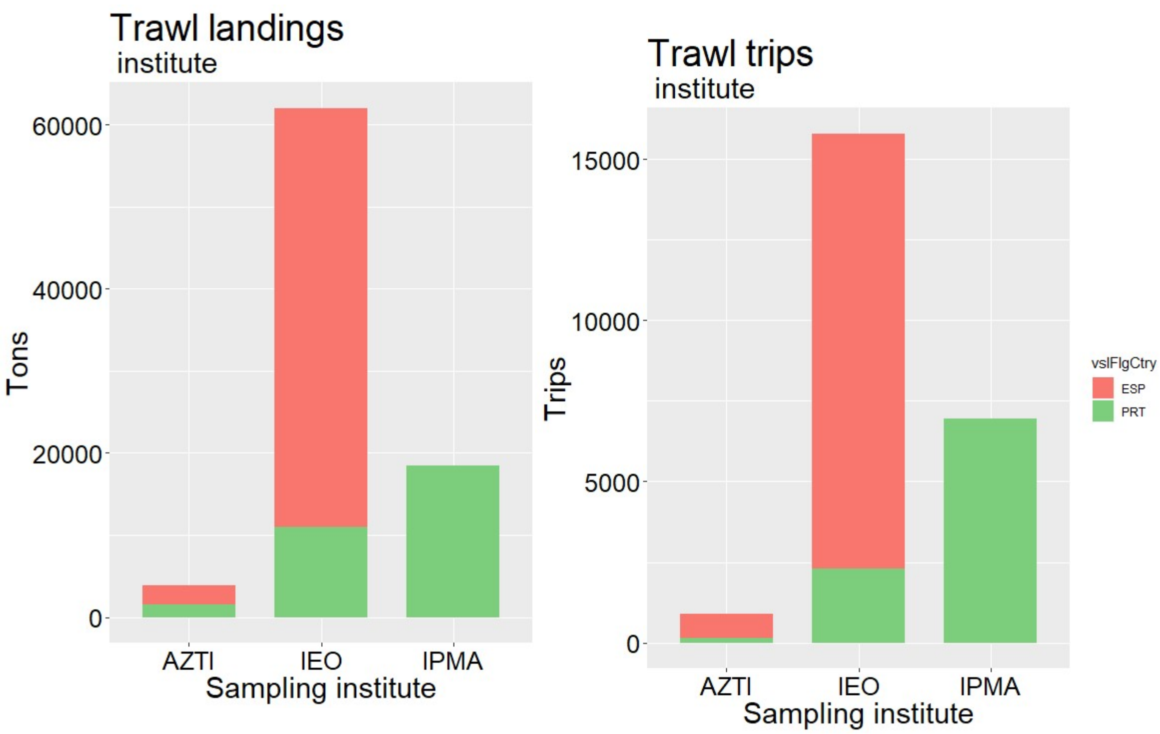


Figure 18. Landings(mean 2015-2016) and Number of trips (mean 2015-2016) by sampling institute. Trawlers in Iberian waters (27.8.c. and 27.9.a.

Landing port

During 2015 and 2016 trawl catches were landed in 58 ports. Among these ports and in total for the two years, 31 present total landings higher than 100 tons, and 22 higher than 1000 tons representing 97.4% of the landings whereas 21 ports reach at least 1% of landings each.

The most important ports in terms of total landings (above 5.000 tons in the total of the two years) are ESLCG, ESSNI, ESAVS, ESGIJ, ESBRL, ESCIO, PTAVE, PTNZR, ESMRS, PTPEN and ESIAS.

Table 5. Landings per port (only top 15 ports). Trawlers in Iberian waters (27.8.c. and 27.9.a).

ibe$landLoc	landings	per_land	cum_per_land	n_trips	rank_trips
ESLCG	29206,1	17,3	17,3	7492	1
ESSNI	25109,7	14,9	32,2	6040	2
ESAVS	13830,4	8,2	40,4	2335	6
ESGIJ	10618,1	6,3	46,7	1816	9
ESBRL	9502,1	5,6	52,3	2620	4
ESCIO	7113,4	4,2	56,5	1125	15
PTAVE	7042,8	4,2	60,7	2630	3
PTNZR	6703,7	4,0	64,7	1936	8
ESMRS	6659,4	3,9	68,6	2066	7
PTPEN	6649,3	3,9	72,6	2518	5
ESIAS	6523,8	3,9	76,4	1681	11
PTFDF	4665,6	2,8	79,2	1621	12
ESOND	4263,6	2,5	81,7	1303	13
ESVGO	4220,9	2,5	84,2	1134	14
PTMAT	3636,2	2,2	86,4	852	19

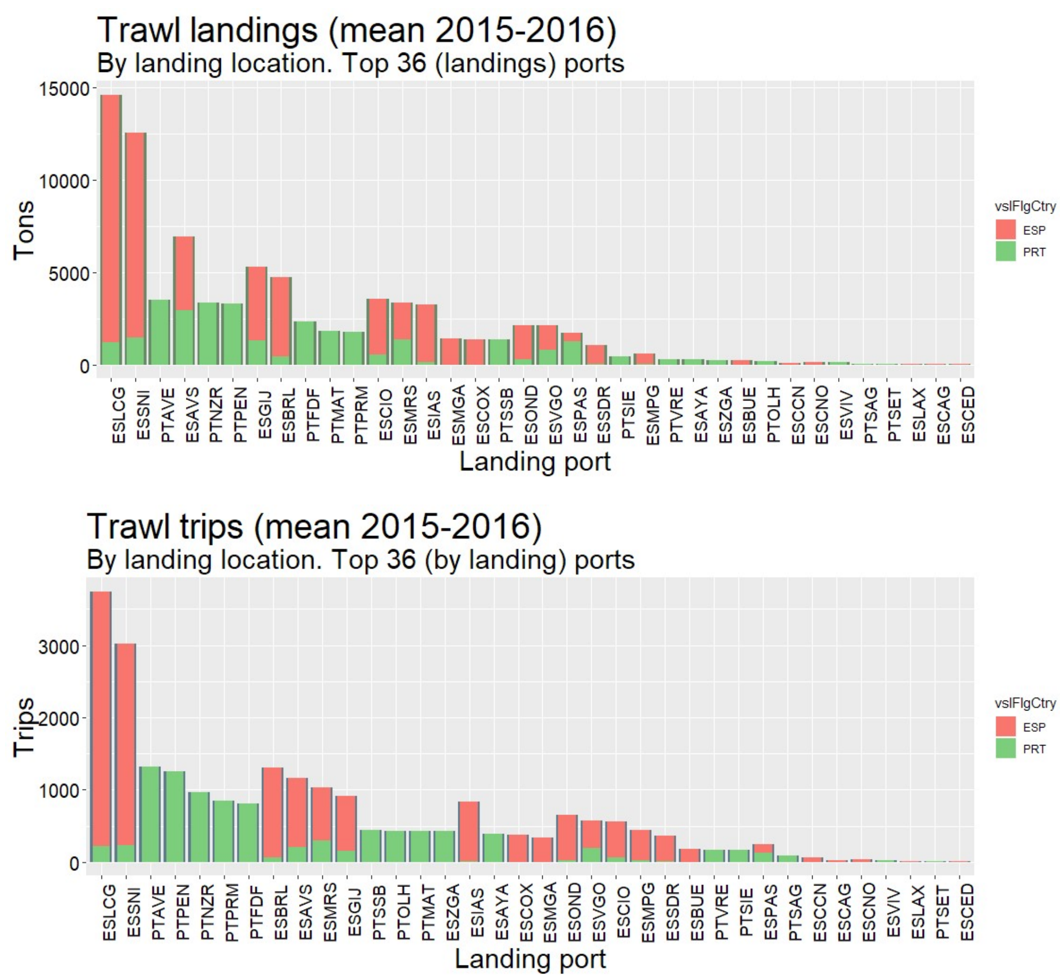


Figure 19. Landings and number of trips by landing port and vessel flag country (mean 2015-2016). Trawlers in Iberian waters (27.8.c. and 27.9.a).

Conclusions

To summarize, the trawl fleet operating in the Iberian area (27.8.c and 27.9.a except 9.a.S) is vastly dominated by industrial vessels over 24m length overall. This fleet operates with four main metiers level 5 but mostly with OTB_DEF; only one of these targeting crustaceans and the remaining targeting demersal or demersal and pelagic fish. The activity is dominated by Spanish vessels (62% of landed weight), but only Portuguese vessels land in Spain with the inverse not occurring.

In all, both divisions of the study area (27.8.c and 27.9.a) have important landings. Landings occur in 58 ports (78% of landed weight in Spanish ports), but with 22 ports representing 97.4% of landed weight. Trawler activity is spread throughout the year, with higher landings in the first half.

Landings are dominated by four species that together represent 95% (blue whiting, horse mackerel/blue jack mackerel, mackerel and hake). Portuguese ports are dominated mainly by JAX landings (except three ports where crustacean landings are dominant/important). Spanish ports are more heterogeneous in terms of species composition, according to the target species of the different metiers operating in the area.

Annex 3

Annex 3.1 EUMAP Annual Work-Plan Tables

Annex 3.1.1 EUMAP Annual Work-Plan Table Templates

The current Annual Work Plan tables 4A-D have been adapted to include pertinent information about sampling designs that is required to fully assess a sampling design and its expected outcomes. These adaptations are proposed as a result of the output required from the simulation studies to compare sampling designs, and much of the information in the proposed tables can be obtained as output from the simulation code. Proposed annual work plan table templates and guidelines are included in the repository of tools described below. Here we include a brief comparison of the original and adapted work plan tables.

The original work-plan tables for catch sampling schemes are as follows:

- Table 4A: Sampling plan description
- Table 4B: Sampling frame description
- Table 4C: Data on the fisheries
- Table 4D: Landings locations

Tables 4A and 4B are appropriate for both on-shore and at-sea designs, where at-sea designs focus on fleets, and on-shore designs focus on landing (or sales or processing) locations, and give an overview of the design, including sampling effort and stratification and sampling frames for the primary sampling unit (e.g. port-days, or fishing trips). Table 4B only contains 3 additional columns compared to table 4A, and the two can easily be amalgamated to better understand the sampling design. The rationale for Tables 4C and 4D were to provide an overview of the populations being sampled by the at-sea and on-shore sampling designs described in 4A and 4B, with totals of landed tonnage, trips, etc by fleet or groups of landing locations. However, if the fleets and locations in Tables 4C and 4D are not grouped into the same strata as used for the sampled fleets and locations in Tables 4A and 4B, comparison between the population and sampling design is difficult.

The proposed new set of tables covers all aspects of the sampling designs for commercial catch, starting with a list of catch sampling schemes for each MS (Table 4a), before describing each scheme in more detail (Tables 4b-4f). These tables include extra information to describe the planned sampling design, amalgamate the sampling designs and overviews of the populations into separate tables for at-sea and on-shore designs, and include additional new tables on biological sampling and expected outcomes.

The adapted work-plan tables are as follows:

- Table 4a: List of catch surveys
- Table 4b: Sampling hierarchies

- Table 4c: On-shore schemes
- Table 4d: At-sea schemes
- Table 4e: Biological sampling
- Table 4f: Expected outcomes by domain

Table 4a is the equivalent list of commercial catch sampling schemes to the list of research vessel surveys in Table 1G. Table 4b adapts the original Table 4B to include the sampling heirarchy at all levels (4b), and whilst this is not necessary for evaluating the schemes, it aids clarity and therefore understanding. Table 4c amalgamates Tables 4A, 4B, and 4C to provide a single overview of the population with the design and effort allocation for at-sea schemes, whilst Table 4d amalgamates Tables 4A, 4B and 4D to provide a single overview of the population with the design and effort allocation for on-shore schemes. This allows the stratification in each design to be set in context. Table 4e contains information regarding the biological sampling for each design, and is the equivalent of Table 1C "Sampling intensity" but is specific to the commercial catch sampling designs in Tables 4. Table 4f gives an overview of the expected sampling outcomes, in terms of numbers of trips sampled by stock, area and metier. Much of this new information in Table 4f can be obtained as output from simulation studies to test sampling designs, such as the ones used in this work-package.

By collating information on proposed commercial catch sampling designs in the same place, and by including additional information on expected outcomes of the schemes, this proposed new table structure will aid clarity and understanding, and will thus improve evaluations of such plans.

For those more familiar with the Annual Work Plan Tables, these new tables are described in more detail below. Excerpts from the tables for the proposed North Sea demersal regional sampling design are included in Annex 3.1.2.

Proposed Annual Work Plan Tables

Table 4a List of catch surveys

This is the catch sampling equivalent of Table 1G: List of research surveys, and includes an overview of each catch sampling scheme undertaken by that member state.

Table 4b Onshore schemes

This is an adaptation of Table 4A for on-shore sampling schemes. It has been adapted to include the three fields in Table 4B that are not already included in Table 4A, and the relevant fields in Table 4D, which summarise the landings for each of the listed on-shore strata. These fields include the total landed weight, the national landed weight and landed weight by foreign vessels, for the species of interest, as well as the number of site-days and trips in each stratum. The inclusion of this information in together with the sampling design allows the planned sampling effort and stratification to be considered in the context of the population to be sampled.

Table 4c At-sea schemes

This is an adaptation of Table 4A, but only for at-sea sampling schemes. It has been adapted to include the three fields in Table 4B that are not already included in Table 4A, and the relevant fields in Table 4C, which summarise the landings and vessels for each of the listed at-sea strata. These fields include the total landed weight, the landed weight into national ports and the landed weight into foreign ports, for the species of interest, as well as the total number of vessels and trips carried out in each stratum. This allows the planned sampling and stratification to be considered in the context of the population to be sampled.

Table 4d Sampling hierarchies

This is a new table, which includes the sampling hierarchies for each of the schemes. Each level of the sampling hierarchy for each scheme and sampling nation is included as a row in the table, so that stratification of lower levels can be different between nations. Although this table in itself is not required for evaluation of the scheme per se, since the sampling levels should be included in Text Box 4A, it aids clarity, and therefore understanding of the statistical description of the sampling scheme, allowing full evaluation of the sampling scheme and comparison across schemes where necessary.

Table 4e Biological sampling

This is the equivalent of Table 1C Sampling intensity, but set up to allow different biological sampling across schemes, and allowing evaluation of the sampling scheme in terms of the expected number of independent samples to be taken. The total number of site-days, trips and individuals sampled is not set as a target, but as an expectation based on the proposed sampling protocols and simulation results. This can then be compared in the annual report with the totals actually sampled in the implementation of the scheme.

Table 4f Expectations by domain

This is a new table, which sets out the expected sample size in terms of primary sampling units (PSUs), trips, and individuals sampled, in terms of the domains for which the nation intends to estimate. This aids evaluation of whether the planned sampling is fit for its planned use.

Annex 3.1.2 EUMAP Annual Work-Plan for North Sea Case Study

The tables described in Annex 3.1.1 have been populated for the selected regional sampling design for the North Sea case study in Tables 1-5. The stratification and effort allocation for the primary sampling unit is included in full in Table 3. Where the tables would be long and repetitive if they included all UK nations in the regional sampling design, excerpts have been included for the Scottish contribution to the design.

Table 1: Example EU MAP Annual Work-Plan for a Regional Design Table 4a: List of commercial catch sampling schemes. Excerpt for Scotland. The first line is the entry for the regional sampling design for Scotland, the additional lines examples of additional catch sampling designs and these are not included in subsequent tables.

MS	Region	RFMO/RFO/IO	Sub-area / Fishing ground	Regional or National	Scheme Type	Fishery/ fleet	Scheme ID	Scheme name	Scheme description
GBS	NSEA	ICES	27.4, 27.3.a, 27.7.d	Regional	On-shore	Demersal	REG-WNS-DEM-ONS	Regional Wider North Sea Demersal On-shore Sampling Scheme	A regional sampling scheme for the on-shore sampling of demersal fisheries in the wider North Sea (27.4, 27.3.a & 27.7.d).
GBS	*NSEA*	*ICES*	*27.4, 27.6*	*National*	*On-shore*	*Demersal*	*GBS-NAT-DEM-ONS*	*Scottish demersal on-shore sampling scheme*	*A national sampling scheme for the on-shore sampling of demersal fisheries in the North Sea, West of Scotland and Rockall (27.4, & 27.6).*
GBS	*NSEA*	*ICES*	*27.4, 27.6*	*National*	*On-shore*	*Pelagic*	*GBS-NAT-PEL-ONS*	*Scottish pelagic on-shore sampling scheme*	*A national sampling scheme for the on-shore sampling of pelagic fisheries in the North Sea, West of Scotland and Rockall (27.4, & 27.6).*
GBS	*NSEA*	*ICES*	*27.4, 27.6*	*National*	*On-shore*	*Shellfish*	*GBS-NAT-SHF-ONS*	*Scottish shellfish on-shore sampling scheme*	*A national sampling scheme for the on-shore sampling of shellfish fisheries in the North Sea, West of Scotland and Rockall (27.4, & 27.6).*
GBS	*NSEA*	*ICES*	*27.4, 27.6*	*National*	*At-sea*	*Otter trawlers*	*GBS-NAT-DEM-ATS*	*Scottish demersal at-sea sampling scheme*	*A national sampling scheme for the at-sea sampling of otter trawl fisheries in the North Sea, West of Scotland and Rockall (27.4, & 27.6).*

Table 2: Example EU MAP Annual Work-Plan for a Regional Design Table 4b: Sampling hierarchies. Excerpt for Scotland. The columns 'MS participating in sampling', 'Region', 'RFMO/RFO/IO' and 'Sub-area/fishing ground' have been removed to improve legibility and as they could be considered redundant as they are already included in Table 4a. Columns shaded blue can be obtained from the landings simulation output, columns shaded in lilac can be obtained from biological data.

MS	Scheme ID code	Sampling unit level	Sampling unit type	Sampling unit stratification	Sampling unit sampling frame description	Method of sampling unit selection	Expected number of units per sample	Expected number of units in scheme
GBS	REG-WNS-DEM-ONS	1	Site-date	Regional stratification into major & minor ports, which are then split by country	List of possible site-dates within each stratum	SRS of site-dates from each stratum	1	
GBS	REG-WNS-DEM-ONS	2	Landings of a fishing trip	No stratification	List of landings present on that site-date	SRS of fishing trip landings present on that site-date	2	
GBS	REG-WNS-DEM-ONS	3	Species	No stratification	List of species present on that landing	Census of species from that landing (concurrent sampling)	3.2	
GBS	REG-WNS-DEM-ONS	4	Box	Stratification into sales categories present	All boxes present in each sales category	SRS of boxes from each sales category	1	
GBS	REG-WNS-DEM-ONS	5	Fish length	No stratification	All fish in selected box(es)	Census of fish in box		

GBS	REG-WNS-DEM-ONS	6	Fish biological information	Stratification by length class per box	All fish in each length class in selected box(es)	First fish encountered in each length class		

Table 3a: Example EU MAP Annual Work-Plan for a Regional Design Table 4d: On-shore schemes – part 1, columns A-P. Information for the full regional scheme is represented here. The columns 'MS participating in sampling', 'Region', 'RFMO/RFO/IO' and 'Sub-area/fishing ground' have been removed to improve legibility and are already included in Table 4a.

MS	Scheme ID code	Stratum ID code	Stratum description†	Sampling frame description†	PSU type	Method of PSU selection †	Catch fractions covered	Species/ Stocks covered for estimation of volume and length of catch fractions	Seasonality (Temporal strata)
BEL	REG-WNS-DEM	REG-WNS-DEM-MAJOR-BEL	Belgian ports of major importance to the regional landings from the wider North Sea	List of site-dates within 2 Belgian ports in the top 37 ports accounting for 95% of the regional landings and xx% of the Belgian landings from the wider North Sea	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
BEL	REG-WNS-DEM	REG-WNS-DEM-MINOR-BEL	Belgian ports of minor importance to the regional landings from the wider North Sea	List of site dates within 2 Belgian ports in the lower 305 ports accounting for the remaining 5% of the regional demersal from the wider North Sea	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
DEU	REG-WNS-DEM	REG-WNS-DEM-MAJOR-DEU	German ports of major importance to the regional landings from the wider North Sea	List of 1 German port in the top 37 ports accounting for 95% of the regional demersal landings from the wider North Sea	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual

DEU	REG-WNS-DEM	REG-WNS-DEM-MINOR-DEU	German ports of minor importance to the regional landings from the wider North Sea	List of 10 German ports in the lower 305 ports accounting for the remaining 5% of the regional demersal landings from the wider North Sea	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
DNK	REG-WNS-DEM	REG-WNS-DEM-MAJOR-DNK	Danish ports of major importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
DNK	REG-WNS-DEM	REG-WNS-MINOR-DNK	Danish ports of minor importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
FRA	REG-WNS-DEM	REG-WNS-MAJOR-FRA	French ports of major importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
FRA	REG-WNS-DEM	REG-WNS-MINOR-FRA	French ports of minor importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual

GBE	REG-WNS-DEM	REG-WNS-MAJOR-GBE	English ports of major importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
GBE	REG-WNS-DEM	REG-WNS-MINOR-GBE	English ports of minor importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
GBS	REG-WNS-DEM	REG-WNS-MAJOR-GBS	Scottish ports of major importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
GBS	REG-WNS-DEM	REG-WNS-MINOR-GBS	Scottish ports of minor importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
NLD	REG-WNS-DEM	REG-WNS-MAJOR-NLD	Dutch ports of major importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual

NLD	REG-WNS-DEM	REG-WNS-MINOR-NLD	Dutch ports of minor importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
SWE	REG-WNS-DEM	REG-WNS-MINOR-SWE	Swedish ports of minor importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual
OTH	REG-WNS-DEM	REG-WNS-MINOR-OTH	Other ports of minor importance to the regional landings from the wider North Sea	Similar text to above…	site date	Random selection from a list of possible site-days	Marketable Landings, BMS	Demersal finfish	annual

Table 3b: Example EU MAP Annual Work-Plan for a Regional Design Table 4d: On-shore schemes – part 2, columns I and R-Z. Information for the full regional scheme is represented here. All columns except the planned PSUs can be obtained from the population data (and is output by the simulation code).

Stratum ID code	**Average number of locations***	**Average number of site days**	**Average number of registered landings***	**Average landed tonnage of relevant species***	**Average landed tonnage of relevant species of national fleet***	**Average landed tonnage of relevant species of foreign fleet***	**Average number of PSU during the reference years**	**Planned number of PSUs**	**Expected number of fishing trips sampled per PSU**[!]	**Expected number of species sampled per fishing trip**[!]

REG-WNS-DEM-MAJOR-BEL	2	482	1452	198335	6349	5923	467	21	1.7	11.4
REG-WNS-DEM-MINOR-BEL	2	331	940	2452	136	80	374	4	1.6	1.9
REG-WNS-DEM-MAJOR-DEU	1	19	21	3524	1090	1090	10	2	1.1	10.7
REG-WNS-DEM-MINOR-DEU	10	85	88	4642	691	691	84	4	1.0	6.9
REG-WNS-DEM-MAJOR-DNK	8	2381	18625	765403	83906	48863	2402	105	1.9	7.5
REG-WNS-MINOR-DNK	49	2331	5360	53970	2944	1889	2561	4	1.5	4.8
REG-WNS-MAJOR-FRA	8	2501	19917	824291	25053	18782	2506	110	1.9	6.3
REG-WNS-MINOR-FRA	52	3788	8035	80901	1724	1713	3587	4	1.5	4.6
REG-WNS-MAJOR-GBE	1	274	1314	25019	962	838	261	11	1.8	8.4
REG-WNS-MINOR-GBE	93	7422	21235	185258	5084	3908	7104	4	1.5	4.8
REG-WNS-MAJOR-GBS	8	1677	5264	1073733	78180	60691	1649	72	1.7	9.9
REG-WNS-MINOR-GBS	25	158	166	35661	871	507	196	4	1.0	4.5
REG-WNS-MAJOR-NLD	10	1860	8681	517026	84582	46844	1771	78	1.7	6.9
REG-WNS-MINOR-NLD	23	743	977	9926	1953	1949	696	4	1.2	2.9

REG-WNS-MINOR-SWE	52	3074	3959	31636	1399	1360	3394	4	1.2	4.1
REG-WNS-MINOR-OTH	7	12	13	17467	756	N/A	10	0	1.1	3.5

Table 4: Example EU MAP Annual Work-Plan for a Regional Design Table 4e: Biological sampling. Excerpt for Scotland. The columns 'MS participating in sampling', 'Region', 'RFMO/RFO/IO' and 'Sub-area/fishing ground' have been removed to improve legibility and as they could be considered redundant as they are already included in Table 4a. Columns shaded blue can be obtained from the landings simulation output, columns shaded in lilac can be obtained from biological data or biological simulations.

MS	Scheme ID code	Species	Catch fraction	Variable	Selection of individuals per sample	Expected number of individuals per sample	Expected number of PSUs to be sampled per nation per scheme	Expected number of site-days to be sampled per nation per scheme	Expected number of trips to be sampled per nation per scheme	Expected number of individuals to be sampled per nation per scheme
GBS	REG-WNS-DEM	Gadus morhua	Commerical landings	length	1 box per category per trip sampled					
GBS	REG-WNS-DEM	Melanogrammus aeglefinus	Commerical landings	length	1 box per category per trip sampled					
GBS	REG-WNS-DEM	Merlangius merlangus	Commerical landings	length	1 box per category per trip sampled					
GBS	REG-WNS-DEM	Pollachius virens	Commerical landings	length	1 box per category per trip sampled					
GBS	REG-WNS-DEM	Pleuronectes platessa	Commerical landings	length	1 box per category per trip sampled					
GBS	REG-WNS-DEM	Solea solea	Commerical landings	length	1 box per category per trip sampled					

GBS	REG-WNS-DEM	Glyptocephalus cynoglossus	Commerical landings	length	1 box per category per trip sampled					
GBS	REG-WNS-DEM	Gadus morhua	Commerical landings	age	1 per cm per category per trip sampled					
GBS	REG-WNS-DEM	Melanogrammus aeglefinus	Commerical landings	age	1 per cm per category per trip sampled					
GBS	REG-WNS-DEM	Merlangius merlangus	Commerical landings	age	1 per cm per category per trip sampled					
GBS	REG-WNS-DEM	Pollachius virens	Commerical landings	age	1 per cm per category per trip sampled					
GBS	REG-WNS-DEM	Pleuronectes platessa	Commerical landings	age	1 per cm per category per trip sampled					
GBS	REG-WNS-DEM	Glyptocephalus cynoglossus	Commerical landings	age	1 per cm per category per trip sampled					

Table 5: Example EU MAP Annual Work-Plan for a Regional Design Table 4f: Expectations by domain. Excerpt for Scotland. The columns 'MS participating in sampling', 'Region', 'RFMO/RFO/IO' and 'Sub-area/fishing ground' have been removed to improve legibility and as they could be considered redundant as they are already included in Table 4a. The column 'Catch fraction' has been removed since this is simply 'Commercial landings' repeated, and similarly 'Reference year' has been removed since this repeated. Columns shaded blue can be obtained from the landings simulation output, columns shaded in lilac can be obtained from biological data or biological simulations.

MS	Scheme ID code	Stock	Sub-area/division/sub-division	Metier / Metier Group	Species	Variable	Total number of PSUs per nation per scheme	Total number of site-days per nation per scheme	Total number of trips to be sampled per nation per scheme	Expected number of PSUs to be sampled per nation per scheme	Expected number of site-days to be sampled per nation per scheme	Expected number of trips to be sampled per nation per scheme	Expected number of individuals to be sampled per nation per scheme
GBS	REG-WNS-DEM	cod.27.47d20	27.4.a	OTC >=120	Gadus morhua	Length	1386	1386	3723	55.8	55.8	78.3	
GBS	REG-WNS-DEM	had.27.46a20	27.4.a	OTC >=120	Melanogrammus aeglefinus	Length	1402	1402	3982	57.2	57.2	83.4	
GBS	REG-WNS-DEM	whg.27.47d	27.4.a	OTC >=120	Merlangius merlangus	Length	1308	1308	3576	52.6	52.6	74.7	
GBS	REG-WNS-DEM	pok.27.3a46	27.4.a	OTC >=120	Pollachius virens	Length	1220	1220	3029	46.6	46.6	62.2	
GBS	REG-WNS-DEM	ple.27.420	27.4.a	OTC >=120	Pleuronectes platessa	length	1221	1221	3314	48.4	48.4	67.1	

GBS	REG-WNS-DEM	sol.27.4	27.4.a	OTC >=120	Solea solea	length	3	3	3	0.1	0.1	0.1	
GBS	REG-WNS-DEM	wit.27.3a47d	27.4.a	OTC >=120	Glyptocephalus cynoglossus	length	926	926	2354	34.4	34.4	46.0	
GBS	REG-WNS-DEM	cod.27.47d20	27.4.a	OTC >=120	Gadus morhua	Age	1386	1386	3723	55.8	55.8	78.3	
GBS	REG-WNS-DEM	had.27.46a20	27.4.a	OTC >=120	Melanogrammus aeglefinus	Age	1402	1402	3982	57.2	57.2	83.4	
GBS	REG-WNS-DEM	whg.27.47d	27.4.a	OTC >=120	Merlangius merlangus	Age	1308	1308	3576	52.6	52.6	74.7	
GBS	REG-WNS-DEM	pok.27.3a46	27.4.a	OTC >=120	Pollachius virens	Age	1220	1220	3029	46.6	46.6	62.2	
GBS	REG-WNS-DEM	ple.27.420	27.4.a	OTC >=120	Pleuronectes platessa	Age	1221	1221	3314	48.4	48.4	67.1	
GBS	REG-WNS-DEM	wit.27.3a47d	27.4.a	OTC >=120	Glyptocephalus cynoglossus	Age	926	926	2354	34.4	34.4	46.0	

Annex 3.2

Annex 3.2.1 Data Sharing Agreement

DATA SHARING AGREEMENT

"Strengthening regional cooperation in the area of fisheries data collection – Biological data collection in EU waters - the North Sea , Eastern Arctic and north atlantic

MARE/2016/22

DATA SHARING AGREEMENT

This Data Sharing Agreement (hereinafter referred to as “the Agreement”) is dated ………………………………………………………………………, hereinafter referred to as “the Effective Date”

AMONG:

1. **THE UNIVERSITY COURT OF THE UNIVERSITY OF ST ANDREWS**, a charitable body registered in Scotland under the registration number SC013532 and incorporated by the Universities (Scotland) Act 1889, as amended by the Universities (Scotland) Act 1966, and having its principal office at College Gate, North Street, St Andrews, Fife KY16 9AJ the ‘Lead Partner’

2. **THE SCOTTISH MINISTERS ACTING THROUGH MARINE SCOTLAND**, Science, Marine Laboratory, 375 Victoria Road, Aberdeen, Scotland, AB11 9DB

3. **THE SECRETARY OF STATE FOR ENVIRONMENT FOOD AND RURAL AFFAIRS** acting through the Centre for Environment, Fisheries and Aquaculture Science (Cefas) Headquarters (Cefas) – Pakefield Road, Lowestoft Suffolk NR33 0HT, UK. Cefas is an Executive Agency of the UK Government Department – Defra

4. **INSTITUT FRANCAIS DE RECHERCHE POUR L’EXPLOITATION DE LA MER**, a public institute of industrial and commercial nature (VAT number FR46 330 715 368) 155, rue J. J. Rousseau, 92138 Issy Les Moulineaux Cedex, France

5. **JOHANN HEINRICH VON THÜNEN-INSTITUTE, FEDERAL RESEARCH INSTITUTE OF RURAL AREAS, FORESTRY AND FISHERIES**, Bundesallee 50, 38116 Braunschweig, Germany

6. **TECHNICAL UNIVERSITY OF DENMARK** Anker Engelunds Vej 1, Bygning 101A, 2800 Kgs. Lyngby, Denmark.

7. **SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES**, Turistgatan 5, Lysekil, Sweden, SE-453 30

8. **WAGENINGEN MARINE RESEARCH,** Haringkade 1 1976 CP Ijmuiden, The Netherlands, An Institute Within The Legal Entity Stichting Wageningen Research,, A Foundation (Stichting) Incorporated Under The Laws Of The Netherlands, With Registered Office At Wageningen, The Netherlands

9. **INSTITUTE FOR AGRICULTURAL AND FISHERIES RESEARCH**, a Flemish Scientific Institute to the Policy Domain "Agriculture and Fisheries" of the Flemish Government, Burg. van Gansberghelaan 92, Merelbeke, Belgium, 9820

10. **INSTITUTO PORTUGUÊS DO MAR E DA ATMOSFERA, INSTITUTO PUBLICO** (IPMA, I.P.), Rua C ao Aeroporto, 1749-077 Lisboa, Portugal com o registo PT510 265 600.

11. **INSTITUTO ESPAÑOL DE OCEANOGRAFÍA** (IEO), a public research body, located at C/ Corazón De María 8, 28002, Madrid, Spain, with VAT number ESQ2823001I

12. **FUNDACION AZTI**, a non-profit private foundation, Txatxarramendi ugartea, Z/G, Sukarrieta, Bizkaia, Spain, 48395

13. **AGRI-FOOD & BIOSCIENCES INSTITUTE,** 18a Newforge Lane, Belfast, Co Antrim, BT9 5PX Northern Ireland, UK

14. **MARINE INSTITUTE,** a public research body located at Rinville, Oranmore, Co. Galway H91 R673, Ireland

hereinafter, jointly or individually, referred to as **"Parties"** or "**Party**"

Relating to the Action entitled **"Strengthening regional cooperation in the area of fisheries data collection - Biological data collection in EU waters: the North Sea, Eastern Arctic and North Atlantic"** in short "FishPi2"and hereinafter referred to as "**Project**"

WHEREAS:

(A) The Parties have all entered into the Consortium Agreement (as defined below) in relation to the Project.

(B) In order to carry out the Project, the Parties require to share the Data (as defined below).

(C) The Data (as defined below) is of a disaggregated and confidential nature and so the Parties wish to specify or supplement binding commitments among themselves in addition to the provisions of the specific Grant Agreement (as defined in the Consortium Agreement) and the Consortium Agreement (as defined below).

NOW, THEREFORE, IT IS HEREBY AGREED AS FOLLOWS:

Definitions

The following definitions will apply to this Agreement: -

"Consortium Agreement" means the consortium agreement set out in Part 3 of the Schedule;

“Data” means all data shared by the Parties under this Agreement as specified in Part 1 of the Schedule;

“Depersonalised Data” means information that relates to individuals where it is not possible to identify individuals from that information, whether in isolation or in conjunction with any other information;

“Non-Personal Data” means information that does not relate to people including information about organisations, resources, projects or information about people that has been aggregated to a level that is not about individuals;

“Security Policy” means the security policy as set out in Part 2 of the Schedule.

Any words or phrases with capitalised letters shall have the meaning ascribed to them in the Consortium Agreement or in this Agreement.

This Agreement is supplementary to the Consortium Agreement. In the event of a conflict in the application or interpretation of terms set out in this Agreement and the Consortium Agreement, the terms of the Consortium Agreement shall take precedence and all Parties to this Agreement must ensure they comply with the Consortium Agreement.

Data Sharing

The Parties agree to share the Data. .

The Parties undertake that they will only transfer Depersonalised Data and Non-Personal Data under this Agreement.

The Parties undertake that they will only use the Data in relation to the Project and for the purposes specified in Part 2 of the Schedule.

Security

The Parties agree to comply with the Security Policy and user access and use policy as set out in Part 2 of the Schedule later in this document.

Duration

This Agreement shall commence on the Effective Date and shall continue for the duration of the Project. The existence of this Agreement is subject always to the Consortium Agreement remaining in full force and effect. In the event that the Consortium Agreement terminates, this Agreement will automatically terminate.

Confidentiality

The Parties agree and acknowledge that the Data shared under this Agreement will be regarded as Confidential Information under the Consortium Agreement and the Confidentiality provisions in section 10 of the Consortium Agreement will apply.

Liability

Any breach of this Agreement by a Party shall be deemed to be a breach of the Consortium Agreement and the Parties’ liability to each other will be as set out in Section 5 of the Consortium Agreement and the Parties shall have all rights and remedies available to them under the Consortium Agreement in relation to the same.

Withdrawal of a Party

If any Party wishes to withdraw from this Agreement, they must follow the procedure set out in the Consortium Agreement.

Assumption of a new Party

If any new party requires to become party to this Agreement, the Lead Partner will, on behalf of the Parties to this Agreement, if directed to do so by the Project Management Committee, assume such new party as a Party to this Agreement by entering into an accession agreement which requires them to comply with the terms of this Agreement.

Execution in Counterpart

This Agreement may be signed in counterpart.

Miscellaneous

If any Party to this agreement is authorised under the Consortium Agreement to grant a third party access to the Data for the purpose of performing their obligations under the Consortium Agreement, that Party will ensure that any such third party complies with the terms of this Agreement. No other third parties should be granted access to the Data without the Project Management Committee's prior written agreement and subject always to them signing up to the terms of this Agreement in accordance with the terms of clause 8.1 or clause 10.8 as appropriate.

Should any provision of this Agreement become invalid, illegal or unenforceable, it shall not affect the validity of the remaining provisions of this Agreement. In such a case, the Parties concerned shall be entitled to request that a valid and practicable provision be negotiated which fulfils the purpose of the original provision.

Except as otherwise provided in Section 0 of this Agreement, no Party shall be entitled to act or to make legally binding declarations on behalf of any other Party or of the consortium. Nothing in this Agreement shall be deemed to constitute a joint venture, agency, partnership, interest grouping or any other kind of formal business grouping or entity between the Parties.

Any notice to be given under this Agreement shall be in writing to the addresses and recipients as listed in the most current address list kept by the Lead Partner.

If it is required in this Agreement that a formal notice, consent or approval shall be given, such notice shall be signed by an authorised representative of a Party and shall either be served personally or sent by mail with recorded delivery or telefax with receipt acknowledgement.

Other communication between the Parties may also be effected by other means such as e-mail with acknowledgement of receipt, which fulfils the conditions of written form.

Any change of persons or contact details shall be notified immediately by the respective Party to the Lead Partner. The address list shall be accessible to all concerned.

No rights or obligations of the Parties arising from this Agreement may be assigned or transferred, in whole or in part, to any third party without the other Parties' prior formal approval. Notwithstanding the foregoing, any Party that is authorised under this Agreement and/or the Consortium Agreement must ensure that the relevant subcontractor has sight of and is bound by this Agreement and the Consortium Agreement.

Amendments and modifications to the text of this Agreement, not explicitly listed in this Agreement, require a separate written agreement to be signed between all Parties.

Nothing in this Agreement shall be deemed to require a Party to breach any mandatory statutory law under which the Party is operating.

This Agreement is drawn up in English, which language shall govern all documents, notices, meetings, arbitral proceedings and processes relative thereto.

This Agreement shall be construed in accordance with and governed by the laws of Belgium excluding its conflict of law provisions.

The Parties shall endeavour to settle their disputes amicably.

Any dispute, controversy or claim arising under, out of or relating to this Agreement and any subsequent amendments of this Agreement, including, without limitation, its formation, validity, binding effect, interpretation, performance, breach or termination, as well as non-contractual claims, shall be submitted to mediation in accordance with the WIPO Mediation Rules. The place of mediation shall be Brussels unless otherwise agreed upon. The language to be used in the mediation shall be English unless otherwise agreed upon. If, and to the extent that, any such dispute, controversy or claim has not been settled pursuant to the mediation within 60 calendar days of the commencement of the mediation, the courts of Brussels shall have exclusive jurisdiction.

AS WITNESS: The Parties have caused this Agreement (consisting of this page and the preceding 6 pages and the Schedule in 3 parts annexed hereto) to be duly signed by the undersigned authorised representatives in separate signature pages the day and year first above written.

THE UNIVERSITY COURT OF THE UNIVERSITY OF ST ANDREWS

Signature
Name

Title

Date

THE SCOTTISH MINISTERS ACTING THROUGH MARINE SCOTLAND science

Signature
Name

Title

Date

Institut Français de Recherche pour l'Exploitation de la Mer

Signature
Name -

Title

Date

Johann Heinrich von Thünen-Institute, Federal Research Institute of Rural Areas, Forestry and Fisheries

SIGNATURE(S)
NAME(S)
TITLE(S)

Date

Wageningen Marine Research, an institute within the legal entity Stichting Wageningen Research

SIGNATURE(S)

NAME(S)

TITLE(S)

DATE

Instituto Português do Mar e da Atmosfera, Instituto Publico

Signature(s)

Name(s)

Title(s)

Date

The Secretary of State for Environment Food and Rural Affairs

Signature

Name

Title

Date

Technical University of Denmark

Signature
Name

Title

Date

Swedish University of Agricultural Sciences

Signature
Name

Title

Date

Institute for Agricultural and Fisheries Research, BELGIUM

Signature
Name

Title

Date

Fundacion AZTI

Signature
Name

Title

Date

INSTITUTO ESPAÑOL DE OCEANOGRAFÍA

Signature
Name

Title

Date

Agri-Food & Biosciences Institute, Belfast

Signature
Name

Title

Date

OFFICE OF MARINE RESEARCH AND DEVELOPMENT, Galway, Ireland

Signature
Name –

Title -

Date

This is the Schedule referred to in the foregoing Data Sharing Agreement entered into by the University Court of the University of St Andrews in relation to the Project entitled "Strengthening regional cooperation in the area of fisheries data collection - Biological data collection in EU waters: the North Sea, Eastern Arctic and North Atlantic"

PART 1

THE DATA

The data required to design the sampling scheme under the Consortium Agreement are highly disaggregated and confidential.

In preparing the project proposal, all project participants have in principle agreed to provide access (where possible) to trip-level log-book, sales note data and sampling data with the caveat that these data will be anonymised, shared and used among project participants for the purpose of sampling design within the time scale of the project.

For the avoidance of doubt, these Data will not be available for dissemination after completion of the project.

Data provided will be in the form of one or more of the following:

Anonymised trip-level landings information

Anonymised trip-level sales information

Anonymised catch sampling data

Anonymised PETS sampling data

RV data on stomach sampling

Small scale fisheries

fleet summaries (no of vessels in fleet register)

anonymised landings information (e.g monthly declarative forms) where available

anonymised sales information

Recreational fisheries

meta-data on recreational fisheries

The security, access and use of any Data supplied will be as set out in this agreement and more specifically described in Part 2 of the Schedule to this Agreement.

PART 2 - THE SECURITY POLICY AND ACCESS TO AND USE OF DATA

The Parties agree and undertake that they will comply with the terms of this Security Policy and the following terms setting out use of and access to the Data.

Use of the Data

The Data can only be used for the purposes of the Project

The Data can only be used during the duration of the Project.

Any publication of data or analysis derived from Data must be authorised by the Project Management Committee (as defined in the Consortium Agreement) and under such authorship as determined by the Project Management Committee.

The Parties agree that all publications will be anonymous in order to protect the source of the Data.

The Data should be used for research and analysis purposes in accordance with the Consortium Agreement and for no other purposes. The raw Data in the form provided by the Parties as per Part 1 of the Schedule should not be published in its raw state.

All Data contributed by another Party will be deleted from SharePoint and shall not be accessed or used by a Party following expiry or termination of the Consortium Agreement.

<u>How the Data will be held/accessed?</u>

The Parties shall upload the Data onto SharePoint under the direction of the Project Management Committee. Each Party will be provided with secure passwords and credentials to allow them to access the Data. The Parties each undertake that they will keep their passwords and credentials secure and that only project members approved by the Project Management Committee that require to access the Data in order to carry out the Project will be granted access to the data. Downloads should be kept securely and in accordance with clause 10 of the Consortium Agreement.

Security Breaches

If any Party:

becomes aware of any unauthorised or unlawful processing of any Data or that any Data is lost or destroyed or has become damaged, corrupted or unusable;

becomes aware of any breach of this Security Policy; or

learns or suspects that any unauthorised third parties have obtained any Data,

that Party shall, at its own expense, promptly notify the Project Management Committee and fully co-operate with it to remedy the issue as soon as reasonably practicable.

The Parties agree to co-operate with the Project Management Committee's reasonable security investigations.

PART 3 – Consortium agreement – please see attached

Annex 3.2.2 WP3 landings data call

fishPi[2] data request

Part 1 Scope

Please provide all the trips in **ICES Divisions 3a, 4, 6, 7, 8 and 9** from *any* of your flag vessels vessels with *any* fishing in these areas. For these trips please provide data on the landed species, by weight. Data are requested for the years **2015** and **2016**.

Part 2 Format

Data should be provided as an R workspace containing two data frames

The R workspace should follow the naming convention CTY_VX_DD_MM.rData where CTY is country, X is the version number, DD_MM is the date and month of the data submission. e.g. NLD_V1_22_02.rda. This will allow for version control in the compilation of the regional data set; hopefully each dataset will only need to be submitted once.

Please assign the data frame within this workspace the name CTY_VX_2015 and CTY_VX_2016, where x is the version number. No other R objects should be within the workspace.

The data frames consists of 14 columns, the first 6 of these columns will be identical and repeated for all trips. From column 9 onwards a new row should be started for each landed fish species recorded on the trip. In the cases where a single trip is deemed to have multiple landings rows 7-9 will record the data and location of those multiple landings (see note 7).

Field	Variable name	Description	Format	Code list or example
1	vslFlgCtry	Vessel Flag Country Country code based on ISO 3166 – 1 alpha-3 code.	Character string of length 3.	Fixed code list consisting of: BEL, DEU, DNK, ENG, ESP, FRA, IRL, NIR, NLD, PRT, SCT, SWE, WLS, GBI, GBC.
2	vslId	Vessel Identifier Unique anonymous vessel identifier.	Character string of length 8. The first 3 characters will be the 3 letter flag country code, the following 5 will be a numeric string with leading zeros.	Examples: SCT01234, NLD00012 DEU00421
3	vslLenCls	Vessel Length Class Vessel length class overall (m) DCF LOA classes	Character string of length 6.	Fixed code list consisting of: VL0010 VL1012 VL1218 VL1824 VL2440 VL40XX
4	fishTripId	Fishing trip Identifier. Unique anonymous fishing trip identifier	Character string of length 14. The first 3 characters will be the 3 letter flag country code, the following 4 will be the year, the last 7 a numeric string with leading zeros.	Examples: SCT20150000001, PRT20160002474 FRA20150056632
5	depDate	Departure date Departure date of the fishing trip	YYYY-MM-DD Character string of length 10. Year, month, day numerics separated by hyphens.	Finite code list; Examples: 2015-12-05 2016-02-12
6	depLoc	Departure location Departure location of the fishing trip	Departure Location LOCODE Character string of length 5 the first 2 letters of which correspond to the country, the remaining 3 the unique location code.	Fixed code list; Examples: NLIJM DKTHN IEKBS
7	landDate	Landing date Landing date of the fishing trip	YYYY-MM-DD Character string of length 10. Year, month, day numerics separated by hyphens.	Finite code list; Examples: 2015-12-05 2016-02-12
8	landLoc	Landing Location	Landing Location LOCODE Character string of length 5 the first 2 letters of which correspond to the country, the	Fixed code list; Examples: NLIJM DKTHN IEKBS

			remaining 3 the unique location code.	
9	rect	ICES statistical rectangle recorded for the species landing	Character string of length 4	Fixed code list; Examples 36E5 09E1
10	area	FAO area codes Corresponding to highest possible resolution ICES sub-area, area, division.	Character string	Fixed code list; Examples 27.4.a 27.8.c
11	foCatEu6	Metier level 6	Character string with gear, target, mesh and selection device components, underscore separated.	Fixed code list; Examples OTB_DEF_>=120_0_0 GNS_SPF_120-219_0_0
12	sppCode	Species code The species codes of all the recorded landings from the trip.	WoRMS Aphia ID Character string of length 6 or shorter, of numeric values.	Fixed code list; Examples 127419 126436 11723
13	sppName	Species name	Accepted WoRMS name corresponding to the Aphia ID	Fixed code list; Examples Capros aper Gadus morhua Sepiidae
14	landWt	Landed Weight The live weight equivalent in KG for each recorded species	Numeric	

Notes

1. Each Institute/Member state is expected to provide the data relating to the operations of their flag vessels, including landings into own country and the landings into all other countries, including non EU member states. Do not include data from flag vessels belonging to other flag countries.

2. Use the same vessel Identifier for all trips of the vessel, and across both years. If multiple institutes are providing data for a single MS please ensure that vessels are not duplicated. (Numbers of vessels by Flag Country to be checked with EU vessel register)

4. Only one vessel is expected to be recorded for a fishing trip (to be checked). If multiple institutes are providing data for a single MS please ensure that fishing trips are not duplicated.

5. Include all fishing trips with departure dates from 2015-01-01 to 2016-31-12, i.e. some landing dates may be after 2016-31-12

6. Departure location, record all departure locations regardless of country, for the flag fleet vessels.

7. Include all fishing trips with landing dates from 2015-01-01 to 2016-31-12, i.e. some departure dates may be before 2015-01-01. A fishing trip should only have one landing date. However if a trip is considered to have multiple landings the date, location, species and landing weights for those landings is expected to be different and each landing should be provided. If landings differ only by date (not location), treat as a single trip with the later landing date. No new fishing operations should have occurred between multiple landings, if they have treat as separate fishing trips.

8. Landing location, this should be the landing location of the trip, not the sales location. Record all landing locations, both own ports and foreign ports.

9. Statistical rectangle should be in the accepted ICES code list. This should relate to the species recorded in column 12.

10. FAO area should be in the accepted FAO code list. The area should be consistent with the specified statistical rectangle.

11. More than one metier can be specified per fishing trip if this is considered appropriate. If so any unique species, rectangle, landing date, landing location combination should have the same metier. Landed weights should not be duplicated across metier on a single trip.

12. Species code should be an accepted WoRMS code. http://www.marinespecies.org/

13. Species name should be the exact spelling of the accepted WoRMS taxonomic name that corresponds to the specified WoRMS code specified.

14. Landed weight in kg., as live weight equivalents. These should be greater than zero and Individual trips should not have more than one weight for any species, rectangle, landing date, landing location combination. Landing weights by species and area should sum to expected national totals (to be checked).

Annex 3.2.3 WP3 biological data call

Email to participants

As part of the *fishPi*^{2} project we request biological sample data from your institute, length frequency data from on-shore or at-sea sampling of commercial catches. The rationale, scope and format of the requested data are set out in the following document.

Data are requested for the years **2015** and **2016** and will be used for the biological simulations in WP3.

The deadline for the provision of these data is the **15. of August 2018**.

Data are to be uploaded to the *fishPi*^{2} SharePoint to the following folder by the individual designated by the national institution, and accepted by the *fishPi*^{2} PMC.

All data supplied will be used and stored according to the terms of the data sharing agreement.

Many Thanks

The WP3 team members

Any questions, please contact Kirsten Birch Håkansson (kih@aqua.dtu.dk), Jose Rodriguez rodriguez@ieo.es

Attached document

Rationale

The data will be used for the biological simulation in WP3.

Scope

Please provide length frequency data raised to trip level for the following species and areas;
North Sea case study;
Areas: 27.3.a, 27.3.a.20, 27.3.a.21, 27.4.a, 27.4.b, 27.4.c, 27.7.d
Species: Cod *Gadus morhua;* Grey Gurnard *Eutrigla gurnardus;* European plaice *Pleuronectes platessa*.
Iberian case study;
Areas: 27.8.c, 27.9.a
Species: Hake *Merluccius merluccius*; Blue whiting *Micromesistius poutassou*; Atlantic mackerel *Scomber scombrus*; Atlantic chub mackerel *Scomber colias*.

Only include samples where you have length measurements from all size categories so that the raised length frequency is representative of the fishing trip. The length frequency can be for catch category; Landings, Discard or BMS.

Please provide as many raised length frequencies as possible for the requested species.

Format

Data should be provided as an R workspace containing two data frames

The R workspace should follow the naming convention CTY_BIO_VX_DD_MM.rData where CTY is country, X is the version number, DD_MM is the date and month of the data submission. e.g. NLD_BIO_V1_22_02.rda. This will allow for version control in the compilation of the regional data set; hopefully each dataset will only need to be submitted once.
Please assign the data frame within this workspace the name CTY_BIO_VX_2015 and CTY_BIO_VX_2016, where x is the version number. No other R objects should be within the workspace.

Field	Variable name	Description	Format	Code list or example
1	**sampFishTripId**	Unique Fishing trip Identifier.	Character string of length 14. The first 3 characters will be the 3 letter flag country code, the following 4 will be the year, the last 4 a numeric string with leading zeros.	Examples: SCT20150001, PRT20162474 FRA20156632 Not required to match the id in the logbook data
2	**sampType**	Sampling type	Character string	Code list; at-sea, on-shore
3	**vslFlgCtry**	Vessel Flag Country Country code based on ISO 3166−1 alpha-3 code.	Character string of length 3.	Fixed code list consisting of: BEL, DEU, DNK, ENG, ESP, FRA, IRL, NIR, NLD, PRT, SCT, SWE, WLS, GBI, GBC.
4	**sampDate**	Unique sampling date per trip. A unique date for the trip - for at-sea the landing or departure date – for on-shore the sampling or landing date. Use the same method nationally used when populating the RDB CS trip table.	YYYY-MM-DD Character string of length 10. Year, month, day numeric separated by hyphens.	Finite code list; Examples: 2015-12-05, 2016-02-12
5	**loc**	Unique location par trip. A unique location for the trip - for at-sea the landing or departure location – for on-shore the sampling or landing location.	Location LOCODE Character string of length 5 the first 2 letters of which correspond to the country, the remaining 3 the unique location code.	Fixed code list; Examples: NLIJM, DKTHN, IEKBS

		Use the same method nationally used when populating the “harbour” field in the RDB CS trip table.		
6	**vslLenCls**	Vessel Length Class Vessel length class overall (m) DCF LOA classes	Character string of length 6.	Fixed code list consisting of: VL0010, VL1012, VL1218, VL1824, VL2440, VL40XX
7	**area**	FAO area codes Corresponding to highest possible resolution ICES sub-area, area, division.	Character string	Fixed code list; Examples 27.4.a, 27.8.c, 27.3.a.20
8	**foCatEu6**	Metier level 6	Character string with gear, target, mesh and selection device components, underscore separated.	Fixed code list; Examples OTB_DEF_>=120_0_0, GNS_SPF_120-219_0_0
9	**sppCode**	Species code - WoRMS Aphia ID The species codes of all the recorded landings from the trip.	Character string of length 6 or shorter, of numeric values.	Fixed code list; Examples 127419, 126436, 11723
10	**sppName**	Species name – scientific name. Accepted WoRMS name corresponding to the Aphia ID	Character string	Fixed code list; Examples Capros aper, Gadus morhua, Sepiidae
11	**catchCat**	Catch category. Landing (LAN) or Discard (DIS) or BMS (if any are available)	Character string of length 3.	Fixed code list consisting of: DIS, LAN, BMS
12	**catchWt**	The estimated weight of the combined fish in the raised length frequency, whole weight in kg. This is the weight per fishing trip, so will be repeated per length class.	Numeric	
13	**lenCls**	Whole length in mm	Integer	
14	**estNum**	Estimated number of fish per length and fishing trip	Numeric	May be decimal as result of having raised samples to trip level

		and the above stratification		
15	**sampNum**	Sum of sampled number of fish per length and the above stratification	Integer	

Annex 3.3 Principles in the implementation of sampling designs

Introduction

Outlined below are the guiding principles underlying a probability based regional sampling design for the collection of fisheries data, involving both on-shore or at-sea sampling programmes. These principles are based on the standard survey methodologies needed to make inferences about a population from a sample of the elements of that population. The implementation of such a design is set out as a series of steps, and it is assumed that in many regional designs that individual countries, or scientific institutions, are likely to be operating as strata within a regional design. It is appreciated that in fisheries data collection there are many challenges to the practical implementation of these statistical principles in the field, but as in any implementation every effort should be made to ensure that the sampling protocol is as close to an unbiased probabilistic design as possible.

Useful texts on sampling include Cochran (1977), Jessen (1978), Kish (1965), Lohr (2010), Thompson (2012), Särndal et al (1992). Moser and Kalton (1992) provide a non-technical appraisal of survey sampling in a social context, which in many ways is highly applicable to the situation found in fisheries sampling. Eurostat (2008) have produced Survey Sampling Reference Guidelines and the European Statistical System Quality Assurance Framework (2015) provides the context in which many European regional fisheries data collection designs are likely to be operating. Additionally the Global Adult Tobacco Survey (GATS) manuals provide a good example of the widespread implementation of a sampling design across diverse sampling strata, where the implementation is by autonomous institutions but the sampling practices are harmonised to common data collection and estimation principles. The work of ICES expert groups specifically related to sampling design can be found in ICES reports WKPRECISE (2009), WKMERGE (2010), WKPICS 1 (2011), WKPICS 2 (2012), WKPICS 3 (2013) and for at-sea sampling SGPIDS 1 (2011), SGPIDS 2 (2012), SGPIDS 3 (2013), and the ongoing work of WGCATCH (2014, 2015). Lumley (2010) demonstrates the use of the "survey" package in the R statistical language for estimation from complex survey designs.

Principal steps in the implementation of a sampling design

The Spatial, Temporal and Biological Scope of the Population

From the end users perspective, the population of interest is the set of individuals about which inference is desired. For example, it might be the catch of species of demersal fish in the North Sea. Hence, in this context, the population will be all of the individuals caught and either landed or discarded by fishing vessels. For this population, one or more characteristics such as the age, length, weight, maturity, are required to be estimated.

The study population are those elements of the population which are accessible or otherwise potentially available to be sampled. For example, while the population of interest may be all fish caught by national flag vessels, the study population may be subtly different being fish of the EU national flag fleets landed into ports in EU countries. The landings into non EU countries may be unavailable for sampling. In this case, the inferences can only be made about the sub-population of fish landed in the EU ports unless some assumptions are made about the fish landed in non-EU ports.

From the sampler's perspective, the statistical population is the set of elements on which measurements are made. For example, if information on the age structure of a stock is desired, then the element is the age of an individual fish. If total weight landed for a species is desired the element might be a box of sorted fish brought into port by a vessel.
These different facets of the population are important for identifying the accessible and available elements about which information is desired and obtainable.

Information Requirements
Determine exactly the purpose of the data collection. Is it to provide the age structure of the catch? Discard weight estimates? Species composition data? Estimates of the bycatch of marine mammals? The end users of the information that can be obtained from a sampling design are critical at this stage. Their input and requirements inform the overall design. For example, are estimates by gear type or country important (e.g. estimates of total catch associated with a particular métier)? Is the variability over the year important? In addition to the need for estimates of the desired population metrics, a statement about the achievable or desired precision of those estimates is also needed. The latter should be clearly related to a realistic assessment of the resources (person time) and finances available, and is likely to require discussion with the end-user. Schemes that are designed to address clearly defined requirements within clear budgets are far more likely to provide good estimates than schemes whose aims are poorly defined and inadequately funded.

The Sampling Frame
The sampling frame is the list of all elements that completely encompass the accessible component of the population. It is through this sampling frame that we gain access to the population and the list that is used when probabilistically selecting which elements in the population to sample. In most instances involving catch sampling over the course of a year (both at-sea and on-shore) a precise sampling frame does not exist a priori; the actual dates and locations of the landings by individual vessels, and the number and activity of vessels operating at-sea over the coming year is not known before they occur. For practical purposes however the sampling frames can be based on last year's logbooks and sales note data, and vessel registers, with an expectation that the temporal pattern of fishing activities for the coming year will be broadly similar to that of the preceding year. Depending on the sampling scheme different sampling frames will be used to encompass different fractions of the population; on-shore sampling frames are typically lists of ports, markets and processors where landings can be accessed, at-sea sampling frames are lists of vessels where the whole catch can be accessed. As much associated information as is possible can be obtained about the sampling elements in order to inform the stratification, likely clustering, multistage sampling, and similar needed to effectively obtain access to the ultimate sampling elements. This provides important information too about the suitability as sampling locations.

A sampling frame for small scale or recreational fisheries may not readily exist and will often have to be compiled from expert knowledge, or through the utilisation of publically available contact information available, e.g. general household surveys, angling club membership records, lists of holiday lodges, phone records, electoral registers etc.

The sampling frame was described above as that part of the population that is accessible and which can be listed for possible selection in a sample. Even when a sampling unit is identifiable it might not be “sample-able”. For example, for on-shore sampling some ports might consign all landings directly to a market and so there is no opportunity for sampling; some processors may simply not allow access. For at-sea sampling some vessels will be unsuitable for carrying observers. These elements need to be retained in the sampling frame but will not be part of the sampling design and any data manipulations should include recognition of the effect of their exclusion from sampling.

Sampling Design

The most common and cost-effective sampling design for catch sampling is a multi-stage stratified random sampling design. Here the population is first divided into non-overlapping subgroups, called strata. Within each stratum, a multi-stage design is usually implemented as this approach recognizes and uses the nested structure of the elements that compose the population.

Stratification

Most fisheries sampling designs will be stratified. This involves splitting the entire sampling frame into a number of non-overlapping groups, the sampling elements of which constitute a unique subset of the sampling frame. Hence every sampling element should be included in a sampling stratum, and no sampling element should be listed in more than one stratum. It is important that the sampling stratum to which a sampling element belongs is clearly and unambiguously recognisable at the time of sampling.

The sampling strata can be used to group the more homogeneous elements together, as a means of increasing the precision of a final estimate (the “stratification principle” (Cochran, 1977)). Quite commonly however in fisheries sampling stratification is used as a means of meeting logistical demands of the implementation of the sampling design. These two purposes may or may not align. For example, if stratification is based on geographic regions, such as might occur if a single sampler is allocated to a set of spatially contiguous ports, this may meet the requirements for logistical efficiency but may or may not group ports with similar characteristics. Care should be taken to consider whether logistical stratification is actually necessary, and the effect it has on the estimates should be checked, for example by using simulation studies to compare different sampling designs.

The use of sampling strata enables sampling effort to be directed disproportionately between different strata, but each sampling unit within a stratum should, with a random selection design, have the same chance of being selected.

It should be noted that when stratifying in order to associate like elements with like within each stratum, there should be relatively few strata within a population. If too many strata are identified and the total available sample size is limited, then each stratum may have so few samples that the standard error of the stratum-level estimates are so large as to completely negate the advantage of stratifying elements into homogeneous groupings. When stratifying for logistical purposes, the number of strata is determined by the optimal allocation of resources in order to ensure good coverage of the population. The perceived benefits of this kind of stratification should be carefully assessed. Of course there is still the need to ensure that the number of strata is not so large as to reduce the sample sizes in each stratum to levels that would not allow precise estimation of the quantities of interest.

Multistage cluster sampling

For most if not all fisheries survey sampling multistage hierarchical cluster sampling will be involved in the selection of the actual fish or shellfish to measure. Cluster sampling is where the elements in the population are presented in distinct groups, such as vessels at a port, or fish within a basket, and a number of these can be sampled at the same time. In fisheries it is generally the case that the elements in these clusters are more similar to each other, than to sampling elements in the population as a whole. Multi-stage sampling is where there is a nesting of clusters in a hierarchical fashion, so that each level in the nested hierarchy has to be sampled in a sequential order, e.g. hauls within a trip, baskets from a haul, fish within a basket. The hierarchy and the clustering is often the result of the working practices of the industry and is thus determined by the exact situations encountered at the time of sampling.

Sampling hierarchy

The primary sampling units (PSU's) are first level of nesting at which sampling elements are available to be selected. In the case of fisheries sampling, the elements in the sampling frame are selected over a period of time hence the PSU commonly will be the combination of a sampling element, say port, and the time interval during when it is selected. It is important to have a clear understanding of what the PSU is for each sampling scheme. For on-shore sampling it will generally be a location (port market or processor) and a day. For at-sea sampling it will be vessel and fishing trip or a trip with a particular start-date, depending exactly on how sampling units are defined and selected.

Once the PSU is identified, the next step in the process is identifying sub-elements to be selected for sampling within the PSU. For example the multistage hierarchical cluster sampling for on-shore markets on a particular day (the PSU in this example) may involve selecting one or more vessels landing at the market. These would be the secondary sampling units (SSU's). Then, having selected a vessel, one or more boxes within the landings of a species (the tertiary sampling unit (TSU)), and finally sampling individual fish within a selected box. For at-sea sampling on a specific fishing trip, the hierarchical cluster sampling may involve sampling: hauls within a selected trip, baskets within selected hauls, finally individual fish within the selected baskets.

Sampling Effort

Having potentially identified the sampling design to be employed (identification of strata, identification of sampling units and the hierarchical structure of sampling units), the next step is to determine the amount of sampling that can be performed. This requires working out the allocation of visits to sampling locations by sampling teams over time (seasonally or annually) depending on the temporal nature of the fishing activity at the port or market (PSU). This requires that development of the sampling design and assessment of the amount of sampling to be performed is an iterative process. The sampling design is dependent on the resources available, for example in the first instance the person hours available for sampling, to ensure that what is planned can be achieved. A typical on-shore sampling design will specify the number of visits to specified sampling sites (ports, markets and/or processors) over a specified number of weeks. For at-sea sampling the design will specify the number of trips to be undertaken over a year.

Once the amount of sampling that can be done at the first stage is done, the number of secondary, tertiary, etc., units that can be sampled is based on similar considerations, for example the amount of person-hours available for sampling, the amount of time required to fully sample the selected units, and the time-window available for sampling.

Selection Protocols

At all the stages of a sampling hierarchy from the PSU down to the individual fish a formalised selection procedure needs to be set up. Thus whenever the sampling team has to make a choice of which elements to sample a selection protocol exists to determine and record that decision. The sampling team should not be selecting which samples to measure based on subjective judgements. These protocols can include printed selection sheets with randomised number strings or electronic recording devices with random selection routines. If verifiable methods can be devised, these are preferable and offer better guarantee of correct implementation. Selection protocols should be based on random or systematic random sampling as this ensures that the samples selected are unbiased and representative of all the possible samples that are available. Probability based selection also underpins the mathematical theory on which the estimates and measures of variance are calculated, hence without probability selection there is no reliable measure of the variability of the estimates derived from the samples. That said, random sampling or systematic random sampling is not always an easy thing to achieve in the field, and the exact protocols adopted will depend on the specifics of the sampling situation. The protocols have to be workable, and suitable recording sheets need to be researched and tested in the field prior to implementation.

Non-response and Refusals

With formalised sampling protocols and a documented selection process in place then non–response rates can be recorded. Non-response encompasses all the instances where elements that were selected for sampling did not provide data. The non-response rate provides an estimate of the proportion of the population from which data is actually obtained, and so potentially allows estimates to be adjusted to reflect the whole population. The extent to which the non-responsive elements in the population differ from those for which data are collected can also be explored to ascertain whether the data collected are biased. The refusal rate is a particular subset of non-response that applies to sampling units that have been contacted and refused to allow data to be collected. In the fisheries context with at-sea sampling the refusal rate provides a useful measure of the level of access observers have to the vessels of a fleet. In the on-shore context it can for example reflect the accessibility of fish on a market. Collecting non-response data is both informative as to the quality of the estimates and facilitates the improvements that can be made to the operation of sampling schemes.

Inclusion Probabilities and Sample Weights

Each of the stages in this multistage hierarchy will generate an inclusion probability, the probability of being included in the sample, which at its simplest is the ratio of the n elements selected from the total N available. The inverse of the combined inclusion probabilities over all stages in the sampling hierarchy generates the sample weight. The sample weight can be usefully considered to represent the total number of individuals in the particular population being sampled that the measured sample represents and, in order to derive unbiased estimates, the sampling weight must be correctly calculated. The correct sample weight is thus an integral part of the collected sample and reflects the circumstances under which the sample was collected.

Estimation

The generation of estimates of population parameters is the whole reason for survey sampling. Hence the estimation process to be used should be determined in association with the design of the survey so that the sampling design, selection protocols, and data to be collected can be set up accordingly. The most widely used and versatile design-based estimator for stratified probability based sampling is the Horvitz-Thompson estimator (Horvitz & Thompson, 1952). This estimator is applicable to many, if not all, of the design stages and protocols outlined here that are based on probability based selection of sampling units. Lumley (2010) outlines the use of the Horvitz-Thompson estimator in the “survey” package of the R statistical language.

Ratio Estimators

In situations where N is not known it can be possible to estimate the sampling probability using a ratio estimator based on an auxiliary variable that is related to the “size” of the population being sampled; historically weight has been commonly used in fisheries sampling. However, the choice of auxiliary variables is not always straightforward as their relationship with the variable being measured needs to be well understood. Inappropriate auxiliary variables can lead to biased estimates.

Data Recording and Storage

Much fisheries sampling data ends up being archived in electronic databases of one form or another, and the critical elements of this process are to ensure that all pertinent data can be stored in a readily assessable fashion, and that the data model underpinning the data base does not impose inappropriate restrictions on what data can be recorded, how it is stored, and how it is accessed. The basic principle of storing raw data as it was collected (and not derived data that has been calculated) should be adhered to. Another basic aim of all scientific sampling is to faithfully record the variability that exists in the sampled population so, while there are legitimate outlier and error trapping routines, these should not be so draconian as to violate that principle.

Optimization of Sampling Designs

Optimization of a sampling design has several aspects, including (1) maximizing the efficiency of the samplers available for taking the measurements, (2) maximizing the efficiency of the statistical estimates of the desired parameters, and (3) finally maximizing the usefulness of the information obtained from the sampling. The sampling designs for fisheries data collection have to be envisaged to run over the medium to long term in order to provide consistency of data collection and of the derived estimates. It needs to be remembered that it is difficult to optimise sampling schemes that seek to provide data to meet a wide range of potentially different data needs.

For (1), this may require structuring sampling to minimize travel among PSUs and setting temporal schedules for visiting PSUs such that samplers are working on a regular schedule. This is often accomplished by structuring geographical strata so that samplers are visiting ports on a regular schedule during the fishing seasons. Visits to sampling locations can be organised in a random or systematic random way across the time period, and will allow practical and sensible decisions to be made about the best use of sampling teams and the coverage of the fishing operations. This requires that the strata boundaries be set based on some measure of the “size” or diversity of the sampling strata. This may be the number of trips, the landed weight the number of species etc. The cost of the sampling may also be a consideration.

For (2), the variance of the estimates is related to choice of stratum boundaries and inversely related to the number of observations taken within each stratum. Adhering to the stratification principle will ensure lower variance of the estimates but in most instances this is not completely possible due to the requirements of the availability of samplers and the wide range of likely data needs. Hence, the number of samples taken within each stratum becomes more important as it is the main method by which variance can be reduced. The best way to accomplish lower variance is to allocate sampling effort in such a way that more effort is expended in the strata that are more variable (for example, ports/markets that are highly variable is the types and sizes of fish being landed). The best approach here is to review the results of prior years of sampling to identify those sampling design aspects and sample sizes that should be modified to increase efficiency.

Item (3) is more difficult to implement without expert knowledge of the study population(s) and end user input into the sampling design. Here the statistician designing the study must ensure that the data requirements of the end users is met or can be met with additional input from other areas. For example it may involve the collection of additional auxiliary information from the sampling elements that allows estimates to be generated for "domains of interest" from particular subsets of the realised sampling data.

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Annex 3.4 North Sea case study

Introduction

Estimates of catch weight and numbers at age or length for fisheries in the North Sea region are at present based on data collected under nationally devised sampling programmes by the different countries with fishing fleets operating in the North Sea region. The design of these national sampling programmes reflects the priorities, commitments, logistics and budgetary considerations that operate within the scientific institutes and national administrations of individual nations. In particular for the demersal species, which are predominantly caught in mixed fisheries operated by a number of different national fleets, such an approach to sampling design is likely to be far from optimal. Despite attempts at harmonisation of regional data collection, through such fora as the previous Regional Co-ordination Meetings (RCM's), the extent to which national sampling designs can be retrospectively coordinated and optimised is limited.

The rationale of a regional design is, from the outset, to provide the best statistical estimates, in terms of the bias and precision, of the catch of the fish species of the region. Here we explore the potential for a single regional (i.e. international) sampling design, designed from the outset to collect data from the different EU MS landing demersal species from the North Sea region. This exercise is based on the simulation of the on-shore sampling of individual fishing trips, and the species landed from those trips. In this way a number of alternative sampling designs, that differ in their stratification and effort allocation, can be compared using objective measures of performance. The feasibility of implementing a regional sampling design, and the implications for different nations are considered. The data set we use has been compiled from the logbook and sales note data provided by the EU MS with significant fisheries in the North Sea region.

Methods

The data

The data used for the simulations was based on collated logbook and sales note data provided by the countries involved in this project. Of these, 7 EU MS account for the majority of the landings from the wider North Sea (Belgium, Germany, Denmark, France, Netherlands, Sweden and United Kingdom (with data from England, Wales, and Scotland). These data collectively account for the majority of the demersal landings from the North Sea and North Atlantic area and include small quantities of landings into Spain, Norway, and Ireland. However, Norway also has substantial landings from the North Sea, and these are not accounted for in this study. The working data set used for on-shore sampling designs was refined according to area and vessel type and split by year; 2015 and 2016 data being available. The data call and a description of the dataset are included in Annex 3.2.2 Appendix 1 respectively.

Here we define a site by day combination as a unique landing location and the unique day of the year on which at least one voyage offloaded the landed fraction of its catch. We define a voyage (or trip) as a recorded landing by a fishing vessel into a landing location; obviously more than one voyage can land to a landing location on a particular day, and individual vessels make multiple voyages over the course of the year. For the individual voyages the species landed weight (in kg) was available for all the recorded landed species. Landing location was classified using UN/LOCODE five digit location codes. Species codes, landing location names, dates, vessel identification codes were standardised using the criteria and methods set out in the data call.

The initial data set comprised all fishing trips from ICES divisions 27.3.a, 27.4.a, 27.4.b, 27.4.c and 27.7.d. To create the study data set, only fishing trips in which demersal species (ISSCAAP[4] codes 31 – 34, but not including boar fish, blue whiting, sand eel and Norway pout) comprised the highest percentage by weight were included. This accounted for 94% of the landings of demersal species from the wider North Sea.

Simulations

All the sampling design simulations were based on two-stage sampling involving, firstly, the selection of the landing location (site or port) and date (day), (the primary sampling unit (PSU)), and secondly, the selection of voyages from each of the given locations and dates (the secondary sampling (SSU)). The data recorded from each of the selected voyages were the landed weight of all landed species, along with other pertinent details of the vessel and the voyage such as the métier, fishing location etc. This equates to a full concurrent sample, in the terminology of the DCF sampling regulations. For the purposes of the simulations, we use the landed weight as a proxy for the age distributions and length distributions that would in reality be collected. The rationale is that total numbers of fish in a trip is highly correlated with landed weight, however the validity of this assumption is one area where further analysis would be merited.

Several sampling scenarios have been simulated to explore the optimal approach to data collection at the regional level. The various scenarios explore increasing the efficiency of sampling by including stratification of landing locations, as well as altering the sampling effort applied, and also consideration of reduced frame coverage – i.e. not sampling all the ports where landings occur.

The stratification of ports was applied by consideration of the regional total landed weight or the regional total number of fishing trips. Ports comprising the top 90%, 95% or 99% of the total (by landed weight or by fishing trips, referred to herein as 'major' ports, were allocated to one stratum, whilst the remaining ports ('minor' ports) were allocated to the other

[4] The International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP) is a nomenclature developed by FAO to classify commercial species into 50 groups and 9 divisions on the basis of their taxonomic, ecological and economic characteristics. It has been developed for the collection of commodities statistics and consists in two numerical characters.

stratum. In most cases, these regional strata were then further split by nation, resulting in 15 strata across the wider North Sea. Stratification which also included area was also considered. Proportional effort allocation was applied to 'major' ports, while assigning a small fixed effort allocation to the remaining 'minor' ports. To consider the effect of reducing the sampling frame, zero effort was allocated to minor port strata. The effect of not sampling the landings of foreign vessels landing into national ports, and the effect of some nations not sampling were also explored.

The stratification and effort allocation was carried out based on 2015 data and simulations were then run using 2016 data, as would be the case in real life. Flexibility in the total effort allocated to the regional design was simulated using effort allocations of 100%, 80%, 60% and 40% of current effort.

Simple random sampling (SRS) of the dataset was used to assess the design effect of any scenario in terms of bias and variance. The random simulations are denoted by the prefix 'R', the various scenarios by the prefix 'S', and the current sampling scheme by 'C'. Each simulated scenario was run many times, with summary statistics calculated. Summary statistics were also calculated for fish species of interest (FOI) and countries of interest (COI). Domains were defined in terms of metier, division and country combinations. The number of simulations to run was determined by plotting summary statistics against number of simulations, to determine when summary statistics were not greatly affected by variability due to the random selection of samples.

Fish of interest were defined as a combination of the top 15 fish species by landed weight combined with all Working Group species, resulting in a list of 20 species: Plaice (PLE), Saithe (POK), Cod (COD), Haddock (HAD), Sole (SOL), Whiting (WHG), Norway Pout (NOP), Hake (HKE), Monkfish spp. (ANF), Turbot (TUR), Tub Gurnard (GUU), Dab (DAB), Surmullet (MUR), Lemon Sole (LEM), Ling (LIN), Brill (BLL), Flounder (FLE), Gunard (GUG), Pollack (POL), Whiting (WIT).

Countries of interest were Belgium, Germany, Denmark, France, England, Scotland, Netherlands and Sweden. For the purposes of this study, all Welsh (GBW) ports were classed as English (GBE).

Estimation & comparison metrics

For each design scenario, each simulation was used to generate estimates of the total landed weights for all species, and by species and by country. The estimator used was the Horvitz-Thompson estimator (Horvitz & Thompson, 1952), applied here using the R package "survey" (Lumley 2014) with the svyDesign function being used to specify the design, the svyTotal function being used to provided estimates of the total landed weight, and the svyBy function being used to generate estimates by species and country domains. For each scenario, estimates were generated for the 1) total landed weight of all species, 2) the total landed weight of each of the species in the data set and, 3) the total landed weight by landing country. The true values of each of these parameters were known from the complete data set.

The percentage deviation of the total landed weight estimates from the true total was calculated as the mean of the estimates for each scenario minus the true total, divided by the true total. The relative standard error RSE (the standard deviation of the estimate divided by the estimate) provided a scaled measure of the precision of an estimate. The mean RSE was calculated for the species of interest to give an indication of the precision possible on average for these species, and a mean RSE was calculated for the landed total of all species by country to give an indication of the precision possible on average by landing country. The design effect, D_{eff}, is the variance of the estimator for a design relative to the variance achieved for a random sample. The design effect for total landed weight was calculated, and also a mean design effect for the fish of interest, using the mean variances of the separate estimate by species. The effective sample size provides an intuitive measure of the merits of a design by scaling the actual sample size of a random sample by the design effect.

$$Design\ effect\ (D_{eff}) = \frac{s^2_{design}}{s^2_{srs}}$$

$$Effective\ sample\ size = \frac{n}{D_{eff}}$$

Designs were therefore assessed on 1) their overall deviation in the estimate of the population total, 2) the RSE for the total landed weight, 3) their RSE over species, 4) their RSE over countries, 5) Design effect, 6) Effective sample size. In addition, sample sizes by domain, species and country were considered. Collectively these measures were used to ascertain which sampling design proved the most effective. The simple random scenario provided a basis on which to gauge the performance of the other designs. The code used for these simulations is available at:
https://github.com/ices-tools-dev/FishPi2/tree/master/WP3

Sampling effort and costs

Annual sampling effort in terms of port-days was requested from each participant institute. Institutes were requested to allocate this sampling effort to each area - 27.4, 27.3.a and 27.7.d as appropriate. In addition, the total cost of this sampling effort was also requested, from which a mean cost per port-day sampled could be estimated. This mean cost per port-day was used to estimate an indicative cost for each nation for each design, given the sampling effort allocated to each country, from which relative indicative costs for the regional sampling design could be calculated. For nations without on-shore sampling, the mean cost per port-day was calculated from the national costs per port-day.

Scenarios

The scenarios tested were as follows:

1. Simple random sampling (no stratification) (SRS)
   Simple random simulations were run with total effort allocations:
   - 711, 570, 430 and 285 PSU (100%, 80%, 60%, 40%, respectively).
2. Regional major/minor port stratification by total landed weight, split by nation
   Major ports were defined as those with the highest landing weights of demersal fish from the wider North Sea, with a cumulative percentage within the specified threshold (90%, 95% or 99%) of the regional landed weight. Minor ports are defined as those not included as major ports. The major and minor strata were then further stratified by nation. Effort was allocated to the major-nation strata proportional to the total number of site days in that stratum in 2015. A standard effort of 4 PSU per nation was allocated to the minor-nation strata.

   - 90 % (24 major ports, 318 minor ports)
   - 95 % (37 major ports, 305 minor ports)
   - 99 % (81 major ports, 261 minor ports)

3. Regional major/minor port stratification by total number of fishing trips, split by country
   Major ports were defined as those with the greatest number of fishing trips, with a cumulative percentage within the specified threshold (90%, 95% or 99%) of the total regional fishing trips. Minor ports are defined as those not included as major ports. Effort was allocated to the major-nation strata proportional to the total number of site days in that stratum in 2015. A standard effort of 4 PSU per nation was allocated to the minor-nation strata.

   - 90% (81 major ports, 261 minor ports)
   - 95% (114 major ports, 228 minor ports)
   - 99% (189 major ports, 153 minor ports)

4. Reduced frame coverage – no sampling of minor ports
   These scenarios removed sampling of minor ports by allocating zero effort to these strata. These scenarios were repeated for 95% major ports, defined by weight, and by trip.

5. Reduced frame coverage – no Belgian or German on-shore sampling
   This scenario removed sampling of Belgian and German ports, as these nations do not currently have on-shore sampling designs. This scenario was repeated for 95% major ports, defined by weight, with 60% of current sampling effort allocated by proportional allocation.

6. Reduced frame coverage – no sampling of foreign landings
   This scenario was repeated for 95% major ports, defined by weight, with 60% of current sampling effort allocated by proportional allocation.

7. Current sampling design
   The current sampling design was replicated by stratifying ports by nation, and then sampling only ports that are currently sampled for each nation. The current national allocation of effort was applied to each nation. In addition 60 % of the current sampling effort was applied to each nation.

   - 100 % current effort allocation (711 PSU)
   - 60 % current effort allocation (430 PSU)

8. Alternative stratification
   Two scenarios were tested:

   - No separation of port-type by nation. This scenario was repeated for 95% major ports, defined by weight, with 60% of current sampling effort allocated by proportional allocation.
   - No stratification by port-type, only by nation. This scenario was repeated for 95% major ports, defined by weight, with 60% of current sampling effort allocated by proportional allocation.

9. Stratification and effort allocation by area
   Three scenarios were tested:

   - We further separate the regional port-type (using 95% of landed weight) and nation port strata by area, so that port-type, nation and area (4, 3a or 7d) define the strata. Sixty percent of current effort was then allocated to major port strata using proportional effort allocation, with 2 port-days being allocated to all minor port strata.
   - As above, but 60% of the current effort allocations by area (rather than the regional totals) were allocated using proportional to the major port strata within that area, with 2 port-days being allocated to all minor port strata. This maintains, but reallocates, sampling effort within an area.
   - The port-types (major/minor) were classified on an area basis (using 95% of landed weight), before being separated by country. 60% of the current effort allocations by area (rather than the regional totals) were allocated using proportional to the major port strata within that area, with 2 port-days being allocated to all minor port strata.

Results

The current sampling effort for each nation is given in Table 1. This varies substantially between nation, with little correspondence between sampling effort and contribution to the fishery, either in terms of landed weight, port-days or days-at-sea (Table 1). This is because sampling designs have been set up, and effort allocated, on a national basis, to support national interests, rather than a regional basis. (Total days-at-sea are used as a measure of fishing activity rather than vessels or fishing trips because there are usually many small vessels, which carry out short fishing trips, and fewer large vessels, which carry out longer fishing trips.)

Port classification by landed weight (95% major) results in 37 ports being classified as "major" and 305 "minor", whilst classification by trips (95% major) results in 114 major ports and 228 minor ports. This is because the larger vessels, which land more fish into larger ports, also have fewer longer fishing trips. Many more smaller ports, with relatively small landings, are included when ports are classified by number of fishing trips. The ports sampled in the current national designs are similar to the major port classification by landed weight (95%), indicating both that this classification identifies major ports on both regional and national scales, and also that the sampling focussed on large ports is a widely accepted approach to take within national schemes, with few nations sampling at the smaller ports. The classification of individual ports can be found in supplementary material on the fishPi[2] repository.

The number of simulations required to obtain stability of results was estimated by plotting RSE for total landed weight against number of simulations for a simple random sample with 430 PSUs (Figure 1). From this, 1500 simulations were considered sufficient.

The sampling effort for a random regional design was compared for several sample sizes (Figure 2). For SRS samples from this population, relative standard error is not substantially improved by increased sample size after around 400-500 samples. This implies that the current sampling effort of 711 could include unnecessary effort. It is important to note however, that this may not be the case when biological parameters are taken into consideration.

The summary statistics for each scenario (Table 2) were compared graphically (Figure 3). As expected, designs which did not cover the whole population were found to be biased, and were excluded from further consideration on statistical grounds. This includes the current national designs, which in general, do not appear to include sampling at minor ports, usually due to issues around feasibility of implementation, for example, the difficulty in randomly sampling a port-day at a port with few port-days. The stratified designs are more efficient (lower RSE) than random samples with the same sampling effort. This is a known phenomenon for nearly all forms of stratification. Of the stratified designs, using port-type classified by landed weight performs better than when classified by trip, and including both regional port-type and nation in the stratification performs better than including only regional port-type or nation. Including area in the effort allocation performs better for species estimates but not for estimates by nation. This is because of the reduced effort for some nations with few major and many ports. This effort allocation method could be considered further and different effort allocations tested but was not taken forward here. Classification of ports by area did not improve the performance of the design. Increasing sample size to 100% of the total effort did improve the performance of the design. In order to allow some sampling effort towards national interests, however, it is not taken forward as the selected design.

Examples of more detailed graphical analyses of simulation output are shown in Figures 4-9.

Thus, stratification of regional major and minor ports (classified by landed weight) by nation, with proportional effort allocation of 60% of the current total effort is proposed for further consideration. The effort allocation for this design to each of the strata is shown in Table 3. The relative cost of this design is a small overall increase (Table 4), but the impact on national costs for some nations is considerable. This is because of the substantial changes in effort across nations, which align relative national sampling effort more closely to relative national fishing activity.

Conclusion & discussion

From a statistical perspective, stratification of regional major and minor ports by nation (in which a port is classified as major if it is in the top ports contributing to 95% of the total demersal landed weight for the region), with proportional effort allocation of 60% of the current total effort is proposed for further consideration. Increased effort allocation, and/or allocation of effort according to area could also be considered further.

However, this conclusion is made on statistical grounds and does not take into account feasibility of implementation, which includes both accessibility of ports, costs and resources. In particular, although the increase in overall costs is small (15%), the chosen design has a substantial impact on the relative costs for several countries, with potential decreases in costs of around 50%, and increases of up to 80%, and though the latter can be reduced by not including an additional national component in the designs, the former will be harder to mitigate.

The original aim of this work package was to agree a regional sampling design and move towards the practical implementation of the design, but it was agreed at the interim meeting that, as the participants in the work package did not have the authority within institutes to agree to increasing or reducing staff resources or budgets, the move from theory to implementation should be taken forward through RCGs and RCG subgroups and not through fishPi[2]. The project therefore focussed on improving tools to aid this discussion, including detailed output to allow consideration of the implications of the sampling design for each nation.

Consideration of these implications should include:

1) Consideration of proposed on-shore sampling locations (for on-shore designs) or fleets (for at-sea designs), in particular the feasibility of sampling at these locations. Pilot trials of sampling at these locations should be considered. Feedback agreement or concerns.
2) Consideration and acceptance of proposed sampling effort. Consideration as to whether national effort is required in addition to regional design. (This is particularly relevant if the regional design requires a substantial increase in effort.) Feedback agreement or concerns.
3) Consideration of regional protocols. Feedback agreement or concerns.
4) Possible recruitment or re-assignment of sampling staff if effort allocation has considerably changed. This is likely to take time and could delay implementation of a regional design.

Once the above issues have been agreed between nations, the regional design is ready to be implemented. It should be noted however, that aspects of the regional design can be implemented by individual nations as progress is made, for example, changes in sampling effort, including new locations, altering sampling frequency at some locations etc. However fishPi[2], strongly recommend that the regional design and its implications are considered in detail by the RCG subgroup on regional sampling designs.

Table 1. Current national effort allocation (port-days) by nationa and area, and total landed weight, ports, port-days and days at sea for the vessels landing demersal fish into each nation.

	BEL	DEU	DNK	FRA	GBE	GBS	NLD	SWE	Total
Current port-days Subarea	0	0	56	20	75	117	120		
Current port-days Division	0	0	56					102	
Current port-days Division	0	0		60	105				
Total effort (port-days)	0	0	112	80	180	117	120	102	711
Demersal landed weight	6.5	1.8	86.9	26.8	6.0	79.1	86.5	1.4	296
Total ports	4	11	55	60	94	33	33	52	342
Total port days	813	104	4713	6289	7696	1835	2603	3704	
Total days at sea (kdays)	201	8	819	905	210	1109	527	33	3811

Table 2. Results for simulation scenarios, with calculations according to fish of interest (FOI) and country of interest (COI), including percentage deviation (% Dev), relative standard error (RSE). In the plots, the characteristic which identifies its difference from the chosen scenario is used as an identifier (highlighted in bold).

Description	**Scenario name** (plot name in BOLD)	**Samp. size**	**Cov. PSU**	**Cov. Tonnage**	**Cov. Trips**	**DEFT**	**Effective Samp. Size**	**Mean Samp. Trips**	**Total % Dev.**	**FOI % Dev.**	**Total RSE**	**FOI RSE**	**COI RSE**
Random	**R.430**	430	100.00	100	100.00			666.3	0.49	0.24	0.23	0.52	0.61
	R.430.own	430	97.06	65.04	93.20			663.9	-19.36	-18.24	0.24	0.56	0.63
	R.711	711	100.00	100	100.00			1102	0.25	0.14	0.16	0.39	0.44
Key scenario	**S.95w.430p.Min4**	430	99.96	99.83	99.99	0.61	1170.4	746.7	0.06	0.32	0.14	0.34	0.57
(2016 allocation)	S.**95w2016**.430p.Min4	430	98.87	99.74	99.67	0.56	1371.4	749.1	-0.21	-0.38	0.12	0.32	0.66
Effort variations	S.95w.**285p**.Min4	285	99.96	99.83	99.99	0.65	670.4	490.7	0.35	0.05	0.16	0.40	0.67
(p = by PSU)	S.95w.**570p**.Min4	570	99.96	99.83	99.99	0.67	1285.5	996.7	0.12	0.01	0.12	0.30	0.60
(w = by weight)	S.95w.**711p**.Min4	711	99.96	99.83	99.99	0.67	1590.6	1247.7	-0.15	-0.39	0.11	0.26	0.53
	S.95w.**430w**.Min4	430	99.96	99.83	99.99	0.71	841.9	742.1	0.51	0.39	0.17	0.36	0.67
% major port	S.**90w**.430p.Min4	430	98.87	99.74	99.67	0.55	1398.8	766.4	0.28	-0.04	0.16	0.36	0.69
Allocations	S.**99w**.430p.Min4	430	99.96	99.83	99.99	0.74	793.4	725.4	-0.56	-0.48	0.17	0.40	0.49
(w = by weight)	S.**100Maj**.430p	430	99.96	99.83	99.99	0.92	505.4	666.1	-0.57	-0.62	0.21	0.50	0.54
(t = by trips)	S.**95t**.430p.Min4	430	99.96	99.83	99.99	0.90	526.9	688.9	0.04	0.08	0.21	0.48	0.56
No minor	S.**95w**.430p.**noMin**	430	33.49	93.69	57.48	1.01	420.3	761.6	-6.25	-6.33	0.13	0.30	0.35
	S.**95t**.430p.**noMin**	430	81.41	94.52	92.48	1.00	428.4	704.8	-3.84	-3.64	0.2	0.47	0.45

No Bel or Deu sampling	S.95w.430p.Min4.**noBD**	430	96.51	97.69	97.30	0.59	1244.2	753.2	-2.73	-3.39	0.14	0.33	0.64
Single minor port stratum	S.95w.430p.**allCtryMin24**	430	100.00	100.00	100.00	0.66	976.3	754.9	0.48	0.57	0.15	0.38	0.89
No foreign sampling	S.95w.430p.Min4.**own**	430	97.02	64.91	93.19	0.55	1399.4	739.1	-19.15	-17.66	0.13	0.33	0.57
Inc. area stratification	S.95w.430p.**areaStrat**	430	99.96	99.83	99.99	0.56	1351.5	754.5	-0.38	-0.43	0.12	0.32	0.64
- area specific effort	S.95w.**430pArea.areaStrat**	430	99.92	99.7	99.98	0.59	1253.9	751.9	-0.57	-0.93	0.14	0.34	0.71
- major ports	S.**95wArea.430pArea.areaStrat**	430	99.96	99.83	99.99	0.66	998.9	739.3	-0.55	-0.61	0.15	0.36	0.64
No country stratification	S.95w.430p.**noCtryStrat**	430	100.00	100.00	100.00	0.68	916.5	752	0.02	0.08	0.15	0.39	0.77
Current sampling	**C.430**	430	57.53	88.17	75.91	0.64	1065.4	715.8	-12.12	-12.66	0.18	0.38	0.39
	C.711.own	711	56.43	57.88	70.84	0.66	1646.2	1172.4	-27.11	-27.09	0.16	0.32	0.36

Table 3: Population totals and sampling effort for each of the strata in the chosen design.

MS	Stratum ID code	Number of locations	Total landed tonnage	Total number of trips	Total number of site-days	Planned number of PSUs
BEL	MAJOR-	2	6349	1452	482	21
BEL	MINOR-	2	136	940	331	4
DEU	MAJOR-	1	1090	21	19	2
DEU	MINOR-	10	691	88	85	4
DNK	MAJOR-	8	83906	18712	2381	105
DNK	MINOR-	47	2944	5397	2331	4
FRA	MAJOR-	8	25053	19917	2501	110
FRA	MINOR-	52	1724	8038	3788	4
GBE	MAJOR-	1	962	1314	274	11
GBE	MINOR-	93	5084	21235	7422	4
GBS	MAJOR-	8	78180	5264	1677	72
GBS	MINOR-	25	871	166	158	4
NLD	MAJOR-	9	84582	8638	1860	78
NLD	MINOR-	24	1953	1020	743	4
SWE	MINOR-	52	1399	3959	3074	4
OTH	OTHER	7	756	13	12	0

Table 4. Sampling effort by nation – current effort and with the proposed design, potential change in effort and indicative changes in cost.

	BEL	DEU	DNK	FRA	GBE	GBS	NLD	SWE	Total
Current total effort (port days)	0	0	112	80	180	117	120	102	711
Proposed regional effort	25	6	109	114	15	76	82	4	431
40% current effort (port days)	0	0	45	32	72	47	48	41	284
Proposed total effort (port	25	6	154	146	87	123	130	45	715
Change in effort (port days)	25	6	42	66	-93	5	10	57	4
Change in effort (%)			37%	83%	-52%	5%	8%	-56%	1%
Change in cost (%)			37%	83%	-52%	5%	8%	-56%	15%

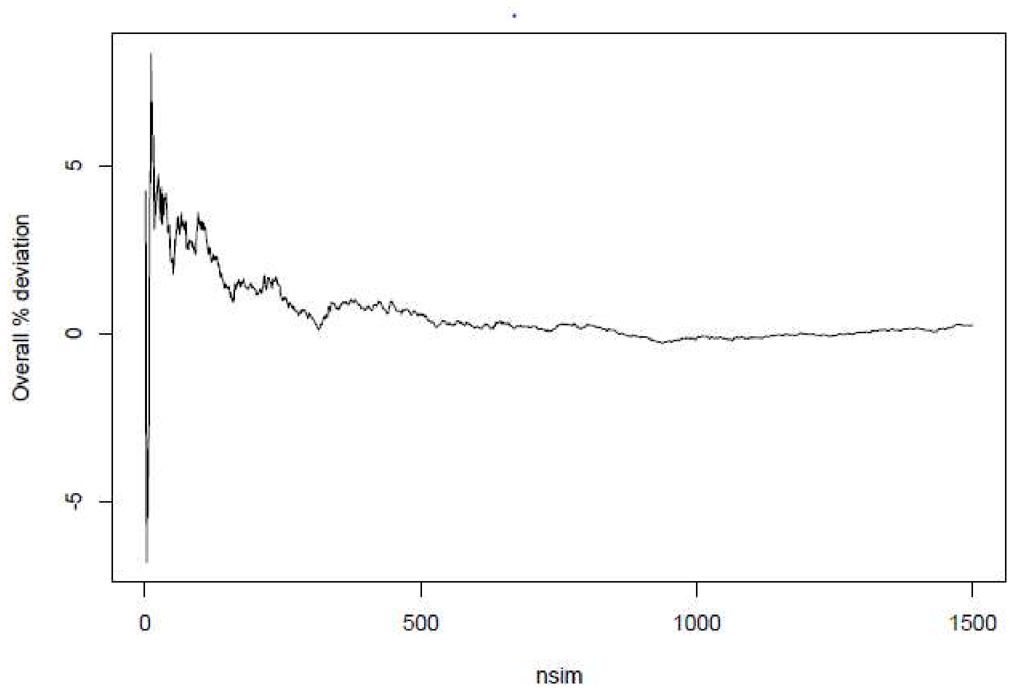


Figure 1. Overall percent deviation against number of simulations for a srs design with 100% current effort.

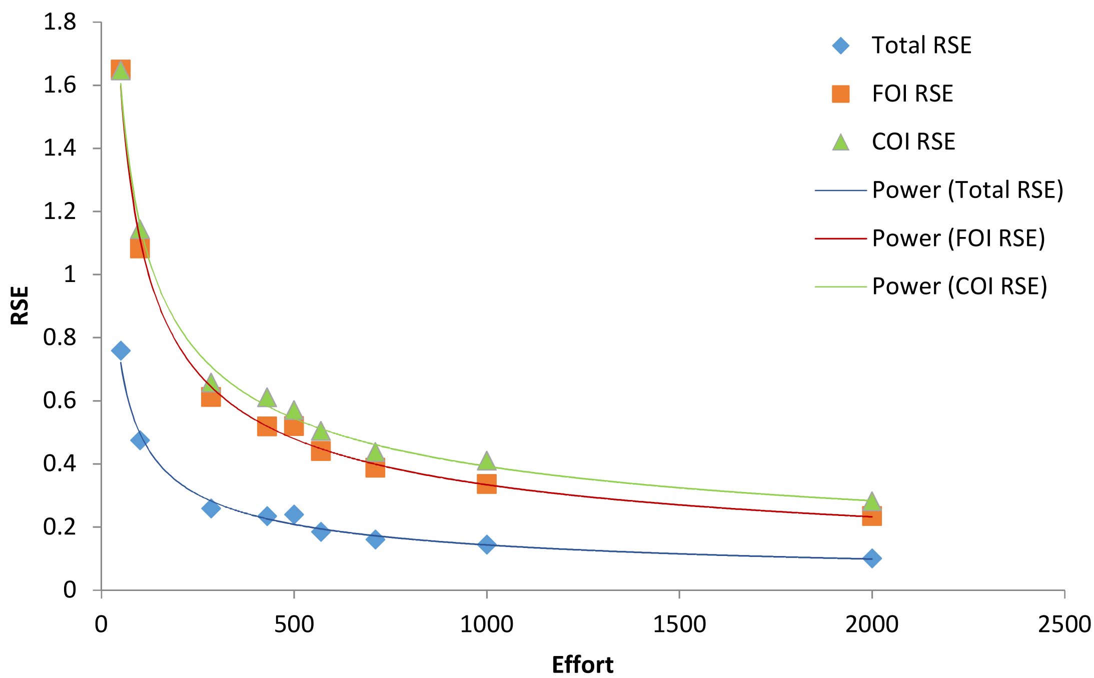


Figure 2. Mean relative standard error (RSE): Total (blue diamond), for fish of interest (FOI) (red square) and for countries of interest (COI) (green triangle), with fitted trend lines.

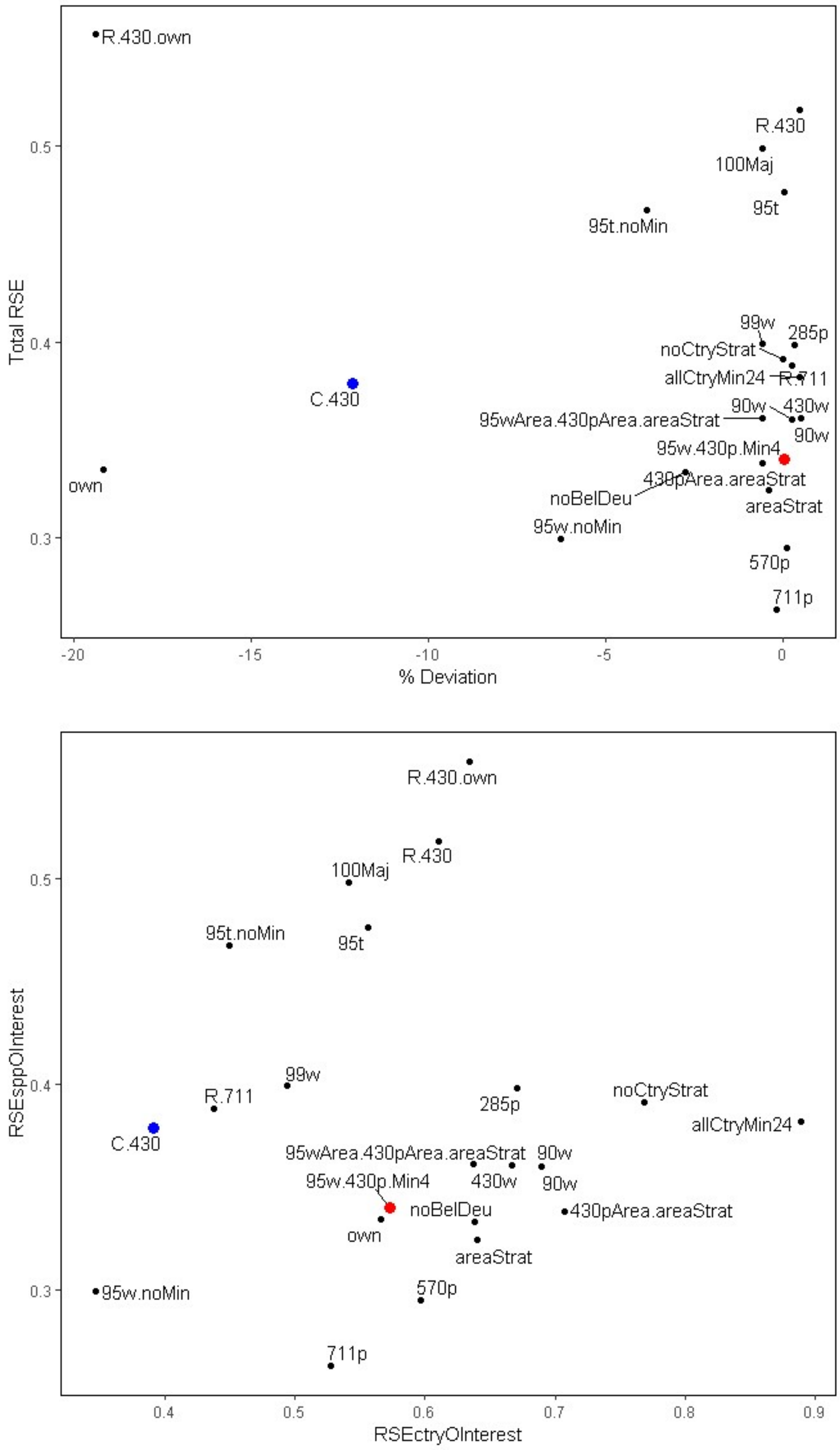


Figure 3. Summary results for tested scenarios. Top: relative standard error of the estimate of total landed weight for all species, versus %deviation, which is a measure of the bias of the estimate of total landed weight. Bottom: mean relative standard error of the estimates of total landed weight for the species of interest, versus mean relative standard error of the estimates of total national landed weight. Scenarios can be identified using the key in Table 1. The selected optimum design is indicated by a red

dot, whilst the current design, with the same effort as the selected scenario, is indicated by a blue dot.

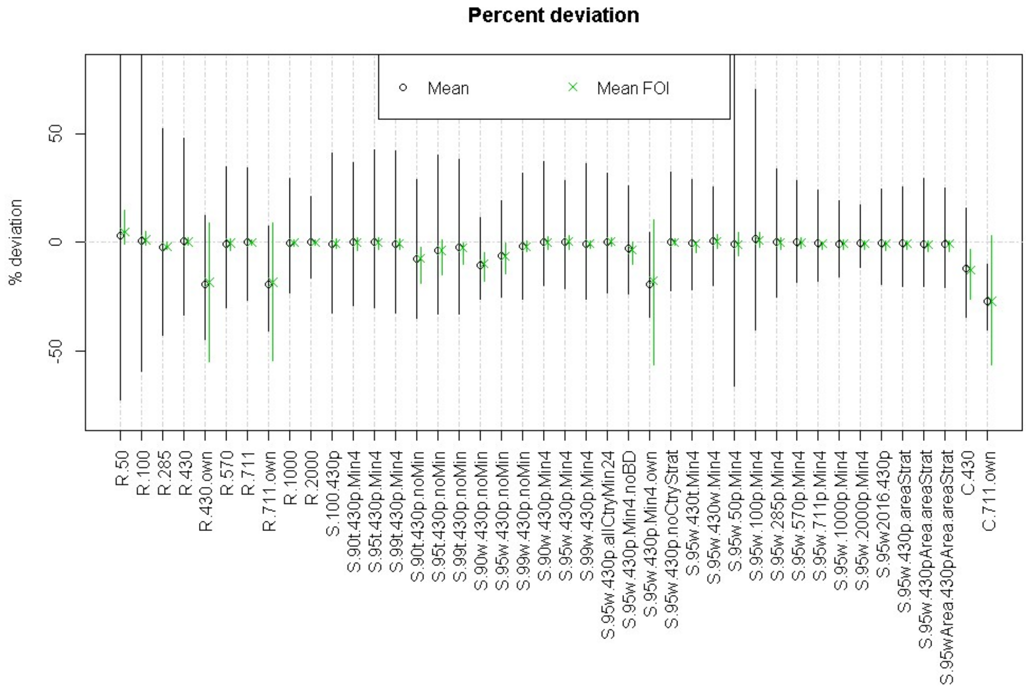


Figure 4. Mean percent deviation calculated overall (circle) and for fish of interest (FOI) (cross) for each scenario, with 2.5% and 97.5% quantiles.

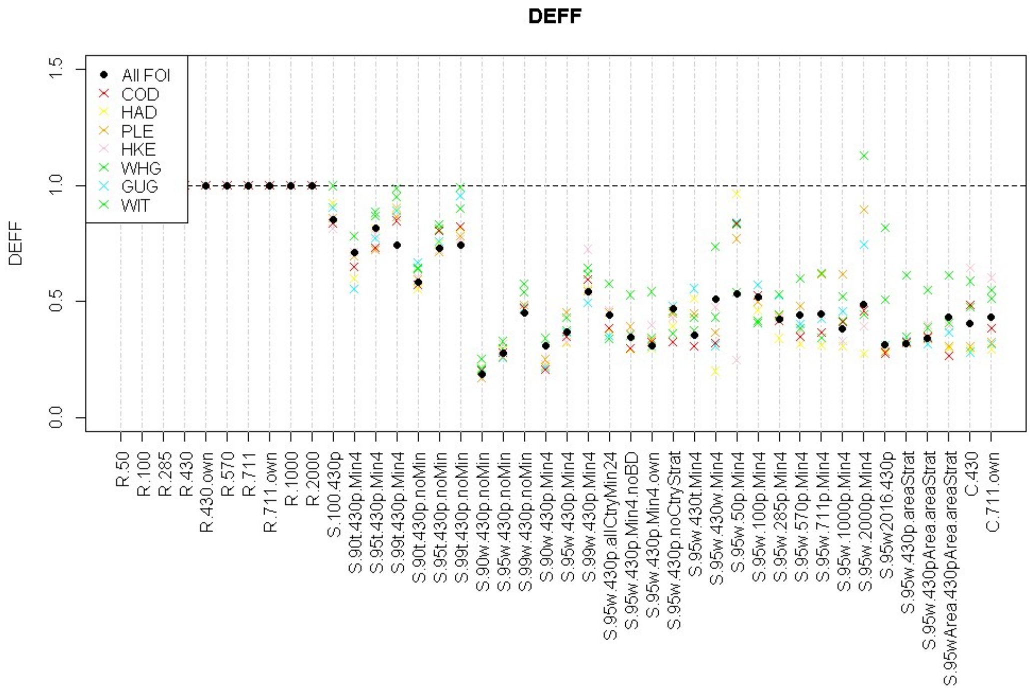


Figure 5. Design effect (DEFF) calculated as a mean (circle) and individual design effects for the species of interest (crosses) for each scenario. Scenarios can be identified using the key in Table 1.

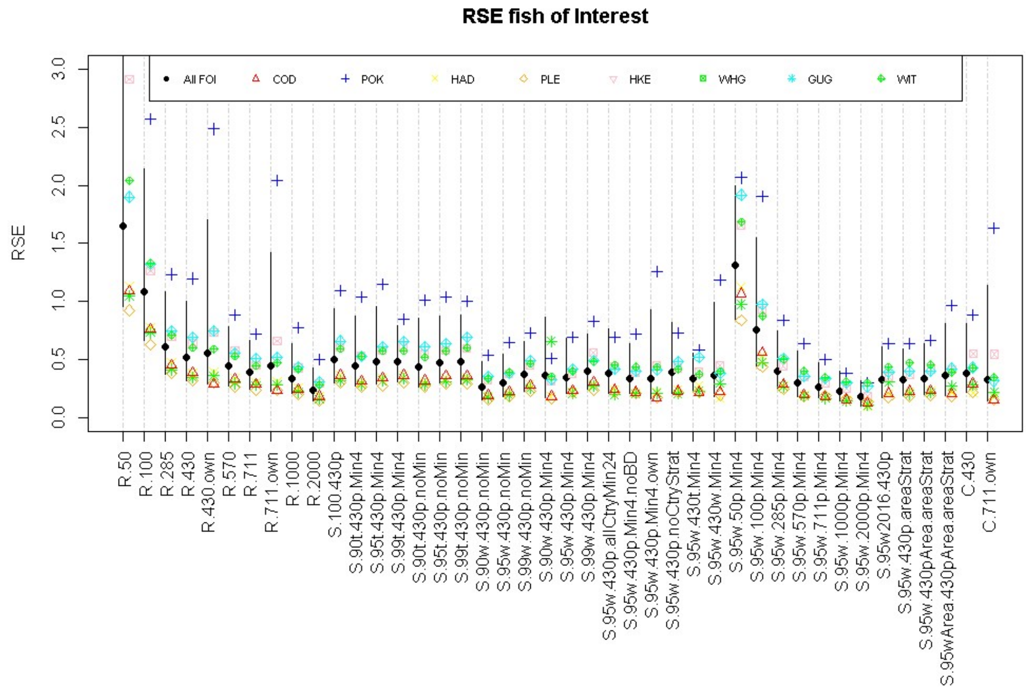


Figure 6. Relative standard error (RSE) calculated as a mean (circle) and for individual species of interest (FOI) for each scenario, with 2.5% and 97.5% quantiles. Scenarios can be identified using the key in Table 1.

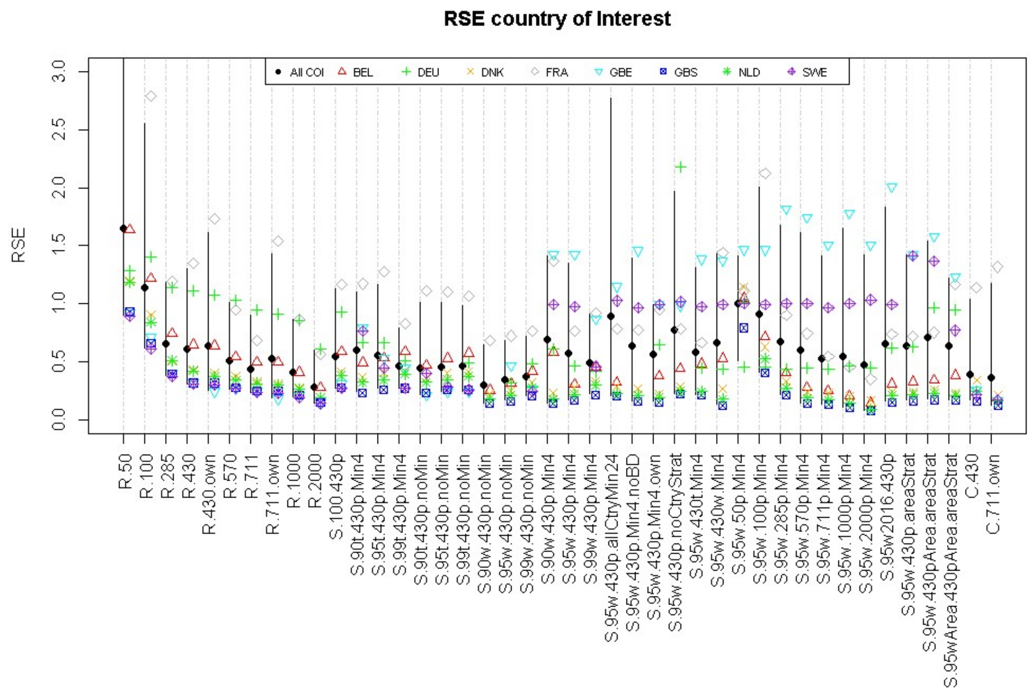


Figure 7. Relative standard error (RSE) calculated as a mean (circle) and individual countries of interest (COI) for each scenario, with 2.5% and 97.5% quantiles. Scenarios can be identified using the key in Table 1.

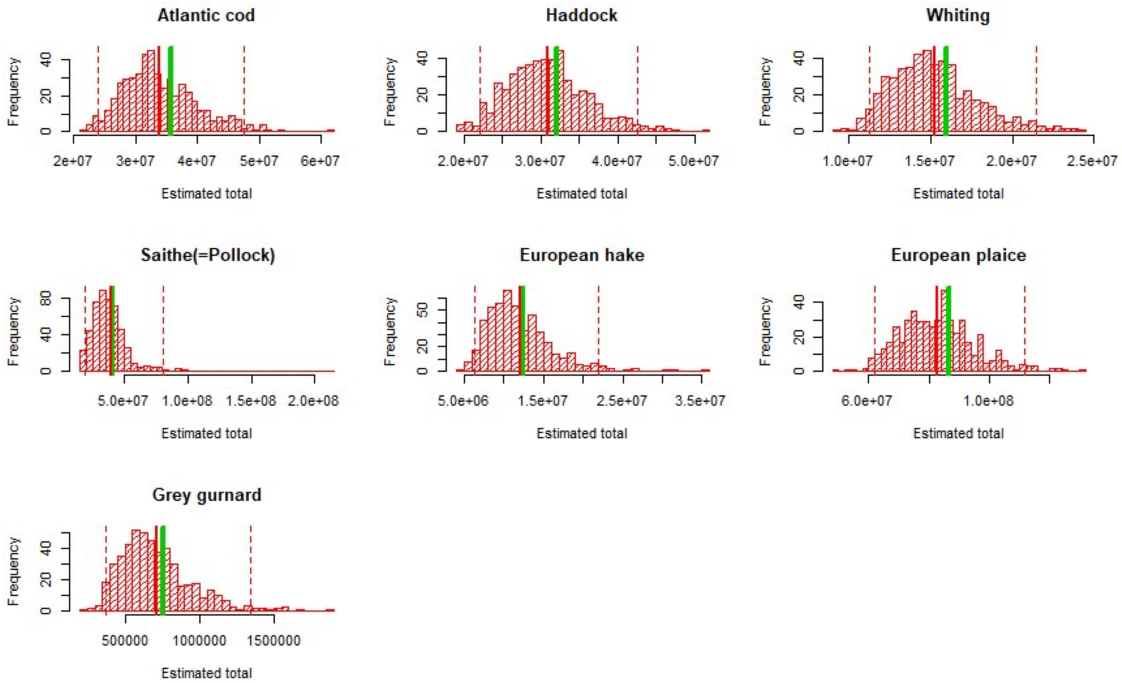


Figure 8. Histograms of estimates of species landed weights for different simulations in an example scenario. The red line indicates the mean of these values, the dotted lines the 2.5% and 97.5% quantiles, and the green line is the true mean from the population.

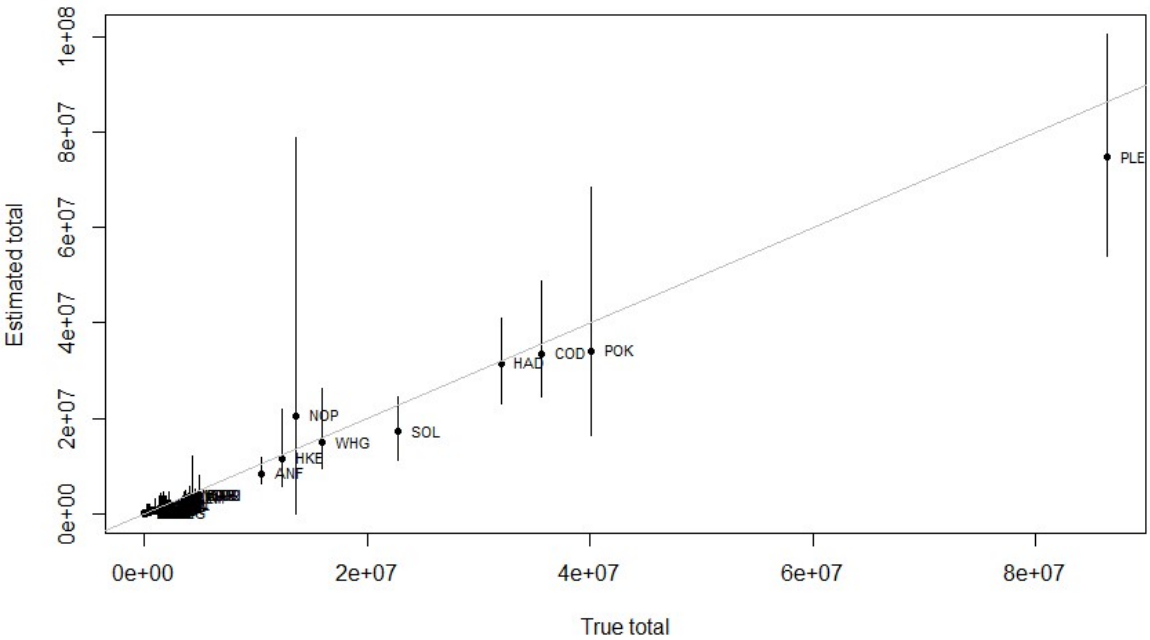


Figure 9. Mean estimates of species landed weights, with the 2.5% and 97.5% quantiles, against the true value for an example scenario.

Appendix 1: Summary of the data set

The data set assembled for WP2 and WP3 consisted of fishing trip records provided by the 13 participating scientific institutes, which collectively submitted information (in order of landed tonnages these are: Denmark, France, UK-Scotland, Netherlands, Spain, Ireland, UK-England, Germany, Portugal, Sweden, UK-Northern Ireland, Belgium, UK-Wales). The request covered all fishing trips in ICES areas 3a, 4, 5, 6, 7, 8 and 9. From these trips all species landed, and the landed weight was requested. The data requested was for the years 2015 and 2016.

The data set for 2015 recorded 2,941,244 tonnes of landings, for 503 unique taxonomic (usually species) codes[5] from 1,084,672 fishing trips relating to 16,036 vessels. Values for 2016 were similar. The distribution of landings by vessel flag country and landing country is shown in Table 1 and Figure 1, and the distribution of vessels and fishing trips by vessel length class are shown in Table 2 and Figure 2, and Table 3 and Figure 3 respectively. Some indication of the national fisheries interest is provided by Table 4, which gives the main species landed by vessels of different countries and the proportion of the total landings that species represents.

[5] In some instances the landings had not been identified (e.g. rarely encountered species), or were not identifiable (e.g. mixed species landings) to species level taxonomic classification. In such instances a higher taxonomic classification were generally used.

As a data set this corresponded to a 6,595,935 row data frame, an R object of approximately 150MB. The fields of the data set were set out in the data call (Annex 3.2.2), and in addition various additional fields where derived from those requested.

		Vessel Flag Country															
		DNK	FRA	SCT	NLD	ESP	IRL	ENG	DEU	SWE	NIR	BEL	PRT	WLS	GBI	GBC	Total
Landing country	DNK	649218	4487	27762	1780	0	1271	4019	24140	55168	4630	3734	0	0	0	0	**776209**
	NLD	346	44034	3267	264644	0	979	66052	72095	0	0	4953	0	0	0	0	**456370**
	FRA	730	363736	0	4503	342	4699	2989	0	0	0	2877	0	0	0	363	**380239**
	GBS	3897	16159	252343	0	3814	3232	15911	1449	1517	4180	0	0	9	219	43	**302773**
	IRL	12678	21848	13978	4124	10429	191343	3780	1210	0	12789	60	0	526	2	0	**272767**
	ESP	0	21369	2228	0	245039	772	1671	1453	0	0	0	0	99	0	0	**272631**
	NOR	34928	161	120639	0	0	7148	0	0	1346	4460	0	0	0	0	0	**168682**
	GBE	353	154	9136	416	0	315	90137	0	0	384	1276	0	736	25	844	**103776**
	DEU	40912	0	0	1043	0	0	8	58997	0	0	0	0	0	0	0	**100960**
	SWE	1847	0	0	0	0	0	0	0	23438	0	0	0	0	0	0	**25285**
	GBN	0	0	777	0	0	3889	116	0	0	17877	0	0	0	2	0	**22661**
	PRT	0	0	0	0	0	0	0	0	0	0	0	22588	0	0	0	**22588**
	GBW	0	0	905	0	0	0	2089	0	0	500	3455	0	5380	264	293	**12886**
	GBI	0	0	3524	0	0	2	327	0	0	992	0	0	32	4152	0	**9029**
	BEL	0	0	0	461	0	0	9	66	0	0	8167	0	0	0	0	**8703**
	FRO	1586	0	0	0	0	3870	0	0	0	0	0	0	0	0	0	**5456**
	GBC	0	0	0	0	0	0	89	0	0	0	0	0	0	0	140	**229**
	GUF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Total	**746495**	**471948**	**434559**	**276971**	**259624**	**217520**	**187197**	**159410**	**81469**	**45812**	**24522**	**22588**	**6782**	**4664**	**1683**	**2941244**

Table 1: Landed tonnages for 2015 by vessel flag country and landing country. The table is organised by greatest landed weight both by column (vessel flag country) and row (landing country).

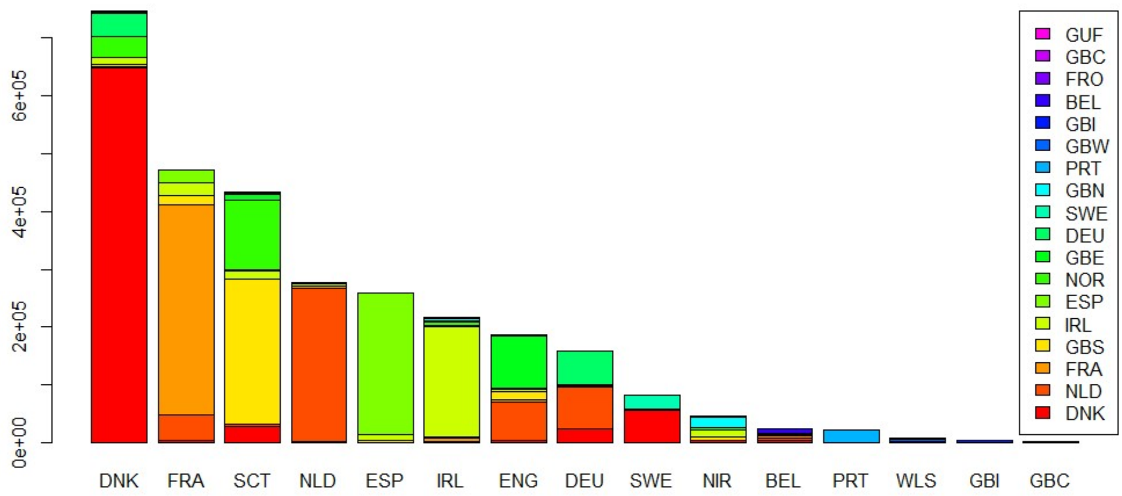


Figure 1: Landed tonnage by vessel flag country and landing country, the height of the bar represents the total landings by the flag vessels of the country, the colour of the bars shows which countries these vessels are landing into. For example most of the tonnage from Danish flag vessels is landed into Denmark, in contrast, Scottish flag vessels are landing substantial

tonnages into Norway, English and German flag vessels are landing substantial tonnages into the Netherlands.

		Vessel Flag Country															
		ESP	PRT	FRA	ENG	SCT	DNK	NLD	IRL	SWE	WLS	NIR	DEU	BEL	GBI	GBC	Total
Vessel Length Clas	VL0010	1906	2529	1318	1815	1126	391	186	25	264	274	142	11	0	37	4	**10028**
	VL1012	369	161	660	160	133	59	24	164	71	19	20	8	0	1	0	**1849**
	VL1218	542	128	168	191	175	195	28	80	50	10	55	116	5	24	3	**1770**
	VL1824	241	0	225	47	131	74	168	81	25	1	54	73	34	0	3	**1157**
	VL2440	295	0	220	67	87	40	73	70	19	2	6	30	35	0	0	**944**
	VL40XX	2	0	98	12	26	30	70	23	11	0	3	13	0	0	0	**288**
	Total	**3355**	**2818**	**2689**	**2292**	**1678**	**789**	**549**	**443**	**440**	**306**	**280**	**251**	**74**	**62**	**10**	**16036**

Table 2: Number of vessels in the data set by vessel flag country and vessel length class.

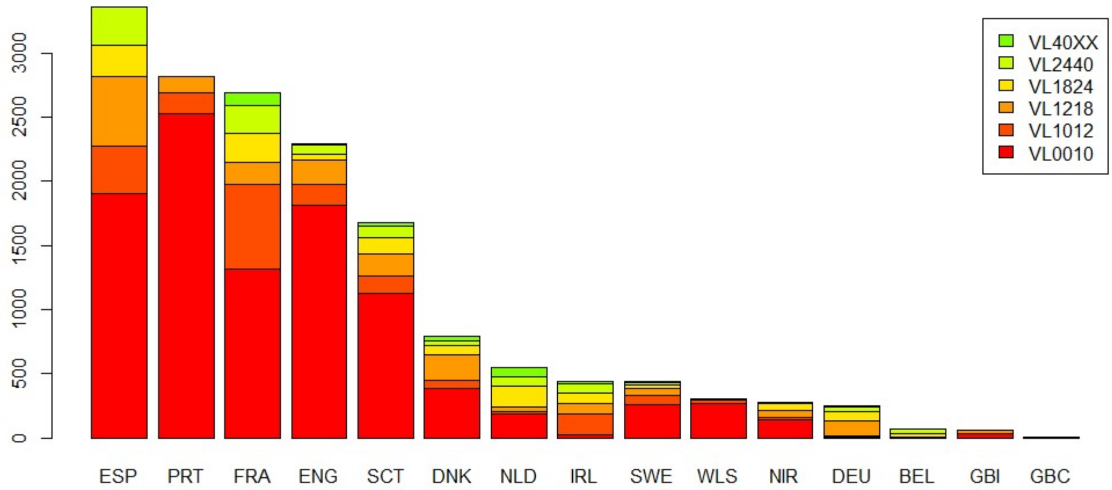


Figure 2: Number of unique vessels in the data set by flag country and length class. As can be seen the most of the vessels are in the under 10m class, though some of the data provided specifically excluded these small vessels in part because it was difficult to obtain.

	Vessel Flag Country															
Vessel Length Clas		ESP	PRT	FRA	ENG	SCT	DNK	NLD	IRL	SWE	WLS	NIR	DEU	BEL	GBI	GBC	Total
	VL0010	118413	161023	117518	94019	25165	12184	3865	965	14660	6749	3074	320	0	2390	11	**560356**
	VL1012	41559	7516	96956	15848	9393	3428	911	9679	5764	1388	1545	476	0	99	0	**194562**
	VL1218	67586	7571	22160	15336	16440	13883	1103	4949	4070	437	4295	8984	507	2413	160	**169894**
	VL1824	29717	0	25079	1957	6769	4704	7893	2948	2036	36	3489	4044	2516	0	210	**91398**
	VL2440	26094	0	14712	2469	3358	1861	4127	2113	601	34	209	1058	1275	0	0	**57911**
	VL40XX	87	0	4868	404	568	814	2945	281	218	0	49	317	0	0	0	**10551**
	Total	**283456**	**176110**	**281293**	**130033**	**61693**	**36874**	**20844**	**20935**	**27349**	**8644**	**12661**	**15199**	**4298**	**4902**	**381**	**1084672**

Table 3: Number of fishing trips in the data set by vessel flag country and vessel length Class.

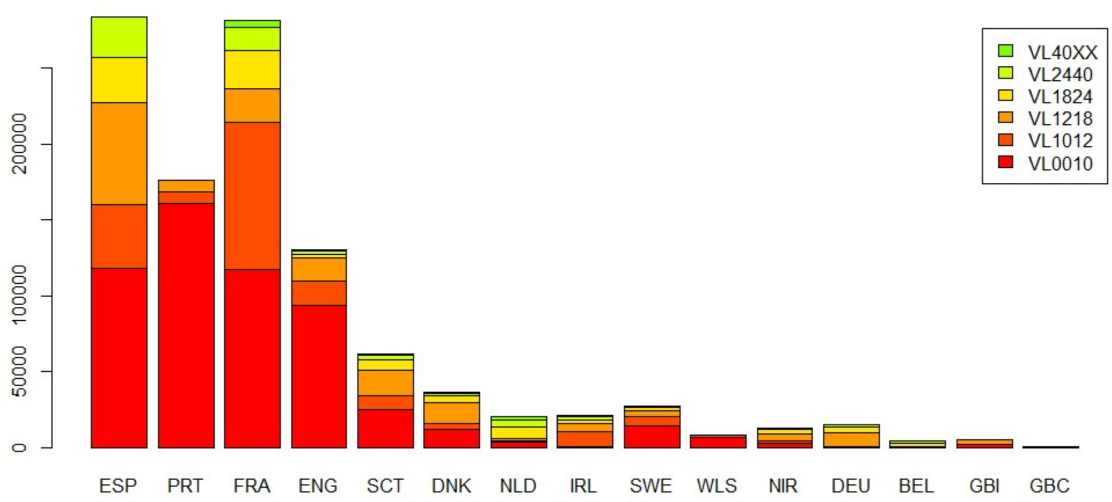


Figure 3: Number of fishing trips in the data set by vessel flag country and vessel length class. A greater proportion of the data are derived from vessels in the larger length classes, when compared to the proportions of vessel length class across the flag countries.

Vessel Flag Country	Vessel Flag Landings	Main Species	Main Species Name	Proportion of total landings
DNK	555343	SPR	European sprat	0.40
FRA	478643	HKE	European hake	0.13
SCT	445152	MAC	Atlantic mackerel	0.42
NLD	302614	HER	Atlantic herring	0.33
ESP	262994	HKE	European hake	0.15
IRL	217746	MAC	Atlantic mackerel	0.33
ENG	180304	HER	Atlantic herring	0.12
DEU	175778	CSH	Common shrimp	0.28
PRT	110823	HOM	Atlantic horse mackerel	0.21
SWE	63981	HER	Atlantic herring	0.57
NIR	29389	NEP	Norway lobster	0.29
BEL	26940	PLE	European plaice	0.35
WLS	7567	WHE	Whelk	0.67
GBI	5032	SCE	Great Atlantic scallop	0.42
GBC	1803	WHE	Whelk	0.60

Table 4: Main Species landed by Vessel Flag Country. The total landings of the flag fleet, the main landed species and the proportion of the total landings that the main species represents.

The North Sea data Set

The data set used for the North Sea demersal case study was defined in terms of the fishing trips active in particular fishing areas, and the taxonomic species classifications of the landed species; the stages of defining these populations and drawing up sampling frames is outline below.

Fishing trips active in the Wider North Sea

Firstly the fishing trips that were active in the wider North Sea area were considered. The wider North Sea was defined in terms of ICES areas, sub areas and divisions ("27.3.a", "27.3.a.20", "27.3.a.21", "27.4.a", "27.4.b", "27.4.c", "27.7.d"). A trip that had any fishing in any of these areas was included in the data set. A consequence of this was that that some areas outwith the wider North Sea were included if they had been fished on the same fishing trip operating in the wider North Sea.

Taxonomic groupings of landed species

All landed species were aggregated into taxonomic groups based on the FAO ISSCAAP codes, and the FAO code for the species. The ISSCAAP groupings are themselves taxonomic groupings of species. (The advantage of this method is that having ascribed all recorded landings to an FAO code then the ISSCAAP classification naturally follows from the FAO species code). These species groups were: "demersal", "crustacea", "cephalopod", "elasmobranchs", "pelagic", "mollusca", "diadromous", "freshwater" and "benthos". The range of the taxonomic groups reflects the wide scope of the data call and the diversity of the landed species recorded.

Landed tonnages for the different taxonomic groups is shown in Figure 5. The 1,205,442 tonnes of pelagic fish, 315,820 tonnes of demersal fish, 99,384 tonnes of Crustacea and 44,720 tonnes of Mollusca landed from the North Sea in 2015.

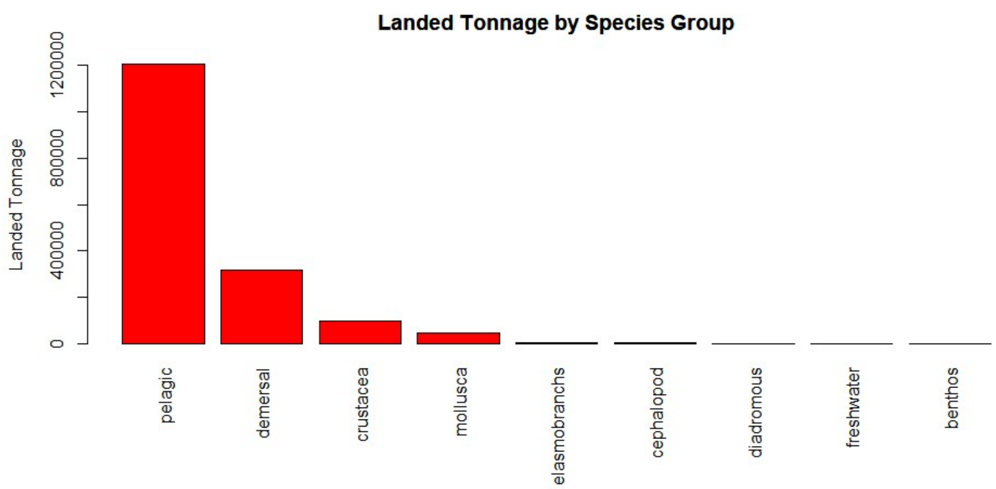


Figure 4: Landed tonnages for the different taxonomic groups.

Allocation of fishing trips to ISSCAAP taxonomic groups

Fishing trips were likewise classified by their landings composition to a main taxonomic group. This was achieved by summing the landed species weights by taxonomic groups and ascribing each fishing trip to the taxonomic group with the greatest landed weight.

In this way the population of all fishing trips active in the North Sea can be defined and allocated to populations of fishing trips that have landings mainly of “demersal”, “pelagic”, “crustacea” species etc.

Heterogeneity of trip landings

Each species was assigned to a group based on its taxonomic ISSCAAP code. The demersal species were defined as all those which fulfilled the ISSCAAP categories 31, 32, 33 34, namely 31: Flounders Halibuts Soles, 32: Cods hakes haddocks, 34: Miscellaneous coastal fishes, 35: Miscellaneous Demersal fishes. From this boarfish, sandeel, Norway pout and blue whiting were removed and reclassified as ISSCAAP 37 “miscellaneous pelagic” because it is the pelagic fisheries that land these species.

As a distinction has been made between the main taxonomic grouping of the fishing trip, and the taxonomic grouping of the individual species being landed, it was then possible to access the extent to which the trip populations correspond to the species populations. Table 5 shows the proportion of the species groups that are landed by the fishing trip groups. This homogeneity of species composition can be measured as the % of the landed weight of the species populations landed by the corresponding trip populations (Table 5). Thus 99.9% of the species classified as pelagic are caught on trips that can be likewise classified as pelagic, based on the totality of their landings. Likewise, 97% of demersal species are landed from fishing trips targeting demersal species,94% crustacea and 99% mollusca are landed by mollusc trips. However, there is no such population of elasmobranchs 16%, cephalopods 22% and diadramous 31% (Table 6). Here these species are landed more as a bycatch of trips that are essentially landing other species as their main landings. Of the totality of the landings only 16% 22% and 31% of these species are landed by when one considers the totality of the landings of these species.

Demersal species landings

The population of demersal landings was defined as all the species where the taxonomic classification was “demersal”. This amounted to 132 different taxonomic species codes in the data set with total landings of 330,065 tonnes; 99% of this landed weight was accounted for by 30 species, plaice 88,000 tonnes, Saithe 41,000 tonnes Cod 36,500 tonnes Haddock 32,000 tonnes being the main species (Figure 5).

Population: demersal fishing trips

The population of demersal fishing trips was defined as all the trips where the landed weight was mainly of species where the taxonomic classification was "demersal". There are 97668 such trips. With a total landed weight of 338485, of which the landed weight of demersal species is 319423. This represents 96.7% of the demersal species landed from the wider North Sea.

Sampling Frame of Ports

A sampling frame for ports for demersal species was defined as all the ports where the population of demersal trips were landed. In total there are 348 individual ports that received landings of the 97668 demersal fishing trips from the North Sea. Of the landed tonnage, which is 95% of the landed weight (320712.2 tonnes) is accounted for by 38 ports (Figure 6). These main ports account for 55330 (56.6%) of the demersal fishing trips. Put another way, 44% of "demersal trips" and 89% (310) of the landing ports amount to only 5% of the total landed tonnage from the demersal trips.

		Fishing trip by main taxonomic group.								
		pelagic	demersal	crustacea	mollusca	elasmobranchs	cephalopod	diadromous	freshwater	Total
Species taxonomic group	pelagic	1124593	2615	112	10	164	177	0	0	1127671
	demersal	4023	319423	3955	269	1535	859	1	0	330065
	crustacea	75	5326	93974	131	46	16	1	1	99570
	mollusca	7	591	50	74046	13	21	0	0	74728
	elasmobranchs	261	5267	107	53	3226	206	0	0	9120
	cephalopod	322	5215	82	115	216	2708	0	0	8658
	diadromous	10	47	12	6	2	0	35	0	112
	freshwater	0	1	1	0	0	0	0	26	28
	benthos	0	0	0	0	0	0	0	0	0
	Total	1129291	338485	98293	74630	5202	3987	37	27	1649952
	Nunmber of trips	12473	97668	112429	38383	5956	4209	627	58	271803

Table 5: Landed tonnages from North Sea fishing trips classified by taxonomic group, against the taxonomic group of the landed species. It can be seen the extent to which fishing trips groups land the species of the same taxonomic group, for example the trips targeting demersal fish land 319,000 tonnes, while a further 4,000 tonnes is landed from "pelagic trips and almost 4,000 tonnes from Crustacea trips.

pelagic	1.00	99.73
demersal	0.97	96.78
crustacea	0.94	94.38
mollusca	0.99	99.09
elasmobranchs	0.35	35.37
cephalopod	0.31	31.27
diadromous	0.31	30.94
freshwater	0.92	91.59

Table 6: The proportion of the species groups landed by the respective populations of trips, 99.7% of pelagic species are landed from "pelagic" trips, 96.8% of demersal species are landed by demersal trips.

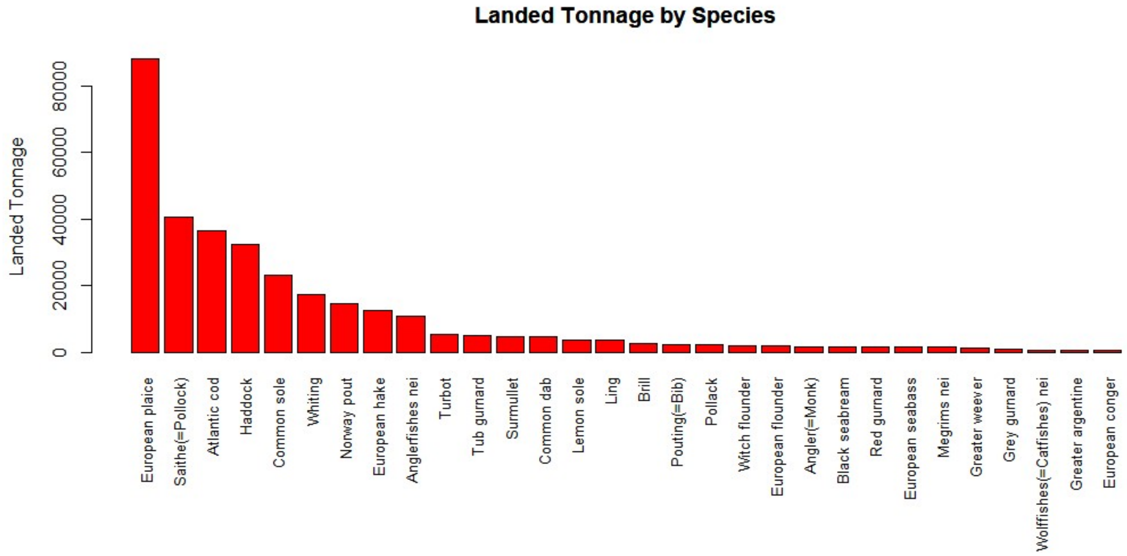


Figure 5: Landed tonnages by species for the top 30 species in the wider North Sea.

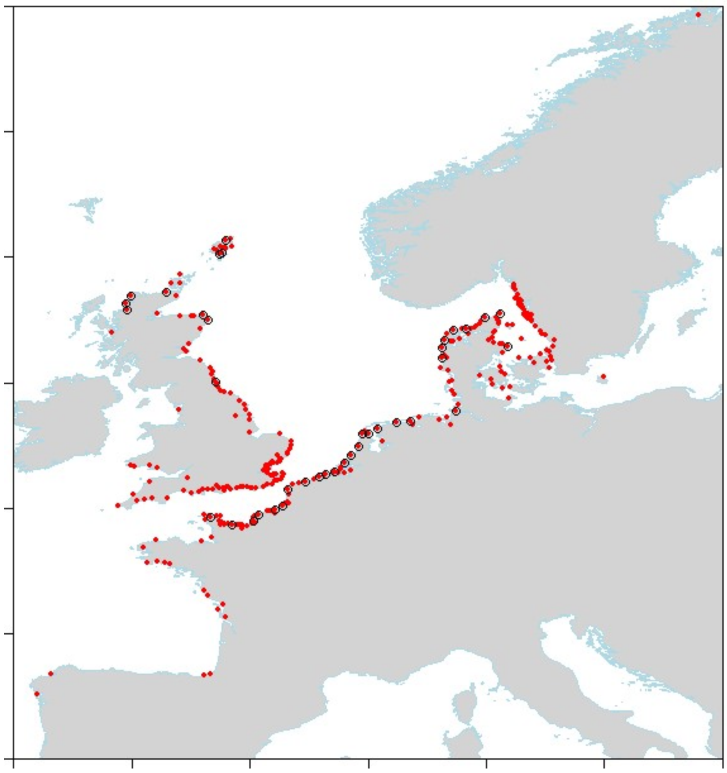


Figure 6: Ports receiving demersal landings from the wider North Sea area. 95% of the landed tonnage is landed in 38 ports, circled.

Annex 3.5 Iberian Case study

Introduction

The Iberian case study of project fishPi[2] is focused in the design of an on-shore regional sampling plan for the trawl fishery in Iberian waters. This comprises the activity of five metiers operating in two ICES Divisions (27.9.a and 27.8.c).

The case study follows a multispecies approach considering all species. The implications of the different sampling designs tested are analysed later on for 10 species of major relevance in this area and fleet, thus allowing an understanding of the implications of the different schemes for the data obtained on these species.

The selected trawl fishery fits in the criteria to select fisheries suitable for a regional sampling plan:

- Catches of targeted stocks shared in relevant proportion by two countries: Portugal and Spain.
- Important landings of commercially important species.
- Multi-specific fisheries, with several species caught together.

As only two countries are involved in the fishery, this CS represents a good opportunity to define and test a methodology to define regional sampling plans following an appropriate statistical approach.

Scope of the Iberian case study:

- Areas: ICES Divisions 27.8.c and 27.9.a (Iberian DCF Fishing ground)
- Vessels: All vessels using demersal trawl gears (OTB + PTB)
- Trips: All trawl trips in the area.
- Species: All species. Focused analysis on a set of species of major interest: ANK (blackbellied angler), MON (angler), HKE (hake), LDB (four spot megrim), MEG (megrim), HOM (horse mackerel), WHB (blue whiting), NEP (Norway lobster), MAC (Atlantic mackerel) and DPS (deep water rose shrimp).
- Years: 2015 and 2016.
- Variable for simulation: landings.
- Statistical package for simulation: survey package.

The Spanish activity in the Southern part of the Division 27.9.a (9aS) is excluded from the study as it's exclusively a Spanish activity which is sampled completely within the Spanish on-board sampling programme. Hereafter in this document Iberian waters refers to 27.9a (except 9aS) and 27.8c.

The case study is focused on the establishment of a regional plan for Spanish and Portuguese trawl fleet since catches by French fleet were considered negligible.

Data

The data needed to develop the simulations follow the guidelines established by the WP2-WP3 team for both case studies.

Data transmitted by Member States were based on official logbooks and sale notes, following the Data Call of the FishPi2 project over the period 2015-2016. The requested data referred to the total fishing activity developed by each country in the study area. Compilation of all fishing activity during years 2015 and 2016 was possible due a Data Sharing Agreement.

The Iberian dataset contained 350660 observations (each observation is one species landed in one trip) which included, among other variables, information of 47297 trips, 307 species, 175 fishing vessels and 58 landing locations. A detailed document with the description of the fisheries based on this dataset can be found in Annex 2.3.

Fisheries description

Analysis plots and maps are presented in the already described Annex 2.3 Iberian Case study: Fisheries Description, under WP2, and were developed taking into consideration two aspects: a) landings (tonnes) and b) effort (number of trips).

Briefly, from a regional point of view, it is important to note that in several Spanish ports there were landings by Portuguese vessels but there were no Spanish landings in Portuguese ports. Moreover, considering the relevance of the landing location for an on-shore sampling programme, it is highlighted that 22 ports represented 97% of the landings of the trawl fleet, with small landings in the remaining ports (Figure 1).

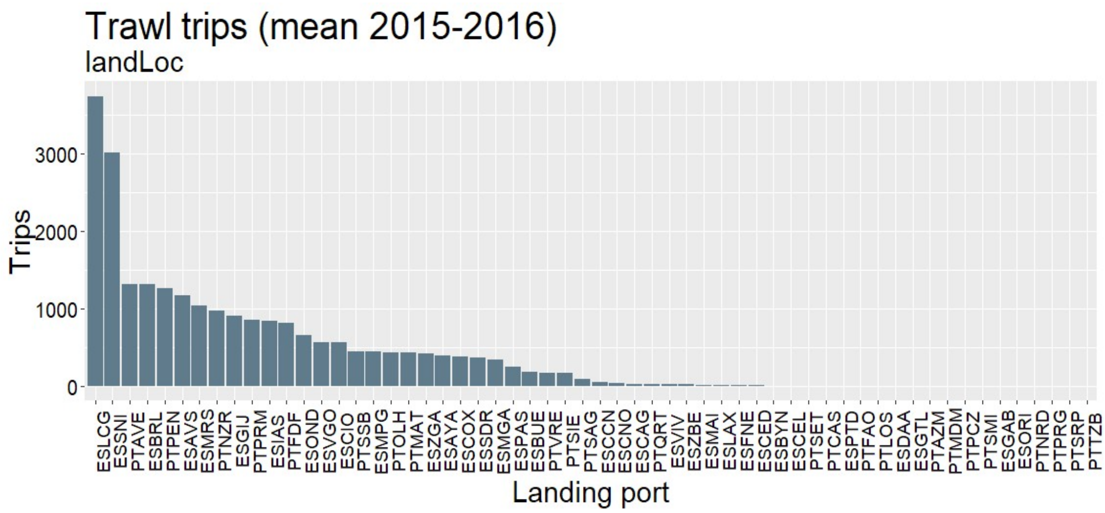


Figure 1. Trips by landing port and vessel flag country (mean 2015-2016)

Nevertheless, landings by this fleet differ among ports in terms of species and metiers (Figure 2). In the Iberian case, several ports (PTOLH, PTSAG, PTVRE) receive a particular fishery targeting crustaceans (NEP and DPS), not relevant in terms of volume of landings and number of trips, but important as a fishing activity targeting two key species in terms of commercial value, in Iberian waters.

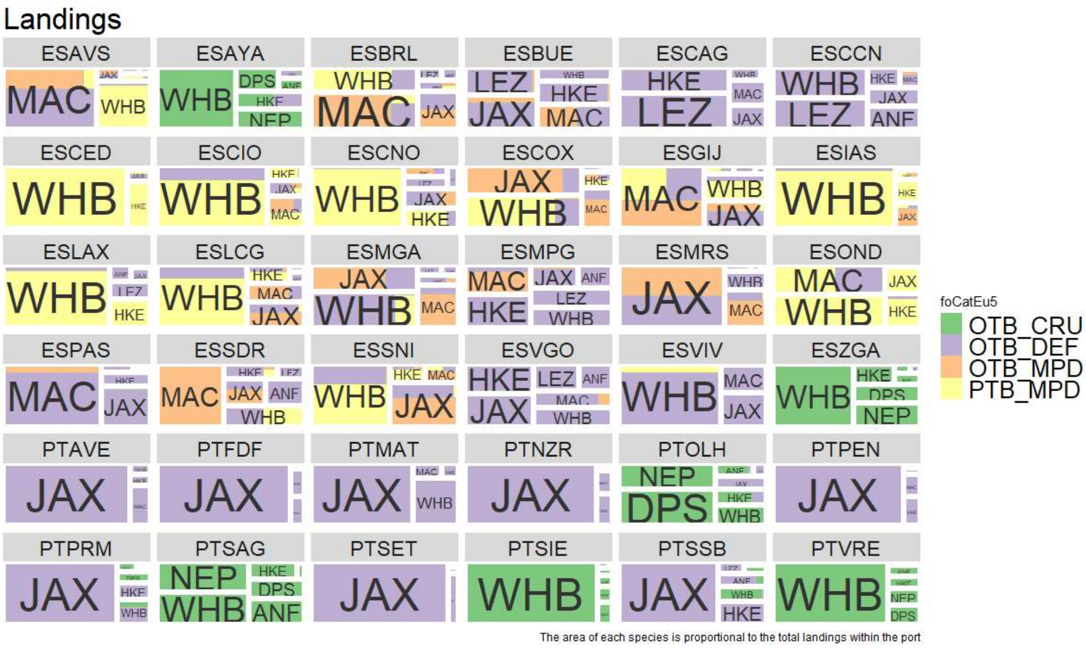


Figure 2. Landings by port, specie and metier level 5.

Methodology

The methodology is based on simulation models used to explore alternative sampling designs (see simulation method in WP3 and North Sea case study). In the simulations, the effect on species landed weight was used as a proxy for the effect on the biological data that are sampled (age and length distributions). The main advantage of using species landed weight for the simulations is that information of the full population is available in logbooks and sales notes and can be used to define the sampling frame and collect the samples following a specific sampling design.

Iberian case study simulations were done based on the simulation script developed by Alastair Pout, Liz Clarke and Jessica Craig, modified by Jose Rodriguez to include “institute” in the estimation.

Species and stocks selected

In the case study of the Iberian trawl fleet, a set of four criteria were adopted to select the set of species/stocks to be analyzed in the process of definition of a regional sampling plan. Sampling in these countries follows a “concurrent sampling” strategy, i.e. sampling is directed at “metiers” and all species landed in a trip are sampled.

The rationale followed was that the definition of a regional sampling plan should focus on a subset of species/stocks:

- **with high landings**. See stocks above the dashed line (Figure 3).
- **with landings by several countries** as evidenced by the maximum proportion of landed weight by a single country's vessels. See stocks left of the dashed line (Figure 3). No threshold was fixed for these two criteria, rather we aimed at a combination of these two criteria (i.e. location of the dashed lines in Figure 3) that would result in a selection of around ten species/stocks (i.e. left upper quadrant in Figure 1), but wider or narrower thresholds could be considered resulting in larger or smaller sets of selected species/stocks.
- **stocks with assessment** (which left out stocks of octopus - occ.27.nea, and Atlantic chub mackerel – vma.ib)
- **stocks that are mainly caught by these métiers** (which included crustacean stocks – dps.ib and nep stocks, and again left out stocks of octopus - occ.27.nea, and Atlantic chub mackerel – vma.ib).

After the application of these four criteria, the list of selected stocks (highlighted in red in Figure 3) is the following: whb.27.1-91214 (blue whiting), jax.27.2a4a5b6a7a-ce-k8.ib, jax.27.9a.ib (horse mackerel), mac.27.nea (Atlantic mackerel), hke.27.8c9a (hake), lez.27.8c9a.ib (megrims), anf.27.8c9a.ib (anglerfishes), dps.ib (deep water rose shrimp), nep.fu.25, nep.fu.2627, nep.fu.2829, nep.fu.30, nep.fu.31, nep.other.ib (Norway lobster). For these selected stocks, the country with the highest proportion in landings is Spain, except for nep.fu.2627, nep.fu.2829 (Norway lobster) and jax.27.9a.ib (horse mackerel) (Figure 3).

In summary, the selection of species/stocks suitable for the implementation of a regional sampling plan took into account four criteria: stocks with high landings, stocks shared by vessels from several countries, and stocks with assessment and stocks fished in large proportion by these metiers (with important landings by this fleet comparatively to other fleets).

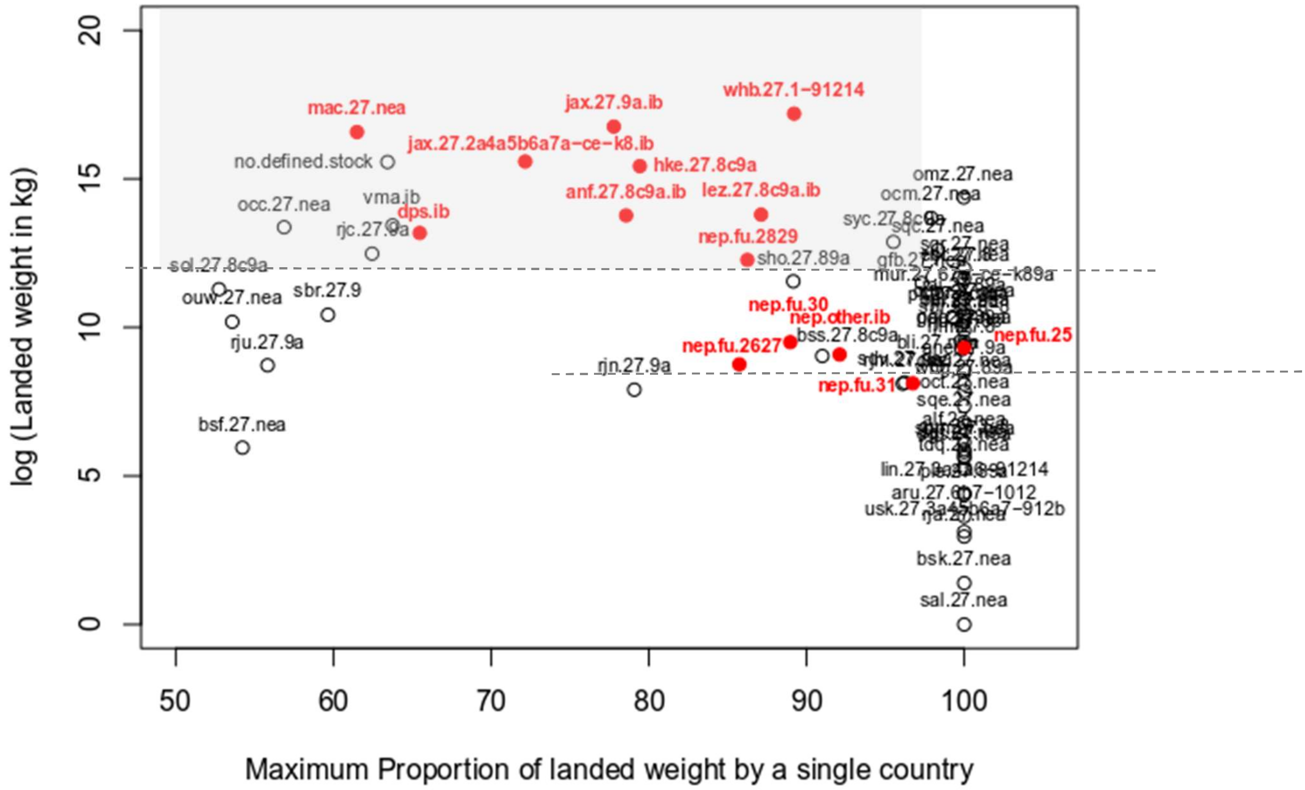


Figure 3. Importance of stocks landed by the Iberian trawl fleet in 2015-2016 represented by log of total annual landed weight (total annual landed weight of each stock is the sum of PRT+ESP total annual landed weight, where each country's annual landed weight is the mean of 2015 total annual landings and 2016 total annual landings, in kg) versus the maximum percentage of this landed weight by a single country's vessels (considering as 100%: the sum of the PRT mean annual landings and the ESP mean annual landings). Stocks in red were selected for the case study analysis, horizontal and vertical dashed lines represent the (non-numeric and non-fixed) thresholds considered for the selection of species (see text above about the four criteria of selection).

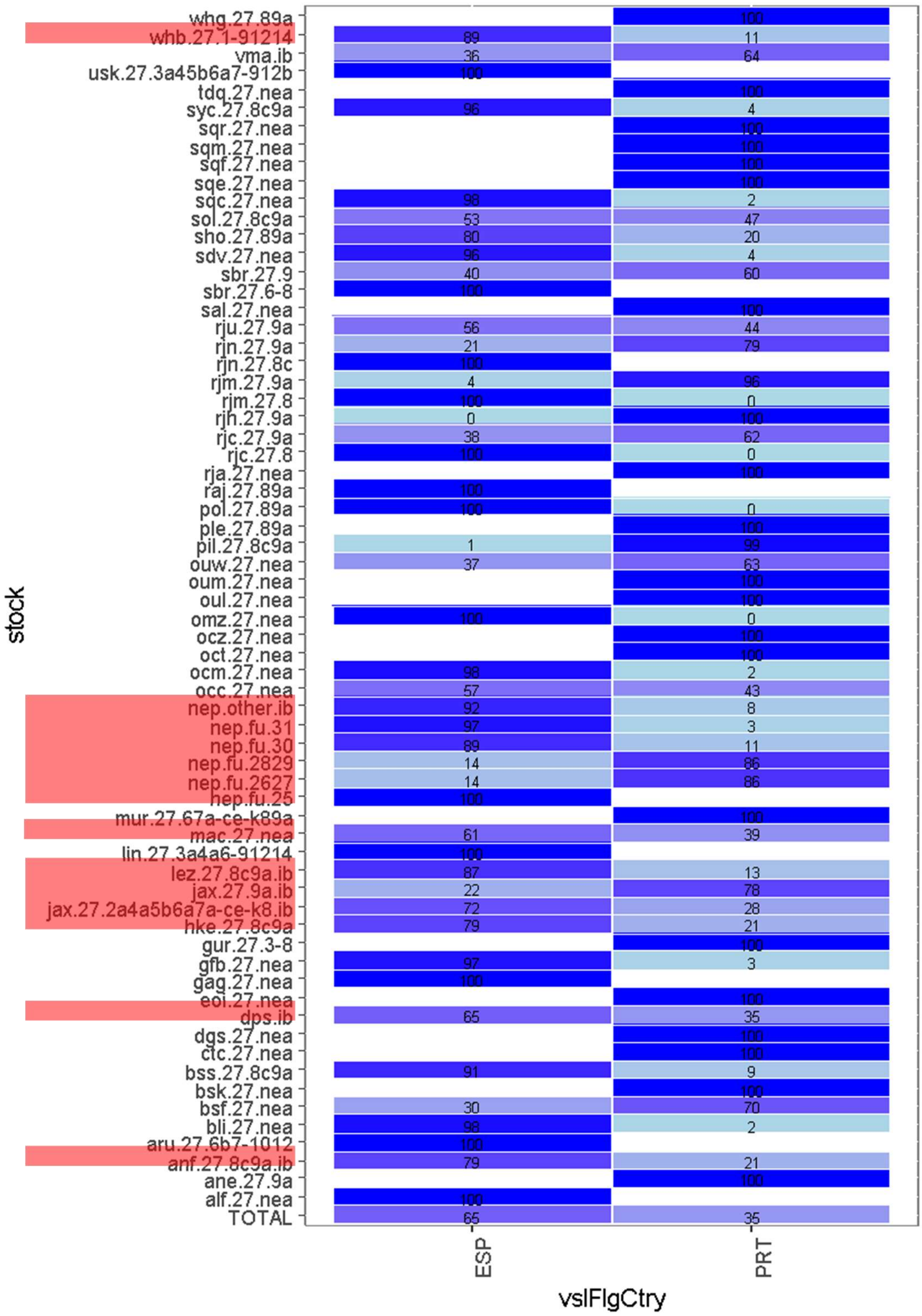


Figure 4. Percentage of total landed weight by vessel flag country for stocks landed by the Iberian trawl fleet in 2015-2016.

In addition to the four variables/criteria considered, other possible criteria/variables were initially considered but disregarded as they did not add more information. Namely, we applied diversity indices to provide simple measures that characterize how the landings of each species/stock are distributed among countries. Diversity indices are commonly used in community ecology to describe how rich and homogeneous ecological communities are, but here instead of comparing sites based on species abundance in each site, we compared stocks based on countries' landings in each stock. We computed a set of classical diversity indices (Shannon diversity index, Simpson diversity index, Pielou's evenness index). Simpson diversity index is based on the probability of two randomly drawn individuals belonging to the same species; it is a dominance index because it gives more weight to common or dominant species, and is less sensitive to richness. Pielou's evenness index describes how evenly are abundances distributed among species (here describes how evenly is a stock landed by different countries). Shannon diversity index increases as both the richness and the evenness of the community increase. When applied to the Iberian trawl fleet data set, this set of diversity indices are highly correlated which each other and with the variable maximum proportion of stock landed by a single country. The variable with the most immediate interpretation and calculation was kept: maximum percentage of landings by a single country's vessels.

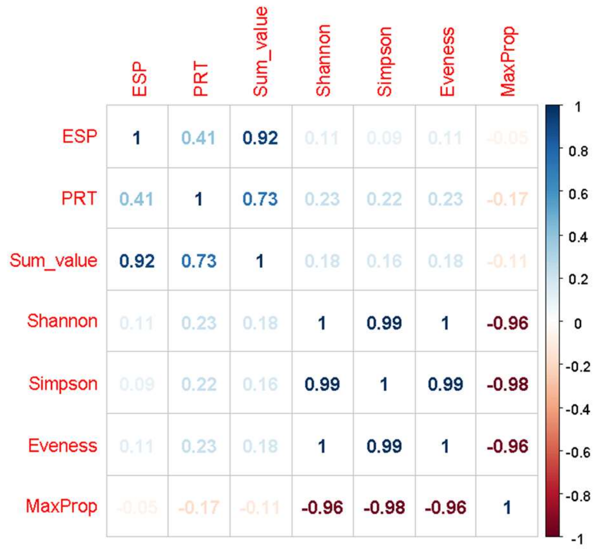


Figure 5. Correlation coefficient matrix for the stocks landed Iberian trawl fleet in 2015-2016, namely for the variables: landings by Spanish vessels, landings by Portuguese vessels, sum of landings by Spanish and Portuguese vessels, Shannon diversity index, Simpson diversity index, Pielou's evenness index, Maximum percentage of landings by a single country's vessels.

Four species account for the 86.7% of the 2015-2016 total landings (blue whiting, horse mackerel, mackerel and hake) (Table 1). From the remaining species, there are 13 with more than 700 tons each which contribute up to the 95.0%. The species/groups of species selected for the Iberian case study account for the 89.3% of the total landings.

Table 1. Landings (tonnes) by species in Divisions 27.8.c and 27.9.a.

sppFAO	landings	per_land	cum_per_land	n_trips	rank_trips
WHB	56007,3	33,2	33,2	21093	3
JAX	49408,1	29,3	62,5	26733	2
MAC	31631,6	18,7	81,2	10853	7
HKE	9237,7	5,5	86,7	32983	1
OMZ	3439,1	2,0	88,7	11994	6
BOG	2049,5	1,2	89,9	3243	29
LEZ	1943,1	1,2	91,1	14034	4
ANF	1806,5	1,1	92,2	13460	5
VMA	1345,1	0,8	93,0	4432	19
BIB	1053,5	0,6	93,6	6751	9
XOD	865,9	0,5	94,1	4326	21
OCM	773,2	0,5	94,6	5677	13
RJC	763,0	0,5	95,0	6506	10
SYC	635,9	0,4	95,4	4508	18
SBA	613,5	0,4	95,8	6233	12
OCC	600,3	0,4	96,1	6336	11
GUX	435,8	0,3	96,4	4205	22
NEP	421,0	0,2	96,6	3966	23
DPS	366,0	0,2	96,8	2930	31

Simulations

Simulation settings

Several sampling scenarios were simulated to explore the optimal approach to data collection at the regional level.

Based on results from the previous project FishPi (CS4, hake case study), which proved scenarios based on port stratification allowed improved estimates, in the present case study port stratification was included in the scenarios.

The fishPi2 dataset was compiled by the participating countries and was used in the simulation study to run the simulations and generate output statistics. For this work, 2015 data set was used to set the strata, and the 2016 dataset to run the simulations on.

General settings

- PSU (primary sampling unit): Site (Port) & Day
- SSU (secondary sampling unit): Trip

- Domain: species/area/metier level 5 (e.g. WHB-9.a-OTB_DEF)
- Number of simulations/scenario: 1.000 simulations
- Variable of interest: landed weight per species per trip (considered as a proxy exercise for an exercise focusing on length and age distributions).

Site and Day were selected with random sampling without replacement from all possible site and day units available. The secondary sampling unit was a random selection of up to two trips, selected without replacement, from the total number of trips available for selection on the site and day.

Effort allocation

Flexibility in the total effort used in the regional scheme was simulated using various effort allocations:

1. Full effort: 100 % (380 PSU, representing the total current national effort)
2. Reduced effort: 80% of full effort: (304 PSU).

In a first stage we compared results of scenarios with equivalent full effort, and in a second stage we compared results of a smaller set of scenarios already including scenarios with different effort (full and reduced).

Scenarios

Different scenarios were run to represent different stratifications (Table 2) and sampling effort (as explained above). The main types of scenarios were:

Simple Random Sampling (SRS)

For the SRS, no stratification is applied, site and day were selected with random sampling without replacement from all possible site and day units available.

Country and Institute

Country and Institute scenarios imply a stratification by country or institute thus mirroring the current situation. Only ports currently sampled are included. The inclusion of the variable institute is explained by the fact that two institutes are in charge of planning and performing sampling the Spanish Fleet, depending on the landing port.

Foreign fleet

Sampling of foreign fleet is accomplished in all scenarios, unless directly specified ("no foreign sampling" scenarios).

Major and minor Ports

Regional approaches without national or institute stratification.

Alternative scenarios included different sets of ports according to their importance at regional level, i.e. sets of ports that contributed to: a) a given percentage of landed weight (80%: 12 ports, 85%: 15 ports, 90%: 17 ports), b) a given percentage of number of trips (80%: 16 ports, 85%: 18 ports, 90%: 21 ports), and finally c) a given percentage of landed weight and number of trips (80%: 16 ports, 85%: 18 ports, 90%: 22 ports). The set of ports in options b) and c) were equivalent, so those analyses were only performed once.

Only ports adding up to the thresholds established are included, unless directly specified ("minor ports standard allocation" scenarios).

Minor standard allocation

Under these scenarios, ports are stratified in two regional strata, major ports and minor ports.

A systematic sampling effort is allocated to the minor ports, namely a standard effort allocation of 4 PSU.

Table 2. Scenarios simulated with 380 PSUs.

ID	Scenario
S1	Simple random sampling
S4	Country
S6	Country, no foreign
S8	Institute
S10	Institute, no foreign
S12	Major Ports by landings at 80%
S13	Major Ports by landings at 85%
S14	Major Ports by landings at 90%
S18	Major Ports by landings at 80%, no foreign
S19	Major Ports by landings at 85%, no foreign
S20	Major Ports by landings at 90%, no foreign
S22	Major Ports by landings at 80%, minor ports standard allocation
S23	Major Ports by landings at 85%, minor ports standard allocation
S24	Major Ports by landings at 90%, minor ports standard allocation
S26	Major Ports by landings at 80%, minor ports standard allocation, no foreign
S27	Major Ports by landings at 85%, minor ports standard allocation, no foreign
S28	Major Ports by landings at 90%, minor ports standard allocation, no foreign
S30	Major Ports by landings and trips at 80%
S31	Major Ports by landings and trips at 85%
S32	Major Ports by landings and trips at 90%
S36	Major Ports by landings and trips at 80%, no foreign
S37	Major Ports by landings and trips at 85%, no foreign
S38	Major Ports by landings and trips at 90%, no foreign
S40	Major Ports by landings and trips at 80%, minor ports standard allocation
S41	Major Ports by landings and trips at 85%, minor ports standard allocation
S42	Major Ports by landings and trips at 90%, minor ports standard allocation
S44	Major Ports by landings and trips at 80%, minor ports standard allocation, no foreign
S45	Major Ports by landings and trips at 85%, minor ports standard allocation, no foreign
S46	Major Ports by landings and trips at 90%, minor ports standard allocation, no foreign
S48	Major Ports by trips at 80%
S49	Major Ports by trips at 85%
S50	Major Ports by trips at 90%

Simulation results

WP3 identified a set of metrics (Table 3) that were computed for each scenario, to be analysed and used in the selection procedure. Coverage metrics (for PSU, tonnage and trips) refer to % of trips included in the sampling frame for each scenario. "Corrected median" and "Bias of the corrected median" were computed as additional metrics: median values were corrected using the trips coverage from each scenario in order to compare the results from the simulation with the true values (include all trips).

Table 3. Metrics obtained for each scenario

overall.Deviation	RSE_WHB	MeanEst_LEZ	TrueVal_ANF
overallDevMedian	RSE_LEZ	MedianEst_HKE	Bias_NEP
X.deviationFishOfInterest	RSE_ANF	MedianEst_LEZ	Corrected_med_WHB (*)
meanSampledTrips	RSE_DPS	MedianEst_ANF	Corrected_med_JAX
coveragePSU	RSE_NEP	MedianEst_DPS	Corrected_med_MAC
coverageTonnage	RSE_ESP	MedianEst_NEP	Corrected_med_HKE
coverageTrips	RSE_PRT	TrueVal_WHB	Corrected_med_LEZ
totRSEest	RSE_IEO	TrueVal_JAX	Corrected_med_ANF
RSEsppOInterest	RSE_IPMA	TrueVal_MAC	Corrected_med_DPS
RSEsppOInterestCiLo	RSE_AZTI	TrueVal_HKE	Corrected_med_NEP
RSEsppOInterestCiUp	MeanEst_WHB	TrueVal_LEZ	Corrected_medBias_WHB
RSEctryOInterest	MeanEst_JAX	TrueVal_DPS	Corrected_medBias_JAX
RSEctryOInterestCiLo	MeanEst_MAC	TrueVal_NEP	Corrected_medBias_MAC
RSEctryOInterestCiUp	MeanEst_HKE	Bias_WHB	Corrected_medBias_HKE
RSEinstOInterest	MeanEst_DPS	Bias_JAX	Corrected_medBias_LEZ
RSEinstOInterestCiLo	MeanEst_NEP	Bias_MAC	Corrected_medBias_ANF
RSEinstOInterestCiUp	MeanEst_ANF	Bias_HKE	Corrected_medBias_DPS
RSE_MAC	MedianEst_WHB	Bias_LEZ	Corrected_medBias_NEP
RSE_JAX	MedianEst_JAX	Bias_ANF	
RSE_HKE	MedianEst_MAC	Bias_DPS	

Full table of results can be found in Appendix I. An example of the analysis of metrics of each scenario is shown, namely: a scatterplot of estimated versus the true value of landed weight by species of interest (Figure 6), a scatterplot of the percentage deviation of estimated landed weight by species of interest in relation to the sample size (i.e number of trips with landings of a given species) (Figure 7), and a histogram of the estimated landed weight of a species of interest in the 1000 simulations (Figure 8).

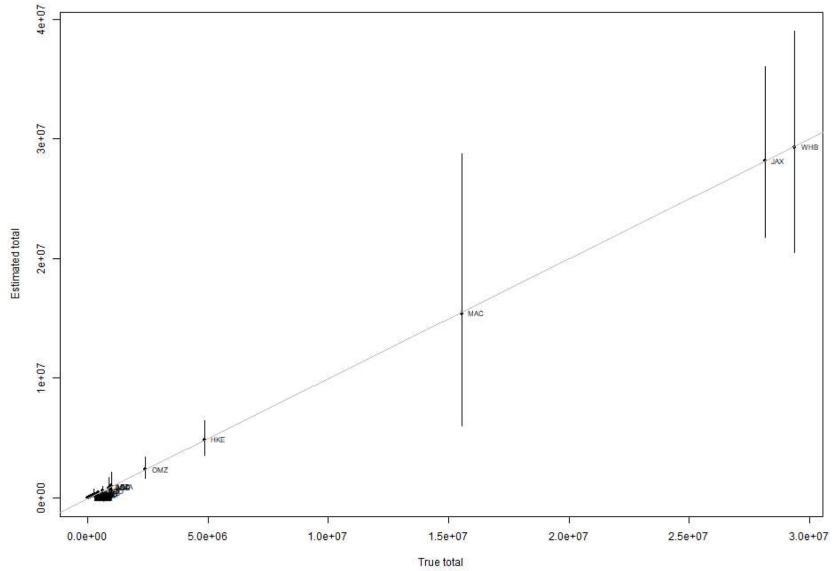


Figure 6: SRS, Estimates and 95% confidence intervals of landed tonnages by species.

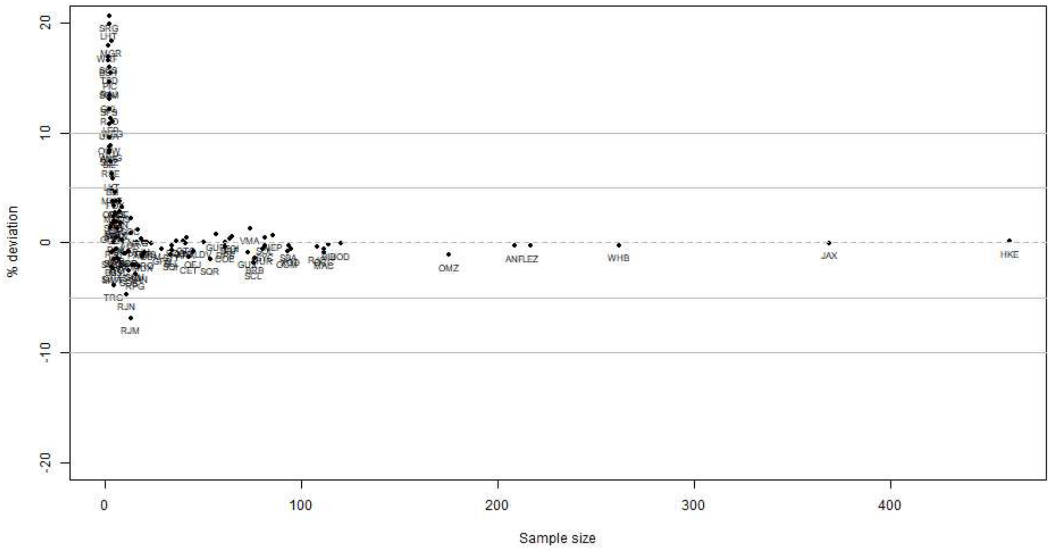


Figure 7: SRS, Percentage deviation of the estimate in relation to the sample size.

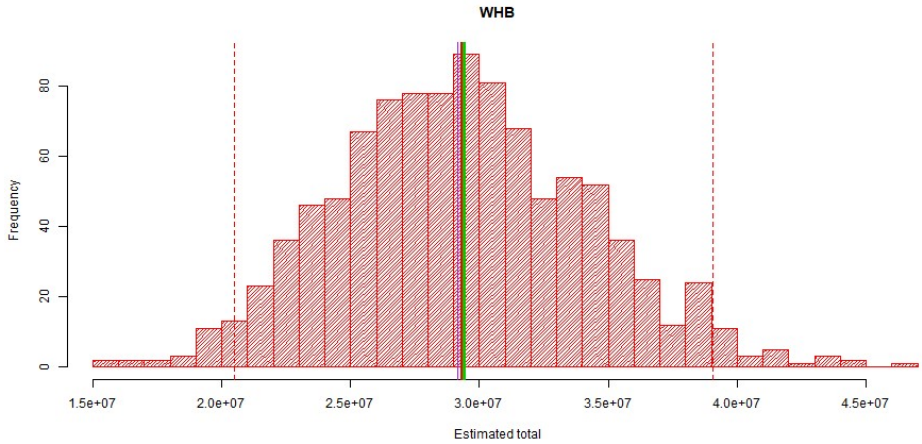


Figure 8. SRS, Distribution of 1000 estimates of total landed weight for selected species: Mean and 95% confidence intervals of the estimates (red lines), median (purple) and true value of the species landed weight (green).

Costs

We determined the total annual sampling cost (in total, per country and per institute) of each scenario, as follows. The cost per PSU in each specific port was determined by each MS. These costs encompassed current cost of staff daily salary and daily subsistence, and cost of travel considering distance to cover by the sampling team from the nearest team base location. Then we considered the mean number of PSU assigned to each port in the 1000 simulations of each scenario.

Process and definition of criteria for selection of sampling design

Process

The present exercise focused on the effects of alternative scenarios of sampling design on the estimated landed weight of the main landed species. Landed weight is not the variable of interest in sampling, but we considered that the effect on that variable could work as a proxy for the effects on the estimated length/age composition of the landings which are the variables of interest in sampling.

A regional sampling design should ensure unbiased and precise estimates of the variable of interest for stock assessment, namely the annual landings length/age composition by species. Therefore, the main criteria used for the scenarios evaluation were:

1. Bias by species and for the group of species of interest
2. Precision by species and for the group of species of interest
3. Overall deviation (overall.Deviation, overallDevMedian, X.deviationFishOInterest)

Equal weight is given by species, due to missing guidance/specification from end-users on data quality of the species landings length/age composition used for stock assessment.

We implemented a process for selection process consisting of four sequential steps (Figure 9). In **step 1** we considered all alternative scenarios of full effort, then we compared these scenarios based on bias and precision of individual species using a traffic light approach (Table 4 & 5). In this manner, we selected for the next step the current scenario (S6) plus a set of 16 scenarios with moderate/good bias (S22-S24, S40-S42) or precision for the species of interest (S13-S14, S19-S20, S30-S32, S36-S38). In **step 2**, we compared the latter set of scenarios based on the overall deviation using the traffic light approach and selected, for the next step, a subset of 8 scenarios with moderate/good overall deviation (S22-S24, S32, S38, S40-S42) plus the current (S6). In **step 3**, we compared each of these latter scenarios considering the full effort (380 PSU) with its counterpart scenario of reduced effort (80%=304 PSU) and since there was no relevant deterioration of bias and precision in all cases, we selected the six reduced effort scenarios presenting lower costs (S7, S25, S35, S53, S55, S57). A description of the selected scenarios can be found in Table 6.

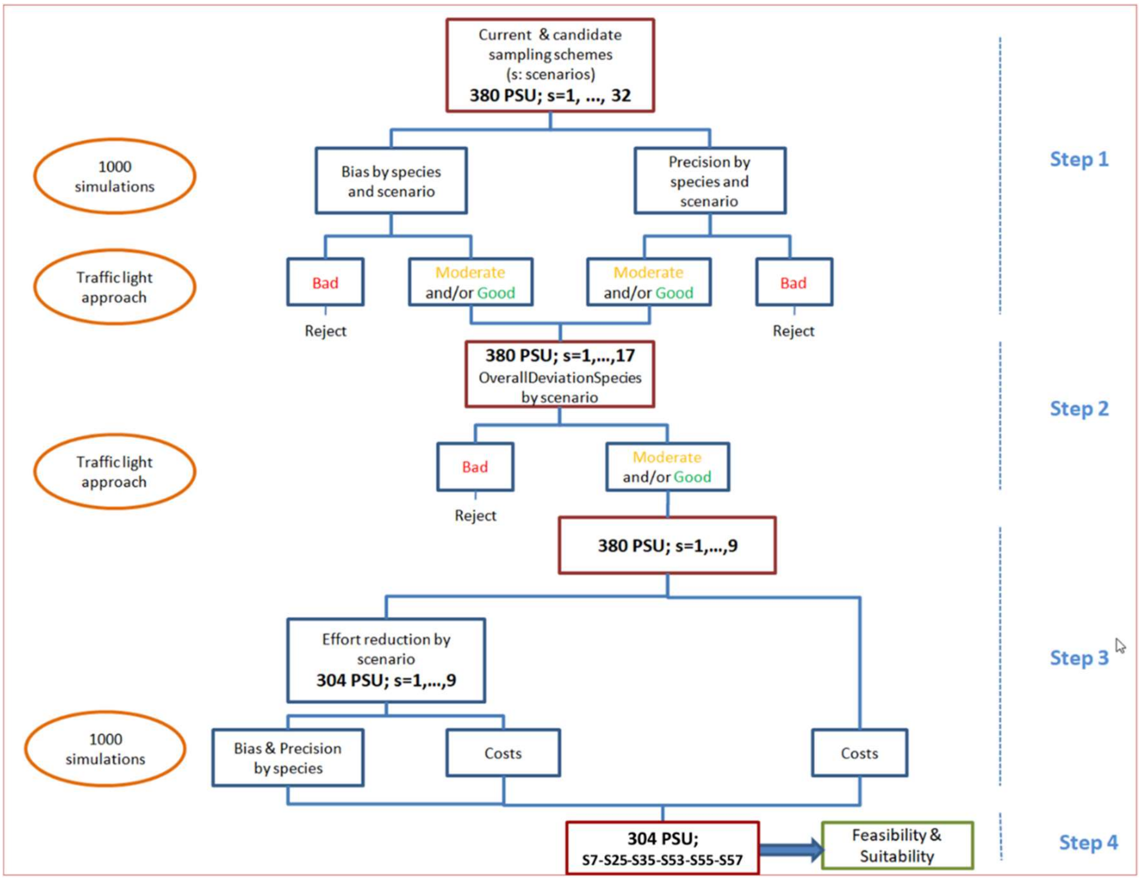


Figure 9: Process established for the evaluation of sampling schemes.

Table 4: Evaluation based on the bias by species (Step 1). Scenario S6 represents the current scheme with full effort.

	BiasMed_WHB	BiasMed_JAX	BiasMed_MAC	BiasMed_HKE	BiasMed_LEZ	BiasMed_ANF	BiasMed_DPS	BiasMed_NEP
S1 _ random_380	0.83	1.10	5.79	0.82	1.02	0.66	1.59	0.10
S4 _ samplingNowCtry_380	16.66	23.72	24.61	18.61	22.12	24.02	33.02	48.66
S6 _ samplingNowCtryOwn_380	8.22	29.86	31.01	11.47	14.08	19.23	33.68	47.07
S8 _ samplingNowInst_380	16.71	23.91	24.41	17.79	23.16	24.44	33.85	47.89
S10 _ samplingNowInstOwn_380	8.57	30.37	29.53	11.33	13.00	18.37	32.26	48.13
S12 _ MajorPorts80_380	12.59	25.19	27.51	24.40	26.76	34.90	99.85	93.56
S13 _ MajorPorts85_380	8.62	12.06	21.79	15.45	25.65	32.68	60.79	76.81
S14 _ MajorPorts90_380	6.42	5.10	21.26	12.63	24.56	32.12	61.29	76.93
S18 _ MajorPorts80Own_380	4.33	34.98	31.27	16.16	17.10	29.88	99.91	93.17
S19 _ MajorPorts85Own_380	0.05	22.16	26.66	6.95	16.19	28.12	61.54	75.57
S20 _ MajorPorts90Own_380	1.03	16.44	27.79	5.25	15.31	26.64	61.01	75.83
S22 _ majorPorts80MinorStd_380	1.62	3.85	17.85	4.04	1.96	8.21	25.38	23.43
S23 _ majorPorts85MinorStd_380	1.68	0.74	15.79	1.69	2.81	6.58	16.02	19.22
S24 _ majorPorts90MinorStd_380	0.20	0.63	14.80	1.57	1.84	5.74	18.23	17.12
S26 _ majorPorts80MinorStdOwn_380	7.10	12.88	20.54	6.94	14.86	1.57	53.28	52.43
S27 _ majorPorts85MinorStdOwn_380	6.84	10.13	21.30	6.08	16.95	5.59	41.00	41.87
S28 _ majorPorts90MinorStdOwn_380	6.38	9.52	19.76	6.54	17.16	6.57	39.34	40.17
S30 _ MajorPorts80Mix_380	8.92	11.75	20.17	14.15	26.83	32.75	46.26	61.40
S31 _ MajorPorts85Mix_380	8.10	9.45	17.88	11.04	21.08	18.03	45.72	54.55
S32 _ MajorPorts90Mix_380	4.82	0.86	16.95	7.61	12.51	13.06	22.31	39.66
S36 _ MajorPorts80MixOwn_380	7.11	19.85	23.61	1.04	10.26	22.58	62.29	76.19
S37 _ MajorPorts85MixOwn_380	6.04	16.76	21.16	0.91	5.15	7.39	61.35	68.77
S38 _ MajorPorts90MixOwn_380	7.43	10.57	20.66	4.48	2.73	3.81	37.74	53.17
S40 _ majorPorts80MixMinorStd_380	1.08	0.93	13.82	2.03	1.14	5.44	15.76	16.18
S41 _ majorPorts85MixMinorStd_380	0.64	0.75	13.86	1.35	1.33	2.15	12.48	15.99
S42 _ majorPorts90MixMinorStd_380	1.38	0.96	13.33	2.46	0.79	1.90	5.19	7.77
S44 _ majorPorts80MixMinorStdOwn_380	15.60	7.79	16.61	12.26	19.80	5.33	41.24	41.51
S45 _ majorPorts85MixMinorStdOwn_380	14.64	7.73	16.16	11.33	19.33	10.39	38.80	39.58
S46 _ majorPorts90MixMinorStdOwn_380	12.86	8.05	16.30	9.61	20.05	11.81	28.82	31.19
S48 _ majorPorts80byTrip_380	9.35	12.42	20.82	14.69	25.51	31.93	45.95	61.87
S49 _ majorPorts85byTrip_380	8.42	9.05	15.35	11.67	20.27	17.75	46.23	55.36
S50 _ majorPorts90byTrip_380	6.87	8.70	18.50	7.37	12.75	12.76	22.74	38.89

Table 5: Evaluation based on the precision by species (Step 1, cont.)

	RSE_WHB	RSE_JAX	RSE_MAC	RSE_HKE	RSE_LEZ	RSE_ANF	RSE_DPS	RSE_NEP	RSEsppOInterest
S1 _ random_380	0.17	0.13	0.38	0.15	0.13	0.14	0.24	0.20	0.19
S4 _ samplingNowCtry_380	0.12	0.12	0.31	0.12	0.11	0.11	0.28	0.28	0.18
S6 _ samplingNowCtryOwn_380	0.12	0.12	0.31	0.12	0.11	0.11	0.30	0.29	0.18
S8 _ samplingNowInst_380	0.12	0.12	0.30	0.12	0.11	0.11	0.30	0.27	0.18
S10 _ samplingNowInstOwn_380	0.11	0.12	0.28	0.12	0.10	0.11	0.29	0.28	0.17
S12 _ MajorPorts80_380	0.11	0.11	0.29	0.13	0.12	0.12	0.94	0.66	0.31
S13 _ MajorPorts85_380	0.12	0.11	0.32	0.13	0.13	0.13	0.32	0.38	0.21
S14 _ MajorPorts90_380	0.14	0.11	0.34	0.14	0.13	0.14	0.35	0.40	0.22
S18 _ MajorPorts80Own_380	0.11	0.11	0.30	0.12	0.11	0.12	0.73	0.60	0.28
S19 _ MajorPorts85Own_380	0.12	0.10	0.32	0.12	0.12	0.12	0.34	0.36	0.20
S20 _ MajorPorts90Own_380	0.12	0.10	0.33	0.13	0.13	0.14	0.36	0.40	0.22
S22 _ majorPorts80MinorStd_380	0.16	0.22	1.11	0.20	0.22	0.33	1.11	0.87	0.53
S23 _ majorPorts85MinorStd_380	0.14	0.13	0.74	0.17	0.20	0.28	0.86	0.69	0.40
S24 _ majorPorts90MinorStd_380	0.14	0.11	0.72	0.16	0.19	0.27	0.67	0.60	0.36
S26 _ majorPorts80MinorStdOwn_380	0.15	0.23	0.85	0.17	0.20	0.32	1.24	1.08	0.53
S27 _ majorPorts85MinorStdOwn_380	0.15	0.14	0.66	0.16	0.18	0.32	0.63	0.67	0.36
S28 _ majorPorts90MinorStdOwn_380	0.13	0.11	0.76	0.14	0.17	0.28	0.61	0.57	0.35
S30 _ MajorPorts80Mix_380	0.14	0.11	0.32	0.13	0.14	0.13	0.28	0.27	0.19
S31 _ MajorPorts85Mix_380	0.14	0.11	0.34	0.13	0.14	0.12	0.30	0.25	0.19
S32 _ MajorPorts90Mix_380	0.15	0.12	0.36	0.14	0.14	0.13	0.26	0.24	0.19
S36 _ MajorPorts80MixOwn_380	0.12	0.11	0.33	0.12	0.12	0.13	0.35	0.38	0.21
S37 _ MajorPorts85MixOwn_380	0.13	0.11	0.33	0.13	0.12	0.12	0.36	0.32	0.20
S38 _ MajorPorts90MixOwn_380	0.14	0.11	0.34	0.14	0.12	0.13	0.30	0.30	0.20
S40 _ majorPorts80MixMinorStd_380	0.15	0.13	0.77	0.16	0.19	0.28	0.56	0.61	0.36
S41 _ majorPorts85MixMinorStd_380	0.14	0.13	0.75	0.16	0.16	0.18	0.50	0.50	0.32
S42 _ majorPorts90MixMinorStd_380	0.15	0.12	0.62	0.15	0.14	0.15	0.34	0.33	0.25
S44 _ majorPorts80MixMinorStdOwn_380	0.14	0.14	0.55	0.14	0.17	0.27	0.63	0.66	0.34
S45 _ majorPorts85MixMinorStdOwn_380	0.13	0.13	0.55	0.15	0.15	0.18	0.56	0.58	0.30
S46 _ majorPorts90MixMinorStdOwn_380	0.14	0.12	0.60	0.15	0.13	0.15	0.29	0.28	0.23
S48 _ majorPorts80byTrip_380	0.13	0.11	0.33	0.13	0.13	0.13	0.28	0.27	0.19
S49 _ majorPorts85byTrip_380	0.13	0.12	0.32	0.14	0.13	0.12	0.31	0.25	0.19
S50 _ majorPorts90byTrip_380	0.15	0.12	0.35	0.14	0.13	0.12	0.26	0.24	0.19

Selection of scenarios

Table 6: Set of scenarios selected in Step 4 of the scenario selection process shown in Figure 9.

Criteria		S7 SamplingNowCtryOwn_204	S25 MajorPorts85MinorStd_304	S35 MajorPorts90Mix_304	S53 MajorPorts90MinorSt_304	S55 MajorPorts90MixOwn_304	S57 MajorPorts90MixMinorStd_304
Bias by species		=S6	<<S6	<S6	<<S6	<S6	<<S6
Precision by species		=S6	>>S6	>S6	>>S6	>S6	>S6
Cost	Ratio **	0.80	0.87	0.87	0.85	0.85	0.87
PSU	ESP PRT	208 96	196 108	188 116	190 114	188 116	187 117
Feasibility issues	 ESP PRT	a) None b) - b) PTSSB	a) High b) T.B.D. b) PTNZR	a) Medium b) Spanish ports in 9aS. ESSDR & T.B.D. b) PTSSB, PTNZR	a) High b) T.B.D. b) PTNZR	a) Low b) ESSDR & T.B.D b) PTSSB, PTNZR	a) High b) ESSDR & T.B.D. b) PTSSB, PTNZR
Suitability issues	ESP PRT	c) - c) -	c) - c) High	c) - c) High	c) - c) High	c) - c) High	c) - c) High

*Bias and Precision by species: relative to current scheme with full effort (S6)

** Ratio: ratio of cost of given scenario relative to current scheme with full effort (S6)

Feasibility issues: a) Uncertainty. Risk of zero samples & expenses loss; b) Logistics

Suitability: c) Zero PSU assigned to port important for DPS,NEP (PTVRE)

In **step 4** of the selection process we compared the set of 6 scenarios selected in the previous step (current scenario (S7) plus 5 others, all with reduced effort). To select among this set of scenarios, we took into consideration the trade-off between several aspects: bias and precision by species; cost; distribution of effort among countries; feasibility and suitability. All five scenarios of reduced effort had a lower bias and a higher precision than the current scenario of full effort, i.e. all were acceptable in terms of bias and precision. Moreover, these five scenarios of reduced effort cost slightly more than the current reduced scenario which seems acceptable (85%-87% versus 80% of cost of current full effort scenario). Three of these scenarios include minor ports which implies more feasibility issues than the current scenarios, namely higher uncertainty associated to those ports (risk of zero samples due to lower mean number of trips per day than in major ports) as well as possible unknown logistic issues since there is no previous experience with some of that ports. Also, several scenarios imply feasibility issues related to logistics (risk of incomplete samples due to incomplete landing of trips in some ports, and risk of no/incomplete samples due to difficulties in accessing landings). In the case of Portugal, these issues are similar to the current scenario. Finally, all five scenarios have lower suitability than current scenario since they do not assign sampling to ports important for the Portuguese fishery directed to crustaceans. Crustaceans have low landed weight (this study was based on landed weight/nr trips) and are landed by a specific metier level 5 (this study could not consider metier level 5 as a strata, since some vessels operate within more than one metier level 5 and distinction of trips can't be established). To avoid this suitability issue it would be necessary for instance to consider species landed value as a variable. In alternative, an additional number of samples could be assigned to these ports.

In the end, two scenarios (S35 and S55) seem to present the best tradeoff between the criteria considered: scenario S35 and S55 (stratified by ports representing 90% of landings and of number of trips, and has 80% of sampling effort) with the main difference between the two being that S35 considers sampling of foreign landings and S55 does not.

Conclusions

In the current study, we compared different alternative regional designs for a regional on-shore sampling of landings of the Iberian trawl fleet. Scenarios were compared in a sequential manner with each step selecting a subset of scenarios to be compared in the next step. The comparison was based on several statistical metrics (looking at bias and precision) and only in the end based on cost and feasibility/suitability issues. The first steps compared designs that differed in the stratification considered and the last steps considered differences in effort as well.

The first step compared the effect on bias and precision of estimated landed weight of the main species of interest landed by this fleet, and the second step compared the effect on the overall deviation. Subsequently, the third step compared each scenario of full effort with its counterpart scenario of reduced effort (80%), and since in all cases there was no relevant deterioration of bias and precision, we selected the scenarios of reduced effort with lower cost. In the final fourth step we considered feasibility and suitability issues and selected two scenarios which are suitable for testing through a pilot study.

In all, selection criteria were based on improving bias while taking into account also cost and feasibility and suitability issues. There was a trade-off between bias and precision of estimated landed weight among scenarios, and bias and precision from current scenario is better than in several of the alternative simulated scenarios, but there is no way to evaluate their absolute values. Moreover, although there were no large differences in cost between statistically pre-selected scenarios, some of them (that included sampling of minor ports) imply higher workload and likely imply costs spent in unsuccessful sampling events. Statistical advantages should prove to be very relevant to take that step which was not the case. Briefly, the two selected scenarios reduce effort and cost, and improve bias, with different feasibility and suitability issues than the current scenario (S35 less issues).

It is important to highlight that the present case study is a simulation study that lacks a practical testing. Moreover we used effects on landed weight as a proxy for effect on actual parameters of interest (length/age distribution). Therefore, before any implementation of a regional sampling scheme (such as the scenario selected here) it is necessary to perform a pilot study simultaneously with the current national schemes and assess/compare the results. Before implementing such a pilot study it is necessary to consider the cost implications especially if the pilot study is to be implemented in the current multi-annual EUMAP where such a pilot study was not planned and budgeted. In this context, it should be noted that the pilot study will need to be implemented in parallel with the current national schemes that are ongoing so that the results can be compared. To make an efficient use of resources, data (PSUs) from the national sampling schemes will be used simultaneously for the pilot study, and only additional sampling PSUs needed specifically for the pilot will bring additional costs.

Appendix I

Table 7 - results obtained for the metrics used in the scenario selection procedure

ID_scenario	scenarioEff	PSUs	RSE_WHB	RSE_JAX	RSE_MAC	RSE_HKE	RSE_LEZ	RSE_ANF	RSE_DPS	RSE_NEP	RSE_ESP	RSE_PRT	RSE_IEO	RSE_IPMA	RSE_AZTI	MeanEst_WHB	MeanEst_JAX	MeanEst_MAC
S1	random_380	380	0.17	0.13	0.38	0.15	0.13	0.14	0.24	0.20	0.13	0.12	0.14	0.12	0.59	29323463	28160974	15412573
S2	random_304	304	0.19	0.15	0.42	0.17	0.16	0.15	0.28	0.22	0.14	0.13	0.14	0.13	0.67	29109512	28193940	15686902
S3	random_228	228	0.23	0.17	0.51	0.20	0.18	0.17	0.32	0.26	0.17	0.15	0.18	0.15	0.78	28992266	28429338	15343194
S4	samplingNowCtry_380	380	0.12	0.12	0.31	0.12	0.11	0.11	0.28	0.28	0.10	0.10	0.11	0.10	0.40	24537082	21577759	12186757
S5	samplingNowCtry_304	304	0.14	0.13	0.35	0.14	0.13	0.13	0.34	0.32	0.11	0.12	0.11	0.12	0.48	24314616	21751179	12204911
S6	samplingNowCtryOwn_380	380	0.12	0.12	0.31	0.12	0.11	0.11	0.30	0.29	0.09	0.10	0.10	0.10	0.27	27014538	19833071	11212556
S7	samplingNowCtryOwn_304	304	0.13	0.13	0.34	0.13	0.12	0.12	0.33	0.31	0.11	0.11	0.11	0.11	0.31	27180585	19743425	11264747
S8	samplingNowInst_380	380	0.12	0.12	0.30	0.12	0.11	0.11	0.30	0.27	0.10	0.10	0.10	0.10	0.46	24559132	21603401	12299724
S9	samplingNowInst_304	304	0.14	0.13	0.33	0.13	0.13	0.13	0.32	0.31	0.10	0.11	0.11	0.11	0.54	24629052	21629834	12371017
S10	samplingNowInstOwn_380	380	0.11	0.12	0.28	0.12	0.10	0.11	0.29	0.28	0.09	0.10	0.09	0.10	0.30	26973753	19778285	11219334
S11	samplingNowInstOwn_304	304	0.13	0.13	0.34	0.13	0.12	0.12	0.33	0.30	0.10	0.12	0.10	0.12	0.33	27005940	19814446	10990660
S12	MajorPorts80_380	380	0.11	0.11	0.29	0.13	0.12	0.12	0.94	0.66	0.09	0.08	0.09	0.08	NA	25667301	21186895	11550985
S13	MajorPorts85_380	380	0.12	0.11	0.32	0.13	0.13	0.13	0.32	0.38	0.10	0.08	0.10	0.08	0.46	26921824	24812309	12700289
S14	MajorPorts90_380	380	0.14	0.11	0.34	0.14	0.13	0.14	0.35	0.40	0.10	0.08	0.10	0.08	0.48	27676469	26770058	12638732
S15	MajorPorts80_304	304	0.13	0.12	0.34	0.14	0.14	0.13	0.88	0.73	0.10	0.10	0.10	0.10	NA	25898698	21060028	11562490
S16	MajorPorts85_304	304	0.14	0.12	0.36	0.15	0.15	0.15	0.39	0.42	0.11	0.09	0.11	0.09	0.49	26813735	24769046	12803388
S17	MajorPorts90_304	304	0.15	0.12	0.37	0.16	0.15	0.15	0.40	0.45	0.11	0.08	0.12	0.08	0.55	27362857	26640077	12689573
S18	MajorPorts80Own_380	380	0.11	0.11	0.30	0.12	0.11	0.12	0.73	0.60	0.08	0.08	0.08	0.08	NA	28227322	18443072	11104440
S19	MajorPorts85Own_380	380	0.12	0.10	0.32	0.12	0.12	0.12	0.34	0.36	0.09	0.08	0.10	0.08	0.31	29520075	21980725	11685109
S20	MajorPorts90Own_380	380	0.12	0.10	0.33	0.13	0.13	0.14	0.36	0.40	0.10	0.08	0.10	0.08	0.32	29836397	23706009	11620309
S21	MajorPorts85Own_304	304	0.14	0.12	0.36	0.14	0.14	0.15	0.39	0.43	0.10	0.09	0.11	0.09	0.33	29560601	22082276	11509783
S22	majorPorts80MinorStd_380	380	0.16	0.22	1.11	0.20	0.22	0.33	1.11	0.87	0.27	0.32	0.11	0.32	2.39	29507117	28293227	16269092
S23	majorPorts85MinorStd_380	380	0.14	0.13	0.74	0.17	0.20	0.28	0.86	0.69	0.18	0.15	0.11	0.15	2.37	29313523	28361352	15235730
S24	majorPorts90MinorStd_380	380	0.14	0.11	0.72	0.16	0.19	0.27	0.67	0.60	0.18	0.10	0.11	0.10	2.19	29609192	28096024	15513244
S25	majorPorts85MinorStd_304	304	0.16	0.15	0.78	0.17	0.20	0.30	0.74	0.65	0.19	0.15	0.12	0.15	2.54	29604465	28387749	15059980
S26	majorPorts80MinorStdOwn_380	380	0.15	0.23	0.85	0.17	0.20	0.32	1.24	1.08	0.20	0.30	0.10	0.30	2.02	32124099	25583663	14810779
S27	majorPorts85MinorStdOwn_380	380	0.15	0.14	0.66	0.16	0.18	0.32	0.63	0.67	0.16	0.16	0.11	0.16	2.24	31945435	25740638	13707078
S28	majorPorts90MinorStdOwn_380	380	0.13	0.11	0.76	0.14	0.17	0.28	0.61	0.57	0.17	0.10	0.11	0.10	2.48	31514341	25600550	14139553
S29	majorPorts85MinorStdOwn_304	304	0.16	0.15	0.82	0.16	0.18	0.29	0.66	0.67	0.19	0.15	0.12	0.15	2.69	31992370	25865872	13751743
S30	MajorPorts80Mix_380	380	0.14	0.11	0.32	0.13	0.14	0.13	0.28	0.27	0.10	0.08	0.10	0.08	0.48	26988602	24852564	12853915
S31	MajorPorts85Mix_380	380	0.14	0.11	0.34	0.13	0.14	0.12	0.30	0.25	0.10	0.08	0.11	0.08	0.48	27077079	25623862	13183538
S32	MajorPorts90Mix_380	380	0.15	0.12	0.36	0.14	0.14	0.13	0.26	0.24	0.11	0.09	0.11	0.09	0.55	28099783	27958330	13465264
S33	MajorPorts80Mix_304	304	0.15	0.12	0.36	0.16	0.15	0.15	0.32	0.30	0.11	0.09	0.12	0.09	0.50	26675201	24866092	12838985
S34	MajorPorts85Mix_304	304	0.15	0.13	0.36	0.16	0.15	0.14	0.35	0.27	0.12	0.10	0.12	0.10	0.57	27000264	25806257	13011338
S35	MajorPorts90Mix_304	304	0.17	0.14	0.40	0.16	0.15	0.14	0.30	0.28	0.13	0.10	0.13	0.10	0.59	27927433	27592122	13483021
S36	MajorPorts80MixOwn_380	380	0.12	0.11	0.33	0.12	0.12	0.13	0.35	0.38	0.09	0.08	0.10	0.08	0.30	31648432	22822480	12319991
S37	MajorPorts85MixOwn_380	380	0.13	0.11	0.33	0.13	0.12	0.12	0.36	0.32	0.10	0.08	0.10	0.08	0.32	31279235	23624806	12607740
S38	MajorPorts90MixOwn_380	380	0.14	0.11	0.34	0.14	0.12	0.13	0.30	0.30	0.11	0.08	0.11	0.08	0.36	31796593	25373486	12885622
S39	MajorPorts85MixOwn_304	304	0.14	0.13	0.38	0.15	0.14	0.13	0.40	0.38	0.11	0.09	0.12	0.09	0.37	31335118	23525244	13025429
S40	majorPorts80MixMinorStd_380	380	0.15	0.13	0.77	0.16	0.19	0.28	0.56	0.61	0.19	0.15	0.11	0.15	2.38	29459434	28193830	15240606
S41	majorPorts85MixMinorStd_380	380	0.14	0.13	0.75	0.16	0.16	0.18	0.50	0.50	0.19	0.13	0.11	0.13	2.27	29412563	28118833	15586012
S42	majorPorts90MixMinorStd_380	380	0.15	0.12	0.62	0.15	0.14	0.15	0.34	0.33	0.16	0.09	0.12	0.09	1.85	29228826	28173782	15489454
S43	majorPorts85MixMinorStd_304	304	0.17	0.15	0.62	0.17	0.18	0.20	0.52	0.53	0.17	0.14	0.12	0.14	1.99	29372646	28203486	15152893
S44	majorPorts80MixMinorStdOwn_380	380	0.14	0.14	0.55	0.14	0.17	0.27	0.63	0.66	0.13	0.16	0.11	0.16	1.98	34217478	26338108	14120115
S45	majorPorts85MixMinorStdOwn_380	380	0.13	0.13	0.55	0.15	0.15	0.18	0.56	0.58	0.14	0.13	0.11	0.13	1.90	33851327	26222078	14229956
S46	majorPorts90MixMinorStdOwn_380	380	0.14	0.12	0.60	0.15	0.13	0.15	0.29	0.28	0.15	0.09	0.11	0.09	1.91	33331392	26134622	14419134
S47	majorPorts85MixMinorStdOwn_304	304	0.16	0.14	0.70	0.15	0.16	0.19	0.57	0.56	0.17	0.14	0.12	0.14	2.28	33884967	26253479	14819416
S48	majorPorts80byTrip_380	380	0.13	0.11	0.33	0.13	0.13	0.13	0.28	0.27	0.10	0.08	0.10	0.08	0.46	26929803	24843154	12709557
S49	majorPorts85byTrip_380	380	0.13	0.12	0.32	0.14	0.13	0.12	0.31	0.25	0.10	0.08	0.11	0.08	0.49	27007971	25694645	13418354
S50	majorPorts90byTrip_380	380	0.15	0.12	0.35	0.14	0.13	0.12	0.26	0.24	0.11	0.09	0.12	0.09	0.54	27722233	25980618	13054136
S51	MajorPorts90Own_304	304	0.14	0.12	0.38	0.14	0.14	0.13	0.40	0.44	0.11	0.09	0.11	0.09	0.35	30030599	23767838	11631526
S52	majorPorts80MinorStd_304	304	0.17	0.21	0.96	0.22	0.22	0.36	1.12	0.88	0.23	0.29	0.11	0.29	2.11	29439116	27994539	15500171
S53	majorPorts90MinorStd_304	304	0.16	0.13	0.75	0.17	0.19	0.28	0.69	0.62	0.19	0.11	0.13	0.11	2.31	29043703	28182917	15444963
S54	MajorPorts80MixOwn_304	304	0.13	0.12	0.35	0.14	0.13	0.14	0.42	0.44	0.10	0.09	0.10	0.09	0.34	31661562	22809261	12276996
S55	MajorPorts90MixOwn_304	304	0.15	0.13	0.40	0.15	0.14	0.14	0.32	0.34	0.12	0.10	0.12	0.10	0.39	32067747	25508548	12862282
S56	majorPorts80MixMinorStd_304	304	0.16	0.15	0.67	0.18	0.20	0.30	0.58	0.63	0.17	0.15	0.13	0.15	2.06	29289798	28144108	15340619
S57	majorPorts90MixMinorStd_304	304	0.16	0.13	0.71	0.17	0.16	0.17	0.34	0.34	0.18	0.10	0.13	0.10	1.98	29736166	28435778	15895673

ID_scenario	scenarioEff	PSUs	MeanEst_HKE	MeanEst_LEZ	MeanEst_ANF	MeanEst_DPS	MeanEst_NEP	MedianEst_WH	MedianEst_JA	MedianEst_MA	MedianEst_HK	MedianEst_LE	MedianEst_AN	MedianEst_DP	MedianEst_NE	TrueVal_WHB	TrueVal_JAX	TrueVal_MAC
S1	random_380	380	4858840	929391	892917	185605	234739	29136569	27867432	14658123	4813463	922519	889814	182595	233343	29400283	28176034	15559755
S2	random_304	304	4807178	924856	896083	188517	230149	28814290	27871680	14762025	4729388	911632	884861	182433	225236	29400283	28176034	15559755
S3	random_228	228	4780695	924884	896650	186519	232146	28301389	27989976	14246461	4689413	907292	884348	180029	226775	29400283	28176034	15559755
S4	samplingNowCtry_380	380	3990274	728216	684833	126537	123366	24501024	21493221	11730910	3949824	725900	680533	124288	119663	29400283	28176034	15559755
S5	samplingNowCtry_304	304	3975072	725523	683416	124590	122843	24526754	21559673	11903356	3964998	722797	679227	124381	122762	29400283	28176034	15559755
S6	samplingNowCtryOwn_380	380	4334247	803926	728188	126102	127587	26984947	19761409	10734545	4296238	800765	723482	123064	123385	29400283	28176034	15559755
S7	samplingNowCtryOwn_304	304	4375316	809991	731533	127077	125907	26808236	19389501	10863664	4250943	806465	722872	126936	123327	29400283	28176034	15559755
S8	samplingNowInst_380	380	4003991	720837	680679	125759	124107	24486787	21439211	11761652	3989520	716139	676797	122746	121460	29400283	28176034	15559755
S9	samplingNowInst_304	304	3991346	725152	682512	128476	127710	24188171	21597664	11937776	3991443	722801	681297	122943	122532	29400283	28176034	15559755
S10	samplingNowInstOwn_380	380	4347975	816871	734189	127861	125305	26880563	19618767	10965619	4303106	810922	731213	125702	120917	29400283	28176034	15559755
S11	samplingNowInstOwn_304	304	4334961	815060	732153	127922	126185	26683464	19815034	10982171	4299228	813435	734466	121103	122828	29400283	28176034	15559755
S12	MajorPorts80_380	380	3697719	687419	584655	340	17548	25698583	21077923	11279308	3668090	682642	583124	275	15009	29400283	28176034	15559755
S13	MajorPorts85_380	380	4150129	698305	609232	73563	56748	26867171	24778628	12169421	4103076	692970	603011	72747	54056	29400283	28176034	15559755
S14	MajorPorts90_380	380	4276528	705922	611850	75169	57195	27512873	26739975	12252295	4240040	703127	607967	71825	53779	29400283	28176034	15559755
S15	MajorPorts80_304	304	3735728	688841	589422	430	17040	25742758	21040956	11193770	3698353	685040	586907	469	13756	29400283	28176034	15559755
S16	MajorPorts85_304	304	4156978	699896	606448	73890	56111	26759889	24427125	12239075	4084997	690912	600105	72990	53782	29400283	28176034	15559755
S17	MajorPorts90_304	304	4271471	707738	609558	74248	56841	27224703	26482801	12340940	4213183	701519	606346	71466	53508	29400283	28176034	15559755
S18	MajorPorts80Own_380	380	4104075	775490	631718	227	18635	28126307	18321277	10694534	4068990	772662	628046	163	15922	29400283	28176034	15559755
S19	MajorPorts85Own_380	380	4542612	782694	650337	73820	58943	29385387	21932537	11411234	4515522	781121	643833	71361	56948	29400283	28176034	15559755
S20	MajorPorts90Own_380	380	4615724	796704	663476	74691	60314	29701888	23543431	11235146	4598395	789368	657123	72344	56329	29400283	28176034	15559755
S21	MajorPorts85Own_304	304	4563397	783856	652647	73107	56679	29380648	21898700	11103262	4536530	774144	648031	70457	53540	29400283	28176034	15559755
S22	majorPorts80MinorStd_380	380	4824517	940864	900793	192321	230016	28923019	27090868	12781811	4656921	913787	822129	138455	178475	29400283	28176034	15559755
S23	majorPorts85MinorStd_380	380	4854179	931681	898659	193121	232908	28906357	27967579	13102480	4770830	905814	836763	155830	188309	29400283	28176034	15559755
S24	majorPorts90MinorStd_380	380	4864559	934141	901097	182138	225329	29457673	27997277	13257532	4777032	914901	844260	151732	193204	29400283	28176034	15559755
S25	majorPorts85MinorStd_304	304	4887071	940566	895749	184787	222624	29234269	28066742	13267129	4808048	924279	832860	148838	184511	29400283	28176034	15559755
S26	majorPorts80MinorStdOwn_380	380	5288725	1095133	996712	149470	162654	31487991	24548098	12364460	5189819	1070529	909740	86688	110883	29400283	28176034	15559755
S27	majorPorts85MinorStdOwn_380	380	5255617	1116850	1025203	134055	163754	31409915	25321753	12244984	5147985	1090020	945818	109483	135495	29400283	28176034	15559755
S28	majorPorts90MinorStdOwn_380	380	5249907	1114851	1027084	137003	158845	31274731	25492314	12485536	5170442	1091941	954571	112557	139455	29400283	28176034	15559755
S29	majorPorts85MinorStdOwn_304	304	5294343	1113259	1001856	136012	162680	31609496	25441826	12167238	5215547	1091978	929061	111318	134855	29400283	28176034	15559755
S30	MajorPorts80Mix_380	380	4181223	691423	608236	103300	91796	26770443	24866100	12421685	4166316	681988	602372	99718	89966	29400283	28176034	15559755
S31	MajorPorts85Mix_380	380	4343387	744069	738964	104529	109025	27020116	25512582	12777342	4317037	735585	734175	100727	105953	29400283	28176034	15559755
S32	MajorPorts90Mix_380	380	4546792	824857	782506	147348	143183	27982978	27932794	12922639	4483864	815400	778708	144148	140654	29400283	28176034	15559755
S33	MajorPorts80Mix_304	304	4149003	700802	614824	101335	89653	26413151	24631302	12433280	4074988	696789	608867	97161	86309	29400283	28176034	15559755
S34	MajorPorts85Mix_304	304	4353986	742660	733440	102805	107020	26786108	25619214	12581556	4284385	737876	730196	98279	103995	29400283	28176034	15559755
S35	MajorPorts90Mix_304	304	4529591	824071	782535	145386	144520	27550424	27339480	12741893	4488889	813355	775022	140695	139489	29400283	28176034	15559755
S36	MajorPorts80MixOwn_380	380	4839836	842893	697931	73055	59143	31489732	22583256	11885445	4802634	836416	693451	69973	55506	29400283	28176034	15559755
S37	MajorPorts85MixOwn_380	380	4925835	886593	832589	73599	75781	31176288	23454198	12266986	4897187	884056	829539	71716	72798	29400283	28176034	15559755
S38	MajorPorts90MixOwn_380	380	5127259	967009	872502	118881	112206	31585642	25198849	12345151	5070217	957523	861576	115521	109152	29400283	28176034	15559755
S39	MajorPorts85MixOwn_304	304	4981362	889412	836081	75328	76377	31228357	23412331	12308701	4913860	883732	833200	72129	71342	29400283	28176034	15559755
S40	majorPorts80MixMinorStd_380	380	4854269	934851	896629	186558	239988	29082147	27913690	13409097	4754377	921372	840973	156306	195374	29400283	28176034	15559755
S41	majorPorts85MixMinorStd_380	380	4863120	936256	903269	184592	226606	29211255	27965532	13403413	4787582	919662	876459	162391	195837	29400283	28176034	15559755
S42	majorPorts90MixMinorStd_380	380	4830043	931930	891373	186685	233008	28995027	27904216	13485009	4733790	924666	878670	175926	214982	29400283	28176034	15559755
S43	majorPorts85MixMinorStd_304	304	4839321	931269	896974	189001	230073	29010130	27810562	13603894	4747299	919141	871999	165006	199068	29400283	28176034	15559755
S44	majorPorts80MixMinorStdOwn_380	380	5529443	1136496	1022889	135025	163108	33988144	25981315	12975347	5447911	1116572	943439	109039	136334	29400283	28176034	15559755
S45	majorPorts85MixMinorStdOwn_380	380	5494885	1128277	1013842	132111	162782	33703962	25998824	13045552	5402824	1112221	988811	113554	140843	29400283	28176034	15559755
S46	majorPorts90MixMinorStdOwn_380	380	5392351	1127544	1014139	132883	162741	33180228	25908192	13023430	5319303	1118925	1001476	132074	160389	29400283	28176034	15559755
S47	majorPorts85MixMinorStdOwn_304	304	5452547	1128125	1018935	132327	163906	33642626	26114605	13203359	5354297	1119224	987496	113262	141329	29400283	28176034	15559755
S48	majorPorts80byTrip_380	380	4191572	697395	614762	102917	91206	26650202	24676011	12320596	4140323	694283	609722	100288	88892	29400283	28176034	15559755
S49	majorPorts85byTrip_380	380	4338276	747263	738933	102841	106429	26924510	25627483	13171486	4286547	743095	736742	99769	104055	29400283	28176034	15559755
S50	majorPorts90byTrip_380	380	4535737	818919	783654	148334	144764	27380401	25726034	12081944	4495182	813219	781426	143359	142448	29400283	28176034	15559755
S51	MajorPorts90Own_304	304	4596690	797453	659976	74242	58242	29854311	23601548	11022661	4566905	789818	656827	71512	54073	29400283	28176034	15559755
S52	majorPorts80MinorStd_304	304	4855669	924442	902923	203560	229195	28989957	27087887	12394283	4700122	896838	813358	135615	170910	29400283	28176034	15559755
S53	majorPorts90MinorStd_304	304	4784130	920097	888588	183393	240947	28934682	27958039	13400975	4701387	901543	837848	158326	190076	29400283	28176034	15559755
S54	MajorPorts80MixOwn_304	304	4890094	842190	708123	72726	59764	31578868	22745535	11803330	4858118	836422	700893	69234	56028	29400283	28176034	15559755
S55	MajorPorts90MixOwn_304	304	5136964	900127	871104	117706	114792	31936334	25506157	12130261	5072929	958758	864892	114340	110905	29400283	28176034	15559755
S56	majorPorts80MixMinorStd_304	304	4872989	932770	889628	188898	233730	29001584	27937934	13439923	4782738	916845	823775	156393	196613	29400283	28176034	15559755
S57	majorPorts90MixMinorStd_304	304	4860502	933416	894240	181317	228792	29594379	28317282	13527351	4768664	930210	874460	170451	214878	29400283	28176034	15559755

ID_scenario	scenarioEff	PSUs	TrueVal_HKE	TrueVal_LEZ	TrueVal_ANF	TrueVal_DPS	TrueVal_NEP	BiasMed_WHB	BiasMed_JAX	BiasMed_MAC	BiasMed_HKE	BiasMed_LEZ	BiasMed_ANF	BiasMed_DPS	BiasMed_NEP	Corrected_med_	Corrected_med_	Corrected_med_
S1	random_380	380	4853015	932042	895711	185554	233101	-0.83	-1.10	-5.79	-0.82	-1.02	-0.66	-1.59	0.10	29136369	27867432	14658123
S2	random_304	304	4853015	932042	895711	185554	233101	-1.99	-1.08	-5.13	-2.55	-2.19	-1.21	-1.68	-3.37	28814290	27871680	14762025
S3	random_228	228	4853015	932042	895711	185554	233101									28301389	27989976	14246461
S4	samplingNowCtry_380	380	4853015	932042	895711	185554	233101	-16.66	-23.72	-24.61	-18.61	-22.12	-24.02	-33.02	-48.66	31882768	27968765	15265235
S5	samplingNowCtry_304	304	4853015	932042	895711	185554	233101	-17.35	-23.25	-24.39	-18.83	-22.79	-24.22	-35.34	-49.51	31345417	28141935	15310030
S6	samplingNowCtryOwn_380	380	4853015	932042	895711	185554	233101	-8.22	-29.86	-31.01	-11.47	-14.08	-19.23	-33.68	-47.07	35115055	25715188	13968682
S7	samplingNowCtryOwn_304	304	4853015	932042	895711	185554	233101	-8.11	-30.56	-30.97	-10.66	-13.57	-19.09	-33.75	-47.58	35155955	25460828	13970460
S8	samplingNowinst_380	380	4853015	932042	895711	185554	233101	-16.71	-23.91	-24.41	-17.79	-23.16	-24.44	-33.85	-47.89	31864242	27898482	15305239
S9	samplingNowinst_304	304	4853015	932042	895711	185554	233101	-16.87	-23.49	-23.49	-18.35	-22.91	-24.02	-32.75	-46.33	31802533	28051121	15492020
S10	samplingNowinstOwn_380	380	4853015	932042	895711	185554	233101	-8.57	-30.37	-29.53	-11.33	-13.00	-18.37	-32.26	-48.13	34979222	25529569	14269374
S11	samplingNowinstOwn_304	304	4853015	932042	895711	185554	233101	-8.54	-30.17	-31.81	-11.29	-13.13	-19.07	-33.25	-47.72	34989275	25603525	13806988
S12	MajorPorts80_380	380	4853015	932042	895711	185554	233101	-12.59	-25.19	-27.51	-24.40	-26.76	-34.90	-99.85	-93.56	36811152	30192429	16156702
S13	MajorPorts85_380	380	4853015	932042	895711	185554	233101	-8.62	-12.06	-21.79	-15.45	-25.65	-32.68	-60.79	-76.81	33451402	30851029	15151733
S14	MajorPorts90_380	380	4853015	932042	895711	185554	233101	-6.42	-5.10	-21.26	-12.63	-24.56	-32.12	-61.29	-76.93	32849805	31926980	14628988
S15	MajorPorts80_304	304	4853015	932042	895711	185554	233101	-12.44	-25.32	-28.06	-23.79	-26.50	-34.48	-99.75	-94.10	36874430	30139477	16034174
S16	MajorPorts85_304	304	4853015	932042	895711	185554	233101	-8.98	-13.31	-21.34	-15.83	-25.87	-33.00	-60.66	-76.93	33317829	30413383	15238456
S17	MajorPorts90_304	304	4853015	932042	895711	185554	233101	-7.40	-6.01	-20.69	-13.18	-24.73	-32.31	-61.48	-77.05	32505736	31619920	14734829
S18	MajorPorts80Own_380	380	4853015	932042	895711	185554	233101	-4.33	-34.98	-31.27	-16.16	-17.10	-29.88	-99.91	-93.17	40288672	26243756	15319060
S19	MajorPorts85Own_380	380	4853015	932042	895711	185554	233101	-0.05	-22.16	-26.66	-6.95	-16.19	-28.12	-61.54	-75.57	36586747	27307457	14207740
S20	MajorPorts90Own_380	380	4853015	932042	895711	185554	233101	1.03	-16.44	-27.79	-5.25	-15.31	-26.64	-61.01	-75.83	35463444	28110372	13414533
S21	MajorPorts85Own_304	304	4853015	932042	895711	185554	233101	-0.07	-22.28	-28.64	-6.52	-16.94	-27.65	-62.03	-77.03	36580847	27265328	13824294
S22	majorPorts80MinorStd_380	380	4853015	932042	895711	185554	233101	-1.68	-0.74	-15.79	-1.69	-2.81	-6.58	-16.02	-19.22	28923019	27090868	12781811
S23	majorPorts85MinorStd_380	380	4853015	932042	895711	185554	233101	-1.68	-0.74	-15.79	-1.69	-2.81	-6.58	-16.02	-19.22	28906357	27967579	13102480
S24	majorPorts90MinorStd_380	380	4853015	932042	895711	185554	233101	0.20	-0.63	-14.80	-1.57	-1.84	-5.74	-18.23	-17.12	29457673	27997277	13257532
S25	majorPorts85MinorStd_304	304	4853015	932042	895711	185554	233101	-0.56	-0.39	-14.73	-0.93	-0.83	-7.02	-19.79	-20.85	29234269	28066742	13267129
S26	majorPorts80MinorStdOwn_380	380	4853015	932042	895711	185554	233101	7.10	-12.88	-20.54	6.94	14.86	1.57	-53.28	-52.43	31487991	24548098	12364460
S27	majorPorts85MinorStdOwn_380	380	4853015	932042	895711	185554	233101	6.84	-10.13	-21.30	6.08	16.95	5.59	-41.00	-41.87	31409915	25321753	12244984
S28	majorPorts90MinorStdOwn_380	380	4853015	932042	895711	185554	233101	6.38	-9.52	-19.76	6.54	17.16	6.57	-39.34	-40.17	31274731	25492314	12485536
S29	majorPorts85MinorStdOwn_304	304	4853015	932042	895711	185554	233101	7.51	-9.70	-21.80	7.47	17.16	3.72	-40.01	-42.15	31609496	25441826	12167238
S30	MajorPorts80Mix_380	380	4853015	932042	895711	185554	233101	-8.92	-11.75	-20.17	-14.15	-26.83	-32.75	-46.26	-61.40	32756442	30419462	15195827
S31	MajorPorts85Mix_380	380	4853015	932042	895711	185554	233101	-8.10	-9.45	-17.88	-11.04	-21.08	-18.03	-45.72	-54.55	31955103	30172231	15111012
S32	MajorPorts90Mix_380	380	4853015	932042	895711	185554	233101	-4.82	-0.86	-16.95	-7.61	-12.51	-13.06	-22.31	-39.66	30501966	30447265	14085917
S33	MajorPorts80Mix_304	304	4853015	932042	895711	185554	233101	-10.16	-12.58	-20.09	-16.03	-25.24	-32.02	-47.04	-62.97	32312017	30132225	15210013
S34	MajorPorts85Mix_304	304	4853015	932042	895711	185554	233101	-8.89	-9.07	-19.14	-11.72	-20.83	-18.48	-47.03	-55.39	31678355	30298338	14879467
S35	MajorPorts90Mix_304	304	4853015	932042	895711	185554	233101	-6.29	-2.97	-18.11	-7.50	-12.73	-13.47	-24.18	-40.16	30030475	29800541	13888900
S36	MajorPorts80MixOwn_380	380	4853015	932042	895711	185554	233101	7.11	-19.85	-23.61	-1.04	-10.26	-22.58	-62.29	-76.19	38522353	27626788	14539829
S37	MajorPorts85MixOwn_380	380	4853015	932042	895711	185554	233101	6.04	-16.76	-21.16	0.91	-5.15	-7.39	-61.35	-68.77	36870363	27737901	14507443
S38	MajorPorts90MixOwn_380	380	4853015	932042	895711	185554	233101	7.43	-10.57	-20.66	4.48	2.73	-3.81	-37.74	-53.17	34428937	27467214	13436444
S39	MajorPorts85MixOwn_304	304	4853015	932042	895711	185554	233101	6.22	-16.91	-20.89	1.25	-5.18	-6.98	-61.13	-69.39	36931942	27088388	14556777
S40	majorPorts80MixMinorStd_380	380	4853015	932042	895711	185554	233101	-1.08	-0.93	-13.82	-2.03	-1.14	-5.44	-15.76	-16.18	29082147	27913690	13409097
S41	majorPorts85MixMinorStd_380	380	4853015	932042	895711	185554	233101	-0.64	-0.75	-13.86	-1.35	-1.33	-2.15	-12.48	-15.99	29211255	27965532	13403413
S42	majorPorts90MixMinorStd_380	380	4853015	932042	895711	185554	233101	-1.38	-0.56	-13.33	-2.46	-0.79	-1.90	-5.19	-7.77	28995027	27904216	13485009
S43	majorPorts85MixMinorStd_304	304	4853015	932042	895711	185554	233101	-1.33	-1.30	-12.57	-2.18	-1.38	-2.65	-11.07	-14.60	29010130	27810562	13603894
S44	majorPorts80MixMinorStdOwn_380	380	4853015	932042	895711	185554	233101	15.60	-7.79	-16.61	12.26	19.80	5.33	-41.24	-41.51	33988144	25981315	12975347
S45	majorPorts85MixMinorStdOwn_380	380	4853015	932042	895711	185554	233101	14.64	-7.73	-16.16	11.33	19.33	10.39	-38.80	-39.58	33703962	25998824	13045552
S46	majorPorts90MixMinorStdOwn_380	380	4853015	932042	895711	185554	233101	12.86	-8.05	-16.30	9.61	20.05	11.81	-28.82	-31.19	33180228	25908192	13023430
S47	majorPorts85MixMinorStdOwn_304	304	4853015	932042	895711	185554	233101	14.43	-7.32	-15.14	10.33	20.08	10.25	-38.96	-39.37	33642626	26114605	13203359
S48	majorPorts80byTrip_380	380	4853015	932042	895711	185554	233101	-9.35	-12.42	-20.82	-14.69	-25.51	-31.93	-45.95	-61.87	32602008	30186920	15072162
S49	majorPorts85byTrip_380	380	4853015	932042	895711	185554	233101	-8.42	-9.05	-15.35	-11.67	-20.27	-17.75	-46.23	-55.36	31842036	30308120	15577142
S50	majorPorts90byTrip_380	380	4853015	932042	895711	185554	233101	-6.87	-8.70	-18.50	-7.37	-12.75	-12.76	-22.74	-38.89	30520582	28676481	14136401
S51	MajorPorts90Own_304	304	4853015	932042	895711	185554	233101	1.54	-16.24	-29.16	-5.90	-15.26	-26.67	-61.46	-76.80	35645434	28179763	13160830
S52	majorPorts80MinorStd_304	304	4853015	932042	895711	185554	233101	-1.40	-3.86	-20.34	-3.15	-3.78	-9.19	-26.91	-24.11	28989957	27087887	12394283
S53	majorPorts90MinorStd_304	304	4853015	932042	895711	185554	233101	-1.58	-0.77	-13.87	-3.12	-3.27	-6.46	-14.67	-15.88	28934682	27958039	13400975
S54	MajorPorts80MixOwn_304	304	4853015	932042	895711	185554	233101	7.41	-19.27	-24.14	0.11	-10.26	-21.75	-62.69	-75.96	38631397	27825309	14439375
S55	MajorPorts90MixOwn_304	304	4853015	932042	895711	185554	233101	8.63	-9.48	-22.04	4.53	2.87	-3.44	-38.38	-52.42	34811198	27802186	13222210
S56	majorPorts80MixMinorStd_304	304	4853015	932042	895711	185554	233101	-1.36	-0.85	-13.62	-1.45	-1.63	-8.03	-15.72	-15.65	29001384	27937934	13439923
S57	majorPorts90MixMinorStd_304	304	4853015	932042	895711	185554	233101	0.66	0.50	-13.06	-1.74	-0.20	-2.37	-8.14	-7.82	29594379	28317282	13527351

Annex 3.6 Biological data Case study

Estimating mean length of landed catch from a given metier for a selection of species with at-sea and on-shore sampling

Context and overview

A description of the data call, data compilation scripts and simulation function tools are presented elsewhere, in the toolbox of the *fishPi*[2] project. In brief, a data call was sent out to all countries participating the project to provide comprehensive market sampling and observer sampling datasets of lengths measurements, or on-shore and at-sea data, for a selection of species and areas.

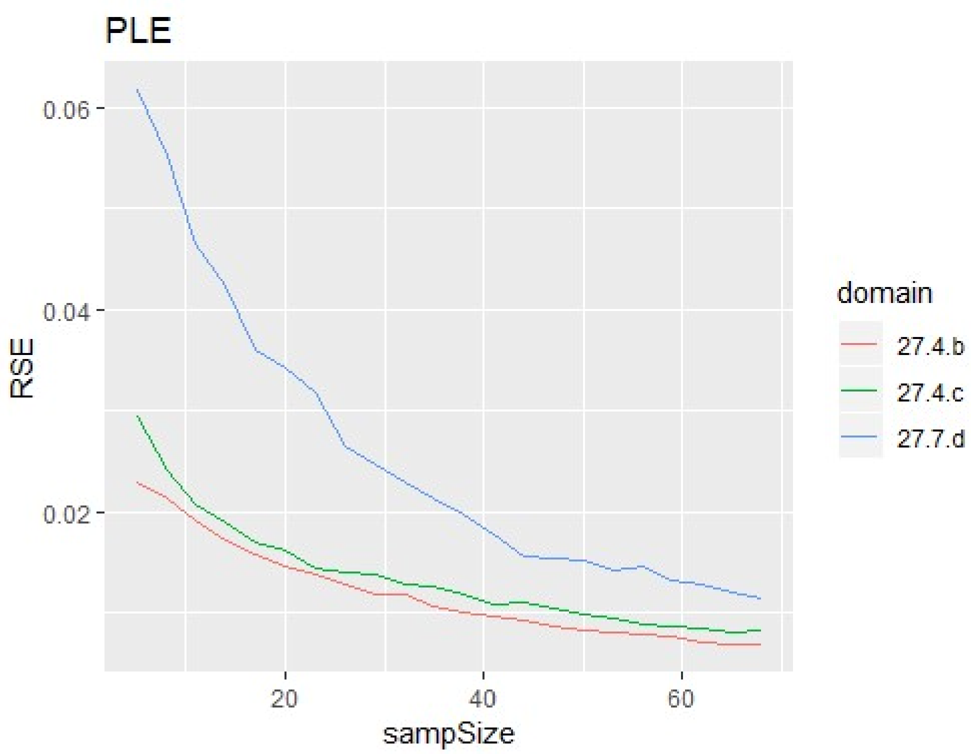
Those species and areas were split north and south. In the north, which the present case study focuses on, the species chosen were cod, plaice and grey gurnard to cover a range of species common and rare. The areas were 27.3.a, 27.3.a.20, 27.3.a.21, 27.4.a, 27.4.b, 27.4.c, 27.7.d.

Data were explored to select a suitable case study. Functions developed into an R package for the *fishPi*[2] WP2 landings data exploration could also be used to get an overview of the biological data. This case study serves to illustrate how the main *fishPi*[2] WP3 simulation framework can be adapted and used to inform on the effect of sampling effort on mean length estimates. The data exploration is presented in Appendices A and B. Here we present an overview of the simulation results for the case study (with code available from the toolbox).

Sampling effort is a measure of number of PSU, i.e. trips sampled at-sea or onshore site visits (day x site, with trips as SSU). Similar considerations must be accounted for in the sampling design to what is discussed under WP3 regarding the sampling of logbooks, or landing weights (e.g., site visit days when no landings etc). Note also that the biological dataset is not comprehensive. It does not include the Scottish data and only focuses on a few species. Further, the simulations do not link up the biological samples dataset with the full logbook datasets. Since only a small proportion of all logbook fishing trips are sampled for length, modelling work would be required to create a population from which to simulate. The present results are therefore not representative of the truth, or true mean length, at the spatial and temporal scales covered by the data, but they are an illustration of the simulation framework that could be used in combination with population data using logbook information. The beam trawl metier TBB_DEF_70-99_0_0 was chosen for the analyses for its high number of trips sampled and it is not sampled by Scotland so there were no missing data. Other metiers could have been grouped to reach a larger sample size and allow similar simulations.

Case study Results

The 2015 dataset, which included exclusively the 3 species of interest in the northern areas as outlined above, contained 90 TBB_DEF_70-99_0_0 trips with measurements of retained and landed fish. 18 of these trips were sampled by Belgium and 66 by the Netherlands, the few others being split between Germany, England and France. As these samples do not originate from concurrent sampling, i.e. we only have data on species presence but nothing on absence, each species was modelled separately. We simulated a random re-sampling of the trips along a gradient of effort, ranging from 5 to the maximum number of existing sampled trips for each species with increments of 3, with 1000 simulations. We present the results by domain for cod (COD) and plaice (PLE), domains being defined here as areas, as a proxy for stock.



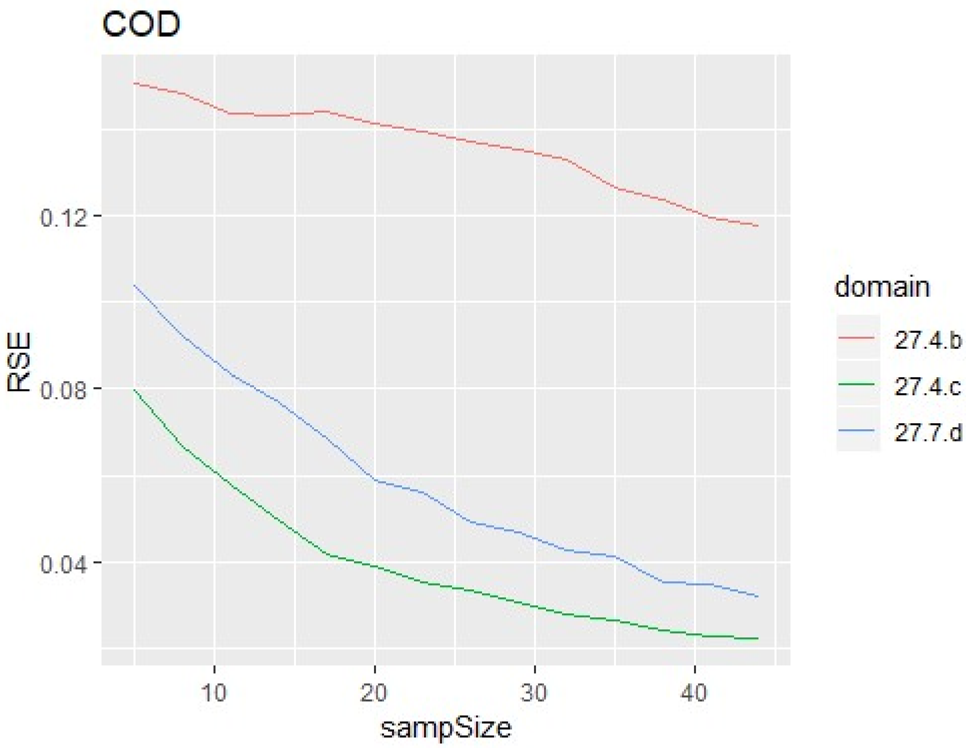


Figure 1. Relative standard error (RSE), calculated as sd/mean, for each domain against sample size, i.e. number of trips sampled (1000 simulations)

Figure 1 illustrates how increasing sample size decreases RSE for both species. All cod stocks have got a higher RSE than PLE. Increasing sample size significantly improves, i.e. decreases, the RSE for cod and to a lesser extent for plaice.

Below we illustrate the results for a sample size of 40 trips.

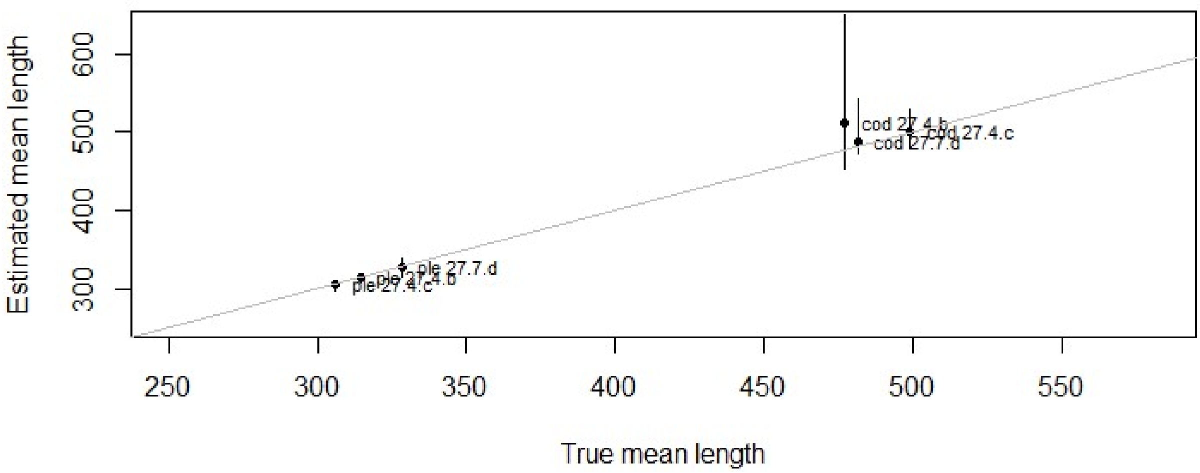


Figure 2. Estimated mean length vs mean length of the full biological sample. Called "true mean length" here, but meaning true in terms of the population sampled from (1000 simulations – 40 trips sampled)

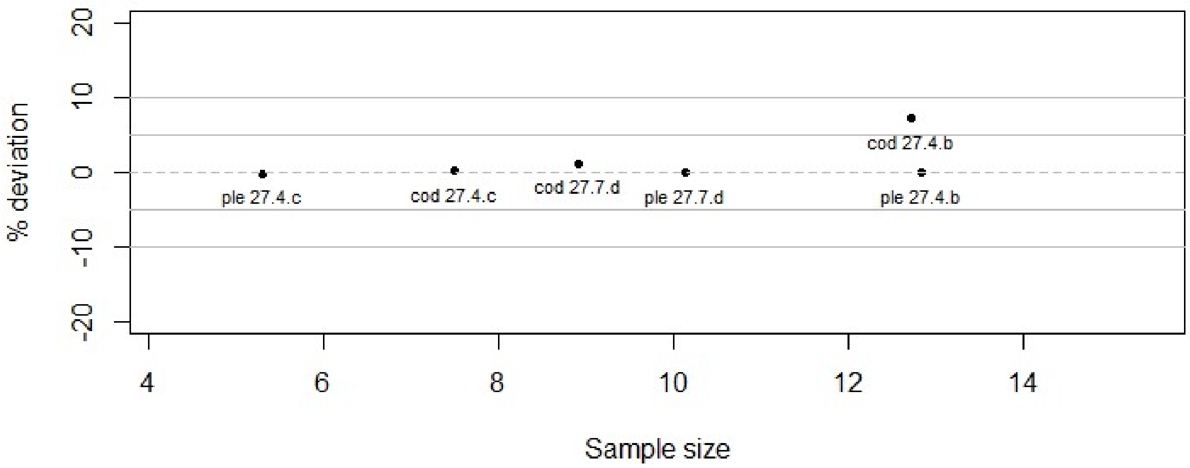


Figure 3. Bias vs actual number of samples where the domain was present, i.e. where we could get an estimate of mean length (1000 simulations – 40 trips sampled).

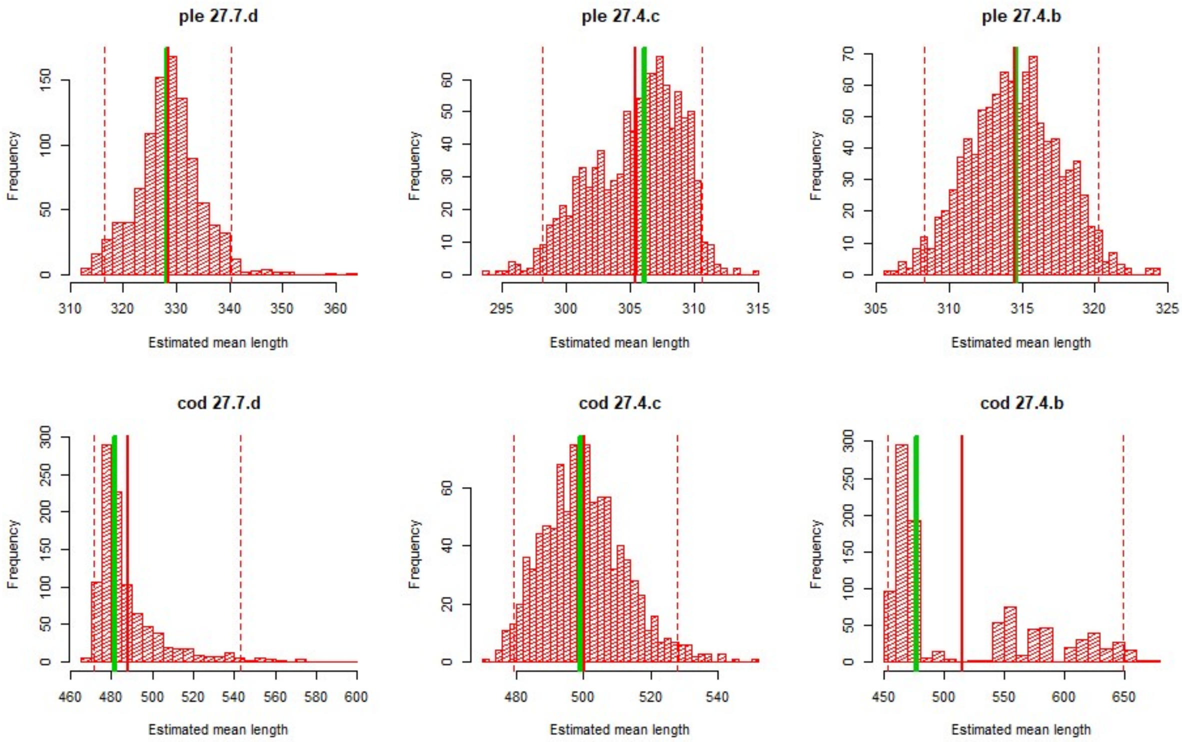


Figure 4. Distribution of mean lengths for 1000 simulations and 40 trips sampled. In red the estimated mean length, in green the target mean length, i.e. mean length of the full population of biological data sampled from.

Appendix A – Data overview for northern area data

Data

Submitted sample and logbook data from 2015 were filtered, so these only have fishing trips with catches or landings of gug.27.3a47d, cod.27.47d20, ple.27.7d, ple.27.420, ple.27.21-23 and cod.27.21 respectively.

Overviews – Full dataset for North Sea species

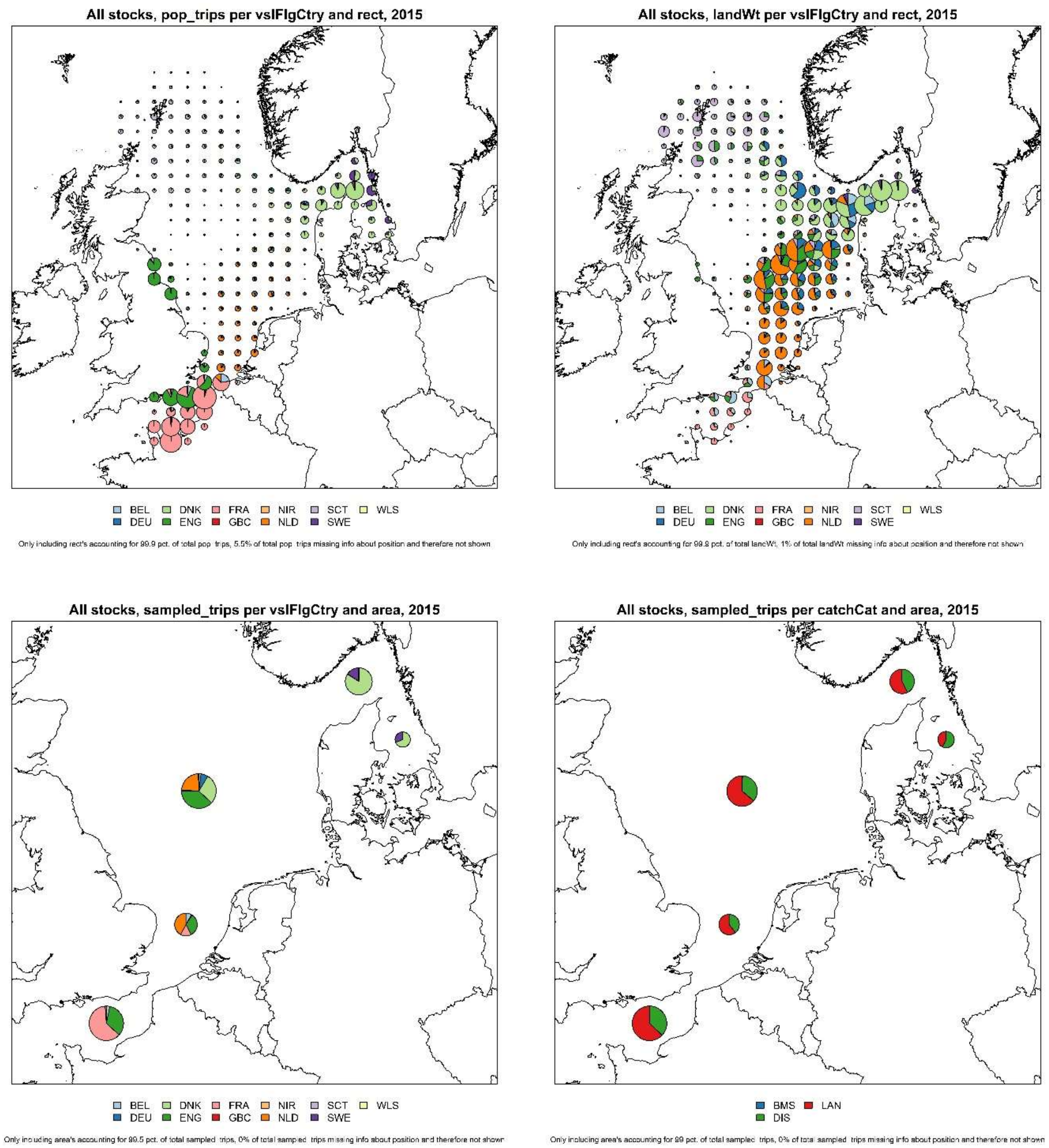


Figure 1 Spatial distibution of all population and sample data from 2015. Number of trips in the population per ICES rectangle and vessel flag country (upper left). Landed weight per ICES

rectangle and vessel flag country (upper right). Number of trips with sampled length measurments per area and vessel flag country (bottom left). Number of trips with sampled length measurments per area and catch category (bottom right)

Table 1 Overview of submitted data 2015 showing the population of trips and the breakdown of biological samples taken from the population

Vessel flag country	Year	Stock	Metier level 6	Trips in population	Tons landed	Sampled trips with length measurement	Sampled trips with length measurement of BMS	Sampled trips with length measurement of DIS	Sampled trips with length measurement of LAN
BEL	2015	All stocks	All	2586	8693	22	0	19	22
DEU	2015	All stocks	All	1228	14098	30	4	18	22
DNK	2015	All stocks	All	26099	32270	321	0	167	228
ENG	2015	All stocks	All	23549	17320	304	2	71	300
FRA	2015	All stocks	All	29301	3822	259	0	198	245
GBC	2015	All stocks	All	1	0	NA	NA	NA	NA
NIR	2015	All stocks	All	118	6	NA	NA	NA	NA
NLD	2015	All stocks	All	6599	31263	150	0	83	67
SCT	2015	All stocks	All	5775	15868	2	0	0	2
SWE	2015	All stocks	All	4542	1405	56	0	50	37
WLS	2015	All stocks	All	25	1	NA	NA	NA	NA

Table 2 Overview of submitted sample data 2015. Note that some countries only sample at-sea and that the majority samples both landings and discard at-sea. Further note, a single country have samples from foreign vessels.

Sampling country	Sampling type	Vessel flag country	Year	Stock	Metier level 6	Sampled trips with length measurement	Sampled trips with length measurement of BMS	Sampled trips with length measurement of DIS	Sampled trips with length measurement of LAN
BEL	at-sea	BEL	2015	All stocks	All	19	0	19	19
DEU	at-sea	DEU	2015	All stocks	All	21	4	18	13
DNK	at-sea	DNK	2015	All stocks	All	170	0	167	77
DNK	on-shore	DNK	2015	All stocks	All	151	0	0	151
ENG	at-sea	ENG	2015	All stocks	All	75	2	71	71
ENG	on-shore	ENG	2015	All stocks	All	215	0	0	215
FRA	at-sea	FRA	2015	All stocks	All	237	0	198	223
FRA	on-shore	FRA	2015	All stocks	All	22	0	0	22
NLD	at-sea	NLD	2015	All stocks	All	83	0	83	0
NLD	on-shore	BEL	2015	All stocks	All	3	0	0	3
NLD	on-shore	DEU	2015	All stocks	All	9	0	0	9
NLD	on-shore	ENG	2015	All stocks	All	14	0	0	14
NLD	on-shore	NLD	2015	All stocks	All	67	0	0	67
NLD	on-shore	SCT	2015	All stocks	All	2	0	0	2
SWE	at-sea	SWE	2015	All stocks	All	56	0	50	37

TBB_DEF_70-99_0_0

Specific overviews relating to métier 'TBB_DEF_70-99_0_0'

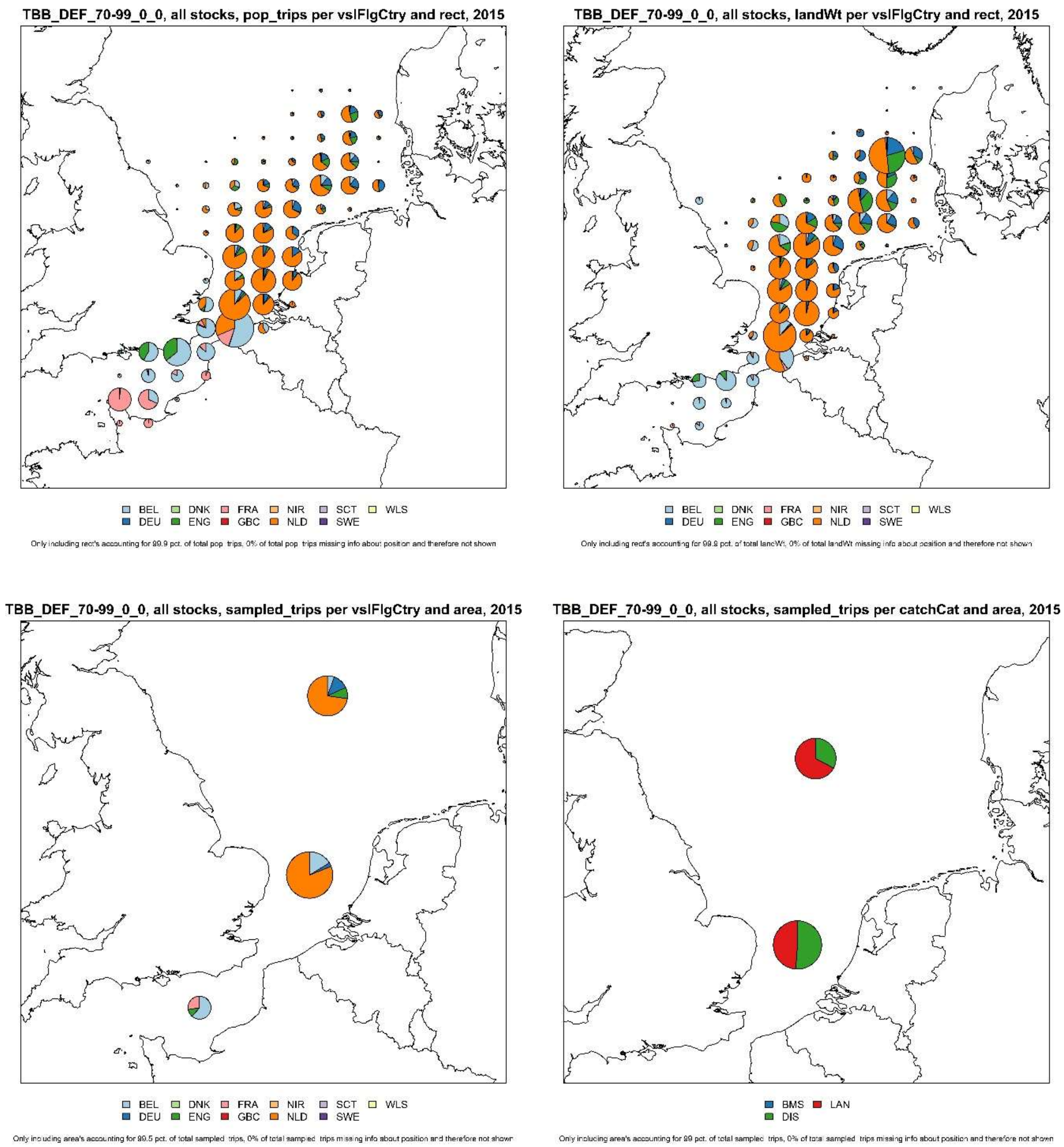


Figure 2 Spatial distibution of population and sample data from trips fishing with TBB_DEF_70-99_0_0 from 2015. Number of trips in the population per ICES rectangle and vessel flag country (upper left). Landed weight per ICES rectangle and vessel flag country

(upper right). Number of trips with sampled length measurments per area and vessel flag country (bottom left). Number of trips with sampled length measurments per area and catch category (bottom right)

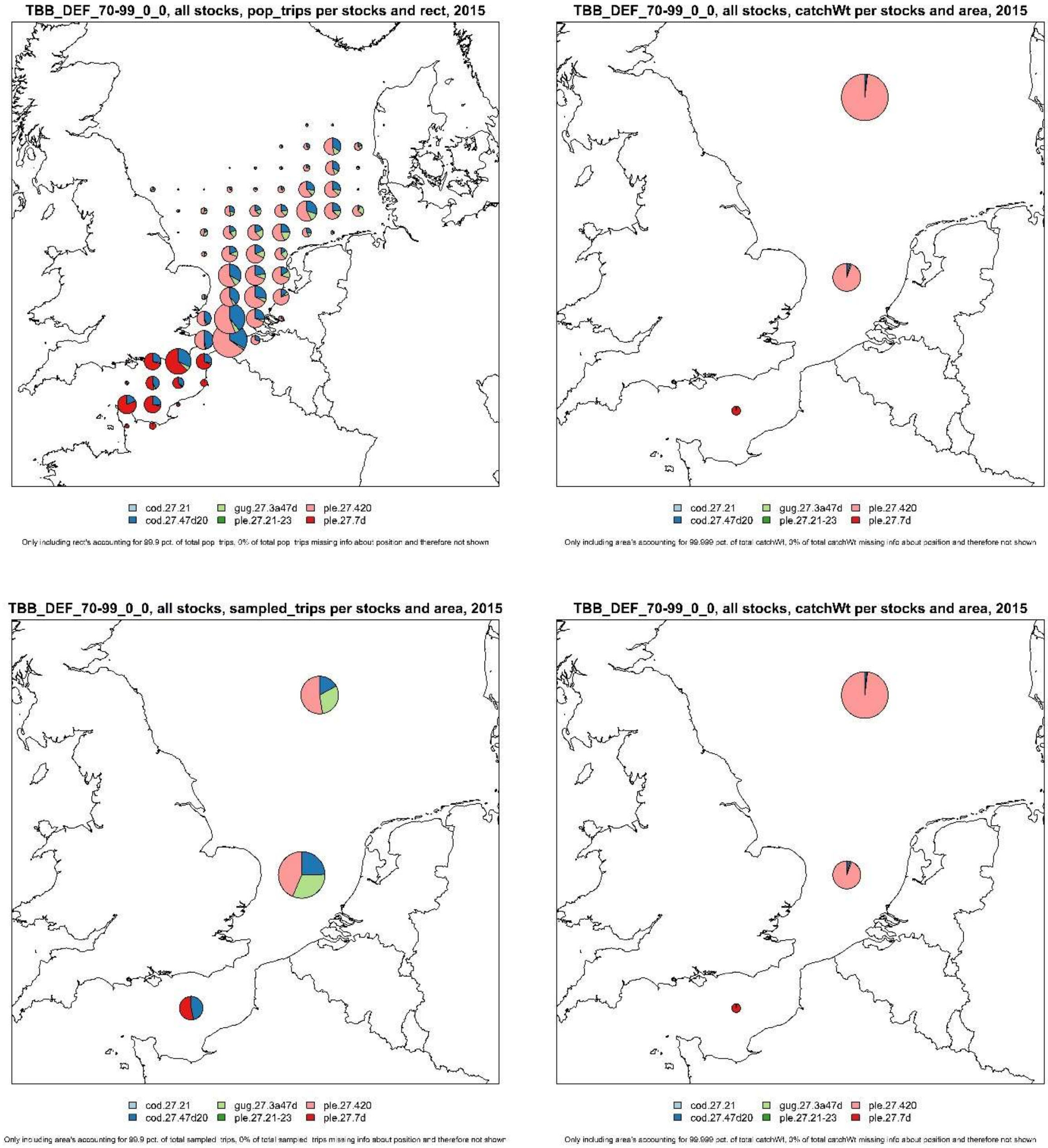


Figure 3 Spatial distibution of population and sample data from trips fishing with TBB_DEF_70-99_0_0 from 2015. Number of trips in the population per ICES rectangle and stock (upper left). Landed weight per ICES rectangle and stock (upper right). Number of trips with sampled length measurments per area and stock (bottom left). Sampled weight from trips with sampled length measurments per area and stock (bottom right)

Table 3 Overview of submitted data 2015. Samples combined with population data.

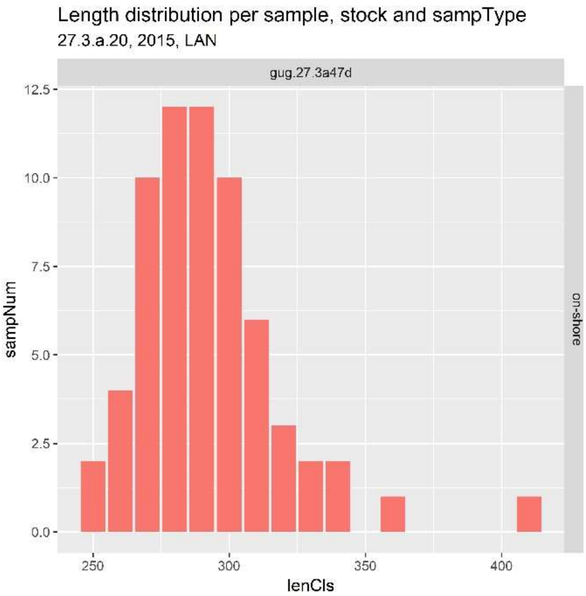
Vessel flag country	year	stock	Metier level 6	Trips in population	Tons landed	Sampled trips with length measurement	Sampled trips with length measurement of DIS	Sampled trips with length measurement of LAN
BEL	2015	All stocks	TBB_DEF_70-99_0_0	1450	3908	18	18	18
DEU	2015	All stocks	TBB_DEF_70-99_0_0	378	2763	9	3	9
ENG	2015	All stocks	TBB_DEF_70-99_0_0	551	2924	7	0	7
FRA	2015	All stocks	TBB_DEF_70-99_0_0	761	138	5	5	5
NLD	2015	All stocks	TBB_DEF_70-99_0_0	3572	16288	101	46	55
SCT	2015	All stocks	TBB_DEF_70-99_0_0	14	233	NA	NA	NA

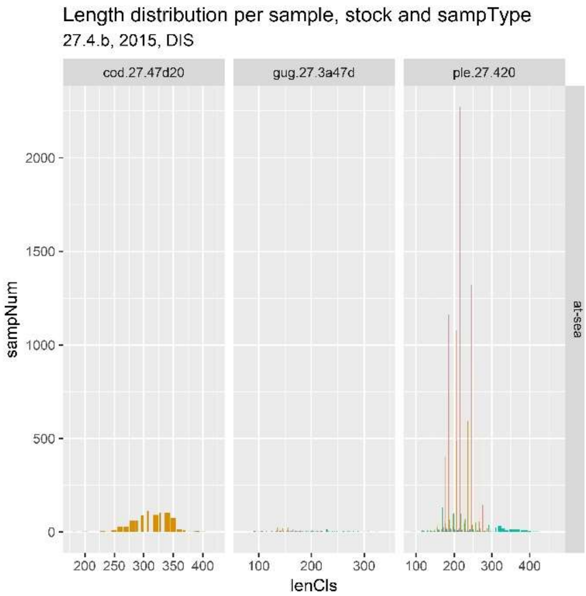
Table 4 Overview of submitted sample data 2015. Note that some countries only sample at-sea and that the majority samples both landings and discard at-sea. Further note, a single country have samples from foreign vessels.

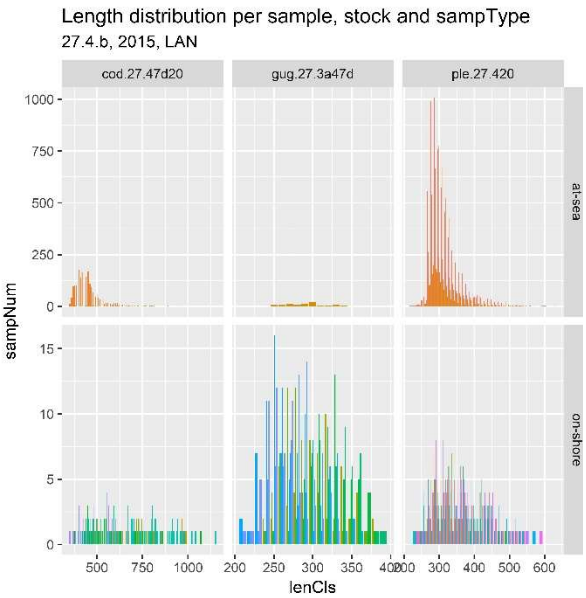
Sampling country	Sampling type	Vessel flag country	Year	Stock	Metier level 6	Sampled trips with length measurement	Sampled trips with length measurement of DIS	Sampled trips with length measurement of LAN
BEL	at-sea	BEL	2015	All stocks	TBB_DEF_70-99_0_0	18	18	18
DEU	at-sea	DEU	2015	All stocks	TBB_DEF_70-99_0_0	3	3	3
ENG	on-shore	ENG	2015	All stocks	TBB_DEF_70-99_0_0	2	0	2
FRA	at-sea	FRA	2015	All stocks	TBB_DEF_70-99_0_0	5	5	5
NLD	at-sea	NLD	2015	All stocks	TBB_DEF_70-99_0_0	46	46	0
NLD	on-shore	DEU	2015	All stocks	TBB_DEF_70-99_0_0	6	0	6
NLD	on-shore	ENG	2015	All stocks	TBB_DEF_70-99_0_0	5	0	5
NLD	on-shore	NLD	2015	All stocks	TBB_DEF_70-99_0_0	55	0	55

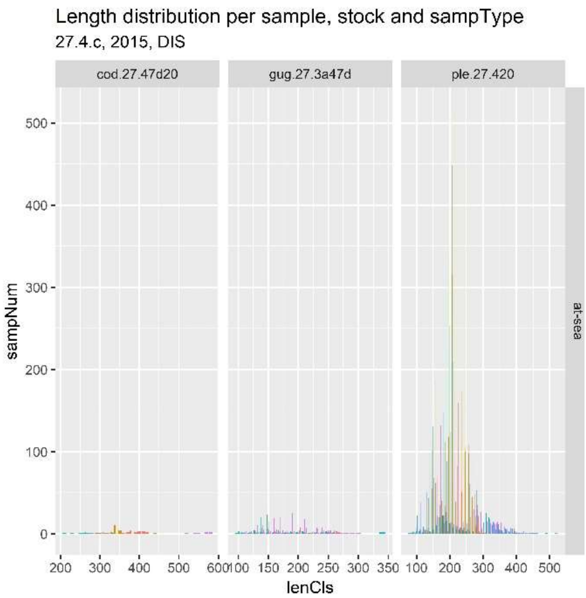
Table 5 Overview of submitted sample data 2015, focusing on length measurement.

Stock	Area	Year	Metier level 6	Catch category	Sampled trips with length measurements	Number of length measurements
cod.27.47d20	27.4.b	2015	TBB_DEF_70-99_0_0	DIS	7	812
cod.27.47d20	27.4.b	2015	TBB_DEF_70-99_0_0	LAN	9	2214
cod.27.47d20	27.4.c	2015	TBB_DEF_70-99_0_0	DIS	15	72
cod.27.47d20	27.4.c	2015	TBB_DEF_70-99_0_0	LAN	22	1356
cod.27.47d20	27.7.d	2015	TBB_DEF_70-99_0_0	DIS	1	3
cod.27.47d20	27.7.d	2015	TBB_DEF_70-99_0_0	LAN	15	1123
gug.27.3a47d	27.3.a.20	2015	TBB_DEF_70-99_0_0	LAN	1	65
gug.27.3a47d	27.4.b	2015	TBB_DEF_70-99_0_0	DIS	17	836
gug.27.3a47d	27.4.b	2015	TBB_DEF_70-99_0_0	LAN	9	588
gug.27.3a47d	27.4.c	2015	TBB_DEF_70-99_0_0	DIS	31	689
gug.27.3a47d	27.4.c	2015	TBB_DEF_70-99_0_0	LAN	9	542
ple.27.420	27.4.b	2015	TBB_DEF_70-99_0_0	DIS	20	30424
ple.27.420	27.4.b	2015	TBB_DEF_70-99_0_0	LAN	29	17350
ple.27.420	27.4.c	2015	TBB_DEF_70-99_0_0	DIS	44	25180
ple.27.420	27.4.c	2015	TBB_DEF_70-99_0_0	LAN	23	5692
ple.27.7d	27.7.d	2015	TBB_DEF_70-99_0_0	DIS	16	46825
ple.27.7d	27.7.d	2015	TBB_DEF_70-99_0_0	LAN	17	21691


Length distribution per sample, stock and sampType
27.3.a.20, 2015, LAN
gug.27.3a47d
on-shore
sampNum
lenCls


Length distribution per sample, stock and sampType
27.4.b, 2015, DIS
cod.27.47d20
gug.27.3a47d
ple.27.420
at-sea
sampNum
lenCls


Length distribution per sample, stock and sampType
27.4.b, 2015, LAN
cod.27.47d20
gug.27.3a47d
ple.27.420
at-sea
on-shore
sampNum
lenCls


Length distribution per sample, stock and sampType
27.4.c, 2015, DIS
cod.27.47d20
gug.27.3a47d
ple.27.420
at-sea
sampNum
lenCls

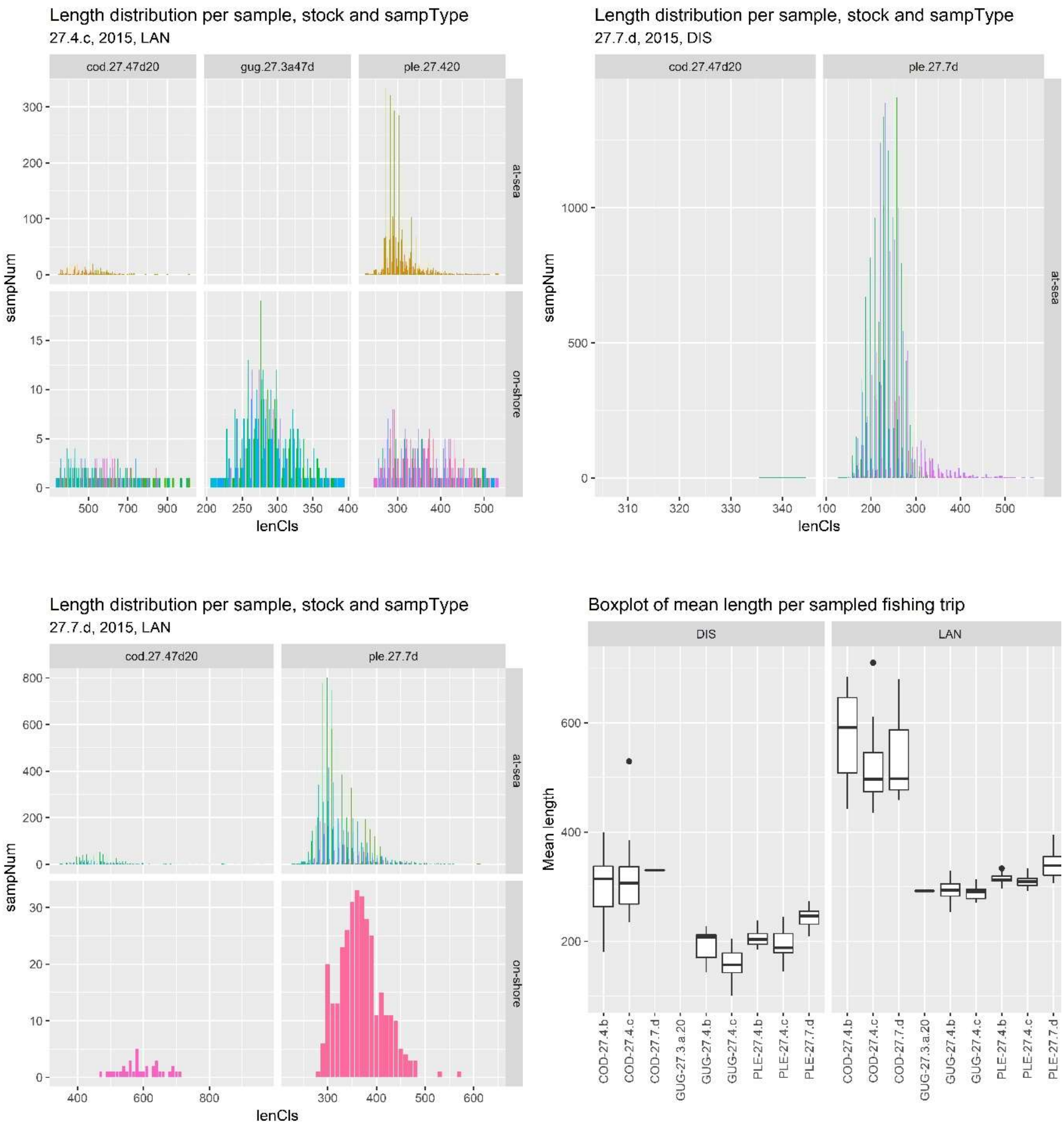


Figure 5 Sampled length distribution per stock and sampling type (upper, bottom left). Boxplot of mean length per trip, stock and catch category (bottom right). Data from TBB_DEF_70-99_0_0, 2015.

Appendix B – Domains in the North Sea

Figure 1 Métiers in logbooks (left) and samples (right), scaled to number of fishing trips.

To optimize for stock totals, e.g. mean length, all domains of interest in the population needs associated samples with a reasonable number of samples. Estimates for unsampled domains can be calculated using post-stratification. Domains, when applying biology, would be a combination of time, space and gear selectivity (métier level 6). The finest aggregation in the submitted date, quarter within year, division / subdivision and métier, will result in 1043 domains in the North Sea, Eastern English Channel, Skagerrak and Kattegat in 2015. The main reason being the overwhelming numbers of métiers in the logbooks, 166 in total across areas and quarters in 2015 of which 72 were sampled, see figure 1. Only 22 of them had 10 or more samples.

In the case study presented here, a single métier is selected, so there is in principal no need for associating samples to all métiers in the population, but it may still be beneficial for increasing the number of samples. On the other hand, if the aim was to optimize for a stock total, then some kind of aggregation of time, space and métiers would be needed and ideas discussed during *fishPi*[2] are presented below.

Input data

Submitted sample and logbook data were filtered, so these only have fishing trips with catches or landings of gug.27.3a47d, cod.27.47d20, ple.27.7d, ple.27.420, ple.27.21-23 and cod.27.21 respectively. The two later are assessed in The ICES Baltic Fisheries Assessment Working Group (WGBFAS), the rest in ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK).

Discussion

Time

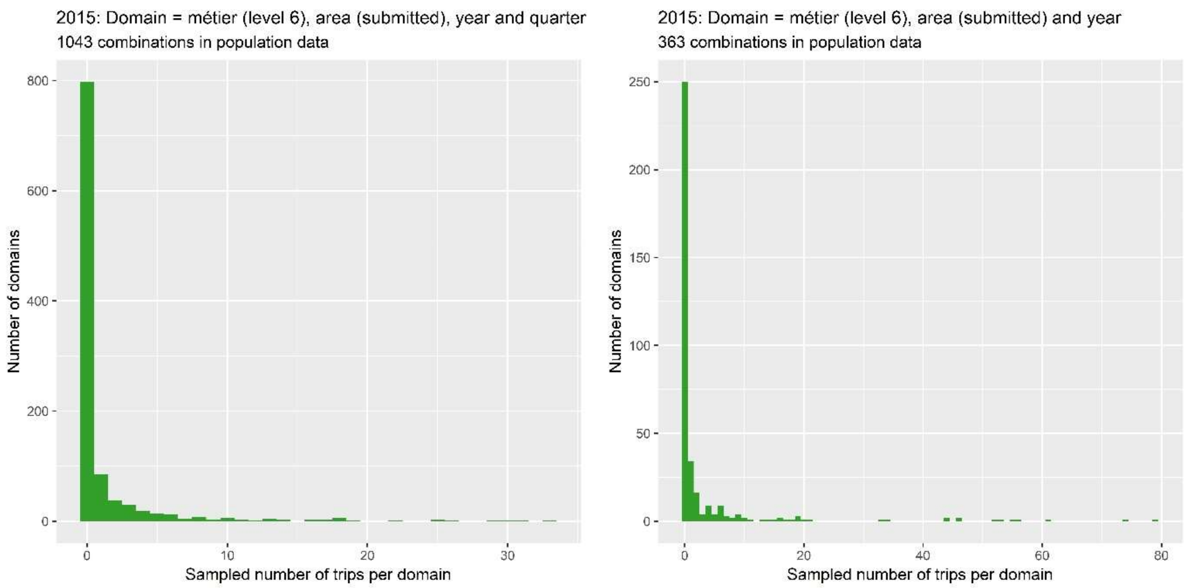


Figure 2 . Number of domains per number of sampled trips per domain. Changing time, quarter within year (left) and year only (right). Note the high number of un-sampled domains.

Data submitted to assessment working groups are often aggregated by quarter, but due to low levels of sampling effort, some countries submit data per year. As expected the number of domains are heavily reduced, when going from quarter to year, but the majority of domains remains un-sampled and only 8% have 10 or more samples, see figure 2.

An alternative could be to combine years or quarter between years, but there is a risk of mixing up year-classes by doing so. Further, we sample more or less the same métiers each year, so the reduction in un-sampled métiers would not be that big, but each domain would have more samples. Applying a combination of sample data from 2015 and 2016 on population data from 2015 results in 228 un-sampled domains, which is very similar to the 250 un-sampled, when only using samples from 2015. Further, domains with 10 or more samples only increases to 12%.

Year seems like a good candidate for aggregating samples in time. An alternative could be combining years.

Space

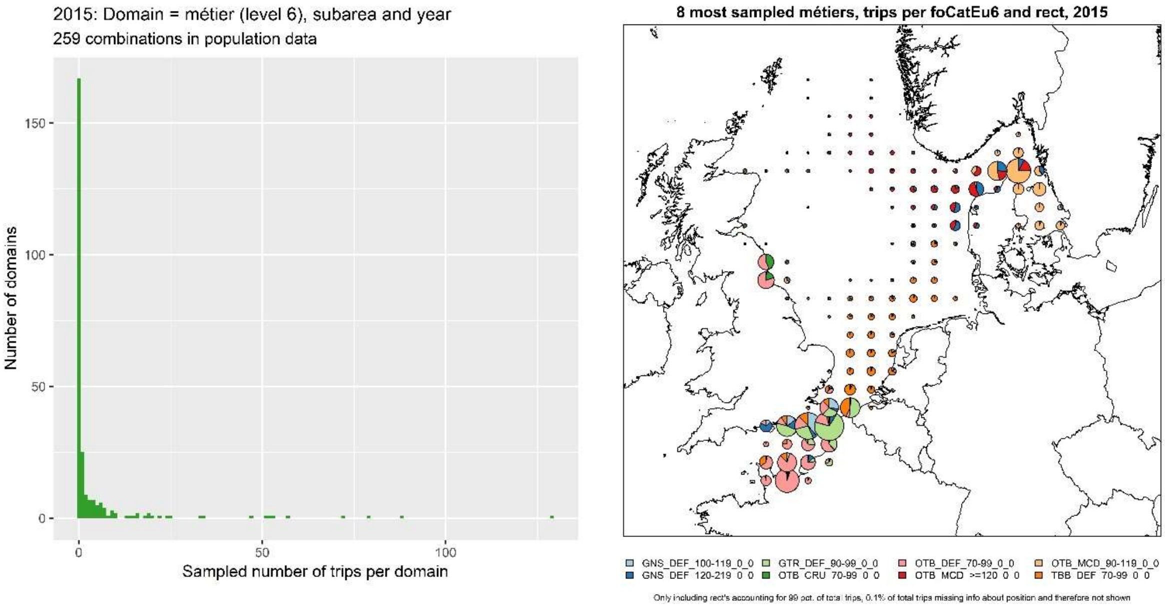


Figure 3 Left: Number of domains per number of sampled trips per domain, when aggregating per subarea Right: Spatial distribution of the métiers with most samples.

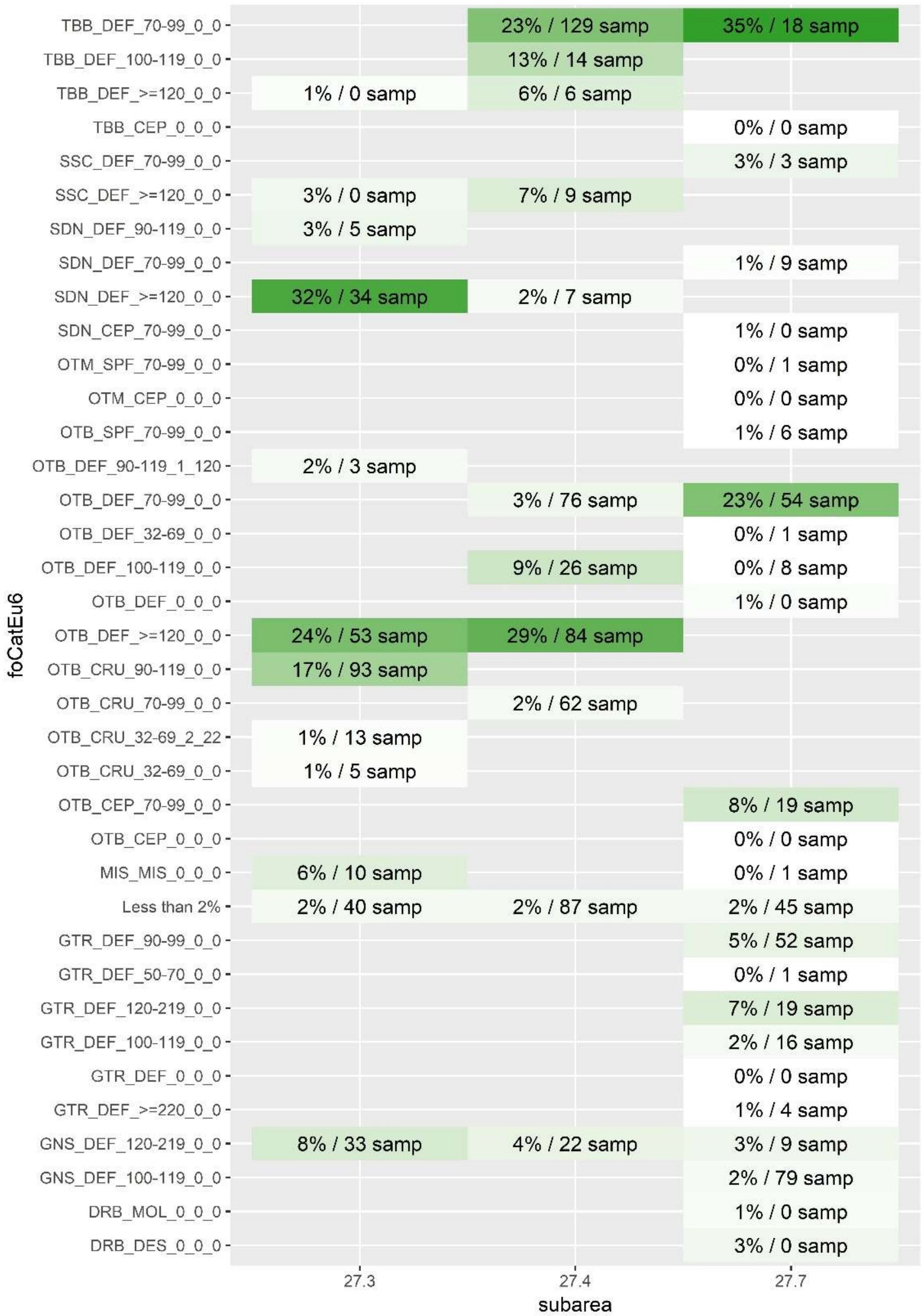
In fishPi2 data from the North Sea and the Eastern English Channel were submitted per division and data from Skagerrak and Kattegat per subdivision, giving the following areas; 27.3.a.20, 27.3.a.21, 27.4.a, 27.4.b, 27.4.c and 27.7.d. One way of minimizing numbers of domains would be to aggregate per subarea, 27.3, 27.4 and 27.7, which is very close to the aggregation normally used when submitting data to WGNSSK. The reduction in number of domains is not that great, which to a certain degree is because the use of a métier is closely related with space, see figure 3, e.g. OTB_MCD_>=120_0_0 are mainly used in 27.4.a, while TBB_DEF_70-99_0_0 is mainly used in 27.4.c.

An alternative could be to combine all areas into a single. This is not recommended for the areas in question, since two sets of technical regulation are in place for, one for 27.3.a and another for 27.4 and 27.7.d (Commission Regulation (EC) 850/98).

Métiers

After combining in time and space, quarter within year and division / subdivision within subarea, we are still left with 259 domains, where 167 are un-sampled and only 10% have 10 or more samples. The un-sampled domains only account for 4% of the landings, but 21% of the landings are from domains with less than 10 samples.

An overview of the métiers can be found in figure 4.



Level 4 or 5

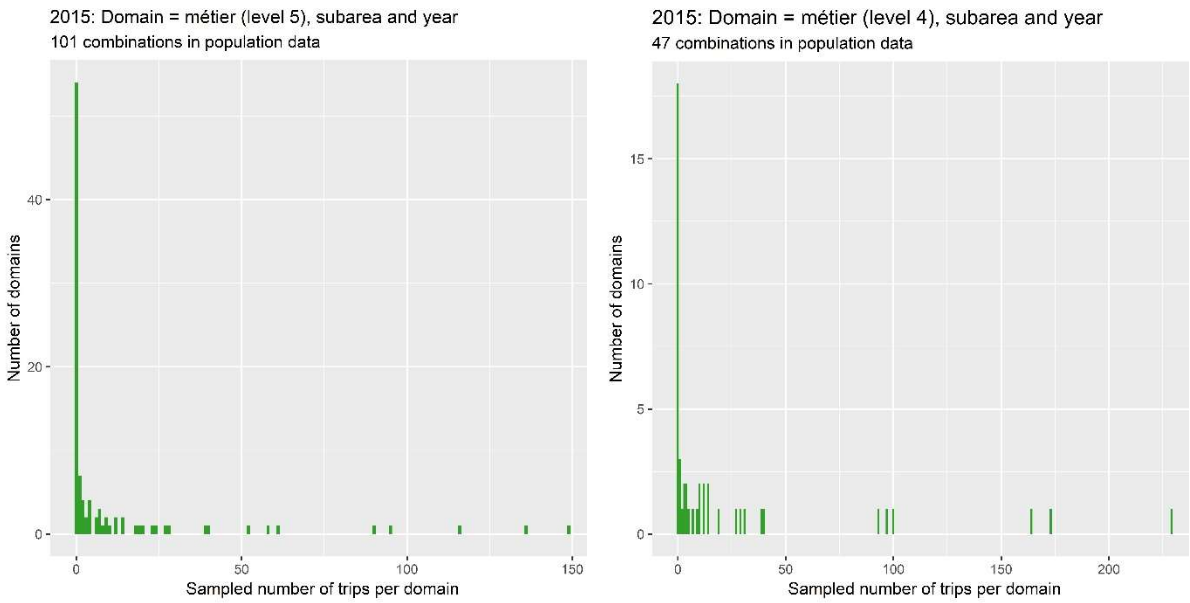


Figure 5 Number of domains per number of sampled trips per domain. Aggregating métiers, métier level 5 (left) and métier level 4 (right).

An easy solution would be to use métier level 5 or 4, gear combined with target species assemblage or gear respectively. As can be seen from figure 5, the number of domains are reduced drastically and results in 54 and 18 domains being un-sampled and the un-sampled domains only account for 0.8% and 0.7% of the landings, level 5 and 4 respectively, so in principal all landings have associated samples. It seems that number of domains with 10 or more samples still are relativity low, 22% for level 5 and 38% for level 4, but again domains with less than 10 samples only account for 6% and 2% of the landing respectively.

These two options were considered too coarse, since both of them ignores the mesh size ranges and thereby ignores a lot of the gear selectivity. Level 4 combines TBB_CRU_16-31_0_0 and TBB_DEF_70-99_0_0 into TBB and level_5 combines OTB_CRU_32-69_0_0 and OTB_CRU_90-119_0_0 into OTB_CRU.

WGNSSK fleets

Data to WGNSSK are submitted per fleets quite similar to the métier level 6 in coding, but reduced in numbers, so only 40 fleets can be used in area 27.3.a, 27.4 and 27.7.d, see table 6. The aggregation of métiers to WGNSSK are done at a national level and documentation of this aggregation is not published.

WGNSSK fleets used in 27.4 & 27.7.d	WGNSSK fleets used in 27.3.a
FPO_CRU_0_0_0	
GNS_DEF_>=220_0_0	GNS_DEF_>=220_0_0
GNS_DEF_100-119_0_0	GNS_DEF_100-119_0_0
GNS_DEF_120-219_0_0	GNS_DEF_120-219_0_0
GNS_DEF_0_0	GNS_DEF_0_0
GTR_DEF_0_0	GTR_DEF_0_0
LLS_FIF_0_0_0	LLS_FIF_0_0_0
MIS_MIS_0_0_0_HC	MIS_MIS_0_0_0_HC
MIS_MIS_0_0_0_IBC	MIS_MIS_0_0_0_IBC
OTB_CRU_16-31_0_0	OTB_CRU_16-31_0_0
OTB_CRU_32-69_0_0	OTB_CRU_32-69_0_0
	OTB_CRU_32-69_2_22
	OTB_CRU_70-89_2_35
OTB_CRU_70-99_0_0	
	OTB_CRU_90-119_0_0
OTB_ DEF _>=120_0_0	OTB_DEF _>=120_0_0
OTB_DEF_70-99_0_0	
OTB_SPF_32-69_0_0	
SDN_DEF_>=120_0_0	SDN_DEF_>=120_0_0
SSC_DEF_>=120_0_0	SSC_DEF_>=120_0_0
TBB_CRU_16-31_0_0	TBB_CRU_16-31_0_0
TBB_DEF_>=120_0_0	TBB_DEF_>=120_0_0
TBB_DEF_70-99_0_0	TBB_DEF_90-99_0_0
	TBB_DEF_90-99_0_0

Allocating métiers according to WGNSSK fleets was not attempted in this study, but it seems like a good approach, since it reduces the number of gear domains and it is use by one of the main end-users of the data collected in these sampling programs. To do this, insight into the national aggregations of métiers into WGNSSK fleets would be needed. Further aggregation of WGNSSK fleets would also be needed to reduce number of un-sampled métiers and increase number of samples per domain. An idea could be to group fleets accounting for less than 10% of the landings and no samples into MIS_MIS_0_0_0 (ICES, 2019). Another idea could be to use the rules for imputations used for the different stocks under WGNSSK. These are described in the WGNSSK reports (ICES, 2016 & ICES, 2015). The problem being that these rules are stock specific, but for the WGNSSK stocks in this study is seems that passive gears are group together if samples are missing.

Gear and mesh size

Another approach would be to combine métier with similar gear and mesh size range (Personal communication, ICES/Probyfish Workshop on identification of target and bycatch species (WKTARGET), 2019). This reduced the number of gear domains to 90, instead of 166 métiers.

References

Council Regulation (EC) No 850/98 of 30 March 1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms.

ICES, 2015. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 28 April-7 May, ICES HQ, Copenhagen, Denmark. ICES CM 2015/ACOM:13.

ICES, 2017. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 26 April-5 May 2016, Hamburg, Germany. ICES CM 2016/ ACOM:14.

ICES, 2019. Data call 2019: Landings, discards, biological sample and effort data from 2018 in support the ICES fisheries advice in 2019

Annex 3.7 Steps in a simulation study to design a regional sampling plan

Introduction

A regional sampling plan for fisheries aims to improve the situation where data collected in a region come from diverse national schemes that may or may not conform statistical and data quality standards. Additionally, there is a risk of incomplete sampling coverage of the regional population, and that the allocation of sampling effort unilaterally at national level does not represent the best use of the available resource. In contrast, a regional sampling plan provides a better coordinated and more statistically sound approach, and it considers fishery activity by several countries in a common framework. It would be designed from agreed objectives based on end-user needs, and it would follow well-established methods of probability-based sampling aiming to provide data on the collective activities of nationally operating fleets that are fishing on shared stocks in regional seas.

Designing appropriate regional sampling schemes is a step-wise iterative process requiring close cooperation between the institutes carrying out the sampling, and also with end users (fishPi: https://datacollection.jrc.ec.europa.eu/docs/regional-grants). The object of this document, together with Annex 3.3, "Principles in the implementation of sampling designs", is to provide a description and guidelines to develop each of these steps to design a regional sampling scheme using simulation models to explore different alternatives.

In the simulations, the species landed weight was used as a proxy for the biological data (age and length distributions) that are actually collected. The main advantage of using species landed weight is that information of the full population is available in logbooks and sales notes and can be used to define the sampling frame and collect the samples following a specific sampling design. However, most of fisheries sampling effort is addressed to get information on other data not provided by fishers, namely biological variables of landed species and discarded species (length, weight, age, maturity, etc). There is a need to include this information in the simulations to move forward more realistic conclusions, but this increases the complexity of the simulations and the evaluation of the simulation results, as the true population is not known. This work-package has begun to address this issue in Annex 3.5 "Biological case study".

Step Plan

1. *Definition of the Case Study*

The definition of the parameters to be estimated and the target population for which these estimates are required to meet end-users needs is the first step in the process. Parameters needed are typically age or length compositions of the catch, discards weight, or species composition. As stated in the definition, the proposal in this document is to use the species landed weight as a proxy for the biological data that are actually collected.

Candidate case studies would have to fulfil the criteria set up in WP2 (section 2.1). An example about how to use the criteria to select a case study can be found in Annexes 2.2 – 2.3. The selected study population would then be fish caught from a particular stock or stocks, and the sampling frame would be defined in terms of certain vessels or landing locations. In summary, to define the case study which is candidate for a regional sampling plan, it is important to determine:

- The purpose of data collection
- The stocks involved
- The fishing fleets and/or landing locations involved
- The nations and sampling institutes involved.

2. Data collection

Disaggregated data are needed to 1) describe the case study fisheries, and 2) to run the simulations. In order to successfully collect and share the data, there is a need for a data call and a data sharing agreement. An example of both can be found in Annex 3.2.

For a simulation study based on catch data, the data requested will come from logbooks and sales notes. This allows us to have information of the full population, which can be used to define the sampling frame and collect the samples following a specific sampling design.

Some issues that should be taken into account in the data call are the following:

- Define the temporal scope. Two subsequent years should be enough: the first one to define the settings, and the next one to run the simulations.
- Data should include all the information required to simulate the sampling design: i.e., if the primary sampling unit (PSU) is port-day, the date and the sampling port should be requested; if the secondary sampling unit (SSU) is the trip, the data should be disaggregated by trip; if quarter or fleet are strata, they should be also requested, or it should be possible to derive them from the data requested.
- Data should include the information required to define the domains of interest for which the end-user requires estimates, e.g. stock, metier, area, etc.
- Make reference to international standardized code lists such as species WORMS, ports UNLOCODES, etc.

- The data requested should cover all trips and all species for the area or fleets or locations of interest. If the data call does not cover all species, it should request that trips with no landings of the targeted species are reported with zero landings.

3. Data cleaning

This step is especially important because data coming from different nations are going to be merged. It often happens that the same variable is interpreted differently, or that nations use slightly different codes (even if internationally standardized code lists are stated, this should be checked). Key variables to check are:

- Species names: particularly the main species for the CS.
- Group of commercial species: Grouping of species depend very much on landing practices which are different from one Country to another. Make sure that species groups contain the same species in all countries.
- Metier codification: Be careful with the codes, small differences in the writing can cause problems.
- Port Names or codes: This is especially important for landings abroad. Even if LOCODES are used, check consistency of the data.
- Stock names: important to use a common updated look up table for stocks.

Automatic checking scripts which cover all these issues are available on the fishPi repository: https://github.com/ices-tools-dev/FishPi2/tree/master/WP3.

4. Description of the fisheries

A description of the fisheries targeted in the CS should be carried out using the data collected. This will allow us to develop appropriate sampling designs. Some of the issues that can be addressed are landings (tonnage) and number of trips per fleet, per metier, per area and per landing port, the main species targeted, the landings abroad and the seasonality of the fishing activity. Examples of such descriptions can be found in Annexes 2.1 – 2.3.

5. Simulations

This is often seen as the most important step to define a regional sampling plan. However, if all the previous actions have not been addressed correctly, the results of the simulations might not be useful. It must be highlighted that the performance of simulations and the interpretation of the results require statistical and fisheries sampling knowledge.

5.1. Define scenarios

Defining scenarios is in fact defining alternative sampling designs. As stated in Annex 3.3, the elements that need to be described to document a sampling design are the following ones:

- **Target population:** The target population is defined alongside with the Case Study, in the first step of the process.
- **Sampling frame:** The sampling frame is a list of non-overlapping primary sampling units (PSU), which will be taken from our cleaned data set. Due to practical constraints, often the data frame does not cover the entire population, and the coverage of the sampling frame is an important issue when defining the scenarios.
- **Definition of the sampling units (SU), sample selection procedures and the hierarchical structure of the sampling**: The most common and cost-effective sampling design for catch sampling is usually a multi-stage stratified random sampling design. Here the population is first divided into non-overlapping subgroups, called strata. Within each stratum, a multi-stage design is usually implemented as this approach recognizes and uses the nested structure of the elements that compose the population. The definition of sampling units and the procedures for sampling selection depend very much on landing practices which can be different from one nation to another, and they are the key to calculating sampling probabilities.
- **Stratification:** The effect of different stratifications of the sampling frame is one of the parameters that can be tested with the simulations.
- **Distribution of sampling effort**: The effect of different sampling effort allocation is also an interesting parameter to include in the simulations: i.e., different distribution among nations or institutes, or increasing or decreasing total sampling effort.

The aim of these simulations is to analyse the performance of the current sampling design, and to compare it with alternative ones. It is important to think carefully beforehand the scenarios that are going to be simulated and find a balance so that they can provide valuable results keeping it as simple as possible. Too complex scenarios will be more difficult to interpret.

Some basic scenarios to test are the following ones:

5.1.1. <u>Scenario 1: Mimic the current situation as closely as possible</u>

- **Coverage of Sampling Frame:** Include implementation issues which prevent a full coverage of the sampling frame in the current sampling schemes: e.g. sampling only of larger ports, ports which are not accessible (i.e. cannot be sampled), or foreign landings.
- **Sampling units and selection procedures**: Define current sampling units (e.g. PSU: vessel or port day, SSU: trip, TSU: species) and selection procedures at each stage, e.g. simple random sampling or stratified random sampling.

- **Strata:** Define the current stratification. At present nation or sampling institute can be considered as the default strata, as sampling is structured in national sampling schemes. National stratification might also be employed. Quarter is also used for stratification in many cases. However, stratification by quarter is often kept out in the simulations for simplicity, assuming that its effect is similar for all scenarios. Keep in mind that in highly seasonal fisheries it should be considered.
- **Sampling effort:** current sampling effort distributed by strata.

5.1.2. Scenario 2: Baseline scenario – simple random sample

- **Coverage of Sampling Frame:** All the population.
- **Sampling units and selection procedures:** Define current sampling units (e.g. PSU: vessel or port day, SSU: trip, TSU: species) and selection procedures (i.e. multi-stage stratified random sampling).
- **Strata:** Stratification is not applied in this baseline scenario.
- **Sampling effort:** Current sampling effort.

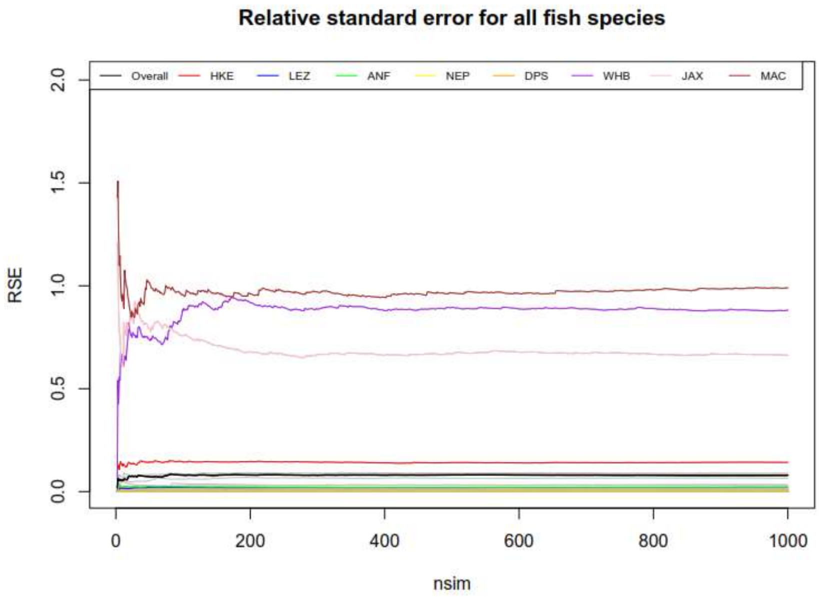
5.1.3. Other Scenarios

- **Coverage of Sampling Frame:** Test the effect of changing the coverage of the sampling frame change: e.g. include ports which are not currently sampled, include foreign landings.
- **Sampling units and selection procedures:** Define current sampling units (e.g. PSU: vessel or port day, SSU: trip, TSU: species) and selection procedures (i.e. multi-stage stratified random sampling).
- **Strata 1:** Test different stratifications: e.g. small and large ports, geographical areas, fleets.
- **Sampling effort:** Test different sampling efforts and different effort allocations among strata.

5.2. Run simulations for each scenario

The fishPi[2] project provides a set of functions and examples of scripts to run the simulations (https://github.com/ices-tools-dev/fishPi/WP3/R-code). The functions have been developed in R, using the Horvitz Thompson estimator (Horvitz and Thompson, 1952) from the R package "survey". For each simulated data set an estimate of total landed weights and sample sizes by various domains (eg. species, country, etc.) are obtained. Repeated simulations enable us to assess the performance of the designs over many iterations, to compare the mean and median estimates of the totals with the known "true" value from the data set, and to determine the variability of the estimates using the relative standard errors.

To have robust results, it is important to run enough iterations for each scenario. The optimal number of iterations should be defined in a first exercise with the data set, by using increasing number of simulations and computing the estimates of interest (e.g, the mean and median estimates of the totals). The value will converge towards a specific value and will eventually reach a point at which any additional iterations won't result in a significant change to the estimate (Figure 2).



6. Calculate associated costs

Each scenario will have an associated cost which will depend on the sampling effort and also on the ports or fleets being sampled. The cost per sampling unit should be determined considering that it depends on the sampled port (because of distance and time/schedules for sampling) and the sampling fleets (because of the number of people needed to sample). The calculation of cost needs to be as accurate as possible. As resources are limited, information on costs may be the determinant to choose one scenario over another.

Costs could be calculated using average costs sampling event for each nation (e.g. the North Sea case study, Annex 3.4) or using more complicated methods, for example having specific costs for each sampling location (e.g. the Iberian case study, Annex 3.5).

7. Interpretation of results

When all the scenarios are simulated and the evaluation metrics calculated, the results need to be interpreted. Usually there is a variety of scenarios and estimates for each scenario (especially in multi-specific fisheries) and it is easy to get lost in the results. There is a need for visual representations and a methodology to guide in the process.

The two case studies take slightly different approaches, but in both cases they take into consideration multiple aspects, such as the statistical quality of the data obtained, the cost and other feasibility and suitability issues.

Iberian case study

Figure 3 shows a graph designed to evaluate the results of the simulations in the Iberian case ctudy. For each metric a heatmap provides information of the performance of each scenario, using a palette of colors (traffic light approach) from orange (lower performance) to green (higher performance). This tool allows to compare the different scenarios with the current sampling scheme, at a glance. The proposed methodology is a step-wise process in which different metrics are compared in each step, and only the scenarios performing better are selected to be tested in the following step. The order in which the different metrics are compared can be determinant to choose one scenario over another and needs to be carefully defined. Since the aim of the sampling programme is to provide precise and unbiased estimates of stock/species length and age composition of the landings (although in the CS landings was used as a proxy for the biological characteristics) we suggest the following order: i) relative standard error and bias estimates by species, ii) overall deviation of the mean or median. At the last stage, a limited number of scenarios will be selected (e.g. 2 or 3), and for them, the effect of reducing/increasing sampling effort can be tested. Also at this stage of the selection process, cost and feasibility/suitability issues will be considered for each scenario. The full explanation of this process can be found in Annex 3.5.

	RSE_WHB	RSE_JAX	RSE_MAC	RSE_HKE	RSE_LEZ	RSE_ANF	RSE_DPS	RSE_NEP
random_380	0.17	0.13	0.39	0.16	0.14	0.14	0.25	0.19
samplingNowCtry_380	0.12	0.12	0.29	0.12	0.11	0.11	0.29	0.27
samplingNowInst_380	0.12	0.12	0.30	0.12	0.11	0.11	0.30	0.28
samplingNowCtryOwn_380	0.12	0.12	0.31	0.12	0.11	0.11	0.29	0.29
samplingNowInstOwn_380	0.11	0.12	0.29	0.11	0.11	0.11	0.30	0.26
MajorPorts80_380	0.12	0.11	0.29	0.13	0.11	0.11	1.00	0.66
MajorPorts85_380	0.12	0.11	0.31	0.13	0.13	0.13	0.36	0.39
MajorPorts90_380	0.16	0.17	1.63	0.22	0.30	0.43	1.31	1.21
majorPorts80byTrip_380	0.14	0.11	0.32	0.13	0.13	0.13	0.30	0.26
majorPorts85byTrip_380	0.15	0.12	0.35	0.13	0.13	0.13	0.33	0.25
majorPorts90byTrip_380	0.15	0.11	0.33	0.15	0.14	0.13	0.26	0.23

North Sea case study

The North Sea case study compared scenarios by considering several summary metrics. First bias was considered and all biased designs (i.e. those which did not have complete coverage of the sampling frame) were rejected, then considered relative standard error (RSE), using RSE of an estimate of total landed weight of all species, mean RSE for some selected species, to ensure results are not unduly affected by poorly sampled, less common or commercially important species, and mean RSE for landed weight by country, to reflect national interests. Low RSEs are preferable, but RSE by species was considered more important, being of regional interest, than RSE by country, which is of national interest. These comparisons were carried out graphically (Figure 4), making it easy to summarise and compare several scenarios at once. In addition, more detailed output from specific scenarios can be considered for example sample sizes by domain. The approach taken by the North Sea case study was that only once a choice had been made on statistical grounds, and feasibility and costs were also taken into account. Thus an incomplete sampling frame might be rejected on feasibility grounds, whilst acknowledging it is the best option on statistical grounds. The full explanation of this process can be found in Annex 3.5.

In summary, the approach to interpretation of results can vary, based on the subjective concerns of the investigators but is likely to include some visual representation of summary statistics for several before considering costs and feasibility in more depth for selected scenarios. The exact choice of metrics to compare may also vary for similar reasons.

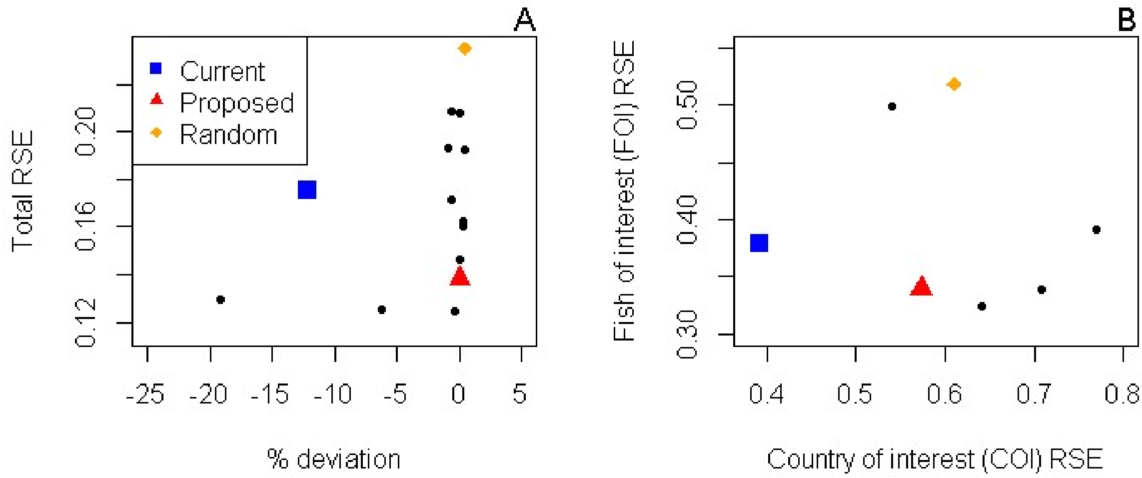


Figure 5. Graphical method for regional sampling design selection, showing the expected A) percent deviation and total relative standard error (RSE), and B) the RSE of estimates of the fish species of interest (FOI) and the countries of interest (COI) resulting from simulations of the current (blue square), proposed (red triangle), random (orange diamond) and other tested design scenarios (black dots). To select the best performing on-shore sample design, summary statistics generated from each simulated scenario were plotted to assess the

relative effect on the bias and precision of results. Departure from zero in percent deviation indicates bias, while higher RSE values indicate greater variation in estimated values.

8. Selection of a Sampling Plan

The analysis described above would help to interpret the results and finish with a manageable set of scenarios from which to decide. Before selecting a regional sampling design, results need to be discussed in terms of the quality of the estimates, cost implications, practical constraints in the implementation of the designs, and also national sampling requirement.

In general, there is also a need for a critical evaluation of the results of the simulations, to assess whether they provide evidence that a regional scheme has advantages over the national ones.

Finally, it needs to be evaluated if simulations of one parameter such as landed weight scale to the ones which are actually needed, such as catch weight or biological parameters. This can be done by incorporating biological data either into subsequent simulation tests. Alternatively, the sampling scheme selected from the simulation analysis could be field tested as a pilot study before fully implementation.

Annex 4

Annex 4.1 - Report on ecosystem components and species for which information would be particularly important to obtain

Updated on January 25th 2019

By

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Summary

This report describes the work towards identifying which type of data to collect for different multispecies models, including the identification of priority species for sampling of diet, abundance and spatial overlap, and on by-catch of protected, endangered or threatened species. The data types needed was broadly the same for the multispecies models capable of producing natural mortalities or growth estimates for stock assessment: Information on length, stanza and/or age of prey for all stocks, proportion of the prey of interest in the diet of major predators and the biomass of the given prey and predator. To improve knowledge on prey mortality, priority should be given to predators which have a high potential impact on total mortality of the stock. To improve knowledge on predator growth, priority should be given to prey which make up a large proportion of the food in at least some life stages and has demonstrated links to growth. Priority can also be given to given to prey and predator species where the interaction is high in only part of time series or only in some years. The likely effects of high priority predators on prey natural mortality are given for the Baltic Sea, Bay of Biscay, Irish Sea, Kattegat and the North Sea including Skagerrak, encompassing a total of 26 predatory species affecting 22 prey species. The likely effects of prey on high priority predator growth are given for the Celtic Sea, Eastern English Channel and the North Sea for a total of 10 predatory species affected by 7 commercially exploited prey species. On by-catch of protected, endangered or threatened species, a table was completed to provide an overview of the information available. A total of 75 case studies by Germany, Greece, Iceland, Ireland, Netherlands, Spain, Sweden, Denmark and the UK were included in the table, covering six types of case study (e.g. pilot study, habitat directive study).

Specific areas of regional cooperation, additional requirements and possible trade-offs on data on stomach content of fish and specific areas of regional cooperation, additional requirements and possible trade-offs on co-occurrence and relative abundance of species/stocks to estimate their ecological relationships

Two issues were considered under this task, what type of data to collect for different models (irrespective of area) and how to identify priority species for sampling of diet and abundance.

Input data needed for priority species in different multistock models, which can be used for stock assessment.

The type of data needed to estimate annual multistock assessments for use in management was investigated for each of the model type. The table below shows an overview of data requirements for candidate model types for use in management advice in the Northeast Atlantic (OSPAR area). (S) denote models aiming at providing strategic (long term, average over decades) and (T) tactical (short term, 1-3 years ahead) advice on fishing opportunities. Models marked with * have been used in multispecies stock assessment based advice in the Northeast Atlantic.

Multi stock assessment model	Proportion of prey in diet	Length, age or stanza of prey in the diet of predators of a given length or age	Consumption by predator	Biomass of prey[1]	Length, age or stanza distribution of prey	Biomass of predator[1]	Length, age or stanza distribution of predator	Spatial overlap
Ecopath with Ecosim (S)	Y	Y	Y	Y	Y	Y	Y	N[2]
Atlantis (S)	Y	Y	Y	Y	Y	Y	Y	Y
Osmose (S)	Y	Y	Y	Y	Y	Y	Y	Y
Le Mans ensemble (S)	N[3]	N[3]	N[3]	N[3]	N[3]	N[3]	N[3]	N[3]
Multispecies biomass (S, T)	Y	N[5]	Y	Y	Y	Y	N[4]	N
SMS (S, T,*)	Y	Y	Y	Y	Y	Y	Y	N[5]
Gadget (S, T, *)	Y	Y	Y	Y	Y	Y	Y	N[5]

[1]Some models require only indicators of temporal development in biomass and then estimate the absolute level from this information.

[2]Ecospace requires detailed spatial information, including migration rates between a large number of cells.

[3]While the Le Mans model does not require data on predator diet composition and length of prey and predators, it requires the possible prey for each predator species and length to be defined by expert judgement, which requires data on diet composition and size to have been collected.

[4]In cases where the length structure of the stock changes due to high or low recruitment, this is likely to impact the rate of loss to natural predators and to correct for this, it is necessary to have information on length, age and/or stanza.

[5]Simple spatial structure (a few areas) can be included but requires information on spatial distribution with the areas.

Generally, the models require rather similar data. Information on length and/or age of prey is needed for all stocks assessed with age- or lengthbased methods. For the stocks which are assessed by biomass based methods, length/age/stanza may not be required directly, but in cases where the length structure of the stock changes due to high or low recruitment, this is likely to impact the rate of loss to natural predators and to correct for this, it is necessary to have information on length, age and/or stanza.

It is not recommended to use models to predict predation impact on a specific stanza, age or length group without incorporating data from the specific area and species. This specifically pertains to information on the proportion of the prey of interest in the diet of major predators and the biomass of the given prey and predator.

Diet composition of predators is traditionally derived from stomach content analyses. These can be performed by sorting the stomach contents to species (usually fish) or prey groups (e.g. molluscs) and then counting, weighing and/or measuring the volume of the amount of each prey species or group. While other methods are also occasionally used, including genetic methods, these are still at the stage where they provide information on than presence/absence rather than the relative contribution of different species in numbers or weight, making it difficult to estimate the diet contribution as there is usually no clear relationship between proportion of stomachs containing a prey and the contribution by weight of the prey to the diet (Rindorf and Lewy 2004). Methods such as stable isotopes provide an index of the average trophic level of the diet integrated over a longer time perspective than a stomach sample. However, unless the diet consists of only two prey types with very different trophic level, this information cannot be used to derive the relative contribution of different prey species to the diet. Hence, stomach content analyses of predators caught in surveys (e.g. fish), recovered dead (e.g. cetaceans) and regurgitating food (e.g. breeding seabirds) as well as analyses of otoliths in scats (e.g. seals) remains the most appropriate method to derive information on the relative contribution of prey to the diet of a predator. The relative contribution of different prey species can be recorded by counting prey of each species, weighing the individual prey or measuring the volume of a given prey and then convert this to weight using a weight to volume relationship. As the information needed is the proportion of each prey by weight, the direct measurement of weight is most appropriate when this can be performed without measurement error (i.e. scales of sufficient precision are available). If this is not the case, counts or volume of prey can be used, supplementing with length measurements when using numbers and volume to weight relationships when using volume. The collection of specimens for diet analyses should cover the distribution of the predator and prey and ideally should track seasonal changes in diet composition. Fish predator samples are usually collected on surveys or on commercial vessels for species not caught in the surveys and seasons where surveys are not conducted. In the coming years, the development in cost efficiency of other methods should be followed closely to ensure that potential cost reductions are utilized immediately.

Biomass of prey and predators can generally be derived from data on commercial catches and stock abundance indices from scientific surveys, sometimes combined with information on catchability of the species to the survey (Walker et al. 2017). Some models require only indicators of temporal development in biomass, and hence a relative indicator of biomass may be sufficient. However, if there are numerous species for which only relative biomass is known, the model estimates of predation impact are likely to be highly uncertain.

Consumption by predator seems to be more stable in space and time and often differs less between species of similar size and habitat than diet composition. Hence, as a first approximation, consumption is often assumed to be a constant fraction of bodyweight. However, it should be noted that this assumption means that changes in consumption due to e.g. shortage of food cannot be followed by the model, which may consequently overestimate food consumption and prey mortality at low prey abundance. Consumption of fish can be estimated from stomach content weight combined with a model of stomach evacuation. The former information is directly available when stomachs are sampled for diet composition. The later requires laboratory experiments or generalisation across species and values obtained from similar species. Stomach evacuation models exist for a range of piscivore fish species in the literature, but models for increasing and invading species are not necessarily available.

Information on length of prey and predator are either obtained by direct measurements (using only reasonably intact prey) or from back calculation from otolith length. Of these, direct measurements is the simplest and least costly, and back calculation from otoliths is typically used when direct measurements are not available. Where the prey is highly digested, it is often difficult to estimate the length distribution, making it necessary to collect more stomach samples to obtain measurable prey for the length distribution.

Age information is generally obtained by applying age-length keys derived from other sources in the same area and time, and hence for species aged in regular surveys, this information is usually available for the surveyed seasons. For species not aged in surveys, age based information is generally not used in the stock assessment and hence length based information is sufficient. Outside the surveyed seasons, stomach samples will need to be supplemented by age-length key samples to derive the age composition of prey. Predators generally exhibit slower growth rates, and hence their age-length key varies less between seasons, reducing the need for seasonal updates between surveys.

Spatial overlap between fish predators and prey is generally monitored through surveys in one or two seasons of the year. In some cases, important prey or predators are not monitored consistently by the surveys or the surveys do not cover the main period of overlap and consumption. This is particularly true for highly mobile pelagic fish (e.g. horse mackerel and mackerel), species with low catchability in traditional surveys (e.g. sandeel), and of overlap in quarter 2, which is characterized by substantially higher temperatures than quarter 1 and as a result, higher consumption rates, but traditionally only surveyed by acoustic surveys. Some species undergo seasonal migrations, which are not necessarily monitored by existing surveys. This is particularly impractical, where the prey is monitored in one type of survey and the predator in another (e.g. quarter 1 groundfish survey and quarter 2 acoustic survey). For species landed consistently in commercial fisheries, catch rates can be used to estimate spatial distribution, albeit with the caveat that low catch rates may be caused by local obstructions to fishing rather than lack of fish and that catchability of species not closely associated with the bottom may depend on depth. If the distribution is stable over time, sufficient information can be obtained by combining all historic data. However, where fish distribution changes over time, this method becomes highly uncertain if the temporal coverage is uneven or low. As 16 out of 21 species examined by WKFISHDISH showed temporal shifts in distribution, and half of these species furthermore shifted distribution across management areas (ICES 2017), spatial information on an annual basis is a requirement to estimate multispecies interactions of fish.

Identification of priority species for sampling of diet and abundance

Priority species of two types were identified: prey species, where it is necessary to include information on variable mortality in assessments, and predator species, where prey abundance below a certain level may decrease somatic growth or fecundity.

For prey species, annual indicators of (absolute or relative) natural mortality can be included in stock assessments to account for changes in natural mortality which otherwise may lead to bias in the estimated stock abundance (e.g. the perception of unallocated landings of North Sea cod being substantially greater before introducing predation from seals in the assessment model). For predator species, improvements in the estimation of weight or fecundity at age can be made if prey abundance is known to be low or high in a certain period and a tight link has been demonstrated between the two.

For improving knowledge on prey mortality, priority should be given to predators which have a high potential impact on total mortality of the stock. An example is the effect of mackerel on smaller pelagic fish. For improving knowledge on predator growth, priority should be given to prey which make up a large proportion of the food in at least some life stages and has demonstrated links to growth. An example of this is the effect of capelin abundance on cod growth. Priority can also be given to given to prey and predator species where the interaction is high in only part of timeseries or only in some years, for example juvenile blue whiting entering the Celtic Sea in high abundance years.

Small pelagics represent a special case, as they are important to many predators, and are likely to have a variable and high natural mortality.

The data needed to assess species priority for sampling varies greatly between populations and areas. However, even where the specific data are very limited, risk assessment can be used to identify potential important interactions. In these cases, there is unlikely to be sufficient evidence for large scale sampling programs but one-off sampling events can be prioritized to increase the data available.

For prey mortality, the possible data dependent situations in order of increasing uncertainty are:

1. use recent and historic data specific to the area on predator diet and abundance of prey and predators
2. use historic data specific to the area on predator diet and abundance of prey and predators
3. use historic data specific to the area on predator diet and historic/uncertain abundance of prey and/or predators
4. use recent and historic data from other areas on predator diet of the same species together with indications of prey and predator abundance specific to the area
5. use size based methods together with morphological traits to determine the potential prey size range together with indications of prey and predator abundance specific to the area

For predator growth, the possible data dependent situations in order of increasing uncertainty are:

1. use recent and historic data specific to the area on prey abundance, predator diet and growth
2. use recent and historic data specific to the area on predator diet and growth
3. use historic data specific to the area on predator diet and growth
4. use recent and historic data from other areas on diet of the same species together with indications of growth specific to the area
5. use size based methods together with morphological traits to determine the potential prey size range together with indications of growth specific to the area

Large scale sampling should only be initiated based on situation 1 and 2, whereas situation 3 and higher can be used to select priority species for one-off sampling events.

It should be noted that presence/absence data are often poorly related to weight proportion, and hence is unlikely to provide sufficient information on diet composition.

Information on prey dependent growth in fish is generally limited to cases where a predator in part of the year or part of its life cycle has a diet dominated by a single prey (e.g. cod feeding on capelin). There are no reported long term effects in the North Sea on predator growth (Engelhard et al. 2014).

To ensure a systematic approach to prioritizing species, the group recommended first completing either the prey or predator table attached. Prey and predator biomass, predator total consumption and prey total production can be estimated from e.g. Ecopath input data together with the fraction of production consumed by known predators. From these values, the prey species for which consumption is more than 20% of their production can be identified together with predators accounting for more than 5% of this consumption. Other sources of information can also be considered. Examples of filled out tables for the North Sea, Celtic Sea, Irish Sea, English Channel and Bay of Biscay are given below. The tables can also be used for seabird and marine mammal predators and examples of these are also given.

Prey mortality prioritization table

The table values are based on averages over multiple years. Local age-based impacts differs from these values, in particular for species which have changed greatly in abundance or distribution. One prey species (lemon sole in the North Sea) was excluded as the diet composition indicated that the number of predators feeding on this prey was underestimated. The table entries are sorted in order of falling number of prey species impacted, with the predators impacting most prey listed first.

Ecosystem	Predator	Data situation	Predator biomass ('000 t)	Prey where consumption>20% of production and predator responsible for >5% of consumption	Prey biomass ('000 t)	Proportion of prey consumption due to predator (average 2000-2013) values based on WGSAM in brackets)	Existing data in ICES database from which years	Predator/prey overlap change? 0: none 1: minor 2: major ?:insufficient information	Reference/contact
North Sea	Whiting	2	330	Cod[1] Whiting[1]	45 128	16% (2%) 26% (2%)	1981, 1985, 1986, 1987, 1991	2 1	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to

				Haddock[1] Norway pout Herring[1] Sprat sandeel sole	163 802 362 333 1780 91	25% (5%) 28% (2%) 30% (2%) 38% (3%) 31% (2%) 26%		1 1 1 1 1 1	fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp. ICES WGSAM 2015 (values in brackets) ICES WKFISHDISH (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.05.pdf)
North Sea	Horse mackerel	2	333	Cod[1] Whiting[1] Haddock[1] Norway pout Herring[1] Blue whiting sandeel	45 128 163 802 362 24 1780	20% (0%) 18% (0%) 28% (0%) 24% (0%) 29% (45%) 40% (26%)	1987, 1991	2 1 0 0 1 1 1	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp. ICES WGSAM 2015 (values in brackets) ICES WKFISHDISH (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.05.pdf)
North Sea	Saithe	2	271	Haddock[1] Blue whiting Norway pout	163 24 802	8% (4%) 27% 28% (5%)	1981, 1986, 1987, 1991	0 1 0	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description

				Herring[1] Sprat	362 333	9% (4%) 23% (0%)		1 1	and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp. ICES WGSAM 2015 (values in brackets) ICES WKFISHDISH (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.05.pdf)
North Sea	Cod	2	138	Cod[1] Whiting[1] Haddock[1] Blue whiting sole	45 128 163 24 91	8% (2%) 6% (1%) 10% (2%) 8% 22%	1981, 1985, 1986, 1987, 1991	2 2 2 2 2	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp. ICES WGSAM 2015 (values in brackets) ICES WKFISHDISH (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.05.pdf)
North Sea	Mackerel	2	989	Herring[1] Sprat Sandeel	362 333 1780	9% (11%) 21% (12%) 22% (12%)	1981, 1991	2 2 2	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description

				Norway pout		(6%)		2	and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp. ICES WGSAM 2015 (values in brackets) ICES WKFISHDISH (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.05.pdf)
North Sea	Hake	2	8	Hake Blue whiting Herring[1]	8 24 362	13% 11% (7%)	2013	2 2 2	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp ICES WGSAM 2015 (values in brackets) ICES WKFISHDISH (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.05.pdf)
North Sea	Gurnards	2	44	Cod[1] Whiting[1] sandeel	45 128 1780	11% (25%) 5% (23%) (17%)	1991, 2013	2 1 1	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description

									and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp. ICES WGSAM 2015 (values in brackets) ICES WKFISHDISH (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.05.pdf)
North Sea	Halibut	3	19	Whiting[1] Haddock[1]	128 163	8% 15%	None	? ?	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp.
North Sea	Haddock	2	223	Sandeel	1795	6% (4%)	1981, 1991	0	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp. ICES WGSAM 2015 (values in brackets) ICES WKFISHDISH (http://www.ices.dk/sites/pub/Publi

									cation%20Reports/Advice/2017/Special_requests/eu.2017.05.pdf)
North Sea	Starry ray	2	63	Cod[1]	45	8% (0%)	1991	?	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp. ICES WGSAM 2015 (values in brackets)
North Sea	Monkfish	3	9	Hake	8	9%	None	2	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp. ICES WKFISHDISH (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.05.pdf)
North Sea	Plaice	3	404	Sole	91	21%	None	2	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp.

									ICES WKFISHDISH (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/eu.2017.05.pdf)
North Sea	Turbot/ brill	3	31	Cod[1]	45	10%	None	?	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp.
North Sea	Megrim	3	20	Blue whiting	24	7%	None	?	Mackinson, S. and Daskalov, G., 2007. An ecosystem model of the North Sea to support an ecosystem approach to fisheries management: description and parameterisation. Sci. Ser. Tech Rep., Cefas Lowestoft, 142: 196pp.
Irish Sea	Cod	2	16	Whiting Haddock Herring Nephrops	38 8 80 40	17% 93% 7% 29%	None	1 1 1 1	Bentley, J., Serpetti, N., Fox, C., Heymans, S.J.J., & Reid, D.G. (2018) Modelling the food web in the Irish Sea in the context of a depleted commercial fish community- Irish Sea Ecopath Technical Report 2017-2018.
Irish Sea	Whiting	2	26	Whiting[1] Sprat	12 92	7% 6%	None	0 1	Bentley, J., Serpetti, N., Fox, C., Heymans, S.J.J., & Reid, D.G. (2018) Modelling the food web in the Irish Sea in the context of a depleted

									commercial fish community- Irish Sea Ecopath Technical Report 2017-2018.
Irish Sea	Gurnards & Dragonets	2	16	Gurnards & Dragonets Nephrops	16 40	18% 6%	None	?	Bentley, J., Serpetti, N., Fox, C., Heymans, S.J.J., & Reid, D.G. (2018) Modelling the food web in the Irish Sea in the context of a depleted commercial fish community- Irish Sea Ecopath Technical Report 2017-2018.
Irish Sea	Plaice	2	7	Sandeel Scallop	35 62	7% 86%	None	1 1	Bentley, J., Serpetti, N., Fox, C., Heymans, S.J.J., & Reid, D.G. (2018) Modelling the food web in the Irish Sea in the context of a depleted commercial fish community- Irish Sea Ecopath Technical Report 2017-2018.
Irish Sea	Haddock	2	4	Nephrops	40	44%	None	1	Bentley, J., Serpetti, N., Fox, C., Heymans, S.J.J., & Reid, D.G. (2018) Modelling the food web in the Irish Sea in the context of a depleted commercial fish community- Irish Sea Ecopath Technical Report 2017-2018.
Kattegat	Harbour seal	4	Approximately 15,000	Cod	SSB 2017: 1746-2157 tonnes	Preliminary estimate is 10% of harbor seal diet	Annual monitoring of seal numbers	2	ICES. 2017. Report of the Benchmark Workshop on Baltic Stocks (WKBALT), 7–10

			individuals						February 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:30. 108 pp. Dietary monitoring feasible. Possible start in 2019 (K. Lundström, SLU).
Kattegat	Great cormorant	4	Approximately 10,000 breeding pairs	Cod (?)	SSB 2017: 1746-2157 tonnes		Annual monitoring in DK. Feasible to monitor also in SE.	2	Dietary monitoring feasible. (K. Lundström, SLU)
Kattegat	Harbour porpoise	4	23,000-77,000 incl. the Belt Seas	Cod (?)	SSB 2017: 1746-2157 tonnes		SCANS surveys	2	Dietary monitoring feasible (Ross et al. 2016)
Skagerrak	Harbour seal	4		Coastal cod (?)			Annual monitoring of seal numbers	2	Dietary monitoring feasible. (K. Lundström, SLU)

Baltic Sea (various areas)	Grey seal/Ringed seal	4	Approximately 45,000/25,000	Cod (?) Herring (?) Salmon (?) Vendace			Annual monitoring of seal numbers	2	Dietary monitoring feasible. (K. Lundström, SLU).
Bay of Biscay	Tuna*	2	¿?	Anchovy	304	?	None	?	Andonegi, E.
Bay of Biscay	Rays	2	149	Hake [2] Blue whiting	100 5129	12.0% 12.0%	None	? ?	Andonegi, E.
Bay of Biscay	Hake	2	157	Blue whiting Anchovy Hake [2] Mackerel Monkfish Megrim Sardine Horse Mackerel Rays	5129 304 100 2390 659 135 680 3632 149	31.0% 14.0% 9.0% 9.0% 8.0% 8.0% 7.0% 5.0% 5.0%	None	? ? ? ? ? ? ? ? ?	Andonegi, E.

Bay of Biscay	Monkfish	2	659	Blue whiting Mackerel Horse mackerel Sardine	5129 2390 3632 680	6.5% 9.0% 9.0% 5.0%	None	? ? ? ?	Andonegi, E.
Bay of Biscay	Megrim	2	135	Blue whiting Mackerel Sardine	5129 2390 680	6.5% 9.0% 5.0%	None	? ? ?	Andonegi, E.
Bay of Biscay	Sea Bass	2	479	Mackerel Anchovy Sardine	2390 304 680	8.0% 10.0% 25.0%	None	? ? ?	Andonegi, E.
Bay of Biscay	Blue whitting	2	5129	Horse Mackerel	3632	12.0%	None	?	Andonegi, E.
Bay of Biscay	Mackerel	2	2390	Anchovy Sardine	304 680	7.0% 7.0%	None	? ?	Andonegi, E.
Bay of Biscay	Horse Mackerel	2	3632	Sardine	680	6.0%	None	?	Andonegi, E.
Bay of Biscay	Sardine	2	680	No fish			None	?	Andonegi, E.

Bay of Biscay	Anchovy	2	304	No fish			None	?	Andonegi, E.
Bay of Biscay	Cephalopods	2	340	No fish			None	?	Andonegi, E.

[1] Juveniles only

[2]Included only in the Atlantis model

Predator growth prioritization table

The table values are based on averages over multiple years. Local age-based impacts differs from these values, in particular for species which have changed greatly in abundance or distribution.

Ecosystem	**Predator**	**Data situation**	**Prey**	**Prey mortality or predator growth effect**[1]	**Prey M/F and Z (in 2017)**	**Prey biomass change**	**Prey /predator overlap change**	**Predator growth link demonstrated**	**Proportion of prey in predator diet (p)**	**Existing diet data from which years**	**Reference/contact**
North Sea	Saithe	1	Norway Pout	predator growth	M/F = 52[6] Z = 0.39[7].	Estimated increase since 2014 (ICES, 2017b)	no, but competition between predators effect	yes	47 to 61 %, occurrence[3]	1981, 1986, 1987, 1991	ICES 2017, Cormon 2015, Cormon et al. 2014,2016/ Pierre Cresson
North Sea	hake	1	Norway Pout	predator growth	M/F = 41[1] Z = 0.39.	Estimated increase since 2014 (ICES, 2017b)	no, but competition between	yes	24 to 54%, occurrence[8]	2013	ICES 2017, Cormon 2015, Cormon et al. 2014,2016/ Pierre Cresson

[6] mainly due to low F in first quarter 2017

[7] Mortality are calculated on age 1 and 2 as in the assessment (ICES, 2017b)

[8] Work is in progress to produce diet percentage instead of occurrence.

Ecosystem	Predator	Data situation	Prey	Prey mortality or predator growth effect[1]	Prey M/F and Z (in 2017)	Prey biomass change	Prey /predator or overlap change predators effect	Predator growth link demonstrated	Proportion of prey in predator diet (p)	Existing diet data from which years	Reference/contact
Eastern English Channel	Seabass	4	*Crangon crangon*	predator growth	Z = 5.8 ((ICES, 2016). Northern Europe Stock.	No clear trend but low levels of biomass	NA	yes	10-15%	1995-1997	Pierre Cresson
Eastern English Channel	Pollack (P. pollachius)	4	*Crangon crangon*	predator growth	Z = 5.8 ((ICES, 2016). Northern Europe Stock.	No clear trend but low levels of biomass	NA	yes	10-15%	1995-1997	Pierre Cresson
Eastern English Channel	Pout (*T. luscus*)	4	*Crangon crangon*	predator growth	Z = 5.8 ((ICES, 2016). Northern Europe Stock.	No clear trend but low levels of biomass	NA	yes	23%	1995-1997	Pierre Cresson

Ecosystem	Predator	Data situation	Prey	Prey mortality or predator growth effect[1]	Prey M/F and Z (in 2017)	Prey biomass change	Prey /predator or overlap change	Predator growth link demonstrated	Proportion of prey in predator diet (p)	Existing diet data from which years	Reference/contact
Eastern English Channel	Pollack (*P. pollachius*)	3	Clupeids	predator growth	Herring (Shared stock EEC/North Sea) M/F= 1.3 & Z = 0.59[9] , NA for other species	increasing trend since 1977 (ICES, 2017a) for herring, NA for other species	NA	no data	15-20%	1995-1997	Pierre Cresson
Eastern English Channel/North Sea	Whiting	3	Clupeids	predator growth	Herring (Shared stock EEC/North Sea) M/F= 1.30 & Z = 0.59 [3] NA for other species	increasing trend since 1977 (ICES, 2017a) for herring, NA for other species	NA	no data	20%	1995-1997, 2015	Pierre Cresson; MSFD data for 2015
Shared stock EEC/N	Whiting	4	*Trisopterus luscus* and/or	predator growth	NA	NA	NA	no data	20%	2015	Pierre Cresson

[9] calculated for age 2-6 as in the assessment (ICES, 2017a)

Ecosystem	Predator	Data situation	Prey	Prey mortality or predator growth effect[1]	Prey M/F and Z (in 2017)	Prey biomass change	Prey /predator or overlap change	Predator growth link demonstrated	Proportion of prey in predator diet (p)	Existing diet data from which years	Reference/contact
orth Sea			*T. esmarkii*								
Eastern English Channel	sole	4	benthic invertebrates	predator growth	NA	NA	NA	yes	90-100%	2009-2015	Pierre Cresson
Eastern English Channel	plaice	4	benthic invertebrates	predator growth	NA	NA	NA	yes	90-100%	2009-2015	Pierre Cresson
Celtic Sea	Hake (adults)	1	Blue whiting	Predator growth	N=0.2 F = 0.4[10]	Increasing since 2010	NA	no data	30%	2014-2015	Rault et al 2017 – ICES WGWIDE 2016

[10] Landings in the 7 e-k very low (most of the harvesting done elsewhere)

Ecosystem	Predator	Data situation	Prey	Prey mortality or predator growth effect[1]	Prey M/F and Z (in 2017)	Prey biomass change	Prey /predat or overlap change	Predator growth link demonstrated	Proportion of prey in predator diet (p)	Existing diet data from which years	Reference/contact
					ICES estimation 2016						Also Dubuit, 1996, Trenkel et al, 2005
Celtic Sea	Black-bellied angler	2	Gobiidae	Predator growth	?	?	NA		Juveniles 40% Adults 25%	2014-2015	Rault et al 2017
Celtic sea	Black-bellied angler (adults)	2	Gadiforms (especially Poor cod)	Predator growth	?	?	NA		30%	2014-2015	Rault et al 2017
Celtic Sea	Whiting (adults)	1	Blue whiting	Predator growth	ICES estimation 2016 M=0.2F = 0.4	Increasing since 2010	NA	?	15%	2014-2015	Rault et al 2017 – ICES WGWIDE 2016

Ecosystem	Predator	Data situation	Prey	Prey mortality or predator growth effect[1]	Prey M/F and Z (in 2017)	Prey biomass change	Prey /predator or overlap change	Predator growth link demonstrated	Proportion of prey in predator diet (p)	Existing diet data from which years	Reference/contact
Celtic Sea	Megrim (adults)	1	Horse mackerel	Predator growth	ICES estimation 2017 M=0.15 F=0.0438	Decreasing(slowly) since 2006	Na	?	22 % (occurrence) [3]	2014-2015	Rault et al 2017 – ICES WGWIDE 2017
Celtic Sea	Angler (adults)	2	Norway pout	Predator growth	?	?	?	?	40% (occurrence) [3]	2014-2015	Rault et al 2017
Celtic Sea	Angler (adults)	1	Horse mackerel	Predator growth	ICES estimation 2017 M=0.15 F=0.0438	Decreasing(slowly) since 2006	?	?	27% (occurrence) [3]	2014-2015	Rault et al 2017 – ICES WGWIDE 2017

Specific areas of regional cooperation, additional requirements and possible trade-offs on by-catch of protected, endangered or threatened species are addressed in each of seven subtasks

On this task, a table was prepared in advance of the meeting and completed to provide an overview of the information available. During the meeting, the ToRs of a new ICES workshop, WKPETSAM were discussed and it was agreed to make a new table format which may be useful to both Fishpi2 and WKPETSAM. This way, WKPETSAM would get detailed information from fisphi^2 partners in advance of the meeting, and fishpi^2 would obtain data from countries not partnering in fisphi^2. The table was completed with a number of examples spanning both dedicated studies and data sampling on commercial catch observer trips and further elaborated on and completed at WKPETSAM. An overview of the cases given in the table is given below.

The purpose of sampling of PET sampling is to derive estimates of catch for derivation of bycatch mortality. It should be noted that the CV of this is dependent on CV of both catch and stock abundance. Hence, costs should be allocated to ensure that the combined CV of the estimated bycatch mortality is acceptable. In fisphi^2, the focus will be on the effect of increased catch sampling by different methods on CV.

When examining the completed table, sampling priority will be given to sampling species/populations which are spatially restricted, at low abundance, show a decreasing trend, have high overlap with fisheries and are sensitive (defined from their life history). The information on population sensitivity and vulnerability will be presented together with the accuracy, precision and cost of current monitoring as well as the cost of improving precision by e.g. 50% if possible. This should provide the necessary basis for prioritizing sampling of species according to importance and cost of obtaining better data.

Country	Year	Year the survey started	Type of monitoring	Main objective of monitoring scheme	Study area	Ecoregion	Target population	Primary sampling unit
Germany	2017	2009	DCF- sea sampling programme	catch composition fish/crustacea species, bycatch of birds and mammals	German coastal area	North Sea	Beam trawl targeting brown shrimp in the German coastal area	Fishing trips
Germany	2017	1995	DCF- sea sampling programme	catch composition fish species, bycatch of birds and mammals	4.,7d	North Sea	Trawlers targeting mackerel, herring in IV, VIId	Fishing trips
Germany	2017	1995	DCF- sea sampling programme	catch composition fish/crustacea species, bycatch of birds and mammals	4, 3a	North Sea	Trawlers targeting gadoids in IV, IIIa	Fishing trips
Germany	2017	1998	DCF- sea sampling programme	catch composition fish/crustacea species, bycatch of birds and mammals	4	North Sea	Beam trawl targeting flat fish in IV	Fishing trips
Germany	2017	1998	DCF- sea sampling programme	catch composition fish/crustacea species, bycatch of birds and mammals	4	North Sea	OTB targeting plaice in IV	Fishing trips
Germany	2017	1980	DCF- sea sampling programme	catch composition fish species, bycatch of birds and mammals	NAFO SA1-2	North Atlantic	OTB targeting Greenland halibut In NAFO SA1-2	Fishing trips

Germany	2017	1995	DCF- sea sampling programme	catch composition fish species, bycatch of birds and mammals	6,7	North Atlantic	OTM targeting small pelagic species in VI, VIIbcjk, VIIe, VIIfgh, VIII, V-XIV, (IVa)	Fishing trips
Germany	2017	1980	DCF- sea sampling programme	catch composition fish species, bycatch of birds and mammals	12,14	North Atlantic	OTB targeting Greenland halibut In XII, XIV, Va	Fishing trips
Germany	2017	1995	DCF- sea sampling programme	catch composition fish species, bycatch of birds and mammals	12,14	North Atlantic	OTM targeting redfish in XII, XIV, Va	Fishing trips
Germany	2017	1998	DCF- sea sampling programme	catch composition fish species, bycatch of birds and mammals	1,2	North Atlantic	Trawlers targeting cod, saithe in I, II	Fishing trips
Germany	2017	1998	DCF- sea sampling programme	catch composition fish species, bycatch of birds and mammals	1,2	North Atlantic	Trawlers targeting herring in II (ASH)	Fishing trips
Germany	2017	2009	DCF- sea sampling programme	catch composition fish species, bycatch of birds and mammals	German coastal area	Baltic Sea	demersal trawlers	Fishing trips
Germany	2017	2009	DCF- sea sampling programme	catch composition fish species,	German coastal area	Baltic Sea	demersal gillnetters and longliners	Fishing trips

				bycatch of birds and mammals				
Greece	2017	2002	DCF- sea sampling programme	Catches/ discards of fish species/ Since 2017: Bycatch of birds, sea turtles and mammals	GSA20, GSA22, GSA23	Mediterranean Sea (Aegean Sea, Ionian Sea)	Trips of all Bottom otter trawls (OTB_DES_>=40_0_0) per GSA	Fishing trips
Greece	2017	2002	DCF- sea sampling programme	Catches/ discards of fish species/ Since 2017: Bycatch of birds, sea turtles and mammals	GSA20, GSA22, GSA23	Mediterranean Sea (Aegean Sea, Ionian Sea)	Trips of all Purse seines (PS_SPF_>=14_0_0) per GSA	Fishing trips
Greece	2017	2002	DCF- sea sampling programme	Catches/ discards of fish species/ Since 2017: Bycatch of birds, sea turtles and mammals	GSA22	Mediterranean Sea (Aegean Sea, Ionian Sea)	Trips of Pots and Traps (FPO_DEF_0_0_0), only in GSA 22	Fishing trips
Greece	2017	2002	DCF- sea sampling programme	Catches/ discards of fish species/ Since 2017: Bycatch of birds, sea turtles and mammals	GSA20, GSA22, GSA23	Mediterranean Sea (Aegean Sea, Ionian Sea)	Trips of all Set gillnet (GNS_DEF_>=16_0_0) per GSA	Fishing trips
Greece	2017	2002	DCF- sea sampling programme	Catches/ discards of fish species/ Since 2017: Bycatch of birds, sea turtles and mammals	GSA20, GSA22, GSA23	Mediterranean Sea (Aegean Sea, Ionian Sea)	Trips of all Trammel net (GTR_DEF_>=16_0_0) per GSA	Fishing trips

Greece	2017	2002	DCF- sea sampling programme	Catches/ discards of fish species/ Since 2017: Bycatch of birds, sea turtles and mammals	GSA20, GSA22, GSA23	Mediterranean Sea (Aegean Sea, Ionian Sea)	Trips of Drifting longlines (LLD_LPF_0_0_0) per GSA	Fishing trips
Greece	2017	2002	DCF- sea sampling programme	Catches/ discards of fish species/ Since 2017: Bycatch of birds, sea turtles and mammals	GSA20, GSA22, GSA23	Mediterranean Sea (Aegean Sea, Ionian Sea)	Trips of Set longlines (LLS_DEF_0_0_0) per GSA	Fishing trips
Greece	2017	2002	DCF- sea sampling programme	Catches/ discards of fish species/ Since 2017: Bycatch of birds, sea turtles and mammals	GSA20, GSA22	Mediterranean Sea (Aegean Sea, Ionian Sea)	Trips of Beach and boat seine (SB_SV_DEF_0_0_0) in GSAs 20 and 22	Fishing trips
Iceland	2017	2014*	Icelandic fisheries monitoring program	Catch/Discards/gear regulations	5a	Iceland sea	Lumpsucker gillnet fishery	Fishing trips
Iceland	2017	2013*	Directed study	Spawning stock of cod	5a	Iceland sea	Cod gillnet fishery in April	Set
Iceland	2017	2014*	Icelandic fisheries monitoring program	Catch/Discards/gear regulations	5a	Iceland sea	Longline fishery	Fishing trips

Iceland	2017	2014*	Icelandic fisheries monitoring program	Catch/Discards/gear regulations	5a	Iceland sea	Demersal trawl fishery	Fishing trips
Iceland	2017	2014*	Icelandic fisheries monitoring program	Catch/Discards/gear regulations	5a	Iceland sea	Pelagic trawl/seine fishery	Fishing trips
Iceland	2017	2014*	Icelandic fisheries monitoring program	Catch/Discards/gear regulations	5a	Iceland sea	Demersal gillnets	Fishing trips
Iceland	2017	2014*	Icelandic fisheries monitoring program	Catch/Discards/gear regulations	5a	Iceland sea	Demersal seine	Fishing trips
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	6a	North Atlantic	Trips carried out by demersal/nephrops trawlers	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7a	North Atlantic	Trips carried out by demersal/nephrops trawlers	vessel x trip

Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7fgh	North Atlantic	Trips carried out by demersal/nephrops trawlers	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7fgh	North Atlantic	Trips carried out by demersal static gears, Gillnets/trammel	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7bcjk	North Atlantic	Trips carried out by demersal trawlers	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7bcjk	North Atlantic	Trips carried out by demersal static gears, Gillnets/trammel	vessel x trip
Ireland	2017	2017	EMFF Enhanced ByCatch sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7bcjk	North Atlantic	Trips carried out by demersal static gears, Gillnets/trammel	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	6a	North Atlantic	Trips carried out by Pelagic trawlers	vessel x trip

Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7a	North Atlantic	Trips carried out by Pelagic trawlers	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7fgh	North Atlantic	Trips carried out by Pelagic trawlers	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7bcjk	North Atlantic	Trips carried out by Pelagic trawlers	vessel x trip
Ireland	2017	2017	EMFF Enhanced ByCatch sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	6a, 7bcjk,7fgh,7a	North Atlantic	Trips carried out by Pelagic trawlers	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	6a	North Atlantic	Trips carried out by Potters	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7a	North Atlantic	Trips carried out by Potters	vessel x trip

Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7fgh	North Atlantic	Trips carried out by Potters	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	7bcjk	North Atlantic	Trips carried out by Potters	vessel x trip
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	ICES Area IV, VIId -North Sea ICES Area I,II - Eastern Arctic	North Sea Eastern Arctic	Trips carried out by Pelagic trawlers	Fishing trips
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of Whelks	7a	North Atlantic	Potters targetting Molluscs	Fishing trips
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of scallops, razors, cockles and fishspecies	7a	North Atlantic	Scallop dredgers	Fishing trips
Ireland	2017	2013	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of scallops and fishspecies	7fgh	North Atlantic	Scallop dredgers	Fishing trips

Netherlands	2017	2004	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	ICES 1-12	NE Atlantic	Trips carried out by Pelagic Trawlers	Fishing trips
Netherlands	2017	2016	self-sampling	Discards of fishspecies	IV	North Sea	Trips carried out by Demersal trawlers	Fishing trips
Netherlands	2017	2016	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	IV	North Sea	Trips carried out by vessel using passive gear	Fishing trips
Netherlands	2017	2016	DCF- sea sampling programme	Bycatch of birds and mammals, catches/discards of fishspecies	IV	North Sea	Trips carried out by shrimp(crangon) beamtrawlers	Fishing trips
Netherlands	2008	2008	Directed study	Bycatch of mammals.	IV	North Sea	Trips carried uit by gill- and trammelnet fishers	Fishing trips
Netherlands	2017	2013	Directed study by Electronic Monitoring	Bycatch of harbour porpoises	IV	North Sea	Trips carried out by gill- and trammelnet fishers	Fishing trips
Spain (Basque Country)	2017	2017	DCF- sea sampling programme	Catches / discards of fish species	II	Norwegian and Barents seas	Trips carried out by demersal trawlers	Fishing trips

Spain (Basque Country)	2017	2017	DCF- sea sampling programme	Catches / discards of fish species	VI	Celtic seas	Trips carried out by demersal trawlers	Fishing trips
Spain (Basque Country)	2017	2017	DCF- sea sampling programme	Catches / discards of fish species	VIIIabd	Bay of Biscay	Trips carried out by demersal trawlers	Fishing trips
Spain (Basque Country)	2017	2017	DCF- sea sampling programme	Catches / discards of fish species	VIIIabdc	Bay of Biscay and Iberian coast	Trips carried out by purse seiners	Fishing trips
Spain (Basque Country)	2017	2017	Pilot study based on questionnaires to skippers	Seabirds bycacth	VIIIabdc	Bay of Biscay and Iberian coast	Trips carried out by the artisanal fleet	Skippers from the artisanal fleet
Spain (Basque Country)	2017	2017	Pilot study using new technologies	Catches / discards of fish species and PETS species	VIIIabdc	Bay of Biscay and Iberian coast	Trips carried out by the artisanal fleet	Fishing trips
Sweden	2017	1997	DCF- sea sampling programme	Catches / discards of fish species	IIIaS	North Sea	Trips carried out by demersal trawlers	Fishing trips
Sweden	2017	2008	DCF- sea sampling programme	Catches / discards of fish species	IIIaS	North Sea	Trips carried out by demersal trawlers using sorting grids	Fishing trips

Sweden	2017	2002	DCF- sea sampling programme	Catches / discards of fish species	IIIaN	North Sea	Trips carried out by demersal trawlers	Fishing trips
Sweden	2017	2005	DCF- sea sampling programme	Catches / discards of fish species	IIIaN	North Sea	Trips carried out by demersal trawlers using sorting grids	Fishing trips
Sweden	2017	2008	DCF- sea sampling programme	Catches / discards of fish species	IIIa, IV	North Sea	Trips carried out by trawlers targeting *Pandalus*	Fishing trips
Sweden	2017	2008	DCF- sea sampling programme	Catches / discards of fish species	IIIa	North Sea	Trips carried out by trawlers using sorting grids targeting *Pandalus*	Fishing trips
Sweden	2017	1996	DCF- sea sampling programme	Catches / discards of fish species	SD 24-26	Baltic sea	Trips carried out by demersal trawlers	Fishing trips
Sweden	2017	2017	Directed study	Bycatch of birds and mammals, catches/discards of fishspecies	SD 23-25	Baltic Sea	Trips carried out by gillnetters/longliners targeting primarely cod	Fishing trips
UK	2016	1996	Habitats directive	Protected species bycatch	27.4, 27.6, 27.7	North Sea, Celtic Seas	Gillnetters	Vessels

UK	2016	2013	812/2004 pilot studies	Cetacean bycatch	27.4, 27.7d-j	North Sea, Celtic Seas	Vessels requiring the use of ADDs under 812/2004	Vessels
UK	2016	2005	812/2004 mandatory monitoring	Cetacean bycatch	27.6, 27.7, 27.8	Celtic Seas , Biscay	Midwater trawlers	Vessels
UK	2016	2005	812/2004 mandatory monitoring	Cetacean bycatch	27.6a, 27.7ab, 27.8abc	Celtic Seas , Biscay	Gillnetters	Vessels
UK	2016	2005	812/2004 pilot studies	Cetacean bycatch	27.6, 27.7, 27.8	Celtic Seas , Biscay	Midwater trawlers	Vessels
UK	2016	2010	Habitats directive and Birds Directive	Protected species bycatch	27.4,27.6,27.7, 27.8	North Sea, Celtic Seas and Biscay	Longliners	Vessels
Denmark	2017	2010	EMFF funded-pilot monitoring studies on bycath of marine mammals and sea birds	Protected species bycatch	21,22,23,24	Skagerrak, Inner Danish waters	Gillnetters	Fishing trips

Assessing risk of by-catch of protected, endangered or threatened species

In recent years there have been a number of studies that have tried to develop risk maps or risk analyses in relation to protected species bycatch, including the fishPi project. In this context, the term 'risk' can be interpreted in several ways. At its simplest, risk may refer to the probability that an individual animal might get caught accidentally in a net. This is a function of the type of fishing and the level of fishing effort in a given area, and is independent of animal density. Areas of highest fishing density are areas of greatest risk to the individual, for a given type of fishing.

Another way of looking at risk is to consider where and when the greatest number of animals might be expected to be killed. This is risk considered at the population level. In this case, the density of the animals and the amount of fishing in the same place and same time are important. This approach assumes that these factors are known (correctly), that the spatial and temporal scales can be correctly aligned to reflect actual risk and that there is a simple relationship between animal density and fishing effort. This is the approach that has often been taken in recent years to predict areas with highest bycatch (see e.g.: Northridge, Coram, & Kingston, 2012, Breen et al 2017). However, when estimates of total bycatch using observer data are overlain on risk maps, they do not necessarily confirm the location of high-risk areas. This is because the risk maps are based on assumed species distributions, where densities are thought to be predictable at small spatial scales when predictions bear little resemblance to reality, and on assumptions that for a given level of fishing effort, the risk of bycatch is directly and linearly related to the number of animals present, which is not necessarily true. The spatially explicit approach often builds on density maps of questionable accuracy or restricted data: Very few cetacean density surface maps have subsequently been validated by fieldwork. The consistency of the distribution of sensitive fish and seabirds remains unknown.

A more accurate way to map areas with highest bycatch rates is to collate observations of bycatches rates along with estimates of fishing effort to generate an observed bycatch risk (density) map, always assuming there are sufficient observations for the area(s) of concern. This direct measure provides an accurate representation of risk if the sampling effort is sufficient (Northridge, Coram and Kingston 2018 in prep).

A fourth way to consider risk in the context of conservation is to ask where greatest *uncertainty* lies in any estimates of bycatch numbers per year for a given area. In this case it is necessary to consider uncertainty in estimates of bycatch rate, fishing effort and population abundance. Here risk is the risk of getting it wrong – the risk of uncertainty in devising management measures. This approach addresses the management question: "given current knowledge, where <u>might</u> the greatest number of bycaught animals be found, and is this number <u>likely</u> to exceed some reference level". The point of the second clause is that even if there is a high level of uncertainty of the absolute number being killed, it may be clear that the absolute level is unlikely to be a concern, which helps focus management actions. This is the approach adopted by the ICES Working Group on Bycatch of Protected Species (WGBYC). Upper confidence limits on observed bycatch rates in the region(s) concerned- (or from adjacent regions if necessary), are applied to estimates of fishing effort for the same region(s) <u>to identify the areas or fisheries where there is most scope for a problem to exist</u>, or where expected rates may most exceed some reference level (see ICES 2013 and also Northridge 2018 in review). This approach is significantly different from the preceding three approaches in that it explicitly addresses uncertainty.

In all four of the above approaches, three key types of information are required: fishing effort, bycatch per unit of fishing effort and population abundance.

In selected cases, observed bycatch rates are available for key species from dedicated surveys (see table in D4.1). However, where bycatch rate estimates are absent or limited, inferences can be made either by expert judgement, by assuming the rates are similar to those found elsewhere, or by using an estimate of density as a proxy for relative bycatch rate. For example, by assuming that bycatch rates are twice as high in areas where animal density is twice as high. This can be used to identify cases where pilot studies are specifically needed to confirm or reject the suspected level of risk. FISHPI used a combination of expert judgement and available data to identify high risk gear, focusing on a full range of species. Results are summarised in the table below.

	AZ	BB	CS	EA	FI	IB	IS	MA	NS	SK	WC	WI	WS	BS
Boat dredge [DRB]	0	27	18	0	0	36	27	0	32	16	36	18	27	NA
Bottom otter trawl [OTB]	0	60	60	36	30	75	60	45	60	48	60	60	60	48
Multi-rig otter trawl [OTT]	0	52	52	0	13	13	13	0	40	30	26	39	39	20
Bottom pair trawl [PTB]	0	39	13	20	13	52	0	0	30	20	13	13	26	36
Beam trawl [TBB]	0	24	36	0	0	48	36	0	36	18	36	12	12	0
Midwater otter trawl [OTM]	0	51	34	45	17	17	34	34	45	30	51	51	51	48
Pelagic pair trawl [PTM]	0	51	34	15	0	34	34	17	45	30	51	51	34	36
Hand and Pole lines [LHP] [LHM]	32	27	27	0	0	36	9	0	24	24	27	18	9	16
Trolling lines [LTL]	0	36	0	0	0	0	0	0	0	0	24	0	0	0
Drifting longlines [LLD]	0	30	15	0	0	45	0	0	0	0	15	30	0	0
Set longlines [LLS]	42	60	45	12	0	60	15	0	36	24	45	60	45	48
Pots and Traps [FPO]	0	44	44	0	0	44	44	22	50	40	44	33	44	52
Fykenets [FYK]	0	45	0	0	0	0	0	0	14	42	0	0	0	72
Stationary uncovered poundnets [FPN]	0	0	0	0	0	0	0	0	0	0	0	0	0	33
Trammelnet [GTR]	0	84	63	0	0	105	21	0	72	54	63	42	21	80

Set gillnet [GNS]	54	84	63	36	21	105	63	0	72	54	84	63	63	110*
Driftnet [GND]	0	75	25	0	0	0	0	0	66	22	50	0	0	0
Purse-seine [PS]	27	30	10	18	0	40	10	0	18	9	20	10	10	16
Lampara nets [LA]	0	0	0	0	0	0	0	0	0	0	0	0	0	NA
Fly shooting seine [SSC]	0	0	22	0	0	0	22	0	30	10	22	22	22	0
Anchored seine [SDN]	0	0	0	0	0	0	11	0	30	30	11	0	0	0
Pair seine [SPR]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Beach and boat seine [SB] [SV]	0	0	11	0	0	0	0	0	0	20	11	0	0	NA
Glass eel fishing	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Key to abreviations:

AZ=Azores; BB=Bay of Biscay; CS=Celtic Sea; EA=Eastern Arctic; EB=Eastern Baltic; FI=Faroe Islands; IB=Iberian Sea; IS=Irish Sea; MA=Mid-Atlantic; ME=Mediterranean; NS=North Sea and Eastern Channel; SK=Skagerrak and Kattegat; WB =Western Baltic; WC=Western Channel; WI=Western Ireland; WS=Western Scotland, BS= Baltic Sea.

This method is continued in WGBYC, which has expanded the evaluation to cover the Baltic Sea. There was some discussion on how to set a limit for risk, below which no further observation of all PETS is required. However, no conclusion was reached, but as an example, risk factors above 50 are used to rank the top 5 risk gear types in the table below. Note that this method identifies gear types posing a risk to several species group but does not identify where one gear is a major threat to a single species. 5 is the gear posing the greatest risk.

	AZ	BB	CS	EA	FI	IB	IS	MA	NS	SK	WC	WI	WS	BS	Total score
Boat dredge [DRB]															0
Bottom otter trawl [OTB]		2	3			3	4		2		3	4	4		25
Multi-rig otter trawl [OTT]			2												2
Bottom pair trawl [PTB]						1									1
Beam trawl [TBB]															0
Midwater otter trawl [OTM]											2	2	3		7
Pelagic pair trawl [PTM]											2	2			4
Hand and Pole lines [LHP] [LHM]	3														3
Trolling lines [LTL]															0
Drifting longlines [LLD]															0
Set longlines [LLS]	5	2				2						4			13
Pots and Traps [FPO]									1					2	3
Fykenets [FYK]														3	3

Stationary uncovered poundnets [FPN]															0
Trammelnet [GTR]		5	5			5			5	5	4			4	33
Set gillnet [GNS]	5	5	5			5	5		5	5	5	5	5	5	55
Driftnet [GND]		3							3						6
Purse-seine [PS]	2														2
Lampara nets [LA]															0
Fly shooting seine [SSC]															0
Anchored seine [SDN]															0
Pair seine [SPR]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
Beach and boat seine [SB] [SV]															0
Glass eel fishing	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA

Key to abreviations:

AZ=Azores; BB=Bay of Biscay; CS=Celtic Sea; EA=Eastern Arctic; EB=Eastern Baltic; FI=Faroe Islands; IB=Iberian Sea; IS=Irish Sea; MA=Mid-Atlantic; ME=Mediterranean; NS=North Sea and Eastern Channel; SK=Skagerrak and Kattegat; WB =Western Baltic; WC=Western Channel; WI=Western Ireland; WS=Western Scotland, BS= Baltic Sea.

From the table, it is evident that set longlines, bottom otter trawl, trammelnet and set gillnet are considered to pose the greatest risk in ascending order. Set longlines, Pots and Traps, Fyke nets, Multi-rig otter trawl, Bottom pair trawl, Midwater otter trawl, Pelagic pair trawl, Hand and Pole lines and Purse-seine were all in the top 5 risk gear in at least one area.

The list of species to be recorded as PETS was discussed. This includes all species of reptiles, mammals and seabirds as these are listed in either in the habitat or bird directives. However, the case is less clear for fish. The directives tend to list diadromous species which have decreased as their freshwater habitat was impacted, and therefore do not provide a good overview of species sensitive to marine fishing. Lists of species considered sensitive to marine fishing are available from the literature for the North Sea (Greenstreet et al. 2012) and from subsequent work in ICES WGECO, which continues to work on identifying sensitive fish species throughout the EU waters. It was agreed to work with ICES to attempt to coordinate these lists.

In conclusion, the most reliable approach to estimating total bycatch relative to population size is likely to require three steps: An estimate of fishing effort by metier, if possible adjusted to reflect changes in gear dimensions, an estimate of bycatch rate by metier and an estimate of population abundance. It is not possible with the current level of knowledge to conclude that specific not yet sampled metier do not pose a risk to PETS. However, it is possible to use the present information to identify metier which are very likely to pose a risk. To allow regional estimates of bycatch relative to population abundance and a fully statistical based method for scaling results from observations to populations, data collection must be harmonised and data on bycatch of protected species collected and stored in commonly agreed and understood formats. The subsequent tasks address these requirements.

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Annex 4.2

Annex 4.2.1.- Manual for stomach sampling

Prioritised predator fish species

Based on the priorities defined in 'D4.1 Report on ecosystem components and species for which information would be particularly important to obtain', a list of species have been identified for either regular sampling or one-off sampling events. These species are included in a 2 to 5 year sampling programme for each area. At the end of this programme, the species included should be reviewed and species discovered to be less relevant based on the updated information obtained can be removed from the sampling programme.

Baltic Sea incl. Kattegat: cod and whiting

Bay of Biscay: tuna, hake, monkfish, rays, megrim, sea bass, blue whiting, mackerel and horse mackerel

Irish Sea: cod, whiting, gurnards, haddock

North Sea and Skagerrak: whiting, horse mackerel, saithe, cod, mackerel, hake, grey gurnard, halibut, haddock, starry ray, monkfish, plaice, turbot, megrim

Species can be sampled in different years in a rolling scheme, ensuring that at least one species for which biological samples are taken (e.g. maturity and/or otoliths) and one species for which this is not the case (and which hence provides a greater increase in work load) is sampled every year and that a maximum of 5 years passes between the sampling of any one species. For example, the stomach sampling scheme could be:

Survey area	Year	Species sampled for biology	Species not sampled for biology
North Sea IBTS	1	Whiting and monkfish	Megrim
	2	Horsemackerel	Starry ray
	3	Saithe (Q1 and Q3) and mackerel (Q3 only)	Gurnard
	4	Cod and plaice	Halibut
	5	Haddock and hake	Turbot
North Sea IESSNS	1	Mackerel	
	2	Horsemackerel	

Irish Sea	1	Whiting	Grey gurnard
	2	Cod and haddock	
Baltic Sea	1	Cod	
	2	Whiting	
Bay of Biscay	1	Hake	Tuna
	2	Blue whiting and monkfish	rays
	3	Horsemackerel	Megrim
	4	Mackerel	Sea bass

In addition to these species, it should be considered to sample rays and sharks to derive estimates of the proportion of commercial fish in the diet of the most abundant elasmobranchs.

Sampling level

- Five stomachs should be sampled per 5-cm length group of each predator species from on average every fifth haul resulting in a total number of stomachs sampled per 5-cm group by a country in a given survey, which is equal to the number of hauls performed by a given country. A wide geographical coverage of samples should be obtained whenever possible and no more than two specimens should be taken per cm group and square.

- Stomachs should be selected randomly within 5-cm groups, but can be taken from fish sampled for maturity and age determination. The stomachs are frozen individually in plastic bags together with a label describing the sampled fish. Only predators larger than 15 cm should be sampled as fish below this size are generally not piscivorous.

- Data are recorded in the ICES exchange format on the labels used for year, quarter, ship and haul consistent with those used for haul information uploaded to DATRAS (Table 2 and 3). This assures accessibility of further haul details if necessary.

The optimal sampling level depends on the overall survey effort, predator feeding strategies, species composition, and distribution overlap between predator and import prey in the specific sea areas. For example, expanding on the concept of intra-haul correlation (Bogstad et al. 1995), more stomachs from predators that are specialists at the individual level (e.g., cod, Hüssy et al. 2016) should be sampled in each haul as compared to species that are specialists at the population level (e.g., saithe).

It is therefore recommended that data obtained in the first 5 year period is reviewed to determine the needed level of future sampling.

Selection of stomachs at sea

The selection of stomachs should be based on the following stomach classification:

1. **Everted stomach**. Some fish have everted stomachs due to the pressure difference between trawling depth and the surface of the sea. Since it not known whether these stomachs contained food or not, such ones **should not be sampled**.

2. **Stomach showing evidence of regurgitatio**n. Some fish have regurgitated all or part of their stomach contents and these stomachs **should not be sampled**. The number of such stomachs encountered during the examination **must however be recorded** to ensure that the proportion of feeding fish in the sample is accurately defined. In practice, it is often difficult to tell whether regurgitation has taken place, except in situations of prey remains in mouth or pharynx. However if the stomach is flaccid or its wall is thin but contains no or little prey remains, experimental work by Robb (1992) indicates that the size of the gall bladder is a useful indicator of the recent feeding history of the fish. A large densely-coloured gall bladder indicates that the stomach has been empty for some time and has not recently lost its content by regurgitation. The criteria are summarized in Table 1 and should be applied when classifying a stomach as either being truly empty or originating from a fish that shows signs of regurgitation.

3. **Non-everted stomach showing no evidence of regurgitation** – with or without contents – **should be sampled**. It should be noted that not all feeding fish have significantly distended stomachs, i.e. feeding does not necessarily mean full.

4. **Empty stomach** is included in the category **Stomach of a fish showing no evidence of regurgitation**. Remember also to check and record the status of the gall bladder of a sampled fish with a seemingly empty stomach (Table 1).

The stomachs sampled at sea should thus originate from feeding fish showing no evidence of regurgitation (category 3) and from non-feeding fish (empty stomachs; category 4). The sampling should continue until at least one stomach classified in one of these two categories is obtained.

Protocol for stomach sampling at sea

1. Collect predators according to the sampling scheme elaborated for each sea area and predator species.
2. Do not sample everted stomachs.
3. Check the individual predators for evidence of regurgitation according to the categorization described above. Do not sample stomachs showing evidence of regurgitation, but remember to record them.
4. Sample the other (valid) stomachs (with and without contents) and avoid loss of prey remains when cutting the oesophagus during removal of the stomach from the fish.
5. Bag the stomachs individually (also empty stomachs) and preserve them by freezing as quickly as possible after removal from the fish. Each bag should contain a label giving the information listed in Table 2.
6. Record further relevant data including the number of regurgitated stomachs using the data exchange format in Table 3.
7. Send the frozen stomachs to the species coordinator upon arrival (Table 4).

It is recommended that the predator species are recorded using WORMS' AphiaID codes (http://www.marinespecies.org/aphia.php).

Laboratory analysis of stomach contents

The stomachs are analysed individually. They are thawed and cut open with scissors after which the contents may be carefully separated using water from a spray bottle in a 200–300 µm sieve. By use of water: remove the prey from the sieve, place it on moistened paper towel and gently dab it with another moistened paper towel to get rid of excess water.

Fish are identified to species or lowest possible taxonomical level possible and weighed individually. When possible, the total length is measured to the nearest mm below. Alternatively, for more digested fish, standard length or reduced standard length is measured – or estimated if still recognizable (Table 8). Be careful to completely unfolding the prey so that the length is not underestimated. Eggs are recorded as having the length 0. The digestive stage of the fish is recorded (Table 5) and pristine fish prey with intact and glistening bodies are categorized as eaten in the trawl and can be left out of the analysis later on to avoid bias introduced by feeding during the catch process.

Invertebrates are generally identified to the taxonomical levels shown in Table 6. The exceptions are the commercial species Norway lobster *Nephrops norvegicus*, northern prawn *Pandalus borealis*, Baltic prawn *Palaemon adspersus*, brown shrimp *Crangon crangon*, edible crab *Cancer pagurus*, common whelk *Buccinum undatum*, king scallop *Pecten maximus*, and queen scallop *Aequipecten opercularis* together with the isopod *Saduria entomon*, sea mouse *Aphrodita aculeata*, and hermit crab *Pagurus bernhardus*, which are identified to species or lowest taxonomical level possible. The latter prey are weighed individually and the other individually or by group as convenient. Invertebrates are measured to nearest mm below according to Table 8. The digestive stages of crabs and shrimps/prawns are recorded to avoid excessively biased estimates of diet composition and food consumption rates (Table 5).

Detached prey remains are handled as follows when water separation is used. If possible, separate the materials into identifiable categories in the sieve. Then, extract water from the materials by use of moistened paper towel to underside of the sieve; use tweezers to *lift* the materials from the sieve; get rid of excess water like it is done for the prey. Detached, prey remains that cannot be assigned to any particular prey are recorded as unidentified.

<u>Notice</u> that it is highly important to identify all prey items including detached materials at the lowest possible taxonomic level to avoid excessive bias arising in the subsequent data analysis. It is therefore not recommended to open the stomach and identify the contents aboard. Dispatch all stomachs to the species coordinator. In addition, it is recommended to use the water separation method described here to avoid dry out smaller amount of materials. This is particularly important for materials originating from small predators that generally in total contain small amounts of prey. Also, do not use alcohol to defrost the stomach contents as it accelerates the drying-up process.

Stomachs with no content and without evidence of regurgitation are classified as empty.

Stomachs with only indigestible remains (polychaete bristles, mollusc shells and opercula, chitin remains from crustacean exoskeletons, fish bones, otoliths etc.) are also categorized as empty to avoid bias when estimating diet composition and food consumption rates by use of a gastric evacuation rate model to stomach content information. For the same reason, indigestible prey remains with no attached organic materials, and that cannot be allocated to identified prey in stomachs with other prey remains, are excepted.

All data obtained from the laboratory processing of sampled stomachs are recorded in the exchange data format (Table 3) and submitted to the ICES database.

All prey species are recorded using WoRMS' AphiaID codes (http://www.marinespecies.org/aphia.php).

Potential use of modern meta-genomic techniques to identify stomach contents to species

Next generation sequencing (NGS) DNA barcoding can potentially be used to underpin stomach content analysis the food web models. While the method will not be able to replace stomach content analysis completely where the prey length distribution is required, it can potentially make screening of important predators more efficient, provide measurements of the relative importance of different prey types in the diet and improve the accuracy of the identification of species in the stomach content. In comparison to more traditional approaches, DNA barcoding allows both for a more accurate snapshot of predator diet and for species-level prey identification. Another advantage of DNA barcoding is that the methodology can be used both for comparative/control reasons (i.e. against previously known/suspected diets) for "*de novo*" diet description.

The application of DNA barcoding in diet studies has gained a major boost with the development of next-generation sequencing (NGS) methodologies. It is now readily feasible to identify even uncommon prey from multiple predators to family, genus and ultimately to species level in a single sequencing run while keeping the ability to individually trace back each prey to the particular samples from which it came. Technical issues related to prey identification from DNA in stomach contents linked to both uncertainty about taxonomic diversity (e.g. number of species) expected in the sample and often poor DNA quality (e.g. resulting from partially digested food) have now been largely overcome through the use of species specific universal DNA primers. The use multiple-universal markers (e.g. 16S, CO1) can amplify and resolve (i.e. identify) species across a broad range of taxa (i.e. Furthermore, the use of multiple-universal markers also allows for a broader taxonomic resolution. These universal markers are designed to target small fragments sizes, thus making amplification of degraded DNA more reliable.

Predator-prey interactions among key commercial species in the Celtic Sea and Irish Sea (e.g. cod, haddock, whiting, hake, plaice, sole, herring, sprat, mackerel, gurnard and blue whiting) is currently in progress. These species are being investigated as models to develop and implement an accurate genomics based approach, based on NGS DNA barcoding that can be reliably used to describe these species food chain interactions. Generated data can be compared with information derived from conventional approaches (e.g. field observation and stomach content analysis). The multi-species approach will also allow for an assessment of the potential effect of secondary consumption (i.e. the identification of the prey within the prey, which can potentially lead to misleading results).

The methodological approach for NGS DNA barcoding follows that described by Bowser et al. (2013) with some modifications to allow for the use of alternative sequencing platforms. |Universal primers (accounting for the species under investigation) targeting small (~130-300bp) regions of the mitochondrial DNA genes 16S and cytochrome *c* oxidase subunit 1 (CO1) fragments can be employed.

Sequencing of PCR products can be carried out through pooled massively parallel sequencing. To allow recovery of specific sample identification from sequencing data a DNA identifier tag can be linked to existing custom universal primers. To account for overrepresentation of host (i.e. predator) DNA from the sequencing analysis, which can potentially reduce detection signal of prey, species specific blocking primers can be employed (Vestheim & Jarman 2008). Following quantification and pooling, libraries can be sequenced using e.g. an Illumina MiSeq platform. After filtering for length and quality control, resulting sequences would be demultiplexed based on the DNA tags and separated by amplicon type (i.e. 16S or CO1). The bioinformatics analysis can be implemented using e.g. jMOTU (Jones et al. 2011) and BOLD (Ratnasingham & Hebert 2007).

The main advantage of these approaches is the ability to analyse a huge number of samples quickly and accurately. Compared to the estimated number per day that can be analysed manually of 30-100 stomachs, metagenomic approaches can perform many thousands of analyses, and at relatively low unit cost e.g. €5-10. There will still be some sample handling time in preparing the stomach samples for analysis, e.g. homogenising the sample, but this would be minimal.

The main disadvantage currently is that metagenomic techniques are only able to identify presence/ absence of each species. However, this makes the method ideal for screening for potential priority predators for more detailed sampling and for species determination.

Cost of sampling and laboratory processing stomachs

When fish selected for biology (maturity, age etc.) sampling are used for collection of stomach as well, it takes less than a minute to remove the stomach, fill-in the label and bag the stomach with label if all other information on the fish already has been acquired and recorded. When the fish is used exclusively for stomach sampling, the time spent is accordingly longer because weighing and length measuring of the fish, opening of the body cavity, and basic data recording is needed. The entire procedure may then take up to five minutes per stomach. In total, this corresponds to a maximum number of 1 to 7 minutes per 5 cm group per haul. Assuming that most predators are in the length range 15-50 cm, this corresponds to 7 to 49 minutes per haul if all species and length groups are caught in the haul (corresponding to 7 length groups sampled for each species). Generally, this will not be the case and hence the time allocation at sea will be less.

The subsequent processing of stomachs in the laboratory is more time consuming. Skilled manpower with a good taxonomic knowledge should be able to work up 30–100 stomachs per person-day depending on the size of the predator and the stomach content composition. Generally, stomach contents from smaller predator individuals and predators that prey on relatively small prey items (e.g. mackerel or haddock) are more time consuming, as are stomachs containing a large proportion of invertebrates. This is because it takes more time to disentangle and identify the different prey.

However, the suggested, coarse categorization of invertebrate prey help reduce the overall time consumption.

With a sampled number of 7 for each species and haul, the maximum cost in days of working up all stomachs are given in the table below.

NUMBER OF HAULS	**NUMBER OF STOMACHS IF 3 SPECIES ARE SAMPLED**	**NUMBER OF DAYS USED TO ANALYSE STOMACHS AT 30 STOMACHS PER DAY**
1	21	0.7
100	2100	70
200	4200	140
400	8400	280

Tables

Table 1. Condition of gall bladder, bile and hindgut, which can be used to differentiate between empty and regurgitated stomachs (from Robb 1992)

Gall bladder	Bile colour	Hindgut	State
Shrunken, empty or with a small amount of bile	Pale	Contains large amounts of bile and digested food material	Feeding*
Elongate	Pale green to light emerald green	Contains some bile and digested food material	Feeding*
Elongate	Dark green	Empty or contains some food particles	Empty
Round	Dark blue	Empty	Empty

*NB: If fish satisfying these criteria are found without food in their stomach, they should be classified as regurgitated

Table 2. Label to be included in each stomach bag

Cruise/survey	
Ship	
Haul number	
Species	
Total body length (mm)	
Sample ID	

To speed up the sampling process, the number of information lines has been reduced (as compared to earlier applied versions). Information on cruise and ship be pre-printed.

Table 3. ICES data exchange format for stomach data (http://ices.dk/marine-data/data-portals/Pages/Fish-stomach.aspx)

Field	Description
Dataset	Dataset name
RecordType	SS for single stomach
Country	Country that collected the data
Ship	Vessel that collected the data
Latitude	Data sampling position – latitude
Longitude	Data sampling position – longitude

Estimated_Lat_Long	Flag whether the sampling position based on the reported area
ICES_StatRec	ICES statistical rectangle
ICES_AreaCode	ICES area code
Year	YYYY
Month	MM
Day	DD
Time	Sampling time: HHMM
Station	Station reference
Haul	Haul number
Sampling_Method	Predator sampling method code (see Table 7)
Depth	Sampling depth
Temperature	º C
SampleNo(FishID)	Predator reference code – Fish ID unique for country, year, quarter and ship
ICES_SampleID	ICES predator reference
Predator_AphiaID	Predator WoRMS AphiaID
Predator_LatinName	Predator taxon Latin Name
Predator_Weight(mean)	(Mean) predator weight
Predator_Age(mean)	(Mean) predator age
Predator_Lengh(mean)	(Mean) predator length
Predator_LowerLengthBound	Predator's length lower bound
Predator_UpperLengthBound	Predator's length upper bound
Predator_CPUE	Predator catch per hour
GallBladder_stage(class)	Gall bladder stage
Stomach_METFP	Method of stomach preservation
Stomach_TotalNo	Total number of stomachs in the pool. Should always be 1.
Stomach_WithFood	Number of stomachs with food. Can be 0 or 1.
Stomach_Regurgitated	Number of stomachs regurgitated. Can be 0 or 1.

Stomach_WithSkeletalRemains	Number of stomachs with skeletal remains. Can be 0 or 1.
Stomach_Empty	Number of empty stomachs. Can be 0 or 1.
Stomach_ContentWgt	Stomach content weight
Stomach_EmptyWgt	Stomach empty weight (This field is in historical data but no longer considered necessary)
Stomach fullness	Stomach fullness (This field is in historical data but no longer considered necessary)
Stomach_Item	Stomach item name
ICES_ItemID	ICES stomach item ID
Prey_AphiaID	Prey WoRMS AphiaID (see Table 6)
Prey_LatinName	Prey taxon Latin Name
Prey_IdentMet	Prey identification method
Prey_DigestionStage	Prey digestion stage (see Table 5)
Prey_TotalNo	Total number of preys
Prey_Weight	Prey weight in grams
Prey_LengthIdentifier	Prey length identifier (see Table 8)
Prey_Length	Prey length in cm
Prey_LowerLengthBound	Prey length lower bound
Prey_UpperLengthBound	Prey length upper bound
Prey_MinNo	Minimum number of preys (This field is in historical data but no longer considered necessary)
Remarks	Any relevant comments

Table 4. List of species (by survey) coordinators

Predator / sea area	Coordinator
…	…
…	…
…	…
…	…
…	…
…	…

Table 5. Digestive stages of fish, crab, and shrimp/prawn

Prey type	Stage 1	Stage 2	Stage 3	Stage 4
Fish	Shiny body surface - probably with scales. Clear eyes	Intact body, which however may be discoloured	Body cavity opened. Parts of the head region may be digested	**a.** Nothing or only some of the body cavity left **b.** Tail muscle mass 'triangle' left **c.** Spine with little muscle mass **d.** Only spine / bones / otoliths left

Crab*	Carapace intact. Some appendages might be detached	Carapace cracked enabling the digestive fluids to work on the inner parts	N/A	N/A
Shrimp/prawn*	Entire body intact. Some appendages might be detached	Cephalothorax detached from the abdominal part	N/A	N/A

*Important for application of gastric evacuation model to data for estimation of diet composition and food ration (Andersen et al. 2016)

Table 6. Invertebrate groups and the corresponding AphiaID codes

Taxonomic level	Prey group	Code
Phylum	Ctenophora	1248
Phylum	Cnidaria	1267
Phylum	Annelida	882
Species	Aphrodita aculeata (sea mouse)	231869
Phyllum	Mollusca	51
Class	Gastropoda	101
Species	Buccinum undatum (common whelk)	138878
Class	Bivalvia	105

Species	Aequipecten opercularis (queen scallop)	140687
Species	*Pecten maximus* (king scallop)	140712
Class	Cephalopoda	11707
Phyllum	Echinodermata	1806
Phyllum	Arthropoda	1065
Subphyllum	Crustacea	1066
Order	Mysida	149668
Order	Euphausiacea	1128
Order	Isopoda	1131
Species	Saduria entomon	293511
Order	Amphipoda	1135
Order	Decapoda	1130
Infraorder	Caridea	106674
Family	Crangonidae	106782
Species	*Crangon crangon* (brown shrimp)	107552
Family	Palaemonidae	106788
Species	Palaemon adspersus (Baltic prawn)	107613
Species	*Pandalus borealis* (northern prawn)	107649
Infraorder	Astacidea	106672
Species	Nephrops norvegicus (Norway lobster)	107254
Infraorder	Brachyura	106673
Species	*Cancer pagurus* (edible crab)	107276
Infraorder	Anomura	106671
Species	Pagurus bernhardus (hermit crab)	107232
	Other invertebrates	9990

Plastic	9991
Litter other than plastic	9992

Table 7. Sampling method codes

Description of fishing gear	Code
Demersal trawl or seine	DEM
Pelagic trawl or seine	PEL
Demersal hook and line	DHL
Pelagic hook and line	PHL
Demersal gill net	DGN
Pelagic gill net	PGN

Table 8. Length measurement by prey type

Prey group	Length measured	Code
Vertebrata	Total length from snout to end of tail fin	TL
	Standard length from snout to basis of tail fin	SL
	Reduced standard length: from first vertebra to basis of tail fin (i.e. the length of the vertebral column).	RL
Crustacea	Total length of small crustaceans like mysids, krill and amphipods and intact nephrops, shrimps, prawns and *Saduria entomon*.	TL
	Length from bases of eye stalks or rostrum to uropods or carapace length in the case of advanced digestion stage of nephrops, shrimps and prawns.	CL
	Carapace width of crabs	CW
	Pleotelson length of *Saduria entomon* in the case of advanced digestion stage.	PL
Cephalopoda	Mantle length	ML
	Beak length in the case of advanced digestion stage	BL
Others	Total length of complete specimens	TL

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Annex 4.2.2 - Distribution and prey overlap of mackerel and horse mackerel

Introduction

Mackerel and horse mackerel are widely distributed in western European waters. North East Atlantic Mackerel are consider as having three spawning components; North Sea, western and southern, representing 7, 83 and 10% of the NEA stock. The North Sea component is considered as being resident there with migrations within the North Sea. The western component is much the largest and displays long distance migration. It is known to spawn along the western shelf edge from the Cantabrian Sea to the Faroes in spring, concluding by July. It then migrates north to the wider Norwegian Sea, considered as a feeding area. Late in the year a large part of the stock moves to the edge of the Norwegian Deeps in the North Sea, prior to a spawning migration starting around December (Reid & Beare 2010). The southern component behaves very similarly to the western and is managed with it. The stock there extends through the Cantabrian Sea and the Portuguese coast.

Horse mackerel are also divided into the same three components, but these are managed as different stocks. There are no egg surveys for horse mackerel in the North Sea, but data are available from the IBTS Q3, and the French Channel Groundfish Survey (CGFS) in Q4. Commercial catches show that the bulk of the stock is found in the southern North Sea (IVc) and the eastern English Channel (VId), which alone represents over 75% of the NS stock catches. The western stock is considered as extending from the inner corner of Biscay through western waters to IVa in the N. Sea. The main nursery areas is considered as being in VIIefgh & VIIIabd. Spawning takes place along the shelf break up to the west of Scotland, and is approximately one month lagged from the western mackerel. The southern stock covers the waters from Gibraltar to Cap Breton canyon. There is some doubt about the mixing of these components, especially the southern stock migrating into the western area to spawn, and the assignment of fish caught in VIIde.

Mackerel and horse mackerel are potentially important predators on forage fish in the North Sea and Western Waters, presumably exerting a substantial natural mortality on species such as sprat, herring, blue whiting and sandeel. In the North Sea mackerel diet is dominated by zooplankton, followed by sandeels making up 26% of the diet, and sprat 6% (Mackinson & Daskalov 2007). They also take small amounts (<1%) of cod, whiting & herring juveniles, as well as Norway pout, blue whiting, horse mackerel and other small gadoids. Outside the North Sea, mackerel diets can be very different. In the Norwegian Sea, the offshore population is mainly planktivorous, 68% consisting of copepods, and 7% of amphipods and euphausids, but including 5% *Maurolicus muelleri* and 1.5% other teleosts (Langoy et al 2012). In coastal waters, this switches to 59% euphausids (incl. Nephrops) and only 6% copepods. Pearlsides were at 7.4%. The picture is different again in north Spanish waters which exhibits seasonal changes (Olaso et al 2005). In spring the diet is predominantly euphausids (78%) and decapods (10%), with few fish. In the winter, it is dominated by fish with 39% blue whiting, 3% anchovy plus salps (23%). Taken together, mackerel tends to be a planktivore by preference, but highly opportunistic, and will take small fish if they are available and in abundance e.g. sandeel in the N. Sea, pearlsides in the Norwegian Sea and blue whiting in Spanish waters.

This picture is complicated by a distinct seasonality in feeding level in mackerel (Lockwood 1988; Olafsdottir et al 2016), mainly feeding in summer and autumn, and not in the winter and spring until they start spawning. Seasonal changes were also recorded by Bullen et al. in 1912, where they showed switches from an all zooplankton diet in the winter to one including fish in the summer.

Horse mackerel has a more diverse diet in the North Sea (Mackinson & Daskalov 2007), again dominated by zooplankton, but with 23% Norway pout, 4% sandeels and less than 1% sprat. They also take larger proportions of other fish than mackerel. In Portuguese waters (Cabral & Murta 2001) the diet is almost entirely dominated by myctophids. Overall there are fewer studies of diet in horse mackerel than mackerel, but the same conclusion of a principally zooplankton diet with opportunistic piscivore mode when the prey are available and abundant.

In terms of species overlap, this is probably substantial for the western and probably southern elements of both species. They spawn in broadly the same areas, and then migrate north to the Norwegian, and possibly northern North Seas. The scale of horse mackerel migrations into these feeding areas is believed to vary with population size (Iversen et al 2002). The greatest scale of the migration was found to be after the huge 1982 year class recruited, creating the highest biomass in recent times. Current biomass is below $B_{msytrigger}$, so the scale of this migration may be less, suggesting that overlap in the Norwegian Sea in Q3, may be less important at present. In the North Sea, the bulk of the horse mackerel are found in IVc, and in the Channel, while western mackerel are mainly believed to be in IVa, and North Sea mackerel in IVab.

Diet overlap is less easy to determine. Both species are identified as planktivores, with an often strong piscivore behaviour when fish are available. Both species will take species such as sandeel, Norway pout, myctophids and blue whiting, as well as small amounts of many other, often juvenile, fish. Both species are also known to be cannibalistic. Taken together, the common prey, and the evidence for opportunistic piscivory, would suggest that where they overlap spatially and temporally in distribution, they will likely also show a high overlap in prey. This would primarily be in all western waters and possibly in the southern Norwegian Sea and in IVa. The recent substantial expansion of the distribution (and abundance) of mackerel in summer in the Norwegian Sea and up to Iceland might suggest that the spatial overlap is less in the recent years, with a low horse mackerel biomass and hence, possibly less movement into this area.

However, while the presence of commercial fish species in mackerel and horse mackerel stomachs has been confirmed by stomach sampling, the actual amount eaten in both the years with stomach samples and in any other year is highly dependent the number of the predatory mackerel and horse mackerel present in an area. The abundance of the predators in the North Sea is derived from assumptions made on the quarterly distribution of the species both inside the North Sea and in the proportion of the stocks which enter the North Sea in a given year. Even if sufficient information existed on distribution of the predators in the year of stomach sampling, the changes in distribution of these species (ICES 2016) and the tendency of particularly mackerel to show evasive reactions to vessel noise makes it unlikely that these observations can be assumed to predict the distribution in other years. The following document outlines a method to derive the number of predatory mackerel and horse mackerel in the North Sea in any given quarter. First, the data sources are described together with information on where this data can be used. Secondly, a method to derive estimates of distributions for consumption estimates in all years and quarters is given.

Data sources available

Commercial landings

Commercial landings are available by ICES statistical rectangle, quarter and year for the period from at least 1995 to 2017. The landings broadly reflect the distribution and biomass of mackerel and horse mackerel as well as considerations about catchability, price, distance to port and legislation. One example of where this may not be the case would be in the Norwegian Sea, where some fishing is restricted to areas outside EU and Norwegian waters. Outside such areas and periods where additional restrictions apply, the catches can give a rough indication of the distribution of the species or at least of whether a changed has occurred in the distribution. Catch distribution was used by WGSAM 2017 to adjust the recent stock distribution of mackerel. It should also be noted that there is a considerable seasonality in the mackerel fishery. The fish are in their best condition after the end of the feeding period, late in the year, and so the main fishing season is Q4 and Q1 when they are in good condition. Condition, and hence prices, are much lower in Q2 and Q3 after spawning has drawn down fat reserves. However, landings, such as they are in Q2 and Q3 still likely represent the main distribution of the stocks.

International egg survey

The international mackerel egg survey in the western and southern areas has been conducted from January to July every three years from 1977 to 2016 and is used as an indicator of mackerel spawning stock biomass. The North Sea mackerel egg survey is carried out the year after the western survey and started in 1968. It is reasonable to assume that the egg distributions reflect that of the mature fish at the time of spawning (ICES 2018a). Both Mackerel and horse mackerel feed between spawning batches and hence the spawning biomass distribution is relevant to species interaction and feeding pattern. Given that, at least in western waters, the two species are collocated in space, and largely in time, we would expect substantial overlap in diet.

International acoustic surveys

Hydroacoustics is currently not used to monitor mackerel biomass because of technical difficulties with acoustic quantification related to its evasive behaviour, vertical distribution and lack of a sound reflecting swimbladder. Acoustic approaches have been used in the Norwegian Sea to track size and direction of mackerel schools (Nøttestad et al 2016b). This study also used acoustic tracking to study the feeding strategies of mackerel in this area, which may be useful for determining feeding relationships. Acoustic surveys (PELGAS & PELACUS) have also been used in Div VIII for horse mackerel abundance estimation, though only covering part of the stock and with some issues (ICES 2018b; Doray et al 2018). Possible acoustic surveys for horse mackerel in the North Sea have been considered, and may be developed in the future (ICES 2018b).

International pelagic trawl surveys

From 2018, the international pelagic trawl survey for mackerel has been conducted around July using standardised methods within and outside the North Sea. This survey potentially supplies both stomach data and distributional data. The survey entitled the International Ecosystem Summer Surveys in the Nordic Seas (IESSNS) covers a wide area of the Norwegian Sea and potentially covers the bulk of the summer feeding distribution of the western mackerel stock (Nottestad et al. 2016a). This is potentially a very important resource for understanding mackerel feeding, as it covers the main location and period for that feeding (Nottestad et al. 2016b). A further study looked at the diet of mackerel and overlaps with herring off the Norwegian coast in 2013 in the same area (Skaret et al 2015).

International Bottom Trawl Surveys

International bottom trawl surveys have been conducted in the North Sea since the 1970's in quarter 1 and since 1991 in quarter 3. From 1991 to 1997, quarter 2 and 4 were also sampled. In western waters additional IBTS surveys have been carried out over much of the western shelf since the start of the 1990s, particularly in the second half of the year. The catchability of mackerel in these surveys probably varies with depth as the trawl covers a greater fraction of the water column in shallow areas (e.g. southern North Sea) than in deeper water (e.g. northern North Sea). In addition there are differences in gear even between those using the GOV gear, and other gears are used in Spain and Portugal. The evasive behaviour of mackerel is likely to depend on season and water column depth. NS-IBTS in Q1 has been used together with similar data from other parts of the European shelf seas, to create an abundance index of survivors during their first winter, because they tend to school close to the bottom during their first winter (Jansen et al 2015). This index has been used since 2014 in the ICES mackerel assessment.

IMR tagging surveys

The Institute of Marine Research in Bergen has annually conducted tagging experiments on mackerel since 1968, both in the North Sea and to the west of Ireland during the spawning season May–June. However, only the information from mackerel tagged west of Ireland is used in the mackerel assessment, and only information on recaptures of mackerel tagged with steel-tags until 2006. A new RFID tagging method from 2011 onwards was accepted and used in the assessment based on the conclusions from the 2017 WKWIDE benchmark workshop (ICES, 2017 & 2018). This material may be able to provide additional data on movements and distributions.

The different data sources are summarised below

Data sources	Time of year	Years sampled	Species catchability consistent?	Fraction in the management areas (NS, west and south) can be estimated?	Distribution can be estimated?
Commercial landings	Monthly	2000*	Depends on effort, gear and legislation	Yes, but may not reflect biomass**	Yes, but only within areas with uniform management
International egg survey	January-July	Southern and western waters: 1977-, every three years	Yes for mackerel in the west and south. Whole season and area not always covered in the North Sea. Yes	Yes for mature mackerel and horse mackerel. Weaker for NS as done in a different year.	Yes for mature mackerel (all areas) and horse mackerel (west and south, not for the North Sea)

		North Sea: 1968- every three years	for horse mackerel in the west and south		
International acoustic surveys	Q1	Since 2000	No for mackerel. Yes for horse mackerel in Div VIII	No	Yes for horse mackerel in Div VIII
International Ecosystem Summer Surveys in the Nordic Seas (IESSNS)	July	2007 outside the North Sea, 2018 inside the North Sea	Yes for mackerel, less so for horse mackerel	Yes for mackerel	Yes for mackerel
International bottom trawl surveys	February	1983-	Yes for horse mackerel, less so for mackerel. Yes for age 0 and 1 mackerel.	No	Yes for horse mackerel, less so for mackerel
International bottom trawl surveys	May	1991-1997	Yes for horse mackerel, less so for mackerel	No	Yes for horse mackerel, less so for mackerel
International bottom trawl surveys	August/September	1991-	Yes for horse mackerel, less so for mackerel.	No	Yes for horse mackerel, less so for mackerel
International bottom trawl surveys	November	1991-1997	Yes for horse mackerel, less so for mackerel	No	Yes for horse mackerel, less so for mackerel

* Earlier catches are available but considered less reliable.

**Jansen et al, 2012.

Estimates of distribution for consumption

North Sea stocks

For the North Sea estimates of predation mortality, the proportion of the total stock of the two species which occurs in roundfish areas 1-7 needs to be determined.

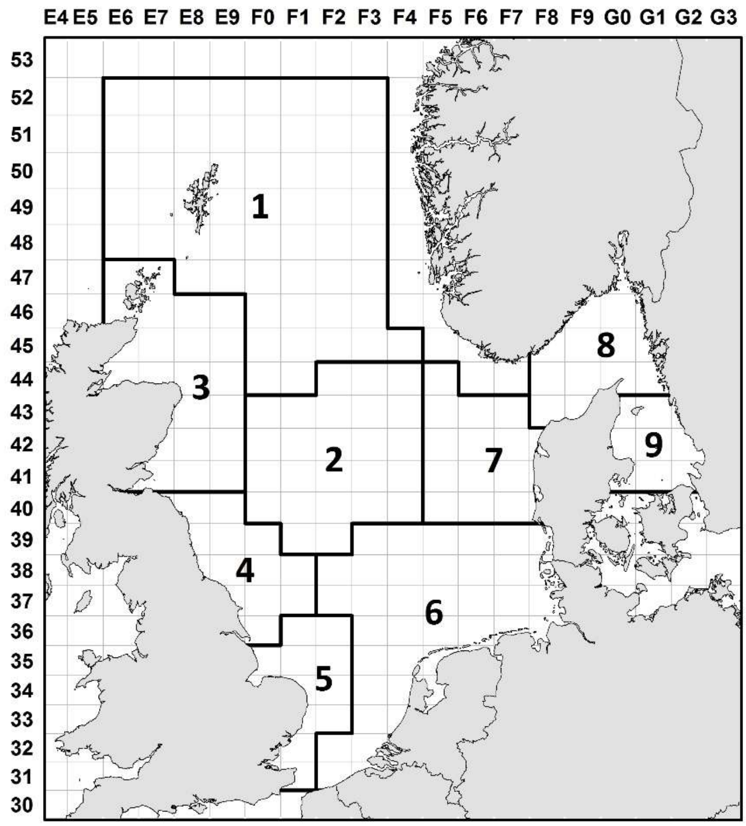

Fig. 1. Roundfish areas in the North Sea.

From stomach sampling and experiments, it is evident that mackerel and horse mackerel are mainly feeding in quarters 2, 3 and 4 when the water is warmer, and for mackerel at least this follows what is known about when mackerel feed (Lockwood 1988). Hence, here focus is on the distribution and likely feeding in quarters 2 to 4. While horse mackerel does not feed at temperatures below 9^{o}C (Temming and Herrmann 2001), mackerel continues feeding at least at temperatures as low as 6.4 ^{o}C (Temming et al 2002.). However, this is below their preferred temperature range, as they will typically avoid colder areas and seek towards optimum temperature around 8.00-8.75°C in winter (Walsh et al., 1995) and 9-13°C in summer (see Olafsdottir et al., 2018).

Mackerel

Mackerel have four available sources of information (commercial catches, egg survey, pelagic trawl and bottom trawl survey). Of these, the bottom trawl survey does not provide information on the proportion of the total stock present in the area relevant for consumption (roundfish areas 1 to 7) and the commercial catches can potentially provide a biased estimate of the distribution.

The differences in temporal coverage and particularly, the one-year swept area survey time series means that assumptions need to be made to distribute the mackerel stock over areas in each quarter back in time.

Years	Quarter 2	Quarter 3	Quarter 4
1974-1990	Proportion and distribution in the North Sea: most recent egg survey Reliability: high	Proportion in the North Sea: Most recent egg survey Distribution in the North Sea: average Q3 trawl survey Reliability: moderate	Proportion in the North Sea: catches Distribution in the North Sea: average Q4 trawl survey Reliability: low
1991-2013	Proportion and distribution in the North Sea: most recent egg survey Reliability: high	Proportion in the North Sea: Most recent egg survey Distribution in the North Sea: annual Q3 trawl survey Reliability: moderate	Proportion in the North Sea: catches Distribution in the North Sea: average Q4 trawl survey Reliability: low
2014-	Proportion and distribution in the North Sea: Average of most recent egg and pelagic surveys Reliability: high	Proportion in the North Sea: Most recent pelagic survey Distribution in the North Sea: Average of most recent swept area survey and annual Q3 trawl survey Reliability: moderate	Proportion in the North Sea: Most recent pelagic survey Distribution in the North Sea: Average Q4 trawl survey Reliability: low

Horse mackerel

Horse mackerel have two available sources of information (commercial catches and bottom trawl survey). Of these, the bottom trawl survey does not provide information on the proportion of the total stock present in the area relevant for consumption (roundfish areas 1 to 7) and the commercial catches can potentially provide a biased estimate of the distribution.

	Quarter 2	Quarter 3	Quarter 4

1974-1990	Proportion in the North Sea: average estimated by WGWIDE Distribution in the North Sea: average Q2 trawl survey Reliability: low	Proportion in the North Sea: average estimated by WGWIDE Distribution in the North Sea: average Q3 trawl survey Reliability: high	Proportion in the North Sea: average estimated by WGWIDE Distribution in the North Sea: average Q4 trawl survey Reliability: low
1991-	Proportion and distribution in the North Sea: most recent egg survey Reliability: high	Proportion in the North Sea: Most recent egg survey combined with catches Distribution in the North Sea: Annual Q3 trawl survey Reliability: moderate	Proportion in the North Sea: catches Distribution in the North Sea: average Q4 trawl survey Reliability: low

Western and Southern stocks

Mackerel

The area occupied by mackerel in western waters is much greater than for the North Sea, and understanding this is probably more manageable over fairly large areas and for specific periods. Based on commercial catches in Q1 (ICES 2018b), the bulk of the western fish were caught along the shelf edge from 50-60°N. Given the season these would mostly be pre-spawning fish that were not feeding. In the south, the catches in Q1 were greatest in the Cantabrian Sea, and into Biscay. Spawning and hence feeding is expected to start in the south by February, and then move northwards. The Q1 commercial catch shows a gap between 48 and 50°N, suggesting that the catches south of 48°N might be southern spawning component. In Q2 when feeding (and spawning) have started across the area, commercial catches are mainly in the same areas. The egg survey data would suggest that the population would be spread along the shelf edge and with a centre of gravity SW of Ireland. Based on the stock definitions, this would suggest that the two components are mixed at this time. Adult samples are taken in the egg survey for fecundity estimation, and these samples (and additional samples as required) could also be used for stomach sampling. It may also be possible, on the basis of stomach sampling to separate this substantial area into subareas on the basis of diets. The egg survey information could allow the partitioning of the biomass. It should be remembered however, that the fish will be migrating through the area so partitioning may be difficult.

In Q3 mackerel is expected mainly to be in the wider Norwegian Sea area. Most of the commercial catches occur in this area in Q3. In this area mackerel are surveyed by the IESSNS which can provide abundance distributions. These fish can be stomach sampled for diets.

In Q4 most of the commercial catches are taken in the northern North Sea (east of the Shetlands), or International waters centred on 62°N and 2°E. It is probable that these two areas are the same, but with different national fleets exploiting them. There is no survey data available for this quarter, and little stomach data. As they may well still be feeding at this time, it would be a priority to obtain stomach samples for this area in Q4.

Horse Mackerel

Much the same logic applies for the western and southern horse mackerel, at least for Q1 and Q2, where the catches are mainly taken in the Cantabrian Sea and west of Ireland. In Q1 it could be assumed that the two stocks remain separate, with the southern stock being found in Biscay and south, and the western north of 50°N. In Q3 the catches are in two areas. The first in the Cantabrian Sea area, and the second along the edge of the Norwegian Deeps in the North Sea, presumably the western stock. Stomach sampling could be carried out in the Cantabrian in the context of the bottom trawl surveys conducted there in Q3. The IESSNS does not generally cover this area, but the IBTS Q3 should cover the North Sea for stomach sampling, and any wider distribution area than that can be tracked by the commercial catches.

In Q4, the picture is less clear. Commercial catches show the same two hot spots as in Q3 (Cantabrian Sea and Norwegian Deeps). However, there are two additional hot spots west of Scotland and Ireland, and in the English Channel. It has to be assumed that the west of Scotland concentration would be the western stock. The Channel concentration is most likely also western stock individuals, dominated by juveniles, as this is a known nursery area (ICES 2018b). Stomach sampling for the Norwegian Deeps area could come from Q4 IBTS in the North Sea. For the west of Scotland, from the Irish Ground fish Survey and the Scottish west coast groundfish survey. For the channel, samples could be collected on the CGFS (Channel GroundFish Survey) conducted by IFREMER in October each year since 2015. For the Cantabrian Sea, there is the Spanish Northern Shelf Ground Fish Survey Q4 conducted since 2012. Horse mackerel is the second most abundant species caught in VIIc in this survey.

One advantage of using these surveys for diet estimation for horse mackerel is that they would also provide information on the fish community upon which they were predating. Given the opportunistic piscivory of this species, this would help characterise the link between prey abundance and proportions in the horse mackerel diet.

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Annex 4.2.3. Detailed sampling protocols for PET sampling

Monitoring incidental by-catch of protected species as part of dedicated or DCF on board sampling schemes

DCF observers routinely sample commercial fish and discards. However, PETS are scarce catch items. Therefore PETS sampling is not the same kind of routine as sampling targeted catch. For the sampling of the fish catch the observer usually takes a basket of the catch and takes weight - and length measurements. This routine differs from the one required for the monitoring of rare species. In PETS sampling, the routine consists of being at the right place at the right time for visual checks of the catch process. An important additional routine for the fish sampling observer is recording the estimated observer effort for PETS sampling in order to be later be able distinguish real zero by-catch from not sampled later. This is explained in the paragraphs below for the three different parts of the catch process: slipping, hauling and sorting. The difference compared to a dedicated PETS monitoring scheme is that the estimated time dedicated to PETS monitoring is (much) lower in DCF and other fish sampling schemes.

This manual has a general scope as it covers many (groups of) species and fisheries. It does not contain detailed descriptions that are required for the monitoring of individual species in different fisheries. It is constructed to be useful for DCF observers but where the control of fisheries occur on 'last haul' basis, it could easily be adapted to be of use also to observers associated with control of fisheries.

Preparation

Before sending observers on board of vessels in a program for the monitoring of protected species, the observers need to be trained. An observer should be familiar with the content described under the headers below. Prior to the trips and as a minimum annually, observers should be briefed by the project leader according to a checklist tailored to the protocol of that specific monitoring program. The goal of the conversations to give the observer the opportunity to prepare him-/herself, to address possible issues and provide (new) background information. Table 1 gives a checklist of possible questions related to PETS.

Table 1. Checklist for briefing	
	What has been discussed?
Manual/protocol	Is the observer aware what is expected of him/her? What samples need to be taken, what will be recorded and how?? Is the observer aware which species (groups) need to be sampled?? Does the observer know what the data are being used for?? Are there specific (extra) issues to be considered? If yes, does the observer know the protocol for this?

	If yes, what (parts of the) protocols have priority?
Equipment	What equipment is needed? Is there a list? Is the equipment arranged? Is the equipment in working order?

Documents

The observer may need some documents during his/her stay on board (licences, dispensations, authorisations). Some documents may be needed for carrying out the work on board, such as manuals and identification guides (table 2). Only those specific to PETS are listed.

Table 2. Documents	
Document	Why?
Manual	Thus the observer can always check the protocols.
Documents concerning animal welfare and nature protection.	Depending on the protocol documents to handle - or to possess (parts of) protected animals may be required
Letter of supervisor/institutes management	This letter explains why the observer is on board and what information is collected. This letter can be showed by the observer in case of (fisheries) inspection on board. If the vessel is fishing in International waters, this letter should be written in English.

Behaviour on board

As a guest on board the observer needs to behave polite. He/she is a representative of the institute that is running the observer project. The observer needs to invest in a good relationship with the crew. Social conversation is an important part of the task on board. For this the observer needs to be aware of the objectives of the monitoring program and for what goals the data will be used. He/she should always be prepared to explain his/her presence on board and be able to show and explain how and why data are being collected.

List of species

In order to distinguish zero bycatch from not sampled, the observer is provided with a list of species that are monitored on board. This list should be hierarchical; it so that it is always possible to enter data on higher hierarchical level (genus, family, order). The list should contain all reptiles, mammals, birds and a number of fish species. The list should be critically assessed before entering the data in the database (for example during the debriefing). Incidental bycatch species are rare and may therefore not be on the list, whereas it is unlikely that the observer would have missed it in a haul: this may be a reason to expand the list afterwards before entering the data in the database. When the observer is in doubt of the species identity or when the observed bycatch is a seabird, a picture must be taken for later identification at land.

Sampling on board

Haul list (cooperation with skipper)

The observer keeps a list with the primary sampling units that have been sampled or observed. Usually these are hauls, but is some cases these may be sets of nets or days. This log should be synchronized with the ships administration. Therefore it is recommended to provide the skipper with a haul list to be filled out at the bridge during the trip. The observer - and the bridge list should be checked and synchronized regularly. This is identical to requirements for discard trips without PETS sampling.

Slipping/hauling/sorting

The exact sampling protocol for the observation or sampling of incidental bycatch depends on the species that are monitored and the fishery where the monitoring takes place. Any recording on forms and data entering applications should always make a distinction between *slipping*, *hauling* and *sorting*. *Slipping* is the catch that never came on board (for example catch that fell out of the net); *hauling* is the part of the catch process when the net comes on board, the opening of the codend or the hauling of longlines or gill nets; *sorting* is the handling and sorting of the catch after ist on board. For each of these three parts the observer needs to indicate if and/or how much has been observed.

Specific sampling instructions, for three parts of the sampling process

The on board sampling protocol needs to cover all three parts of the catch process (*slipping*, *hauling* and *sorting*; see above). It depends on the type of fisheries and the monitored species how this is done. It should always contain instructions of how to estimate the percentage of monitoring coverage.

Examples: In Gill nets and longlines the quotient of the number of hooks observed/total number of hooks, distance of net observed/total distance of nets or time of hauling observed/total time of hauling; a check for large bycatch during opening of the codend in trawl fishery can be 100% coverage for the *hauling* part. The quotient of minutes observed and minutes sorted on the sorting belt can be used for an estimation of coverage of *sorting*.

Any forms or data entering application should stimulate the observer to indicate the coverage of the three part of the catch.

Circumstances that may obstruct the observation process

The observer should make record of circumstances that may hide the observation of incidental bycatch incidents. These should allocated to one of the three parts of the catch process mentioned above for data entry.

Species identification and measurement

As incidental by-catch is by definition a rare event, the observer will have to identify species which may be unknown to him/her. Therefore the observer needs to have sufficient identification guides for species recognition. The protocol should include instruction on documentation on the collection of (parts of) by-caught animals in order to ensure correct species identification. Normally it is sufficient to takes pictures of specified parts and from specified angles. Species on the list should be measured for total length except in the case of seabirds and the exact measure to be taken should be identified in the protocol.

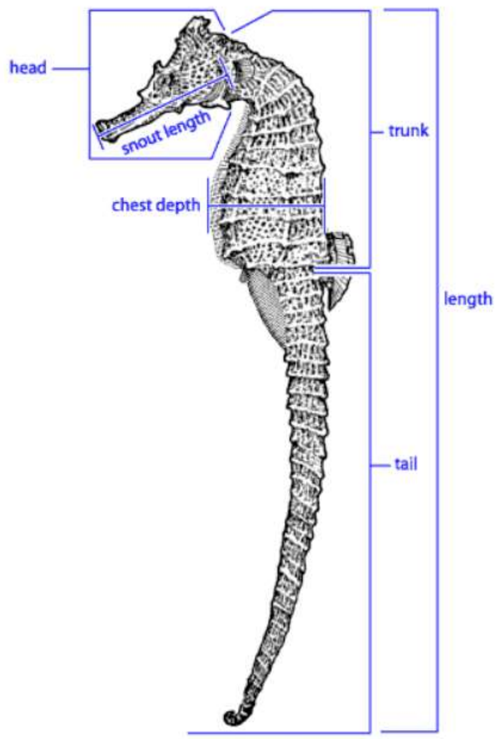
Detailed information on the bycaught protected specimens have not been collected in many European discard or observer programs. In many programs the only information available is the number of bycaught species. In many of the described monitoring methods that is also the only information that can be collected as for example in certain REM monitoring. There can also be difficulties to collect information such as weight of cetaceans, pinnipeds and sharks onboard fishing vessels. Due to the fact that we are early in the process of implementing bycatch monitoring we suggest to prioritize the collection of information on number of and the length of the bycaught species.

In general all fish species should be length measured from snout to tail tip along a strait ruler (Standard Length). For practical – and sometime historical – reasons some species are measured differently and therefore how to measure some species might be decided on a regional basis. In this manual we suggest to follow the on deck manual of the Northeast Fisheries Science Center (NOAA 2013) for large pelagic species.

Seahorses

Standard body length is measured from the tip of the head (coronet) to the enrolled tip of the tail (straight).

http://www.seahorse.org/library/articles/anatomy.shtml

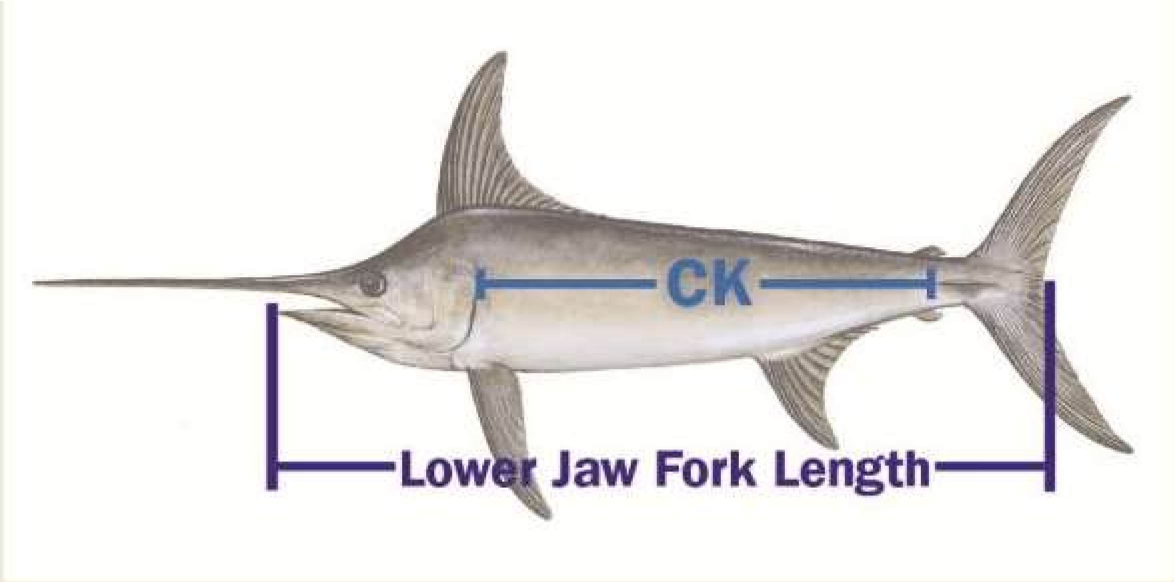


The following large (pelagic) fish species have specific standard length requirements:

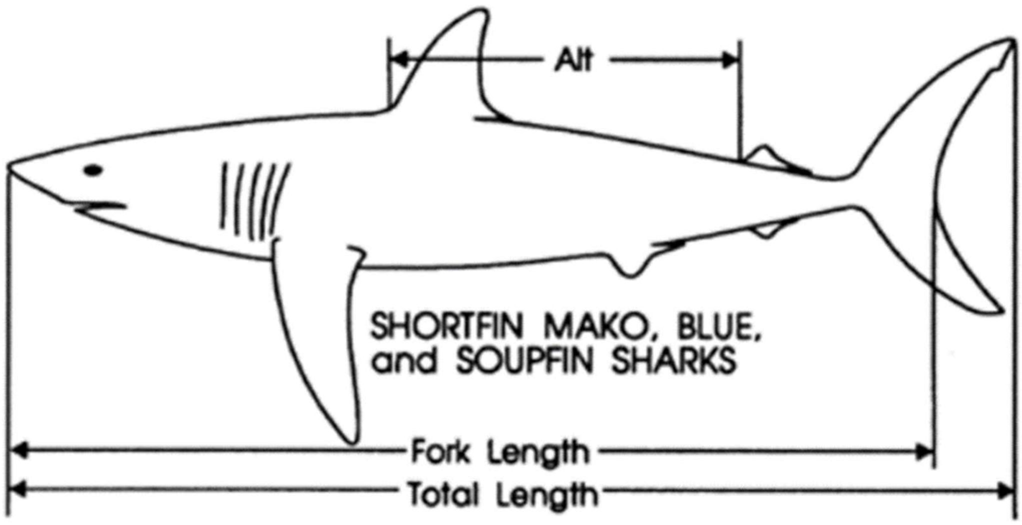
https://www.nefsc.noaa.gov/fsb/manuals/2016/On_Deck_Reference_Guide.pdf

Species	Standard length #1	Standard length #2
Swordfish & billfish	Lower jaw - Fork (curvilinear)	Swordfish: Cleithrum – keel (curvilinear)
		Billfish: Pectoral – Fork (curvilinear)
Tunas & Bonito	Tip of upper jaw – Fork (straight)	Pectoral – Fork (straight)
Sharks	Tip of upper jaw – Fork (straight)	Tip of upper snout – tail tip (straight)
Rays	Tip upper snout – end of tail (straight)	Disc width (widest point; straight)
Other large pelagics	Tip of upper snout – fork (straight)	

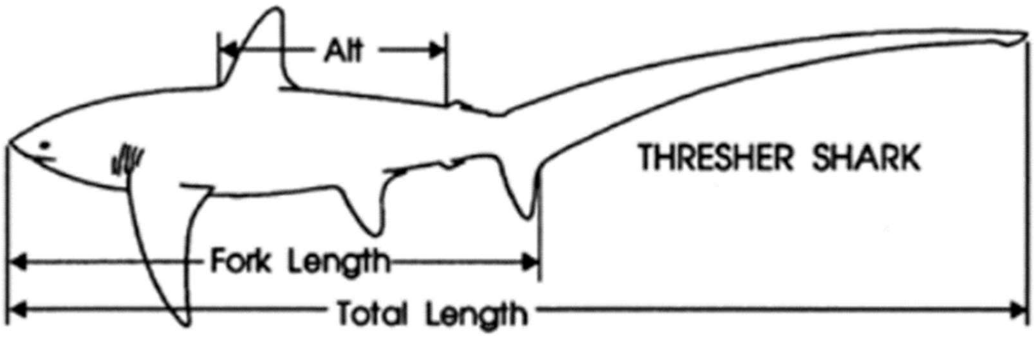
Estimated length should refer to Standardlength 1#



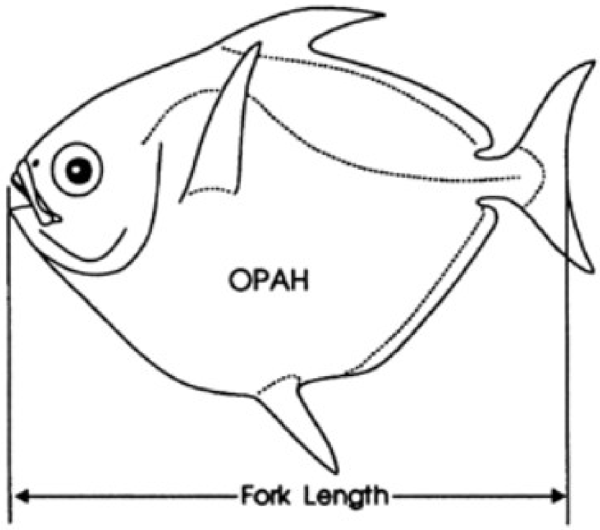
Swordfish and billfish are measured from the tip of the lower jaw to the tail notch. Preferably in addition the cleithrum to fork length should be measured https://offshoreanglerspompanobeach.org/swordfish-september-species/



Sharks should be measured straight from the snout tip to the notch (1st priority) ***and*** **from the tip of the snout to the tail tip.** Illustration from (Hanan et al. 1993).



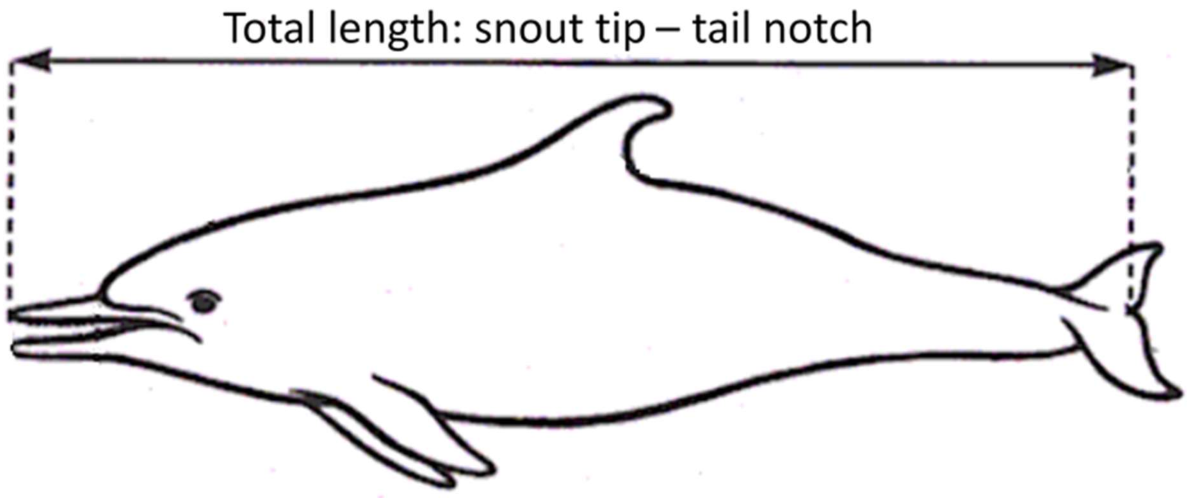
This refers especially to thresher sharks! Illustration from (Hanan et al. 1993).



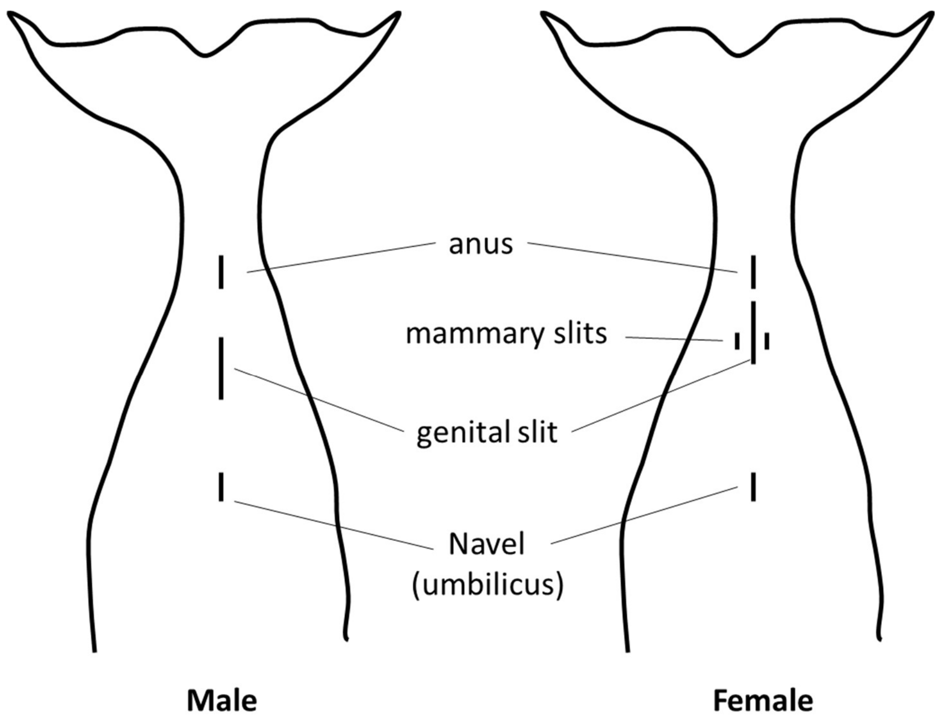
Example of "other" large pelagics: Opah. Standard length from snout tip to tail notch. Illustration from (Hanan et al. 1993).

Cetaceans

Length of all cetaceans are measured from the tip of the snout to the tail notch, straight (Standard Length). Sex can be identified by the difference in relative distance between anal opening and genital slit between males and females. Females have two mammary slits on either side of the genital slit.



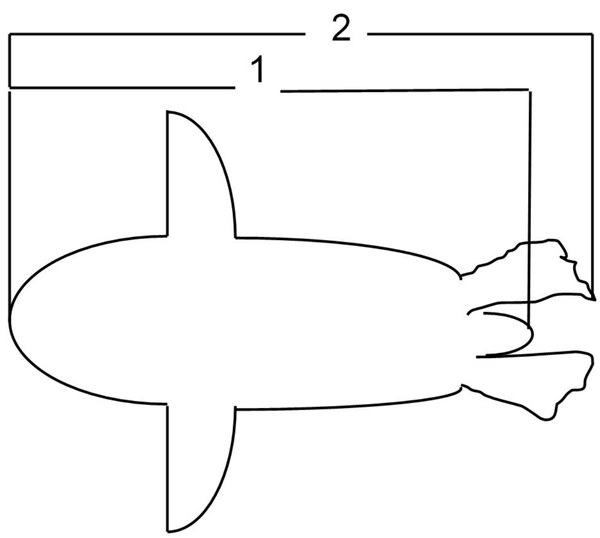
Length of cetaceans is measured from the tip of the snout to the tail notch, straight (Standard Length).



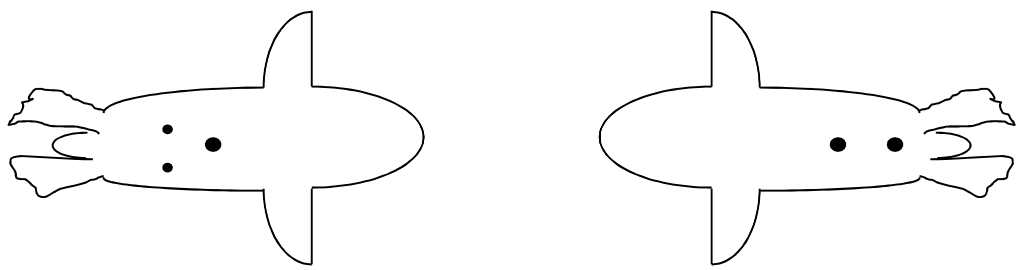
Sex in cetaceans can be identified be looking at the relative distance between anus and genital slit. In addition females have mammary slits.

Seals

Length of all pinnipeds (*Phocidae* and *Otariidae*) is measured straight (1; Standard length) from the tip of the snout to the tip of the tail and/or straight from the tip of the snout to the tip of the hind flippers (2; Total length). Preferable sex should be identified (see figure).



Seals are measured in two ways. 1. Standard Length: tip of the snout to tip of the tail. 2. Total Length: tip of the snout to tip of the rear fins.



Females in seals have an umbilicus and sometimes visible nipples (may be more than 2). In males the umbilicus and the penile opening is visible.

Birds

Bird typically have reached their maximum body length when fledged. Therefore in general length measurements do not give an indication of age or whether they are juvenile or adult. Some species may differ in size depending on the subspecies (e.g. puffin, *Fratercula arctica*). The standard measurement is from the tip of the bill to the tip of the tail. Sex can be identified with help of specialized bird field guides.

Turtles

Total length in turtles (curved carapace length) is measured from the center of the Nuchal (front) notch to the posterior most tip of the carapace.

http://www.ivis.org/advances/wyneken/6.pdf?LA=1

Released dead or alive

The protocol should ideally contain instructions to indicate whether the bycaught specimen is dead or alive when released/discarded. It may be necessary to provide guidance on how to recognize whether an animal is dead or alive.

Aftercare

A trip needs some aftercare. As a cruise report should be send to the skipper/crew of the vessel, this should be dealt with within a few weeks after the end of the trip. The aftercare also involves a debriefing within one week after the trip (tables 3 and 4).

Table 3. Checklist of tasks after an observer trip		when
1	Forward samples and/or pictures to the responsible person or experts. Check species identification accordingly.	Within one week after the trip
2	Enter the data collected on paper forms digitally, including the correct species identification.	Within two weeks after the trip
3	Before entering the data into the institutes database the data needs to undergo a data validation process.	Within two weeks after the trip
4	Prepare cruise report for internal use and for the crew.	Within two weeks after the trip
5	Debriefing.	Within one week after the trip
6	Adjustment of protocols and species list if required.	Within two weeks after the trip

Table 4. Checklist for debriefing	
1	Evaluation of forms and software applications
2	Evaluation of the on board sampling protocol, including the species list
3	Evaluation of equipment
4	How was the interaction with the crew?
5	Are there any signals that may have effect on the fisheries, research and cooperation between the two?

Monitoring of PETS bycatch by use of portable cameras

When observing protected species both slipping, hauling and sorting needs to be observed. Sorting the catch on a trawler and at the same time observing the hauling and what is happening outside the boat i.e. slipping might not be possible for an onboard observer or a fisher. A solution is use cameras during the hauling and slipping operation to document any slipping and/or release of protected species on deck or outside the boat, while observers or fishers are focused on the sorting processes. Remote Electronic Monitoring, REM, used mainly as an alternative to dedicated observers observing marine mammals and birds, has shown to be even more successful with regards to true bycatch estimates than onboard observers for estimating bycatch of harbour porpoise in passive fishing gears. Harbour porpoises slipping out from the nets before hauling procedure were captured on film more often than directly by the observers or fishers.

A pilot project filming gillnet fisheries using small camera set-ups that can record high quality film for long time period sending video films to a server over a GSM network has been conducted in Sweden. Cameras were placed on board fishing vessels with a view of the nets coming out of the water recording the slipping and hauling process. The fishers volunteered to participate in the study and were responsible for starting and stopping the camera in connection with the hauling of the nets. These cameras can be handed out to fishers in conjunction with DCF sampling or as a separate project. A difference from the REM described below is that the responsibility of collecting data (turning the camera on) is on the fishers. They will be responsible for delivering data on their bycatch. This can be seen as both an advantage and a disadvantage. It might increase the willingness to have cameras on-board if fishers are responsible for the project and in control of when to record. However, it might also introduce bias if fishers choose when the cameras are on or off. An advantage is that the camera set-ups are cheap and you can have several cameras circulating among fishermen enabling a random selection of vessels to be monitored.

This type of monitoring requires close contact and cooperation with the involved fishers. There needs to be a good relationship between fishers and scientists and a common understanding why monitoring is needed and to what it is used for. The procedure for screening the films would be in the same as described in the REM monitoring below.

Alternatively, cameras can be brought by DCF observers to ensure that bycatch not entering the sorting area is not left unrecorded. Combining cameras and discard observers has not been attempted on a large scale and it is recommended to carry out a pilot project to evaluate its cost and effectiveness for monitoring.

Mounting cameras

In the Swedish pilot project, the cameras were set up to observe bycatch in passive gears. The camera was connected to an external battery placed in an underwater housing and mounted on the rail of the vessels participating in the study. The camera had a view of the nets coming out of the water (Figure 1a and b). Observers should bring one to two cameras onboard and after discussion with the skipper of the boat place cameras in positions where the slipping as well as the hauling process can be monitored. The cameras should be developed with a housing that can easily be mounted on different boats and places depending on what vessel and what to observe. For example a housing including a large suction cup could enabled mounting the camera on the outside of the boat. The camera should also have a housing that enables changing batteries easily and being able to start the camera on the waterproof housing.

It is recommended to start the camera well in advance before nets, pots or trawls are being hauled and turned off at the end of the fishing procedure. Cameras should have a switch that turns on and off with the battery switch so that when the camera is turned off so is the battery and therefore the batteries will not be drained after switch off.

1a. Simple camera set up used in a pilot project in Sweden to monitor bycatch in passive gears. 1b. View of the net coming out of the water with a bycaught harbor porpoise filmed with portable camera.

Protocols for when portable cameras are used by observers

The protocols described under 'Monitoring incidental by-catch of protected species as part of dedicated or DCF on board sampling schemes' can also be used for combined observer and camera monitoring. However, there needs to be an extra column for camera coverage. These types of protocols can be used if films are screened onboard immediately after all catch processes are finished to establish the number of bycaught specimens and if there are dead specimens that can be measured. If it is possible to screen directly onboard, then the possibility to collect dead bycaught species to measure length and weight might be available. The skipper of the boat should also be aware that the films will be screened directly and that all bycatch of protected species should be saved onboard for further measurements. If it is not possible to screen films directly then protocols should focus on number of individuals.

Incidental Bycatch				
Slipping observer coverage:		0	%	
Slipping camera coverage:		50	%	
	Species	length (cm)	weight (kg)	sex
Specimen 1	0			
Specimen 2				
Specimen 3				
Hauling observer coverage:		0	%	
Hauling camera coverage:		100	%	
	Species	length (cm)	weight (kg)	sex
Specimen 1	Harbour porpoise	120	25 kg	F
Specimen 2	Harbour porpoise	125	26 kg	M
Specimen 3	Guillemot	34	NA	NA
Sorting observer coverage:		100	%	
	Species	length (cm)	weight (kg)	sex
Specimen 1	Raja clavata	60	2,46	female
Specimen 2				
Specimen 3				

Figure 2. Example of protocols if videos are screened directly onboard and the bycatch has been collected for measurements.

If there is not sufficient time to screen videos while still onboard, videos can be screened at land and focus will then be on identifying protected species and counting the number of individuals on the video. The same manuals as used when screening REM monitoring could most likely be used for screening the videos from the cameras combined with fisheries observers.

Monitoring of PETS bycatch by use of CCTV/REM

Within the last decade, Remote Electronic Monitoring (REM) has been developed as an approach to document by-catches in fisheries. The initial development of EM systems was largely an industry-led process to cope with management reforms and gear theft, however it was recognised that EM could also be used for monitoring in fisheries challenged by poor coverage of at-sea observations.

Many different systems are now available for REM monitoring with different possibilities and features. It is important to find the system and software most suited for the given type of vessels and monitoring program. In general, REM systems comprises a control box (computer) and a setup of different sensors. The most frequent used sensors comprises a hydraulic pressure sensor, a GPS (generally recording ever 10 sec) and waterproof armoured-dome closed-circuit television (CCTV) cameras. The control box includes a computer that monitors sensor status and activates image recording.

Installation and placement of units

Most control boxes are placed in the wheelhouse as they need to be placed in a sheltered location. The hydraulic pressure sensor is mounted on the highpressure side of the hydraulic system and records the pressure activity in the net drum. The hydraulic sensors can in principle be used to stop camera recording outside of the active fishing operations, which can save some storing capacity of the system. However, this has not been systematically applied in practice yet, and hence experience is limited. Cameras can in many cases be mounted on existing structures. However, in some cases additional mounting brackets need to be installed for correct positioning of the cameras. The number of cameras required differ depending on the vessel, however, two locations are particularly important to monitor by-catch on gillnet vessels. One camera needs to record the net when it breaks the water surface prior to the entry to the hauler. Marine mammal carcasses tends to fall out at this specific point due to their heavier weight in air than water. To ensure that the net hauling stays in the video frame, the camera needs to view a larger area around the position, where the net breaks the water, as the net changes position during hauls (see Figure 3 and 4 for correct video positioning). Another camera should records where the nets passes the net hauler and enters the vessel as especially bird species are better identified from a closer view (see Figure 5, 6 and 7 for correct camera positioning). Other cameras can be setup to record other view of e.g. catch sorting if needed. Some systems have the opportunity to providing live view. This is very convenient during the installation process as responsible video viewers can check the camera positioning during the installation process of the cameras.

Training of video viewers

Before viewers starts the review of the video footage, they require training. Thorough knowledge on recognition of characteristics of the relevant species is very important. Often, the carcasses are highly entangled in net material or they can only be seen from obscure angles which makes it difficult to identify the correct species. Test video should thus be used to train video viewers and test their abilities to detect the species concerned.

Cameras can be set to record at different resolutions. For many applications, low resolution seems to be adequate. In current systems, low-resolution camera feeds can record at higher frame rates, which offers a smoother view and allows for better detection. However, low resolution images may hamper species identification. High-resolution camera feeds have lower frame rates and use considerably more hard disk space than low-resolution camera feeds. The videos can be played back at different speeds depending of species concerned and video quality. In general, marine mammals can be detected at 10 times real time where detection of seabirds requires the video to be played at 3-4 times real time due to their smaller size and most high entanglement in net material.

The analysis is most efficient if conducted in a dedicated review software that merges the multiple sensor and video data, so that all can be viewed together. When inspecting video, users can fast forward, rewind or pause, along with normal video viewing tools such as zoom. The high spatial and temporal resolution of GPS position data allows for accurate effort calculation including net length and soak time. Furthermore, video viewers have the possibility of saving pictures of by-catch events for documentation or for further inspection (e.g. species determination). Additionally, annotations stating if the viewers assess that the fishers have seen or not the by-catch can be valuable information when explaining results of REM to participating fishers as in many cases e.g. marine mammal carcasses drop out before entering the vessel. This means that the bycatch perceived by fishers may be substantially less than the true bycatch, leading to lack of acceptance in the fishery of the recorded bycatch rates.

REM systems have some limitations compared to observers on board. Information on gear e.g. mesh and twine size cannot be determined from video footage and species information like weight, age, length and bird plumage details needs to be provided by the fisher. In trials monitoring bird bycatch, fishers have been asked to note these features and lift the birds up in front of the camera to allow better species identification of birds. Automatic picture recognition is however far in the development process and will with time be available for certain species.

Data storage

Data storage is an important point under REM monitoring and currently, either exchangeable hard drives or automatic wireless upload are available, depending on system. For both types, all data from the various sensors and cameras are saved on a hard drive on the control box. Once full, hard drives can be replaced by empty drives by authorized persons, e.g. fisheries inspectors, DCF observers or fishers can be instructed to change hard drives themselves. To avoid the manual replacement of hard drives wireless transmission of data via 3G, 4G or Wi-Fi networks can be used. This allows daily checks of system functionality and video quality and will in most cases reduce the cost. However, in areas with poor or expensive internet connections the option of replaceable hard drives is still relevant.

REM acceptance

REM trials have until now always been based on voluntary participation, although substantial incentives have been given, including additional quota. The participation in REM trials has in general been good with long term participation of fishers. However, concerns are expressed by many fishers against REM. Most are of ethical nature, related to the potential misuse of video data and to the “Big Brother” intrusion of the constant presence of video surveillance. This first decisions to implement REM in the EU was a result of a political process and successful by-catch monitoring with REM is still considered to require incentives and political support.

Figure 3.

Figure 4

Figure 5

Figure 6

Figure 7

Database

The database should be designed to hold the information collected. In line with the description above, for PETS sampling it is important to make record of the estimated observer effort that was spent to (visually) check for a reference list of species. This should split in the three parts of the catch process slipping, hauling and sorting. It should be possible to record for every part the number of bycaught individuals with species, length and weight measurements as parameters.

The data entering application should contain an incidental by-catch section, where it is obligatory to enter the observer coverage. Figure 8 presents an example of how this section may look.

Incidental Bycatch

Slipping coverage	*0*	%		
	species	length	weight	sex
specimen 1				
specimen 2				
specimen 3				
…				

Hauling coverage	*100*	%		
	species	length	weight	sex
specimen 1	*delphinus delphis*	*156*	*NA*	*male*
specimen 2				
specimen 3				
…				

Sorting coverage	*10*	%		
	species	length	weight	sex
specimen 1	*Raja clavata*	*60*	*2.46*	*female*
specimen 2	*Raja clavata*	*42*	*1.27*	*female*
specimen 3				
…				

Figure 8. A data entering application to the database should contain an “Incidental by-catch” section where the observer is obliged to fill in the coverage of the three parts of the catch process, slipping, hauling and sorting.

References

Hanan, D. A., D. B. Holts, and A. L. Coan. 1993. *The California drift gill net fishery for sharks and swordfish, 1981-82 through 1990-91*. Vol. 175: State of California, Resources Agency, Department of Fish and Game.

NOAA. 2013. *Northeast Fisheries Observer program Manual*. Woodshole: Northeast Fisheries Science Cente.

Annex 4.2.4: Compilation of stomach content data for estimation of population diet or food ration

Introduction

Compilation of data from individual stomachs to population level is not trivial and the most appropriate method depends on the question asked. Stomach data are often collected to get information on the average diet or food ration of a given species within a given area to inform multispecies assessment models (e.g. SMS or Gadget). Such models require data on diet and biomass eaten (food ration) for the predator species and size classes. The average "population" diet or food ration should basically be calculated from a stratified mean of the individual stomach content samples, weighted by strata abundances of the predator and strata areas. This seems simple, but patchy sampling often makes it necessary to use a series of *ad hoc* solutions.

In general a series of data compilation methods must be applied:

1. Read and check data from agreed exchange format;
2. Grouping of data into suitable size classes.
3. Bias correction to account for variation in evacuation rate;
4. Bias correction to account for regurgitated stomachs;
5. Allocation of unidentified or partly identified prey items;
6. Weighting of average diet per sampling unit for calculation of population diet or ration.

This sequence of steps, of which some of the steps might be repeated, will depend on the individual sampling design and the quality of the analysed data.

This document describes the methods above and how these can be applied based on experience from compiling stomach data for the North Sea for use in the MSVPA/SMS models.

Data exchange format

Data must be recorded, stored and exchanged on an agreed and documented format suitable for the purpose of sampling. The presently used ICES data exchange format for stomachs (see Appendix 1) is based on the "Year of the stomach" sampling for North Sea stocks in the period 1981-1991 (see Appendix 2). The updated version produced in FISHPI2 includes some extensions to improve the inclusion of stomachs sampled outside the "Year of the stomach", e.g. from national sampling programs with less standardized recording. Another change is that the new exchange format uses the WoRMS AphiaID (http://www.marinespecies.org/index.php) species taxonomic ode, where the old format used the NODC codes (https://www.nodc.noaa.gov/General/CDR-detdesc/taxonomic-v8.html).

The DAPSTOM data base (Pinnegar, 2014) maintained by CEFAS uses another exchange format. The database includes data from around a quarter million stomachs from 449 distinct research cruises in the period since 1837 from mainly British surveys. However, a large part of these data are more limited in resolution having e.g. sampled only occurrence or frequency by numbers rather than weight for individual prey and predators. The method described can therefore not be used directly for this database.

The examples and variable names used are based on a data set on the ICES exchange format (Appendix 1).

Grouping of data by sampleID

Stomach data can be sampled, analysed and recorded by the individual fish or by size group (“pooled stomach data”) for the individual sample unit, e.g. trawl haul. To save time during sampling and analysis of the stomach contents in the historic sampling events, the “Year of the stomach” data were sampled and analysed by pre-determined size classes (Table 1). Pooled stomachs do not provide information by the individual fish and on the variation in stomach contents, which is preferable in e.g. estimation of daily food ration and diet. Grouping of stomachs by size classes is however often necessary in the later compilation of data, as data are to scarce to be compiled by each cm group separately. While pooling stomachs before analyses introduces a bias in the estimated consumption (Rindorf and Lewy 2004), this is not the case when stomachs are pooled after estimating consumption.

In the North Sea, grouping stomach data based on single stomachs in the size classes used in 1991 by “Year of the stomach” sampling (Table 1) when estimating population level consumption retains consistency. That means that the variables in the data exchange format

- Predator_LowerLengthBound
- Predator_UpperLengthBound
- Prey_LowerLengthBound
- Prey_UpperLengthBound

are set from the length information on the individual predators (“Predator_Lengh(mean)”) and preys (“Prey_Length”) , if not already included in the data and defined by the sampling design.

The next stage is to calculate the average stomach content on a haul or sample basis. The exchange format includes several variables to define a unique sample ID (“My_sampleID”), e.g. defined from the data base variables: Country, Ship, Year, Month, Day, Time and Haul.

Table 1. Size classes (for items larger than 5 cm) used for sampling and compilation of stomach data in the North Sea “Year of the stomach” 1991 sampling.

Length class, 1991	Length (cm)
50	5-5.9
60	6-6.9
70	7-7.9
80	8-9.9
100	10-11.9
120	12-14.9
150	15-19.9
200	20-24.9
250	25-29.9
300	30-34.9
350	35-39.9

400	40-49.9
500	50-59.9
600	60-69.9
700	70-79.9
800	80-99.9
1000	100-119.9
1200	>120

Bias correction: Taking number of empty and regurgitated stomachs into account

Ideally each stomach should be classified as: with food, with food but regurgitated, with skeletal remains only or empty. This information is included in the presently used exchange format.

Database variable	**Comments**
Stomach_WithFood	Stomachs with (recently ingested) food
Stomach_Regurgitated	Stomach with food, but evidence of regurgitation of parts or all the stomach contents.
Stomach_WithSkeletalRemains	Stomachs with practically indigestible remains and the fish is not considered feeding recently
Stomach_Empty	No stomach contents

Stomach contents from regurgitated (or everted) stomachs should not be included in the estimation of diet as the proportion regurgitated is unknown. The number of fish with regurgitated stomachs should however be recorded ("Stomach_Regurgitated"). With the assumption that the regurgitated stomachs sampled within "My_sampleID" have had the same stomach contents as the feeding (non-regurgitated) fish each observed prey item weight and number should be corrected by a factor to calculate the mean stomach contents of a predator within "My_sampleID".

$$factor = \frac{(N_F + N_R)}{N_F * (N_F + N_{SR} + N_R + N_E)}$$

Where

N_F = Number of feeding fish ("Stomach_WithFood")
N_R = Number of feeding fish, but regurgitated ("Stomach_Regurgitated")
N_{SR} = Number of non-feeding fish, stomachs containing only skeletal remains ("Stomach_WithSkeletalRemains")
N_E = Number of non-feeding fish with empty stomachs ("Stomach_Empty")

In practice it is difficult to detect fish with regurgitated stomachs, and later data analysis often show that there is a clear difference in the proportions of regurgitated stomachs between vessels surveying in the same area at the same time.

Another issue is how to distinguish "Stomach_WithSkeletalRemains" from "Stomach_WithFood". In the original compilation of the 1991 "Year of the Stomach" (ICES, 1997), N_{SR} was added to the numerator in the calculation of the factor above. However, "Stomach_WithSkeletalRemains" should be considered as stomachs from not (recently) feeding fish and should be treated as empty stomachs.

Bias correction: From stomach contents to diet.

It is often assumed that diet is the same as the observed stomach content. This is however not the case as the stomach evacuation rate of an individual stomach depends on e.g. the average meal size, average energy density of the meal, prey armament and temperature. Large energy rich meals will for example have lower evacuation rates compared to small energy poor meals. Therefore, large energy rich meals will be present in a stomach a longer time and thereby detectable for a longer time, than stomach contents from small energy poor meals.

In the two subsections below it is described how to correct for the effect of variable stomach evacuation rate and thereby how to estimate food rations and diet composition from the observed stomach contents data. Ideally, this bias correction should take place at the level of sampling, i.e. by the individual stomach or by the pool of stomachs by sample site.

Estimation of food ration from stomach contents data

Food rations (= evacuation rate of stomach contents) can be estimated from the observed stomach content mass using the evacuation model suggested by Andersen and Beyer (2005 a, b). This model takes into account the differences in evacuation rates between prey types due to their energy density and their resistance to digestion (armament).

Ration R_i (g h^{-1}) by prey group *i* obtained from pooled stomachs is calculated from:

$$R_i = \rho_i M_i b_i L^{\lambda} e^{\delta T} E^{-\xi} K \left(\frac{N_T}{N_F}\right)^{\alpha-1} S^{\alpha}$$

M_i = armament of prey group *i*
b_i = proportion of prey group *i*
T = temperature (°C)
L = predator length (cm)
E = average energy density (kJ g^{-1} wet weight) of the stomach contents
N = number of stomachs in the sample, total (T) and with food (F)
S = average stomach content mass (g)

$\rho, \delta, \lambda, \xi, \alpha$ and K are model parameters (Table 1)

Values of M_i and energy density of individual prey groups used in the compilation of the North Sea stomachs are presented in Table 2.

Ration for all prey groups obtained from pooled stomachs is calculated from:

$$R = (\textstyle\sum_i \rho_i M_i b_i L^{\lambda} e^{\delta T} E^{-\xi}) K \left(\frac{N_T}{N_F}\right)^{\alpha-1} S^{\alpha}$$

When data exist for the individual predators *j*, the contribution to ration by prey group *i* for each predator can be calculated as:

$$R_{i,j} = \rho_i M_i b_i L^{\lambda} e^{\delta T} E^{-\xi} S_j^{\alpha} \text{ ,}$$

where S_j is total mass of contents in its stomach. The contribution of predator *j* to total ration can be calculated as:

$$R_j = (\sum_i \rho_i b_i M_i L^{\lambda} e^{\delta T} E^{-\xi}) S_j^{\alpha}$$

Based on the set of $R_{i,j}$ values for the individual predators from e.g. a sampling site (trawl haul), the average ration of the of the individual prey *i* can be calculated by taking the number of feeding, empty and regurgitated stomachs into account. This average ration by prey group is in this case expressed as g wet weight per hour and can easily be aggregated with average rations of preys from other strata. These rations can finally be transformed into diet data (weight proportions by prey item).

Species	ρ	λ	δ	ξ	α	K
Cod	0.00224	1.30	0.083	-0.85	0.5	0.85
Haddock	0.00191	1.30	0.083	-0.85	0.5	0.85
Saithe	0.00171	1.35	0.081	-0.85	0.5	0.85
Whiting	0.00171	1.35	0.081	-0.85	0.5	0.85
Mackerel	0.00174	1.30	0.080	-0.85	0.5	0.85

Estimation of diet from stomach contents data

The method for bias correction in the calculation of food ration as outlined above can also be applied to calculate the ration of the individual prey item and thereby the average diet. For e.g. for individual stomachs the Ration (R) of prey item *i* becomes:

$$R_i = \rho\, M_i\ b_i\ e^{\delta T}\ L^{\lambda}\quad E^{-\xi}\ K$$

Redistribution of unidentified and partly identified prey items

Parts of the stomach contents are not fully identifiable to species (group) or size class. With the assumption that the unidentified items follow the same species and size distribution as the identified prey items, it is possible to allocate the unidentified items proportionally to the identified species and size class. However, with the same assumptions it can be claimed that the unidentified items can be ignored for diet studies focusing only on relative composition of the diet as the weight proportions of the individual food items would be the same with and without the unidentified items. If the stomachs are used to determine overall feeding level, the unidentified material should be included.

The allocation of unidentified items to identified items is not simple in practise. A stomach may for example contain remains of an unidentified fish and identified invertebrates. In such case it would not be sensible to allocate the remains to the identified preys. However other stomachs from the same predator and size class from the same haul might include identified fish preys which could be used a “distribution key” for unidentified items. If a given haul does not include identified preys for a “distribution key” an alternative key could be obtained from the neighbouring hauls or from another size classes within the haul. For this reason, it is preferable to include unidentified material when determining overall feeding level but not when estimating the relative composition of the diet.

It is not possible to give specific rules on how to allocate unidentified prey items, other than the distribution key should be derived from “local” data as far as possible. By “local” is meant from the same haul, time period, predator size class, ICES rectangle, roundfish area *etc*.

With 250.000 stomachs sampled in the North Sea as basis for multispecies models a pragmatic approach was needed for allocation unidentified items. The former used NODC codes for preys are not maintained anymore, however NODC codes are still very useful for compilation of stomach data as they are based on a 10-digit "intelligent" code. By "intelligent" code numbers it is meant that information about taxonomy was built into the codes through the use of 2-digit couplets to represent one or more levels of the taxonomic hierarchy. For example, a species assigned a 10-digit code would belong to the genus represented by the first 8 digits of the code. In the compilation of stomach data, this hierarchy makes it easier to assign (by an algorithm) partly identified food items, to the identified items within the same genus, family or order. Lookup table exist in the ICES system to assign a NODC code to the WoRMS AphiaID code system presently used by ICES. The section “Compilation of stomach data for use in the North Sea SMS model” provides examples on how allocation of unidentified items could be done.

Aggregation of stomachs

The average diet should basically be calculated as a stratified mean of the individual stomach content samples, weighted by strata abundances (indices) of the predator and strata areas. For the initial compilation of the “Year of the stomach” an average stomach contents was first calculated by ICES rectangles and finally aggregated to population level (ICES, 1997). When there was more than one sample within a rectangle the rectangle value was calculated as the weighted mean of the sample (haul) average values, the weighting factors being the number of stomachs from each sample. Four methods were tried to calculate the “population” average stomach:

i. The rectangle values were averaged disregarding the number of stomachs sampled within each rectangle.
ii. The rectangle values were weighted by the sample size (total number of stomachs sampled within the rectangle).
iii. The rectangle values were weighted by the survey catch rates within the rectangle.
iv. The rectangle values were weighted by the square root of survey catch rates within the rectangle; this reduces the influence of occasional very large catch rates

The compilation (ICES, 1997) ended up using option *iv* for the predators cod, haddock, whiting and mackerel, while option *ii* was used for saithe because the survey catches were very patchily distributed.

This 1997 compilation did not include any bias correction for variable evacuation rate, but this has been added in the compilation of the stomach data used by the SMS model today. The compilation of data for the SMS model deviates from the original method used. Average stomach contents by ICES rectangle are derived in the same was as done initially, but the SMS model then calculates the weighted mean of stomach contents by ICES roundfish area using the square root of the mean rectangle survey cpue (option iv) as weighting factor (but option ii are used for saithe). This extra stratum made it possible to redistribute most of the unidentified and partly identified prey proportionally to the identified preys within a stratum. The "Bias correction: From stomach contents to diet" was also applied to the average stomach contents by this stratum level.

The calculation of the population diet for SMS from the bias corrected and fully identified stomach contents data was a weighted average of the strata (roundfish area) average diet weighted by the product of the average strata survey cpue and area of the strata.

Compilation of stomach data for use in the North Sea SMS model.

The section outlines the compilation of stomach data sampled in the North Sea "Year of the stomach" (mainly 1981 and 1991 data) for use in the North Sea SMS model.

The compilations steps applied using the 6 basic methods already presented are:

1) Read data from the exchange data and select the wanted combination of predators, period and area.
2) Group predators and preys by size class and sampleID (trawl haul).
3) Bias correct: Adjust for regurgitated stomachs and calculate average stomach contents by sample unit and predator size class. Result: average prey weight and prey number by time period, sampleID, predator, predator size class, prey, prey size class, digestion stage
4) Aggregate data. Calculate weighted average of average stomach contents by ICES rectangle using the total number of stomachs sampled by SampleID within the ICES rectangle as weighting factor. Result: average prey weight and prey number by time period, ICES rectangle, predator, predator size class, prey, prey size class, digestion stage.
5) Aggregate data. Calculate weighted average of average stomach contents by sub-area (e.g. ICES roundfish areas) using average survey CPUE (predator, size class) as weighting factor. Result: average prey weight and prey number by time period, predator sub-area, predator, predator size class, prey, prey size class, digestion stage.
6) Redistribute partly identified preys. Assign length class to species identified fish preys with no length information.
   a) Create distribution key from species identified fish preys with length class by time period, predator sub-area, predator, predator size class, prey and prey size class
   b) Redistribute partly identified preys using the key by time period, predator sub-area, predator, predator size class and prey
7) Redistribute partly identified preys. Assign species and length class to partly identified fish preys with information on family.
   a) Create distribution key from species identified fish preys with length class by time period, predator sub-area, predator, predator size class, prey family and prey size class, using the following families:
      i) Clupeidae: sprat, herring and non-commercial clupeidae
      ii) Gadidae: cod, haddock, saithe, whiting, Norway pout and non-commercial gadidae
      iii) Pleuronectidae: plaice, dab lemon sole, non-commercial pleuronectidae
      iv) Soleidae: sole and solenette
   b) Redistribute partly identified preys using the key by time period, predator sub-area, predator, predator size class and prey family.
8) Redistribute partly identified preys. Assign species and size class to partly identified fish preys.
   a) Create distribution key from species identified fish preys with length class by time period, predator sub-area, predator, predator size class, prey and prey size class

   b) Redistribute partly identified fish preys using the key by time period, predator sub-area, predator, predator size class and prey equal fish.
9) Redistribute partly identified preys. Assign species and size class to partly identified preys (remains).
   a) Create distribution key from species identified fish preys with length class by time period, predator sub-area, predator, predator size class, prey equal invertebrate or fish and prey size class
   b) Redistribute partly identified preys using the key by time period, predator sub-area, predator, predator size class and prey equal invertebrate or fish and prey
10) Bias correction: From stomach contents to diet. Make the bias correction on the average stomach contents by sub-area, time period, predator sub-area, predator and predator size class assuming that the average stomach contents have been derived from a pool of stomachs in the sample with total number of stomach and number of stomachs with food as observed within the sub-area. The average sea temperature by sub-area must also be provided.
11) Aggregate data. Calculate average diet for the population.
    a) Estimate sub-area population numbers (or indices) of the predator and predator size classes from e.g. IBTS surveys and area of the sub-area
    b) Calculate the diet for the population as a weighted mean of diet by sub-area weighted by the sub-area population numbers, by time period, predator and predator size class.

Comments to the applied stomach data compilation

The sequence of compilation steps applied in this case reflects the sampling design where pooled stomachs were applied. Ideally stomachs should be sampled and analysed individually, such that the "Bias correction: From stomach contents to diet" is done on the individual stomachs as early as possible in the data compilation, i.e. before any grouping or aggregation of data. With pooled stomachs, the effect of timing is less. Another issue is that the bias correction ideally requires fully identified stomach contents as energy density and armament differs between preys. The "Year of the stomach" data include a substantial number of records with partly identified prey items, like prey equal to "Gadidae", "fish meat" or "remains", with or without size classes. Some of those could probably have been assigned with high probability to one of the identified prey items within the stomachs analysed from the same trawl haul, potentially with a flag indicating that the identification of the prey identification was "uncertain". Given the frequency of partly identified preys, it was necessary first to group and aggregate data by roundfish area before all unidentified prey items could be redistributed proportionally to the fully identified preys.

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Table 2. Average energy density and armament of prey groups as applied in the compilation of stomach for use in the North Sea SMS.

Prey Group	Quarter	Length Lower (mm)	Length upper (mm)	Energy density (kJ/g wet weight)	Armament
Gadus morhua	1	10	120	3.6	1
Gadus morhua	1	150	250	3.8	1
Gadus morhua	1	300	500	4	1
Gadus morhua	2	10	120	3.9	1
Gadus morhua	2	150	500	4.1	1
Gadus morhua	3	10	80	3.9	1
Gadus morhua	3	100	150	4.1	1
Gadus morhua	3	200	500	4.4	1
Gadus morhua	3	10	80	3.9	1
Gadus morhua	3	100	150	4.1	1
Gadus morhua	3	200	500	4.4	1
Gadus morhua	4	100	150	4.1	1
Gadus morhua	4	200	500	4.4	1
Gadus morhua	4	10	80	3.9	1
Gadus morhua	4	100	150	4.1	1
Gadus morhua	4	200	500	4.4	1
Melanogrammus aeglefinus	1	10	120	3.6	1
Melanogrammus aeglefinus	1	150	150	3.7	1
Melanogrammus aeglefinus	1	200	200	4.3	1
Melanogrammus aeglefinus	1	250	500	4.7	1
Melanogrammus aeglefinus	2	10	200	3.9	1
Melanogrammus aeglefinus	2	250	250	4	1
Melanogrammus aeglefinus	2	300	500	4.5	1
Melanogrammus aeglefinus	3	10	100	3.9	1
Melanogrammus aeglefinus	3	120	200	4.2	1
Melanogrammus aeglefinus	3	250	250	4.6	1

Melanogrammus aeglefinus	3	300	300	5	1
Melanogrammus aeglefinus	3	350	500	5.5	1
Melanogrammus aeglefinus	4	10	200	3.9	1
Melanogrammus aeglefinus	4	250	250	4.5	1
Melanogrammus aeglefinus	4	250	250	4.6	1
Melanogrammus aeglefinus	4	300	300	5.2	1
Melanogrammus aeglefinus	4	350	500	5.5	1
Merlangius merlangus	1	10	80	3.9	1
Merlangius merlangus	1	100	100	4.1	1
Merlangius merlangus	1	120	120	4	1
Merlangius merlangus	1	150	150	4.3	1
Merlangius merlangus	1	200	200	4.8	1
Merlangius merlangus	1	250	500	5	1
Merlangius merlangus	2	10	150	3.9	1
Merlangius merlangus	2	200	200	4	1
Merlangius merlangus	2	250	500	4.3	1
Merlangius merlangus	3	10	120	3.9	1
Merlangius merlangus	3	150	150	4.7	1
Merlangius merlangus	3	200	200	5.3	1
Merlangius merlangus	3	250	500	5.4	1
Merlangius merlangus	4	10	120	3.9	1
Merlangius merlangus	4	150	150	4.2	1
Merlangius merlangus	4	200	500	5.3	1
Pollachius virens	1	10	350	4.2	1
Pollachius virens	1	400	400	4.8	1
Pollachius virens	1	500	500	5.5	1
Pollachius virens	2	10	350	4.5	1
Pollachius virens	2	400	400	4.2	1
Pollachius virens	2	500	500	4	1
Pollachius virens	3	10	200	4.1	1
Pollachius virens	3	250	300	4.7	1

Pollachius virens	3	350	350	4.8	1
Pollachius virens	3	400	400	5.2	1
Pollachius virens	3	500	500	5.6	1
Pollachius virens	4	10	350	4.9	1
Pollachius virens	4	400	400	4.8	1
Pollachius virens	4	500	500	5.2	1
Trisopterus esmarki	1	10	70	3.9	1
Trisopterus esmarki	1	80	80	4.3	1
Trisopterus esmarki	1	100	100	6.2	1
Trisopterus esmarki	1	120	120	6.4	1
Trisopterus esmarki	1	150	500	4.7	1
Trisopterus esmarki	2	10	70	3.9	1
Trisopterus esmarki	2	80	80	4.5	1
Trisopterus esmarki	2	100	100	4.2	1
Trisopterus esmarki	2	120	150	4	1
Trisopterus esmarki	2	200	500	4.4	1
Trisopterus esmarki	3	10	70	3.9	1
Trisopterus esmarki	3	80	80	4.6	1
Trisopterus esmarki	3	100	100	5.7	1
Trisopterus esmarki	3	120	120	6.3	1
Trisopterus esmarki	3	150	150	5.7	1
Trisopterus esmarki	3	200	500	6	1
Trisopterus esmarki	4	10	70	3.9	1
Trisopterus esmarki	4	80	80	4.8	1
Trisopterus esmarki	4	100	100	5.2	1
Trisopterus esmarki	4	120	500	7	1
Clupea harengus	1	10	70	4.4	1.08
Clupea harengus	1	80	80	4.6	1.08
Clupea harengus	1	100	100	4.7	1.08
Clupea harengus	1	120	150	4.4	1.08
Clupea harengus	1	200	200	6.5	1.08

Clupea harengus	1	250	500	8.5	1.08
Clupea harengus	2	10	80	4.5	1.08
Clupea harengus	2	100	100	4.6	1.08
Clupea harengus	2	120	120	4.5	1.08
Clupea harengus	2	150	150	4.4	1.08
Clupea harengus	2	200	200	5.7	1.08
Clupea harengus	2	250	500	4.9	1.08
Clupea harengus	3	10	40	4.1	1.08
Clupea harengus	3	50	50	4.2	1.08
Clupea harengus	3	60	70	3.9	1.08
Clupea harengus	3	80	80	4.5	1.08
Clupea harengus	3	100	100	4.4	1.08
Clupea harengus	3	120	120	5.2	1.08
Clupea harengus	3	150	150	10.1	1.08
Clupea harengus	3	200	200	11	1.08
Clupea harengus	3	250	500	11.9	1.08
Clupea harengus	4	10	100	4.6	1.08
Clupea harengus	4	120	120	6.3	1.08
Clupea harengus	4	150	150	7.1	1.08
Clupea harengus	4	200	200	8.5	1.08
Clupea harengus	4	250	500	8.8	1.08
Sprattus sprattus	1	10	40	4.4	1.08
Sprattus sprattus	1	50	50	4.6	1.08
Sprattus sprattus	1	60	60	4.7	1.08
Sprattus sprattus	1	70	70	6.5	1.08
Sprattus sprattus	1	80	500	8.5	1.08
Sprattus sprattus	2	10	40	4.5	1.08
Sprattus sprattus	2	50	50	4.6	1.08
Sprattus sprattus	2	60	60	5.1	1.08
Sprattus sprattus	2	70	70	6.7	1.08
Sprattus sprattus	2	80	80	8.6	1.08

Sprattus sprattus	2	100	100	10.5	1.08
Sprattus sprattus	2	120	500	10.9	1.08
Sprattus sprattus	3	10	50	4.7	1.08
Sprattus sprattus	3	60	60	5.2	1.08
Sprattus sprattus	3	70	70	6.7	1.08
Sprattus sprattus	3	80	80	8.1	1.08
Sprattus sprattus	3	100	100	11.4	1.08
Sprattus sprattus	3	120	500	11	1.08
Sprattus sprattus	4	10	50	4.6	1.08
Sprattus sprattus	4	60	60	6.7	1.08
Sprattus sprattus	4	70	70	7.8	1.08
Sprattus sprattus	4	80	80	11.4	1.08
Sprattus sprattus	4	100	100	11	1.08
Sprattus sprattus	4	120	500	11.5	1.08
Ammodytidae	1	1	70	4	1
Ammodytidae	1	80	80	4.4	1
Ammodytidae	1	100	100	5	1
Ammodytidae	1	120	120	5	1
Ammodytidae	1	150	500	5.5	1
Ammodytidae	2	1	60	4	1
Ammodytidae	2	70	70	4.6	1
Ammodytidae	2	80	80	5	1
Ammodytidae	2	100	100	5.4	1
Ammodytidae	2	120	120	5.8	1
Ammodytidae	2	150	500	6.1	1
Ammodytidae	3	1	50	4	1
Ammodytidae	3	60	70	3.7	1
Ammodytidae	3	70	70	4.6	1
Ammodytidae	3	80	80	4.2	1
Ammodytidae	3	100	100	5.6	1
Ammodytidae	3	120	120	6.2	1

Ammodytidae	3	150	500	6.1	1
Ammodytidae	4	1	60	4	1
Ammodytidae	4	70	70	4.6	1
Ammodytidae	4	80	80	5	1
Ammodytidae	4	100	100	5.4	1
Ammodytidae	4	120	120	5.8	1
Ammodytidae	4	150	500	6.1	1
Pleuronectes platessa	1	15	500	4	0.94
Pleuronectes platessa	2	15	500	4	0.94
Pleuronectes platessa	3	15	500	4	0.94
Pleuronectes platessa	4	15	500	4	0.94
Solea solea	1	15	500	4	0.94
Solea solea	2	15	500	4	0.94
Solea solea	3	15	500	4	0.94
Solea solea	4	15	500	4	0.94
Limanda limanda	1	15	500	4	0.94
Limanda limanda	2	15	500	4	0.94
Limanda limanda	3	15	500	4	0.94
Limanda limanda	4	15	500	4	0.94
Maurolicus	1	5	500	4	1.08
Maurolicus	2	5	500	4	1.08
Maurolicus	3	5	500	4	1.08
Maurolicus	4	5	500	4	1.08
Other fish	1	0	500	4	1
Other fish	2	0	500	4	1
Other fish	3	0	500	4	1
Other fish	4	0	500	4	1
Astacidea	1	1	500	5	0.3
Astacidea	2	1	500	5	0.3
Astacidea	3	1	500	5	0.3
Astacidea	4	1	500	5	0.3

Anomura mm	1	1	500	5	0.3
Anomura mm	2	1	500	5	0.3
Anomura mm	3	1	500	5	0.3
Anomura mm	4	1	500	5	0.3
Caridea	1	1	500	4	0.6
Caridea	2	1	500	4	0.6
Caridea	3	1	500	4	0.6
Caridea	4	1	500	4	0.6
Euphausiacea	1	1	500	4	1
Euphausiacea	2	1	500	4	1
Euphausiacea	3	1	500	4	1
Euphausiacea	4	1	500	4	1
Other Crustaceans	1	1	500	4	1
Other Crustaceans	2	1	500	4	1
Other Crustaceans	3	1	500	4	1
Other Crustaceans	4	1	500	4	1
Cephalopoda	1	1	500	4.5	1
Cephalopoda	2	1	500	4.5	1
Cephalopoda	3	1	500	4.5	1
Cephalopoda	4	1	500	4.5	1
Echinodermata	1	1	500	2.5	0.25
Echinodermata	2	1	500	2.5	0.25
Echinodermata	3	1	500	2.5	0.25
Echinodermata	4	1	500	2.5	0.25
Annelida	1	1	500	2.7	1
Annelida	2	1	500	2.7	1
Annelida	3	1	500	2.7	1
Annelida	4	1	500	2.7	1
Other Inv.	1	1	500	4	1
Other Inv.	2	1	500	4	1
Other Inv.	3	1	500	4	1

Other Inv.	4	1	500	4	1
Other	1	1	500	4	1
Other	2	1	500	4	1
Other	3	1	500	4	1
Other	4	1	500	4	1

Supplementary Material - Appendix 1. ICES data exchange format for stomach data (http://ices.dk/marine-data/data-portals/Pages/Fish-stomach.aspx)

Field	**Description**
Dataset	Dataset name
RecordType	SS for single stomach
Country	Country that collected the data
Ship	Vessel that collected the data
Latitude	Data sampling position – latitude
Longitude	Data sampling position – longitude
Estimated_Lat_Long	Flag whether the sampling position based on the reported area
ICES_StatRec	ICES statistical rectangle
ICES_AreaCode	ICES area code
Year	YYYY
Month	MM
Day	DD
Time	Sampling time like HHMM
Station	Station reference
Haul	Haul number
Sampling_Method	Predator sampling method
Depth	Sampling depth
Temperature	° C
SampleNo(FishID)	Predator reference code
	Fish ID unique for Country, year, quarter and ship
ICES_SampleID	ICES predator reference
Predator_AphiaID	Predator WoRMS AphiaID
Predator_LatinName	Predator taxon Latin Name
Predator_Weight(mean)	(Mean) predator weight
Predator_Age(mean)	(Mean) predator age
Predator_Lengh(mean)	(Mean) predator length
Predator_LowerLengthBound	Predator's length lower bound
Predator_UpperLengthBound	Predator's length upper bound

Predator_CPUE	Predator catch per hour
GallBladder_stage(class)	Gall bladder stage
Stomach_METFP	Method of stomach preservation
Stomach_TotalNo	Total number of stomachs in the pool – for single stomachs always 1.
Stomach_WithFood	Number of stomachs with food
Stomach_Regurgitated	Number of stomachs regurgitated
Stomach_WithSkeletalRemains	Number of stomachs with skeletal remains
Stomach_Empty	Number of empty stomachs
Stomach_ContentWgt	Stomach content weight
Stomach_EmptyWgt	Stomach empty weight
Stomach fullness	Stomach fullness
Stomach_Item	Stomach item name (see Appendix B)
ICES_ItemID	ICES stomach item ID
Prey_AphiaID	Prey WoRMS AphiaID
Prey_LatinName	Prey taxon Latin Name
Prey_IdentMet	Prey identification method
Prey_DigestionStage	Prey digestion stage
	0= Intact prey (skin, fins, legs and flesh is complete), 1= partially digested prey (prey in more advanced stages of digestion), 2= partially digested prey (prey in more advanced stages of digestion), 3= skeletal material (no flesh, only bones, shells, otoliths)
Prey_TotalNo	Total number of preys
Prey_Weight	Prey weight in grams
Prey_LengthIdentifier	Prey length identifier
Prey_Length	Prey length in cm
Prey_LowerLengthBound	Prey length lower bound
Prey_UpperLengthBound	Prey length upper bound
Prey_MinNo	Minimum number of preys
Remarks	Any relevant comments

Supplementary Material - Appendix 2. Data exchange format used by the North Sea stomach sampling program 1981-1991,

Copied from *ICES Coop. Res. Rep. No. 219 , pp 421-422*

Position	**Name**	**Type[a]**	**Range of values**	**Comment**
1-2	Ecosystem name	2N	1-8	Footnote[b] for coding scheme
3-4	Year	2N	01-99	Year - 1900
5	Quarter	1N	1-4	
6-9	Square	4AN		ICES rectangle
10-19	Predator code	10N		NODC 10-digit, see footnote[c]
20-24	Sample number	5N	1-99999	Unique fish ID
25-27	Country	3A		ICES alpha codes, No data:XXX
28-31	Ship	4A		ICES alpha, if available, No data: XXXX
32-34	Sampling method	3A		Footnote[d] for coding scheme No data:
35-40	Station/haul	6AN		Use national system No data: XXXXXX
41-42	Month	2N	01-12	Not known: 99
43-44	Day	2N	01-31	Not known: 99
45-48	Time of day	4N	0-2399, 9999	Local time, hh/mm, start of tow Not known: 9999
49	Quadrant	lN	1-4, 9	See footnote[e] Not known: 9
50-53	Latitude	4N	0-9000, 9999	dd/mm, Not known: 9999
54-58	Longitude	5N	0-18000, 99999	ddd/mm Not known: 99999
59-61	Depth (meters)	3N	1-999	Mean depth of tow Not know: 999
62-64	Temperature	3N	-9.9 to	XX.X one implied decimal Not known: 999
65-68	Predator (mean)	4N	1-9999	mm XXXX
69-73	Predator (mean)	5N	1-99999	grams XXXXX Not known: 99999
74-75	Predator (mean) age	2N	0-99	Not known: 99
76-79	Predator lower length bound	4N	2958101	mm XXXX
80-83	Predator upper length bound	4N	2958101	mm XXXX
84-90	CPUE	7N	1- 9999999	Weighting coefficient for sample Not known: 1
91-93	Number with food	3N	0-999	0, 1 for individual samples
94-96	Number regurgitated	3N	0-999	0, 1 for individual samples

97-99	Number with skeletal remains	3N	0-999	0, 1 for individual samples
100-102	Number empty	3N	0-999	0, 1 for individual samples
103-112	Prey species code	10N		NODC 10-digit
113-116	Prey lower length	4N	1-9999	mm XXXX Not known: 9999
117-120	Prey upper length	4N	1-9999	mm XXXX Not known: 9999
121-128	Prey weight	8N	1-	Total weight mg XXXXXXXX
129-134	Prey number	6N	1-999999	Total number Not known: 999999
135	Digestion stage	1N	0-2, 9	See footnote[f]

a) All numeric fields (N) right justified, zero filled; all apha (A) and mixed alpha/numeric fields (AN) left justified, space filled

b) North Sea=l, Baltic Sea=2, Barents Sea=3, Iceland=4, Northeastern Newfoundland=5, Northeastern USA=6, Southern Shelf=7, Faroes=8

c) NODC codes for predators:

Cod	*Gadus morhua*	8791030402
Whiting	*Merlangius merlangus*	8791031801
Haddock	*Melanogrammus aeglefinus*	879103130
Saithe	*Pollachius virens*	8791030901
Mackerel	*Scomber scombrus*	885003030 2

d) DEM=demersally caught by trawling or seining gears PEL=pelagically caught by trawling or seining gears DHL=demersal hook and line

PHL=pelagic hook and line DGN=demersal gill net PGN=pelagic gill net

e) Quadrants for position identification are: l=NE, 2=NW, 3=SW, 4=SE (The axes of the quadrants are the equator and the Greenwich meridian)

f) Digestion stages are: 0 =Pristine, 1 =Affected by digestion, 2=Skeletal remains, 9=Unknown

Supplementary Materail - Appendix G: Estimating PETS bycaught number per fleet from data

The estimation of bycatch per unit of fishing effort is complicated by the fact that bycatch is usually a rare event and by the fact that the relevant unit of fishing effort is not always recorded in the logbook. Further, the fleets which experience the greatest bycatch are not necessarily the fleets for which the uncertainty in data collected for the DCF is greatest, and hence they are often less frequently sampled by DCF observers than fleets with lower bycatch.

Generally, the logbook information for mobile gears such as trawls can be combined with VMS or similar information to provide estimated of gear type, haul duration and speed. Together, these are likely to provide reasonable estimate of fishing effort for species bycaught in this type of gear. However, of the 4 gear types posing the greatest risk to PETS (Appendix A), only one is mobile (bottom otter trawl). If gear that is considered high risk in at least one area is included, 6 out of 12 are mobile gear (bottom otter trawl, Multi-rig otter trawl, Bottom pair trawl, Midwater otter trawl, Pelagic pair trawl and Purse-seine). The static gears are deployed in a way that means the actual fishing effort (e.g. number of longlines set or the length of gillnet) is not registered in the logbook and cannot be detected by VMS. Further, the relationship between bycatch and actual fishing effort is poorly know for most gear types: Is the number bycaught proportional to e.g. soak time, gear length etc?

The discussion of gillnet effort has tended to focus on whether days at sea are sufficient to estimate effort. The variation in gear type, gear size and gear efficiency over time is often not documented on a historic basis, and to produce time series of effort, assumptions on the relationship between effort (days at sea) and gear catch rates are required. In addition, VMS is not available for smaller vessels and hence the effort for this fleet segment must be estimated using other information, e.g. AIS or measures related to number of vessels or catches. Several ICES working groups work with estimating effort from this type of data, and these groups could be tasked with producing summed effort by gear or metier.

A simple method to estimate actual fishing effort could be to estimate the development in catch per day of the main target species relative to the biomass of this species. For example, if one fishing day in year 2000 caught 10^{-8} times the target fish biomass while one fishing day in 2010 $1.5*10^{-8}$ times the target fish biomass, the conclusion would be that gear size and efficiency has increased by 50% from 2000 to 2010. The relationship between gillnet catch rates and biomass of cod in the North Sea shows that the catch per day relative to the total biomass increases when stock size is low (Rindorf and Andersen 2008). This could be a result of setting longer or more numerous gillnets in order to maintain catches at low target stock density. To get a quantitative estimate of the development in soak time and net length, ICES EGs on gear development and VMS data could be consulted. However, to achieve the estimates, they are likely to require data sets containing concurrent measurements of these parameters, and these data are not necessarily available at present. If this is the case, an effort must first be made to ensure the appropriate data are collected.

Bycatch can be a rare event either because the species itself is rare, because the species has low catchability in the fishing gear or a combination of the two. In both cases, it holds that the lower the catch rate in the fishery, the greater sampling effort needs to be exerted to obtain a specific CV of the bycatch rate. This has led to the suggestion that a simplification of indicators for sensitive species of fish to relate only to the sufficiently sampled species should not bias the result for the community as a whole (Greenstreet et al. 2012). If this suggestion is followed, sampling effort in fisheries with suspected PETS fish bycatch can be set at levels which are sufficient to monitor the bycatch of the main bycaught species with an acceptable CV. That bycatch is a rare event means that even multiplying the sampled percentage of the trips by 3 or 5 may not be sufficient to observe more than a few specimens.

Among the sampling methods, the least costly both involve use of cameras, either in combination with observers, as mobile camera units carried for one or a few trips or a permanent CCTV system. Further, as the coverage of high risk metier is often low in observer programmes and observation of PETS is rare even with dedicated observers, an automatic recording such as cameras on either parts of the fleet or, preferably, parts of the trips conducted by a fleet is by far the most cost efficient way to monitor bycatch. However, for cameras to be a realistic solution, the general resistance among fishers to having cameras on board must be addressed. While some progress can be made by ensuring that cameras do not record the movement of people more than absolutely necessary, it is not possible to construct a system which cannot also in some way be used to detect behaviour on board the vessel in addition to bycatch (e.g. discarding). Possibly, a system where 10% of the trips of each vessel are observed rather than all of the trips on 10% of the vessels is more acceptable, and this will certainly provide a better statistical representation of the entire fleet. Such a setup can be attained by mounting cameras on all vessels and agreeing with the firshers on 10% of the trips where the camera is recording or by implementing a movable system. Such a movable system has not yet been fully developed and hence would require more development before implementation. Both camera based observation systems is likely to require a firm commitment either through the political system or through market forces such as requirements for documentation of bycatch to sell to the US market or to attain MSC certification in combination with a dialogue process with the industry.

Until widely covering standardised data has been collected, it is recommended to sample 10% of all trips in high risk fleets. If after at least two years a given metier exhibits very few bycatch, the sampling effort can be downscaled. It is recommended that this initial sampling level is evaluated after obtaining five years of data to ensure that the most value is derived from the costs expended. In this process, the method used to upscale data to fleet level by e.g. WGBYC should be revised based on data from several fleets/areas/member states.

References

Rindorf, A., & Andersen, B. S. (2008). Do North Sea cod (*Gadus morhua*) fisheries maintain high catch rates at low stock size?. Canadian Journal of Fisheries and Aquatic Sciences, 65(9), 1800-1813.

Simon P. R. Greenstreet, Axel G. Rossberg, Clive J. Fox, William J. F. Le Quesne, Tom Blasdale, Philip Boulcott, Ian Mitchell, Colin Millar, Colin F. Moffat 2012. Demersal fish biodiversity: species-level indicators and trends-based targets for the Marine Strategy Framework Directive, ICES Journal of Marine Science, Volume 69 (10), pp 1789–1801, https://doi.org/10.1093/icesjms/fss148

Annex 4.3. Estimates of costs of collecting and analyzing data using different methods, task allocation, lessons learned and documentation of process (i, ii and iii)

Cost of compiling stomach data to derive population ration and diet

This section describes the anticipated work days needed for compilation of a batch of newly sampled stomach data to produce estimates of population diet and food ration to be used in multispecies models. The compilation of data can be described by three main steps.

1) Quality check of data on exchange format.
2) Creation of additional information like
   a) Stock distribution maps used for stratification and weighting the individual samples
   b) Compilation of data for use in evacuation models (prey energy density, armament, ambient temperature, *etc*) to produce food ration and diet
3) Compilation of data to produce food ration and diet

Quality check of data on exchange format

Quality check should be done immediately after data have been entered a database, preferably concurrently with the analysis of the stomach contents, to actually be able to correct suspicious data. After a short period of time it becomes practically impossible to correct for wrongly identified or coded preys. Ideally, the database program should include features for a graphical presentation of newly entered data and comparison with previously entered data. Software to support such concurrent quality check does not yet exist, but development of such database program with extensive quality checking and presentations might be beneficial in the long run, even though it requires substantial resources to develop.

The process outlined above, should be made before data are released for estimation of diet and food rations. It is thereby assumed that exchange data are of a quite good quality. However even so, two days will probably be used on a final quality check, reporting back, and new exchange of data for a batch of stomach data.

Creation of additional data

Stomachs are most often sampled during scientific surveys with the main purpose to estimate abundance indices of commercial important fish stocks. Therefore, data on stock distribution used for weighting of the individual stomach samples are already collected and available from ICES data bases, e.g. the North Sea IBTS data. For most demersal species distribution maps can be made as simple means from the of the average mean catch rates per ICES rectangles, as done for the calculation of ICES abundance indices used by stock assessment. Other more complex methods for stock distributions like the delta-Gam approach (see e.g. Berg et al., 2014) could be used, but simple approaches are probably sufficient for most demersal species. Some pelagic stocks (e.g. mackerel and horse mackerel) and semi pelagic stocks (e.g. saithe) have contagious distribution and a variable catchability in demersal trawl survey, such that these surveys may be insufficient to get a complete and accurate distribution map. A separate description of how to estimate the distribution of these species is also provided in FISPI2. It is difficult to estimate the manpower needed for such analysis; for the experienced user within exchange formats and creation of distribution maps, it is estimated to take 5 days on average. For the novel user it may take weeks.

Parameters for evacuation rate models should be obtained from the literature or simply copied or modified from the table 2.

Ambient temperature can be obtained from model output of hydrographical models (1 day).

Compilation of data to produce food ration and diet

If the appropriate software is already in place, this is estimated to take 2 days. If new software has to be developed this will likely take several weeks.

A SAS program has been developed by DTU and used to compile the "Year of the Stomach" data. The program uses and a series of additional input files including lookup tables for the various species code system and cpue by predator size class are available on request. However this suite of software and additional data files will probably not be that useful for other users, and for other areas than the North Sea. A new, area and sampling design independent, software package should be developed to basically perform the basic steps 1-6, presented in the introduction of this document. Such software could be developed as an R-package. It is estimated that this will take 50 days to develop.

Total manpower used

The total manpower used for compilation of stomach data will depend on the amount data, defined by the number of predators, areas and time periods. More strata will take longer to process, but time used per stratum will decrease significantly by increasing number of strata. It is estimated that compilation of data from one predator in one model area, from one year and four quarters will take 5 days in total for an experienced user, which has the software in place already. For the novel user or where code has to be developed for new areas, this will likely take 3 to 6 months (60 to 120 work days).

With a sampled number of 7 for each species and haul on average, the maximum cost in days of working up all stomachs are given in the table below. Values before and after – denotes the number when sampling 1 and 3 predators, respectively.

Number of hauls	Number of stomachs	Number of workdays used to collect stomachs	Number of workdays used to analyse	Number of workdays used to analyse	Number of workdays

			stomachs at 100 stomachs per day	stomachs at 30 stomachs per day	used to compile data
1	7-21	0.02-0.11	0.07-0.21	0.23-0.70	5-15
100	700-2100	1.6-11	7-21	23-70	5-15
200	1400-4200	3.2-22	14-42	47-140	5-15
400	2800-8400	6.3-44	28-84	93-280	5-15

Depending on the number of predators sampled, the total number of workdays spent as a function of number of hauls in the survey is given in the table below.

Number of hauls	1 predator, 100 samples worked up per day	1 predator, 30 samples worked up per day	3 predators, 100 samples worked up per day	3 predators, 30 samples worked up per day
1	5	15	5	16
100	14	47	30	96
200	22	79	55	177
400	39	143	104	339

PETS

Costs for use of dedicated fisheries observers and use of DCF fisheries observers

The working days for staff on land depends to a certain degree on the numbers of vessels involved. For some features, the working time differs little between, say 10 or 50 vessels, if the appointments are made with an organisation representing crews of fishery vessels. For example, this is the case for negotiations with the industry on the use of data, making appointments about the burden of having observers on board across the fleet and organisational aspects.

Observation of PETS on board during dedicated trips is mainly: staying alert, keep observing and communicate with the crew. Bycatch events are normally rare. The number of hours an observer is working is defined as 12 hours per day, which is 1.5 day. This is essentially equal for dedicated - and piggy bag trips. In piggy bag trips, the effort dedicated to PETS may be at the cost of the effort dedicated to fish sampling depending on the breaks between hauls/sampling occasions on board.

The estimation of working *days per year* is for twenty trips of one day each distributed over 20 vessels conducted by five observers, each observing 10 days (a total of 200 trips of one day each).

On land or on board	Activity	Dedicated survey (days)	Additional when piggy bagging on fishery surveys (days)
On land	Administration costs applying for licenses to possess -, handle – and transporting (samples of) protected species	3	2
	Making appointments with crews of fishery vessels and/or shipowner firms about the having observers on board, contribution across the fleet and the ownership and use of collected data	4	1
	Transportation to and from vessels	4	0
	Data validation	3	1
	Reporting	20	5
	Training of observers, including trainer-staff and observer time	4	1
	Un foreseen issues, PR	3	3
On board	Observer days (one day fishing equals 1.5 days)	300 days	0
Total 200 trips		**41 days on land + 300 days on board**	**13 days on land**
Total per trip		**0.205 days on land + 1.5 days on board**	**0.065 days on land**

Cost for use of portable cameras

An estimated cost of the portable cameras, based on cameras used in the Swedish pilot project, is 300-500 euros, but this is likely to go down if the demand increases. The costs for distributing the cameras will be dependent on if the cameras will be delivered in connection with harbour sampling or through a separate project. If they are delivered in connection with harbour sampling there will be an additional cost of 1-4 hours for mounting cameras per visited fisherman. If there is a specific project with the aim to deliver cameras to fishermen the estimated cost to deliver cameras to 2-6 fishermen, where the cameras would be filming for many weeks would be 16 man-hours. The procedure and cost for screening the films would be in the same as described in the REM monitoring above. In the table below we have estimated costs for 200 fishing trips using 3 camera units on three vessels each year.

Total expenses for portable cameras operated by fishers for 200 observed trips using 3 camera units

On land or on board	**Activity**	**First year**	**‘ Following years**
On land	Camera and storage devices	1000 euro	500 euro
	Installation cost	3 day	3 day
	Training of observers (on land)	14 days	
	Video review (100%) (on land)	80 days	80 days
	Reporting	5 days	5 days
Total 200 trips		**1000 euro+ 102 days on land**	**500 euro+ 88 days on land**
Total per trip		**5 euro+ 0.50 days on land**	**2.5 euro+ 0.44 days on land**

Total expenses for portable cameras operated by DCF observers for 200 trips using 3 camera units

On land or on board	**Activity**	**Costs when piggybacking on DCF**
On land	Camera	1000 euro
	Viewing film and data validation	80 days
	Reporting	5 days
	Training of observers, including trainer-staff and observer time	14 days
Total 200 trips		**1000 euro+ 99 days on land**
Total per trip		**5 euro+ 0.50 days on land**

Costs for use of CCTV/REM

Calculating costs of REM is not straightforward and will depend on many different factors including choice of suppliers for system, software, internet and data storage plus the level of coverage, salary levels and species to register. The prices given can thus only be seen as approximate costs.

System (prices per vessel)

The cost of a system will depend on the supplier, number of cameras and sensors. Thus different trials will have different needs depending of goals and vessel. The system price given below is based on expenses used in Danish trials and correspond to 200 trips of one day each.

	Price in euro per vessel
System	4200
Installation	4000
Running costs, maintenance	400 (per year)
Internet connection	390 (per year)

Review of video footage

The costs of video analysis will depend on the coverage needed and type of fishery. E.G. analysis time of gillnet hauls is very much different from trawl as the gillnet is hauled continuously over a long period where one only needs to review the catch sorting process of trawl hauls.

A general rule about how much video data one needs to process will depend on the abundance of the species one needs to register. Highly abundant species can give valuable results with low coverage where rare species or lumped will need much higher review. Several project have reviewed 100% for registering bycatch of marine mammals and sea birds as incident are rare.

Approximate costs of review are given below.

	Cost per vessel per year
Software license	3000 euro (per year for up to 5 vessels)
Training of observer (14 days)	450 euro
100 % review of video	80 days (per year)

Data storage

Likewise data storage costs will depends on project demands will thus vary significantly depending on the criteria for backup, data redundancy, data retrieval time and whether cloud options are permitted or only in-house storage is allowed. In this calculation we have set the needs to be 3 TB per vessel when fishing approximately 200 days pr year.

	Price in euro per vessel
3 TB data storage	116

Total expenses for 200 trips

On land or on board	**Activity**	**First year**	‘ **Second to fourth year**
On land	Camera, installation and storage devices	8316 euro	600 euro
	Running costs: maintenance, internet, licence (assuming 5 vessels share one license)	1390 euro	1390 euro

	Training of observers (on land)	14 days	
	Video review (100%) (on land)	80 days	80 days
	Reporting	5 days	5 days
Total 200 trips		**9706 euro+ 98 days on land**	**1990 euro+ 85 days on land**
Total per trip		**48.5 euro+ 0.49 days on land**	**10.0 euro+ 0.43 days on land**

Cost comparison of observation of 200 trips

The three approaches which use camera surveillance have comparable costs, precision and accuracy for a specific trip. The working days are around a third of that used when observing in a dedicated survey, and the work requires a minimum of education. The cost of these working days is therefore substantially less than that of the working days on board which must include allowance and typically involves more educated staff.

It is very cost efficient to monitor fishing trips by requiring DCF observers to monitor bycatch also of PET species by using a portable camera. Without the use of cameras, DCF observers introduce a bias due to the PETS often not reaching the sorting area and hence, these observers can only provide a minimum estimate of actual bycatch. However, for the bycatch which is observed, observers provide the opportunity to measure and sex the bycaught animals and take other samples as requested. The method can only be based on the coverage of fleets already required in the DCF, and hence the sampling effort for high risk bycatch fleets is likely to be less than that required to monitor bycatch of rare species. A combination of this method with camera based methods not requiring on board observers may therefore be necessary to achieve an acceptable accuracy of bycatch estimates of high risk fleets.

The camera options (portable camera used by observers, portable camera used by fishers, fixed CCTV) differ in the coverage they will provide of the fishery: observers will provide the widest coverage across years whereas the other methods are limited to fewer vessels thereby reducing the coverage of the fleet. Using one or a few vessels minimizes the impact of vessel differences on identification of e.g. seasonal and spatial hot spots for bycatch but increases the impact of vessel differences on the average bycatch at fleet level. It is also possible that the concept of all vessels requiring for example a 10% camera coverage of trips differs in social acceptability from requiring 10% of the vessels to have a 100% camera coverage.

In addition to differences in coverage, the methods differ in the extent to which they have been used to date in pilot projects, and hence the likely accuracy of the cost estimates. Observer costs and costs of CCTV have been estimated based on experience from long term projects, whereas the option to cost-efficiently use portable cameras has just emerged with the decrease in price of these units, and hence there is less knowledge to support the estimates of cost using this method. These methods would benefit from further pilot studies to investigate their long term benefits, challenges and costs more accurately.

On land or on board	**Dedicated survey**	**Additional when piggy bagging on fishery surveys**	**Portable camera used by fishers First year**	**Portable camera used by fishers following years**	**Portable cameras combined with fisheries observers**	**CCTV/REM First year**	**CCTV/REM Second to fourth year**
On land*	41 days	13 days	1000 euro+102 days on land	500 euro+88 days on land	1000 euro+ 99 days on land	9706 euro+ 98 days on land	1990 euro+ 85 days on land
On board**	300 days	0	0	0	0	0	0
Total 200 trips	**41* days on land + 300** days on board**	**13* days on land**	**1000 euro+102 days on land**	**500 euro+88 days on land**	**1000 euro+ 99* days on land**	**9706 euro+ 98* days on land**	**1990 euro+ 85* days on land**
Total per trip	**0.205* days on land + 1.5** days on board**	**0.065* days on land**	**5 euro+ 0.50 days on land**	**2.5 euro+ 0.44 days on land**	**5 euro+ 0.50* days on land**	**48.5 euro+ 0.49* days on land**	**10.0 euro+ 0.43* days on land**

*work requiring a minimum of education

**working days on board which must include allowance and typically involves more educated staff.

Allocating tasks to Member States for the collection and analysis of these data

The allocation of tasks to member states for the collection of stomach data could follow the allocation of tasks for the specific surveys to be used (bottom trawl, beam trawl, pelagic trawl etc). However, the analysis of stomachs collected on surveys requires substantial expertise, and it would be preferable to allocate the analysis of all stomachs of a specific species to one MS, while costs can still be allocated to a range of member states. The cost associated with the analysis could follow the TAC distribution of the particular species. After entering all data in the common format into the ICES stomach data base, the cost of the analyses of data can be shared in the same way.

The principles behind the distribution of sampling tasks for PETS among countries should ideally mirror the expected risk. This could be obtained by Member States following the fishing effort in high risk fisheries, areas and seasons. However, due to lack of data on the actual effort (e.g. soak time and length in gillnet fisheries), landings of fish (total across all species targeted in gillnets) can be used to allocate sampling requirements proportionally.

Lessons learned

Under Fishpi2, a method has been developed to prioritize fish predators according to their relevance for determining species interaction (D4.1). The method developed under Fishpi to identify high risk gear types has been applied to Baltic fisheries and the highest risk gear types identified for all regions. Manuals have been developed for sampling stomach data and distributional data as well as methods by which these data should be combined to determine consumption by fish predators as well as manuals for sampling PETS bycatch on board commercial fishing vessels. In both cases, tentative timelines for data delivery and initial sampling levels are provided. It is suggested to evaluate the appropriateness of the manuals and sampling levels after 5 years of sampling.

Annex 5

Annex 5.1 - SSF case studies. Implementation of different sampling programmes to collect SSF data.

Introduction

Four case studies were considered under the project where several specific sampling programmes focused in monitoring SSF have been implemented. The case studies are from Portugal (IPMA), France (IFREMER), United Kingdom (England and Wales,CEFAS) and Spain (Basque Country, AZTI).

Based on the experience of these institutes, all issues related to the implementation of these programmes were covered. With this objective in mind, a common structure and sections to cover was agreed:

- Characterization of the SSF by each country, MS, region etc.
- Main objectives of the sampling (catch data, effort, biological data, others…)
- Coverage of the fleet: (i.e. total coverage, partial for specific gears, segments by LOA etc.)
- Data collection methodologies used (census, directed sampling schemes etc.)
- Data sources
- Estimates provided and resolution (catch, effort by trip, week month etc. biological data as length structure for some stocks etc.)
- When possible, compare estimates obtained from official data sources (transversal data) vs sampling data.

In this Annex, a detailed information is provided for each of the case studies covering different regions along the Atlantic area.

Spanish case study (Basque Country, AZTI institute)

SSF characterization

Small Scale Fisheries (SSF) are very important in many countries from the socioeconomic and ecological points of view for which the Basque Country is not an exception. The Basque Country SSF fleet is composed by 129 vessels (Table 1). As typical for many SSF, the Basque SSF fleet is polyvalent in terms of gears and target species, developing a seasonal activity which involves a large amount of species of high diversity and a variety of different names for the same species.

Table 1: Basque Country artisanal fleet distribution

Province	Ports	Number of vessels	% of vessels by port
Gipuzkoa	Hondarribia	7	5
	Pasaia	15	12
	Donostia	8	6
	Getaria	13	10
	Mutriku	2	2
Bizkaia	Ondarroa	4	3
	Lekeitio	8	6
	Mundaka	8	6
	Bermeo	38	29
	Armintza	13	10
	Plentzia	1	1
	Santurtzi	8	6
	Zierbena	4	3
	Total vessels	**129**	**100**

Despite the importance of these fisheries scarcity, limited access and/or low reliability of data and information on SSF are constraining the implementation of efficient management programs. This is the main reason why a survey of the fleet is required to improve the knowledge about its activities.

Objectives of the sampling programmes

The main objective of this specific sampling programme is to get Basque Country´s catch and effort estimates. Biological information, species length data is also collected. Based on the data collected catch and effort estimates are calculated and then compared with the data coming from official transversal data (logbooks and sale notes information). Furthermore, differences in catch composition are also compared between both data sources and main differences are highlighted.

Coverage of the fleet

Under this programme, all the fleet that is considered as SSF by the Basque Government is covered. In the Basque Country, a "fleet with traditional fishing gear" is considered an SSF fleet. The gear is handcrafted in keeping with the tradition of the local cultural area. The fleet works throughout the year using the so-called "minor fishing gear", mostly along the shorelines, close to the coast, making short trips. Most of the boats are of a small or medium size, with very few fishermen on board. It should be noted this definition does not consider the overall length of the vessel. However, the regional administration also introduces the overall length of 18 meters to characterize the considered small scales vessels, although most of the vessels are under 15 meters total length.

Sampling methods

➢ Census approach

A survey is conducted to all active skippers located at Basque Country fishing ports, using questionnaires designed to compile required information on fishing practices, socio-economics, fish selling channels, equipment etc. With the data obtained, the Fleet Census is updated (official active vessels vs. real active vessels). The survey is conducted as described below:

- - A logbook is given to each of the skippers of the artisanal fleet. This log-book had to be filled every fishing day. The required data are: catches, gear, effort, fishing location, prices, vessel technical characteristic (GT, Power, total length).
- - For discards sampling a self-sampling scheme is used. Some skippers are selected and trained for this porpoise by scientific staff.

➢ Specific on-shore sampling programme

Traditionally, the AZTI onshore sampling program targeted the artisanal fleet only for the mackerel and tuna seasons, where most of the fleet switches to hand lines and trolling lines, respectively. This sampling program was in line with the ranking system established by the Data Collection regulation (DCR) in 2001, under which only most relevant metiers in landings, effort or value were sampled. Ports, days and vessels were selected by the samplers, with a view to get a representative sample of the activity of the fleet and to minimize biases related to the selection of the vessels

In 2015, the AZTI onshore sampling program moved towards a more probability-based sampling design. The sampling scheme for the SSF is based on a multistage cluster sampling with monthly stratification (Table 2), with harbor*day as primary sampling unite (PSU) and trips as secondary sampling unit (SSU).

Table 2. Sampling scheme for the Basque SSF

Sampling scheme	Artisanal fleet (fixed list of vessels)
Frame	Matrix port*day
Stratification 1st SU	Month
1st SU	Day*Port
Selection 1st SU	Systematic simple random
Stratification 2nd SU	-
2nd SU	Vessel landing event
Selection 2nd SU	Random
Stratification 3rd SU	Commercial species & Commercial size category
3rd SU	Box
Selection 3rd SU	First box in the tower
Stratification 4th SU	-

4th SU	Fish (length)
Selection 4th SU	Representative sample

The selection of the harbor*day is systematic random, based on a matrix of ports and days (Figure 1). The matrix consists of 6 ports, representing the 90% of the landings. In the case that landings do not occur for one harbor*day, the matrix determine the following harbor to choose. The selection of the trip is a bit trickier. A methodology based on the selection of the first vessel landing very 20 min was proposed at the beginning of the year. However, it was difficult to put this into practice and we are probably selecting vessels as before: with a view to get a representative sample and to minimize biases related to the selection of the vessels, but with any standard methodology. This sampling plan is intended for three full-time samplers.

port	sampler	02/01/2017	03/01/2017	04/01/2017	05/01/2017	06/01/2017	09/01/2017	10/01/2017	11/01/2017	12/01/2017	13/01/2017	16/01/2017	17/01/2017	18/01/2017	19/01/2017	20/01/2017	23/01/2017	24/01/2017	25/01/2017	26/01/2017	27/01/2017	30/01/2017	31/01/2017
mes	**mes**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
dia semana	**dia semana**	**L**	**M**	**X**	**J**	**V**	**L**	**M**	**X**	**J**	**V**	**L**	**M**	**X**	**J**	**V**	**L**	**M**	**X**	**J**	**V**	**L**	**M**
ON_OTB	MCruz+Julen/Alex	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
ON_PTB_VIIIabd	MCruz+Julen/Alex	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
ON_PTB_VIIIc	MCruz+Julen/Alex	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
GE_Cerco	Julen	3	1	1	2	2	2	1	2	1	2	3	3	1	1	2	3	1	1	2	3	3	2
LE_Artesanal	Julen	2	3	2	1	3	3	2	1	2	3	1	2	2	2	1	2	3	2	1	2	1	3
AR.PL_Artesanal	Julen	1	2	3	3	1	1	3	3	3	1	2	1	3	3	3	1	2	3	3	1	2	1
ON_Cerco	M Cruz	3	3	1	1	3	1	1	3	3	1	2	1	3	1	2	1	1	3	3	1	2	3
ON_Artesanal	M Cruz	2	1	3	3	2	2	3	2	1	2	1	2	2	2	1	3	3	1	2	2	3	1
BE_Artesanal.Cerco	M Cruz	1	2	2	2	1	3	2	1	2	3	3	3	1	3	3	2	2	2	1	3	1	2
HO_Cerco	Alex	1	3	1	2	1	1	3	2	1	1	3	2	1	1	2	2	1	2	1	3	3	2
HO_Artesanal	Alex	3	1	2	3	2	3	2	1	3	3	1	3	3	3	1	3	2	1	3	2	2	1
PA_Artesanal	Alex	2	2	3	1	3	2	1	3	2	2	2	1	2	2	3	1	3	3	2	1	1	3

Figure 1. Harbor day matrix (e.g. January).

In table 3, the effort made in sampling the SSF is shown. A total of 372 trips from a total of 5092 trips made by this fleet were sampled. The ports of Armintza, Bermeo, Hondarribia, Lekeitio, Ondarroa and Pasaia are the ones selected for this sampling, because they are the ports where most of the landings of this fleet are made. The ports of Getaria, Mutriku and Santurtzi are outside our sampling design because they are considered as ports with little activity in terms of landings for this fleet.

Table 3. Sampling effort by port against total number of trips by port.

Puerto	N mareas total	N mareas muestreados
Armintza	109	3
Bermeo	1007	41
Getaria	109	0
Hondarribia	127	10
Lekeitio	731	109
Mutriku	73	0
Ondarroa	118	17
Pasaia	2508	192
Santurtzi	310	0
Total general	**5092**	**372**

- **Method for calculating estimates**

The landed weight was estimated for four target species of the artisanal fleet: hake (*Merluccius merluccius*) (HKE), mackerel (*Scomber scombrus*) (MAC), sea bass (*Dicentrarchus labrax*) (BSS) and red mullet (*Mullus surmuletus*) (MUR). The estimates were made from the data collected during onshore sampling, and the total weight was estimated, only for the ports in where some sampling was carried out. This means that those ports that were not sampled were left out of the analysis. To calculate the estimates, the Horvitz Thompson estimator (Horvitz and Thompson, 1952) was used from the R "survey" library, adjusted by post-stratification by metier. The scripts used have been adapted from the code developed in the fishPi project (EU MARE 2014/19).

Onshore sampling design is a multi-stage stratified sampling (multistage cluster sampling), where the combination of port * day is the primary sampling unit (PSU), and the sale is the secondary sampling unit (SSU). The variable sampled is the total weight landed per species. It is important to note that the sampling is concurrent, so all the species landed in each trip are sampled. Sales notes data stored in the AZTI Fisheries Database, which is a combination of the information collected from the “cofradías” and the official first sale notes that come through the European Control Regulation, were used. These data are considered as the best available information from landings in Basque Country ports. These data have been used to:

1. Obtain the total number of sales by stratum (to calculate the estimates)
2. Compare the obtained estimates versus the official data.

Results

This section offers the results of the estimates obtained from the catches of the four species identified in the previous section (Hake, Mackerel, Sea Bass and Red Mullet), as target species of the SSF. The estimates obtained based on the sampling are also compared with the landings obtained in the data base of AZTI through data from “cofradias” and the official Sales Notes. These estimates of these species are given by metier and by quarter taking into account the information obtained from the 2018 onshore sampling surveys and “cofradía” data and official Sales Notes from the same year.

Variables definitions:

1. **Metier**: a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterised by a similar exploitation pattern:
    a. **GXX:** Netters (Gillnets and Trammel nets)
    b. **LHM:** Hand lines
    c. **LLS:** Longlines
2. **Wt Samp**: catch Weight estimate (Kg).
3. **se**: Standard deviation
4. **Wt BD:** Landings based on AZTI´s data base

5. **Ratio Samp/BD:** Ratio between the estimate Weight and landings on AZTI´s data base

Hake catch estimates

In table 4 the estimates obtained for hake are shown by metier and quarter. The **se** and the **Ratio Samp / BD** are also provided. The number of trips sampled from the total trips are also included.

Table 4. Hake catch estimates

Species	Metier	Wt Samp	se	Wt DB	Ratio Samp/DB	N mareas total	N mareas muestreados
HKE	GXX_DEF_60-79_0_0_1	3611	992	7738	0.47	216	22
HKE	GXX_DEF_60-79_0_0_2	5523	2839	10642	0.52	284	27
HKE	GXX_DEF_60-79_0_0_3	5412	1420	9074	0.60	290	31
HKE	GXX_DEF_60-79_0_0_4	5946	969	28079	0.21	395	35
HKE	LLS_DEF_<=1000_1	15739	6720	15711	1.00	149	9
HKE	LLS_DEF_<=1000_2	60020	18601	73151	0.82	341	18
HKE	LLS_DEF_<=1000_3	9987	1379	16186	0.62	153	14
HKE	LLS_DEF_<=1000_4	26215	13486	20525	1.28	218	7

Although the total effort by the netters in the number of trips is greater than the longlines, 58% compared to 42%, the catch estimates of the total landings in AZTI data base are higher in the case of the longlines. This is mainly because in the case of netters, although hake is one of the target species, the catch composition is more diverse in terms of species. In the case of longlines, hake usually comprises almost all the catches among the total of the species. The sampling coverage was 10% in the case of the netters and 5% for the longlines. However, when comparing the estimates of catches obtained by metier with those of AZTI´S data base, these are more similar in the case of the longlines compared to netters. In the case of longlines, first quarter data are very similar, compare to the second and fourth quarters, they show a deviation close to 20% and it is in the third quarter that it seems more biased.

In the case of netters, the estimates based on the sampling data show similar total of catches in all the quarters, when in the case of AZTI´s data base, there are important differences. Comparing **Ratio Samp / BD** there are important differences between the obtained values.

Mackerel catch estimates

In the case of mackerel, the estimates obtained can be seen in Table 5. Although the table shows that this species catches come by three different metiers, in this study we will focus on the metier of hand lines, which is by far the most important metier, since the effort during this seasonal fishery and the catches are close to 100% of the total. This seasonal fishery happens between the months of March and April depending on when this species enters to the Basque coastal waters, as this species is a migratory one. In the case of 2018, the fishery was between these two months, although the effort and catches were higher in the first quarter, specifically in the month of March.

Table 5. Mackerel catch estimates

Species	Metier	Wt Samp	se	Wt DB	Ratio Samp/DB	N mareas total	N mareas muestreados
MAC	GXX_DEF_60-79_0_0_1	1623	456	4894	0.33	162	12
MAC	GXX_DEF_60-79_0_0_2	5801	4425	1753	3.31	103	7
MAC	GXX_DEF_60-79_0_0_3	457	105	3623	0.13	138	9
MAC	GXX_DEF_60-79_0_0_4	214	70	1376	0.16	104	9
MAC	LHM_SPF_0_0_0_1	2211044	203319	2536831	0.87	692	74
MAC	LHM_SPF_0_0_0_2	1002634	104064	977194	1.03	275	19
MAC	LLS_DEF_<=1000_1	119	64	18850	0.01	62	2
MAC	LLS_DEF_<=1000_2	284	113	2782	0.10	38	2
MAC	LLS_DEF_<=1000_3	22	0	27	0.81	7	1
MAC	LLS_DEF_<=1000_4	27	0	450	0.06	41	1

The sampling effort in this case was proportional to the total effort of this métier. Regarding the comparison of the estimates of catches obtained from the sampling compared to what is collected in the AZTI´s data base, it can be seen that in the case of the second quarter the catches are very similar while in the first quarter there is a deviation of 13%.

Sea bass catch estimates

In table 6 the results obtained for sea bass. Although this species catches come from two metiers, this study will focus on longlines since for this metier it is a target species and in the case of netters, the catches can be considered as bycatch. The most important catches of this species occur mainly in the months of autumn and winter and in some cases in early spring.

Table 6. Sea bass catch estimates

Species	Metier	Wt Samp	se	Wt DB	Ratio Samp/DB	N mareas total	N mareas muestreados
BSS	GXX_DEF_60-79_0_0_1	282	102	142	1.99	56	4
BSS	GXX_DEF_60-79_0_0_2	128	44	222	0.58	48	3
BSS	GXX_DEF_60-79_0_0_3	45	2	65	0.69	43	5
BSS	GXX_DEF_60-79_0_0_4	128	34	306	0.42	82	4
BSS	LLS_DEF_<=1000_1	1078	356	1495	0.72	116	6
BSS	LLS_DEF_<=1000_2	1252	623	866	1.45	54	7
BSS	LLS_DEF_<=1000_3	1301	247	1678	0.77	103	19
BSS	LLS_DEF_<=1000_4	1430	482	2374	0.60	176	9

The sampling coverage of this metier was 9% of the total effort exerted. Based on the estimates obtained from the sampling, the Kg captured are quite similar in the four quarters. On the other hand, there is greater variability in the data obtained from AZTI´s data base. For the **Ratio Samp / DB**, there is a difference between 30 and 40% in the different quarters.

Red mullet catch estimates

In table 7, the results obtained for the red mullet. In the case of the red mullet, this study will be focused on the results obtained for the netters as the catches for the other métiers are residual. This species is one of the target species for this métier.

Table 7. Red mullet catch estimates

Species	Metier	Wt Samp	se	Wt DB	Ratio Samp/DB	N mareas total	N mareas muestreados
MUR	GXX_DEF_60-79_0_0_1	715	233	742	0.96	164	12
MUR	GXX_DEF_60-79_0_0_2	1430	373	2272	0.63	262	20
MUR	GXX_DEF_60-79_0_0_3	6027	1224	6356	0.95	324	29
MUR	GXX_DEF_60-79_0_0_4	6170	1350	3968	1.55	367	29
MUR	LLS_DEF_<=1000_1	168	53	118	1.42	37	2
MUR	LLS_DEF_<=1000_2	111	0	85	1.30	15	1
MUR	LLS_DEF_<=1000_3	1	0	14	0.07	4	1
MUR	LLS_DEF_<=1000_4	210	14	766	0.27	81	2

The largest catches of this species occur in the third quarter, in the summer season, when this species is the target, although there are also important catches the rest of the year.

Regarding the sampling coverage against the total of the trips, this was 8%. Taking into account the **Ratio Samp / BD**, it can be seen that in the quarter where the highest catches occur, the values obtained through the samplings and the AZTI database are very similar. The greatest differences are found in the second and fourth quarters, being the deviation between 40 and 55%.

Differences in the catch species composition between the estimates obtained through the onshore sampling programme and official data.

Table 8 shows that in 42% of the trips of the SSF, the number of species observed during the sampling was greater than the number of species recorded in the official sales notes. 15% of the trips presented the opposite situation: there were more species registered in the official sales notes than in the sampled trips. When reviewing these trips more in detail, it is observed that some sales notes include the general concept "marine species" that it´s not observed in the sampled trips and also that in some of the trips the specific composition of the sales notes is very different from the sampling.

Table 8. Comparison between the species observed in the sampled trips versus the official sale notes.

market	n trips sp registered< sp sampled	n trips sp registered = sp sampled	n trips sp registered > sp sampled	n trips sampling but no sales notes
Armintza	2	1	0	0
Bermeo	1	37	3	0
Hondarribia	0	6	4	0
Lekeitio	74	32	3	0
Ondarroa	0	17	0	0
Pasaia	81	65	46	0
	42%	42%	15%	0%

Below, these differences are analyzed in detail for the target species covered in the previous sections.

a. **Hake**

In 25 of the 163 trips sampled with hake catches, this species was not recorded in the corresponding first sale notes. The incomplete trips appear only in the metier assigned as netters, and practically in their totality this occurs in the port of Lekeitio (Fig. 2).When comparing the sampled kilograms of hake to those recorded in the official sales notes, a good adjustment is observed for the netters, although with some underestimation of the weight of the official sales notes in the port of Lekeitio. Most of the longlineS sales notes also coincide with the sampled weight, although in Armintza they appear to be underestimated, and in Pasaia there are both positive and negative deviations in some trips (Fig. 2).

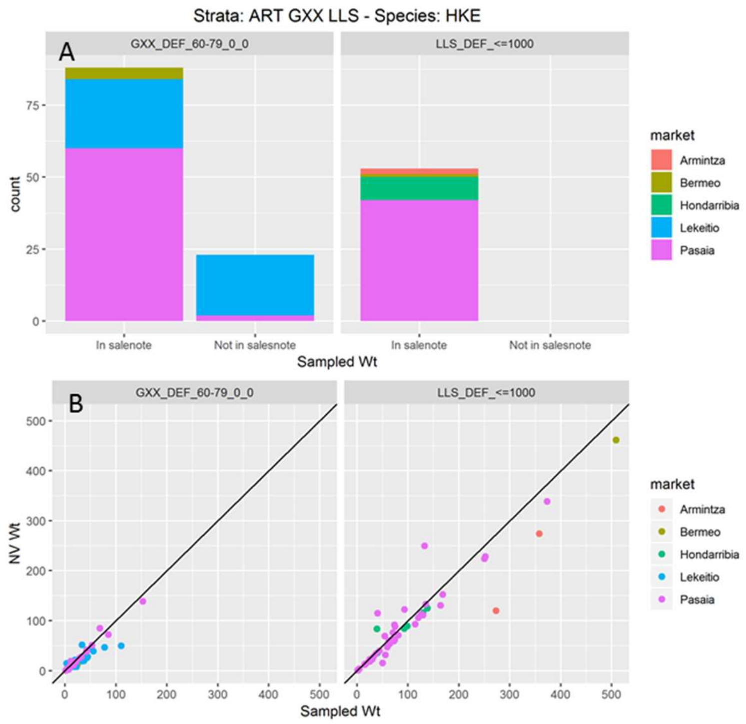


Figure 2. Comparison between official first sale notes and sampling data for hake. **A**: number of trips sampled in which the species was not registered in the corresponding first sale note, by metier and port. **B**: landing weight recorded in the sales notes against the sampled weight, per metier and port.

b. Mackerel

In 20 of the 136 trips sampled with Mackerel catches, this species was not registered in the corresponding first sale notes. The incomplete trips appear mainly in netters in the port of Lekeitio, although some have been observed in Pasaia and in longline trips (Fig. 3). However, for the most important metier for this species, the hand lines, in all the trips with mackerel catches in the sampling, were also recorded in the sales notes. When comparing the sampled kilograms of mackerel, compared to those recorded in the sales notes, a good adjustment is observed, except for three trips sampled in Lekeitio, in which the weight registered in the first sale notes was underestimated, and one in Bermeo where it was overestimated (Fig. 3).

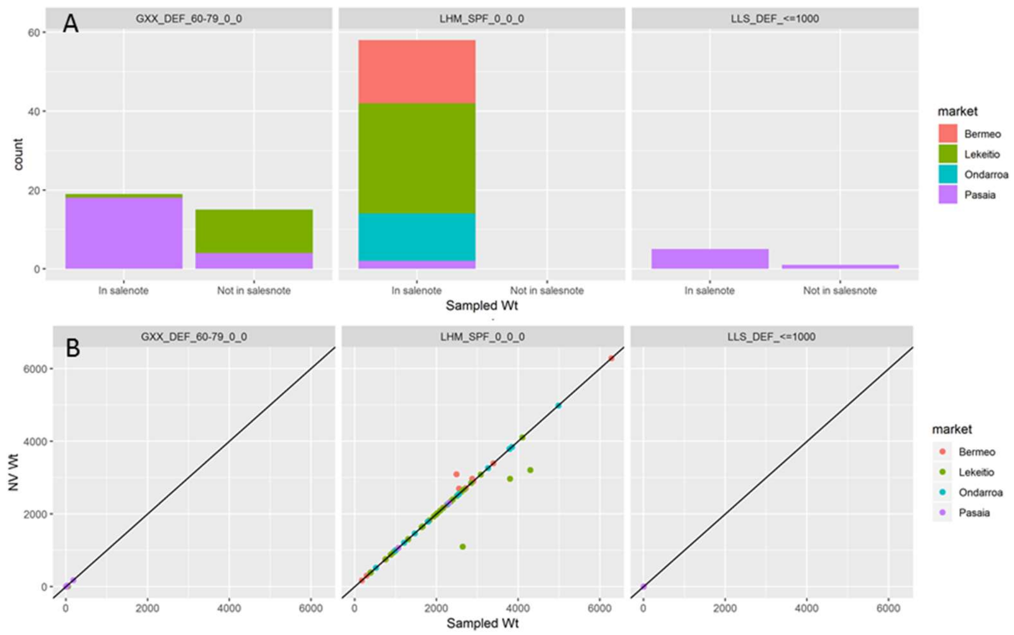


Figure 3. Comparison between official first sale notes and sampling data for mackerel. **A**: number of trips sampled in which the species was not registered in the corresponding first sale note, by metier and port. **B**: landing weight recorded in the sales notes against the sampled weight, per metier and port.

c. Sea bass

In 8 of the 57 trips sampled with seabass, this species was not registered in the corresponding first sale notes. The incomplete trips appear only in those trips assigned netters in the port of Lekeitio (Fig. 4). When comparing the sampled kilograms of seabass, compared to those registered in the sales notes, a very good adjustment is observed in the trips assigned to netters. In the trips assigned to longliners, the general adjustment is good, although some underestimation is observed in the kilograms of the first sale notes in Pasaia and Armintza, and a trip in Lekeitio in which they were overestimated (Fig. 4).

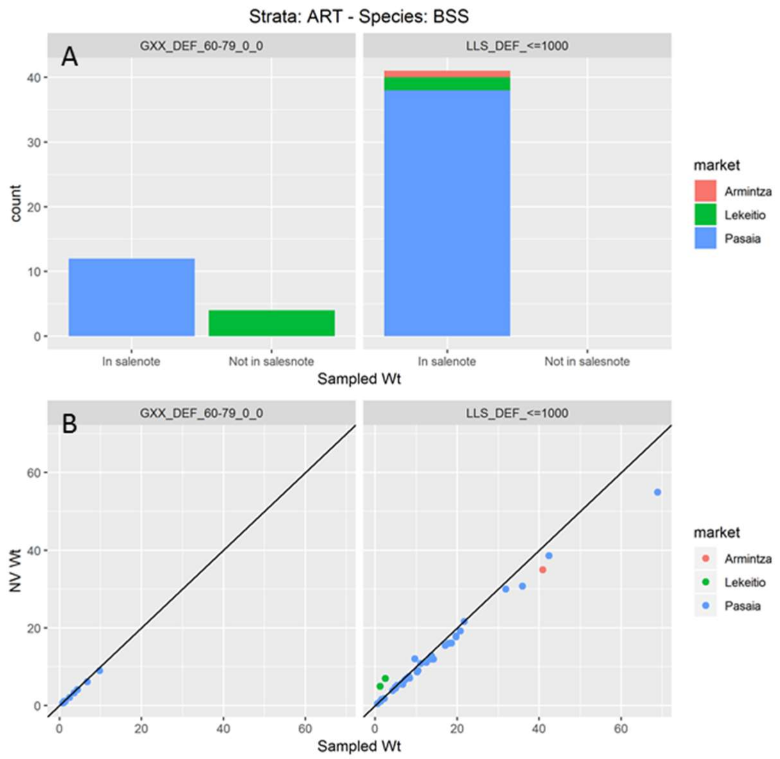


Figure 4. Comparison between official first sale notes and sampling data for seabass. **A**: number of trips sampled in which the species was not registered in the corresponding first sale note, by metier and port. **B**: landing weight recorded in the sales notes against the sampled weight, per metier and port.

d. Red mullets

In 6 of the 96 trips sampled with red mullet catches, this species was not recorded in the corresponding first sale notes. The incomplete trips appear only in netters, and mainly in the port of Lekeitio, although it has also been observed in Pasaia (Fig. 5).When comparing the sampled kilograms of red mullets, compared to those recorded in the sales notes, a very good adjustment is observed in the trips sampled in Pasaia, but significant deviations in Lekeitio, with the sales notes both underestimated and overestimated (Fig. 5).

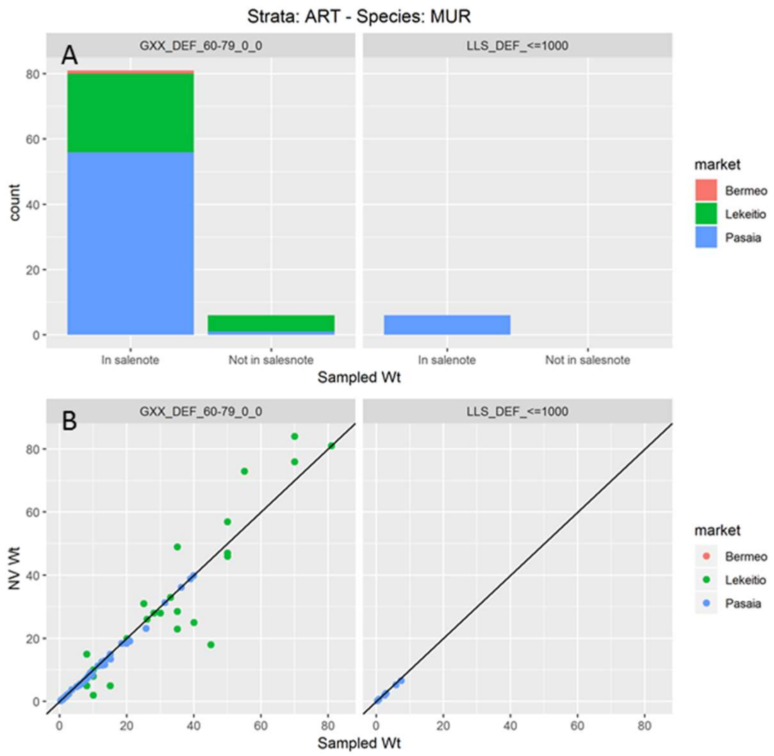


Figure 5. Comparison between official first sale notes and sampling data for red mullets. **A**: number of trips sampled in which the species was not registered in the corresponding first sale note, by metier and port. **B**: landing weight recorded in the sales notes against the sampled weight, per metier and port.

Discussion

The importance of having a specific sampling programme for the artisanal fleet is one of the recommendations that has been made during the last years through ICES. In ICES monitoring and sampling working groups (WGCATCH, WGRFS), this has been one of the most relevant issues covered. The artisanal fleet, due to its specific characteristics mentioned, is a difficult fleet to monitor if compared with more industrial fleets. Furthermore, this fleet has some exceptions in terms of reporting catch and effort data through the Control Regulation, that has an important impact in the quality of the data obtained from the official statistics.

In AZTI since 2016 a specific sampling programme of this fleet is carried out. The main objective is to obtain estimates of catches through the information collected from this onshore sampling programme. One of the main tasks is to compare the estimates obtained through the sampling data with what is collected in AZTI´s data base through the official data. Four target species have been selected and analyzed. In these analyses it is been observed that in some cases, the estimates of total captures obtained from the sampling programme are very similar to those obtained from official channels, but in other occasions the observed estimates have important differences in the **Ratio Samp / BD**.

One of the main reasons for these differences, is believed to be the low sampling coverage of this fleet, compared to the total effort. The increase in sampling effort is very likely to improve catch estimates. However, one of the problems is that this implies an increase in human resources with a corresponding economic cost that limits the possibility of increasing the sampling .Another reason for these differences is the great variability that occurs in the landings in the total of the trips that are very difficult to cover with the sampling that is carried out. As mentioned in the previous paragraph, the increase of effort in sampling would be one of the solutions.

In addition, there is still discussion in the code used, especially in the functions that perform post-stratification. Work continues on this code within the ICES groups mentioned above and it is expected that this part will be improved.

Another important point of having a specific onshore sampling programme covered with scientific personnel is the quality of the data obtained. This is evident in the number of species that appear in the trips sampled compared to the data held in the AZTI database coming from official statistics. The scientific staff can identify the landings at higher taxonomic level of resolution, at species level in most cases. This does not happen in the data collected through official channels, where these species are usually grouped at lower taxonomic levels such as genus, family, etc.

In addition, it is a common behaviour in this fleet to sell certain part of the catches through unofficial sales channels and these catches are not reflected in the official data. However, these species are recorded in the sampled trips.

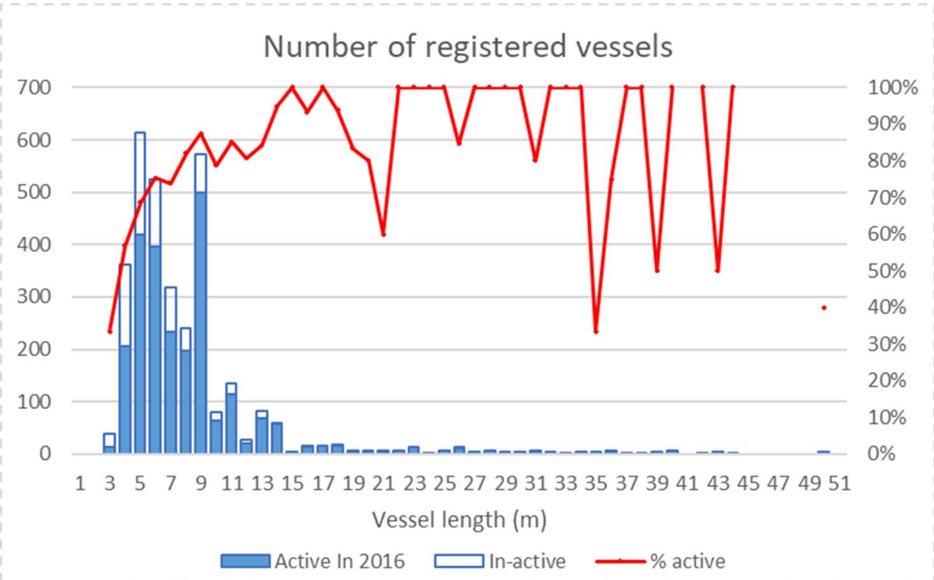
As main conclusions, it can be assured the importance of carrying out a specific sampling of this fleet through scientific personnel, since it allows to improve the quantity and quality of the basic data necessary for a good management of this fleet. Although it is true that this can be a great effort in terms of human and economic resources due to the characteristics of this fleet, as discussed throughout this report.

United Kingdom case study (England and Wales,CEFAS)

Characterization of the SSF in England and Wales.

In characterising the small-scale fisheries and fleet activity we have to consider the English and Welsh fleet as a whole. WKSSF (Nantes) and WGCATCH have tried to classify what constitutes small scale. More commonly it refers to fleets with vessel size <12m but might not be limited by vessel size in some instances. One of the key characteristics of the English and Welsh fleet is as a consequence of EU and national regulations and the level of monitoring, reporting and scrutiny the vessels and fleets and fisheries are under. This has had an influence on size categories for the English and Welsh Fleet (under 10m, 10-11.99m and 12m and above). Historic legislation has had a clear impact on the physical makeup of the fleet creating a class of vessel/fisherman which avoids the additional administration and scrutiny required of vessels over 10m. The spike in the number of vessels of 9m in Figure 8 is indicative of a fleet of vessels that makes the most of their size – a lot of these vessels are often termed as ‘rule beaters’ or ‘super under 10s’. This length class alone accounts for around 18% of the total landings by weight and value, around 75% of the landings for the all the under 12m fleet higher than any other length category (Figure 9).

Using the official statistics collected by our national control agency, the Marine Management Organisation (MMO), only 74% of the under 10m English and Welsh fleet were active in 2016. For this analysis, any registered vessels that did not record official effort or landings over this period was classed as inactive.



Most of the UK quota is allocated on the basis of track record to Producer Organisations (PO). The POs are effectively cooperatives that represent and manage the allocated quota on behalf of their members (vessel owners). 98% of the under 10 metre vessels are “non-sector” vessels where they do not belong to a producer organisation (PO) and are limited based on their licences to allocated monthly quotas from a quota pool managed by the control body. Only 35% of the over 10m vessels are “non-sector”, the rest are members of a PO. Although still restricted by their licence conditions, the PO vessels will be able to fish more flexibly from a pooled annual quota managed by that PO.

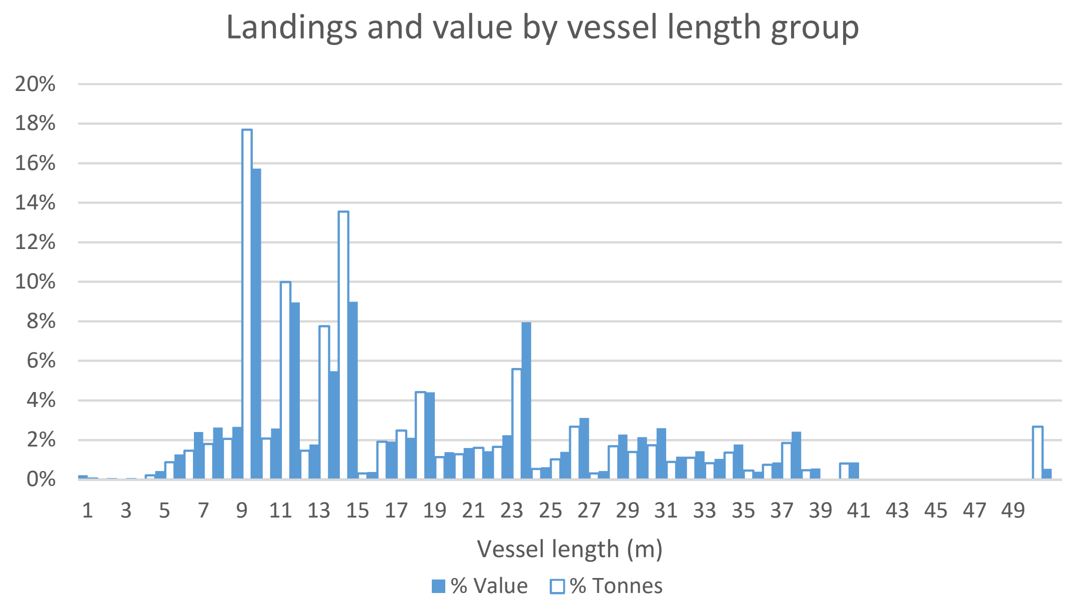


Table 7 shows the relative size and impact of the different size categories of vessel within the English and Welsh fleet in 2016. Around 1960 active under 10m vessels operate in England and Wales. 80% of the English and Welsh fleet account for around 60% of the activity (days at sea) but are only responsible for 16% of the finfish landings and 22% of the shellfish landings.

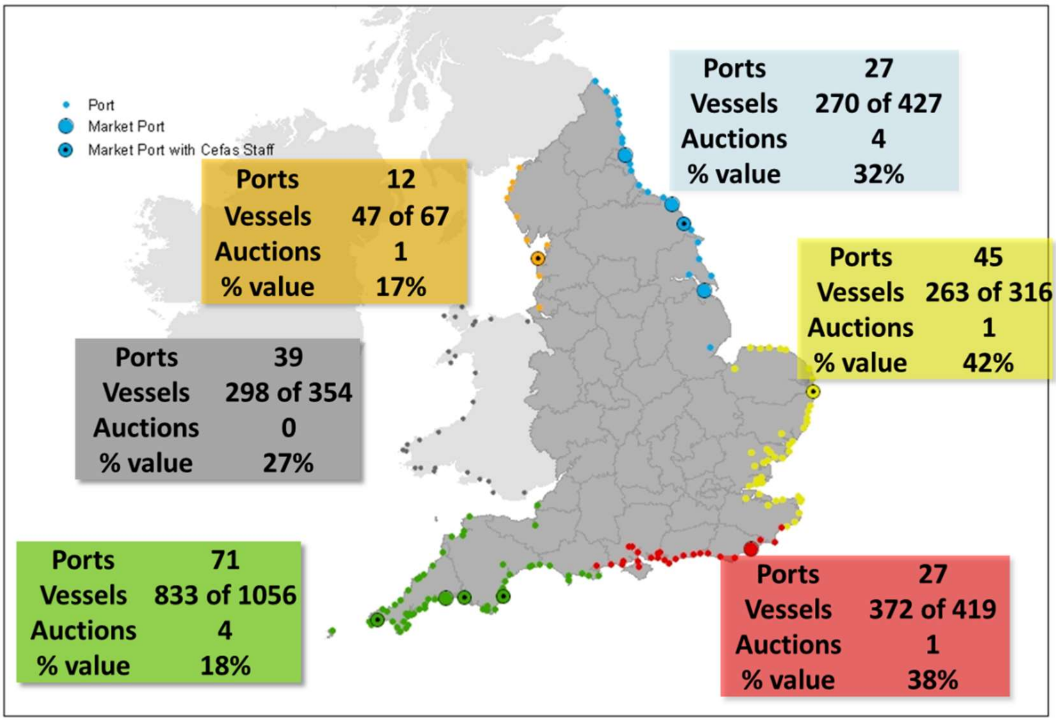
Vessel size range	<10m	10-11.9m	>=12m
No. registered vessels	2666	215	333
No. active vessels	1964	178	295
No. trips ('000s)	100	1712	19
No. days ('000s)	101	20	49
Finfish ('000 tonnes)	7546	4008	36054
Shellfish ('000 tonnes)	19137	9903	41058

Table 8 provides a summary of the landing statistics for the different size categories of vessels with the species groups ranked by value for the under 10m vessels. The contribution of the under 10m fleet is highest for species common in inshore waters and non-TAC species.

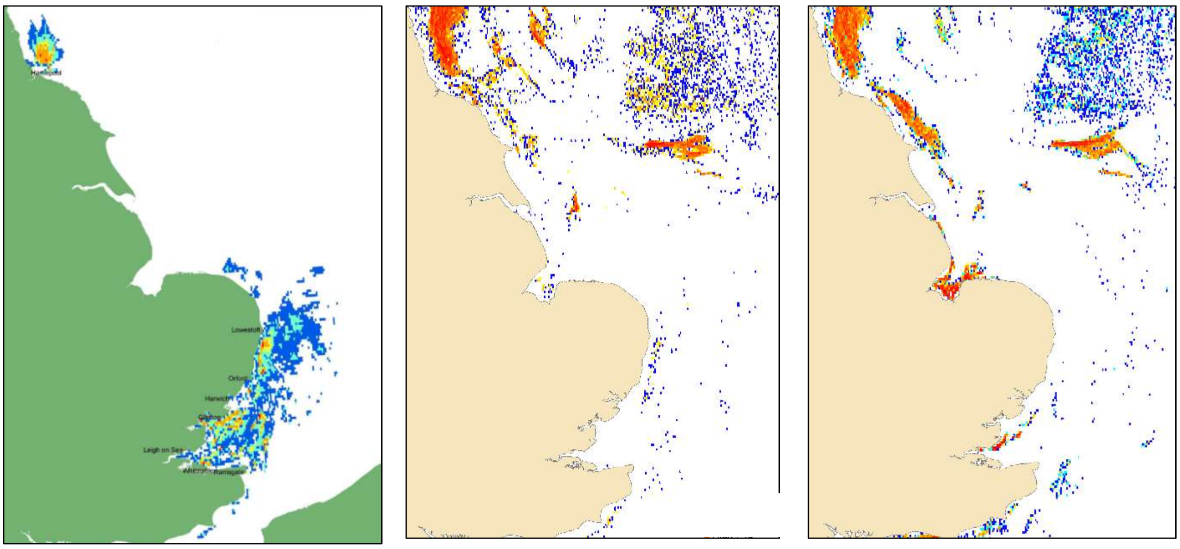
Vessel size	<10 m		10 - 11.9m		≥12 m		% t <10 m
	Weight (t)	Value (£'000s)	Weight (t)	Value (£'000s)	Weight (t)	Value (£'000s)	
Lobsters and crawfish	1175	14522	364	4412	437	5787	59%
Whelks	9390	9572	4325	4524	6136	6188	47%
Brown crab	5046	6797	2757	3780	8461	12382	31%
Seabass	456	4158	32	302	46	401	85%
Sole	542	4062	58	463	1460	13845	26%
Cephalopods	975	2349	406	1350	4355	12776	17%
Nephrops	583	2059	110	406	2719	8951	17%
Scallops	918	2026	1413	3109	9657	21654	8%
Other gadoids	1331	1917	546	766	4495	6712	21%
Other flatfish	993	1610	431	1310	4699	10998	16%
Other finfish	563	1542	301	797	5272	12913	9%
Small pelagic fish	1914	1293	1772	536	13158	4277	11%
Elasmobranchs	1212	1192	769	615	2286	2152	28%
Turbot and brill	150	1009	46	333	763	5621	16%
Other bivalves	311	954	31	95	4223	1845	7%
Shrimps and prawns	113	834	156	610	562	1969	14%
Cod	384	813	49	117	3875	2952	9%
Other crabs	274	275	56	58	30	26	76%
Cockles	274	157	0	0	4721	3359	5%
Other crustaceans	6	135	7	170	1	19	43%
Velvet swimming crab	39	65	16	25	19	34	53%
Other gastropods	35	47	0	0	0	0	100%
Diadromous fish	1	8	4	35	0	0	20%
Total	**26685**	**57396**	**13649**	**23813**	**77375**	**134861**	**23%**

The high value species landed by the under 10m fleet such as seabass caught by nets and lines and lobsters caught by pots (85% and 59% of the landings by the entire English and Welsh fleet respectively) show the significance of these fleets. Table 8 also hints at the diversity of the gears used within the small scale fleet. The 86% of the recorded landings by this fleet being from vessels using passive gears in fisheries, ranging from pot fisheries at the top of the table to hand picking of winkles and highly restricted salmon/sea trout fisheries at the bottom.

The English and Welsh small-scale fisheries are regionally distinct. England and Wales has a very diverse coastline with many landing sites for small boats including creeks and beaches. The fisheries are very diverse ranging from, for example, Nephrops pot fisheries in the north east of England to handline fisheries for mackerel and pollack in the southwest. Larger ports centralise a lot of the merchants and industry auctions and outlets. Most of the active ports in Figure 10are the exclusive domain of SSF vessels with the over 10m fleet being restricted to the larger ports. At a national level the relative importance of the regional fisheries is eclipsed by the over 10m landings from the Southwest beam, net and trawl fisheries that target high value demersal and pelagic stocks. The landings from these over 10 m fisheries limit the national value of the small scale fisheries to just 25% (£58M) of the finfish and shellfish landings.



The under 12m fleet is not currently obliged to carry a vessel monitoring system. A project that fitted a VMS system on 30 under 10m fishing vessels over the period from August 2008 to 2009 (Elson et al. 2009) provided an insight on the range and coverage of a relatively small fleet of vessels. VMS data was available for all vessels over 15m in 2009 and more recently all vessels over 12m. Although not directly comparable (because of the incomplete periods, vessel size ranges, the frequency of the satellite signals and methods for determining fishing activity) the plots in Figure 11 do demonstrate that large coastal areas are often the exclusive domain for the under 10m fleet.



Main Objectives of the sampling

For marine resource management and economic sustainability of this fleet, we should have good information on what they do, what fisheries they are involved with and their impact on stocks. For assessments, management advise and marine planning, national and international scientific ‘needs’ include good quality estimates of catch (landings and discards) and spatial fishing effort. The removals from most assessed stocks need to be characterised by age, length, sex and maturity.

Data sources, Data collection methodologies and the coverage

In England and Wales our official source for landings and effort data for under 10m vessels is sales note data collected and processed by the English control agency, Marine Management Organisation (MMO) and Welsh Government (Table 9). These landings data and their value are allocated a gear, area fished, and effort value based on the knowledge of local fishery officers, the vessel license and historic declarations. The 10-12m vessels are required to complete and submit paper logbooks and a landing declaration. In addition to the reporting in Table 9 all under 10m vessels with a shellfish entitlement have to complete Monthly Shellfish Activity Returns (MSAR) as a condition of their licence and these are processed and used by Cefas and Inshore Fisheries and Conservation Authorities (IFCA). The MSARs provide daily catch and spatial effort values for crustacean pot fisheries.

Stage	Document	Description	Relevant vessels	When required	Responsibility	Data input
Fishing	**Electronic Log**	Documents the provenance of the catch. Date(s) and location(s) of fishing, gear used, estimated weight of catch	> 12m	Done during fishing. Submitted before docking.	Vessel master	XML file emailed to MMO from E-Log systems
	Paper Log		10m – 12m	Done during fishing. Submitted within 48 hours of docking	Vessel master	Manual data entry by coastal MMO staff
At Port	**Landing Declaration**	Documents fish caught and actual weight. Not needed if there is an e-log	>10m	Submitted within 48 hours of docking	Vessel master	>12m: Electronic 10-12m: Manual entry
	Sales Note	Documents fish caught, actual weight and price	All. For U10m this is the only documentation.	To be submitted 48 hours after the sale of fish	Buyer	Electronic (merchants >EUR200K) Manual (merchants <EUR200K)

An English and Welsh onshore sampling programme of around 1200 sampling days is used to capture the numbers at size and age and other biological data from finfish and shellfish landings onshore. Sampling effort is allocated to where most of the fishing activity and landings are available within a region (Figure 10). Vessels size is not used as a stratification so if the landings from these vessels are regularly available at the main access points – auctions, merchants and quaysides then they will be well represented. There is a perception that some landings, particularly direct sales, will not be available at these regular access points. The sampling effort allocation is based on the official effort and landings data for the entire UK fleet.

The offshore sampling programme of around 525 sea days, which provides numbers at length and age for discards as well as landings is stratified by quarter, vessel length, gear and coastal region. The under 10m stratifications are not defined by gear although vessels that are either under 7m or are predominately potting are excluded – either because of safety or resource management and data needs.

Data issues: Control/transversal and biological data

Control data

There is no legal requirement for the completion of EU logbooks for the under 10m fleet. Some of these landings might not have sales slips due to EU Control Regulation 1224/2009 exemptions where sales of single species of <30 kgs do not need to be reported. These exemptions are on condition that a Member State (MS) has a sampling plan in place to capture this information. The Marine Management Organisation conducted a study in 2015-16 which demonstrated potential gaps in landings and uncertainties in the activity of the fleet in different regions. The study consisted of on-site vessel interceptions by independent observers in 3 areas of England to compare observed landings with the submitted sales not data. The study showed that 18% of landing events recorded on the quay had no matching fishing record. Cross checks showed that 12-53% of quay-side recorded landings were higher than officially recorded (Mangi et al. in press, 2018). The conclusion was that the current regulation and reporting systems for the under 10m fleet means the effort and landings may go unrecorded and in some instances over recorded. There is a risk that the <30kg rule could be exploited. Private sales to an individual that is <30kg do not need to be reported on a sales note. However, fishermen could exploit this rule by bundling their catch into multiple <30kg loads and selling larger quantities of fish unreported.

Resolution: New e-logbook scheme and VMS system for Under 12m vessels

Since the end of the 2016 study the MMO in England resolved to improve the reporting from this fleet sector and is well on the way to implementing a mobile application based electronic catch reporting system for under 10m and 10-12m vessels by the end of March 2019 (pers. comm. 01/10/2018). The aim is for the system to be compatible with the proposed changes to the EU Control Regulation. The requirement to complete an electronic catch record will either be by statute or condition of the licence (at the time the MMO were still waiting on legal advice). In addition, all 6-12m vessels will be required by statute to carry an Inshore Vessel Monitoring System (IVMS). Details are available on this website – https://www.gov.uk/government/publications/inshore-vessel-monitoring-system-ivms. In some regions IFCAs may require closer monitoring for some over 12m and under 6m vessels.

Biological data

Onshore sampling

There is no sampling effort directed towards this fleet. All the major outlets and fish markets are sampled and trips randomly selected for sampling. The frequency and size of the active under 10m fleet mean that their landings are well represented. However, the large number of vessels and landing sites, part time fishing and difficulty getting access to vessels and landings that are sold directly to the public can complicate the collection of representative data from these vessels.

In most instances the biological data collected onshore is from landings laid out pre-sale on a market floor or at a merchant, both situations are often remote from the vessel and skipper. Vessel data and related effort is dependent on the merchant or tags on the boxes and assumptions about the date of landing. The sampler is often reliant on the official data to get information for the trip (area and gear) based on the vessel name and assumed date of landing. This is less of an issue in the offshore observer programme as the observer records the fishing activity live.

Offshore sampling

For the smaller vessels in this fleet there can be difficulties getting observers safely onboard. The limited space and number of crew can affect how well the bycatch and discard sampling in some of these fisheries are covered. Cefas safety policy is that only vessels over 7m can be sampled and at least 3 crew need to be onboard (including the skipper and observer). These vessels are often single handed and although we may able to send two observers to satisfy policy there may not be sufficient space for crew and observers.

Using new technology and encouraging self-sampling to enhance the coverage of these fleets is being considered and industry initiatives encouraged. Self-sampling has been successfully employed in some fisheries – particularly the small pelagic fisheries (Carpi et al, 2018 and Rodriguez-Climent et al, in prep).

Comparisons of the two sources of data – biological data and control data.

Both sources of data are collected independently, and vessel activity is recorded by both. This has given us the opportunity to compare the metadata from the two different sources. The comparisons reflect those made by Mangi et al, 2016. However, the observed data, in this instance, is collected remotely from the vessel and skipper rather than at source so any differences may reflect flaws in how the details are assumed or sourced for both the control and biological sampling.

The meta-data (vessel registration, date of landing, and landed weights) from the two sampling programmes (onshore and offshore) were compared with the official records between 2015 and 2016 and the results are given in the text tables below. A tolerance for the landing date was required because, for the onshore sampling and sales note data, it is often assumed based on the date of sale (either from the sales note or the date of sampling). The tolerance appears quite broad and extending the range from 5 days to 15 days only makes a difference of 1 or 2 percentiles for each vessel group. 15 days is more likely to allow for monthly summaries that might be submitted by sellers.

Offshore sampling v official records

2015-2016	*<=10*	*10-12*	*>=12*	*Reason*
Matched trips	172	60	157	
Un-matched trips	11	7	5	*No record within 15 day range*
Total trips	**183**	**67**	**162**	
% mis-matches	6%	10%	3%	

Onshore sampling v transversal

2015-2016	*<=10*	*10-12*	*>=12*	*Reason*
Matched trips	1911	405	1278	
Un-matched trips	239	21	28	*No record within 15 day range*
Total trips	**2150**	**428**	**1306**	
% mis-matches	11%	5%	2%	

Mis-matches could be simply down to assumptions about the port of landing and port of sale when working remotely from the landing event. The offshore trips appear to be better matched which could be down to the observer being at the point of landing and witnessing the entire fishing activity. The larger proportion of mismatches for the under 10m vessels on the onshore sales could be as a result of the dependence on sales note data and exemptions in the control regulation with small landings being sampled and not recorded in the sales.

Comparing the actual species and quantities recorded for the matched trips onshore indicates 11-27% of the trips across the different regions were less than those recorded by the sampler. Conversely 12-20% of the trips had landings greater than recorded by the sampler and the sum of the differences tends to balance out. However, this does not account any regional differences, or the species sampled.

Figure 12(**b)**

Figure 12 (b), the <10m fleet has been combined with the 10-12m vessels for a simple comparison with the over 12m vessels and the sum of the residuals is provided for the different species groups overall, and across the different regions. These plots show the tendency for the official landing to be above (when the bar is above 0) or below (when the bar is below 0) the weight recorded when sampling. These plots tend to suggest that the sampler is not necessarily seeing all of the reported landings for some of the crustacean fisheries and for some of the sole fisheries for example there is tendency for the sampler to see more than is recorded.

Figure 12 (a)

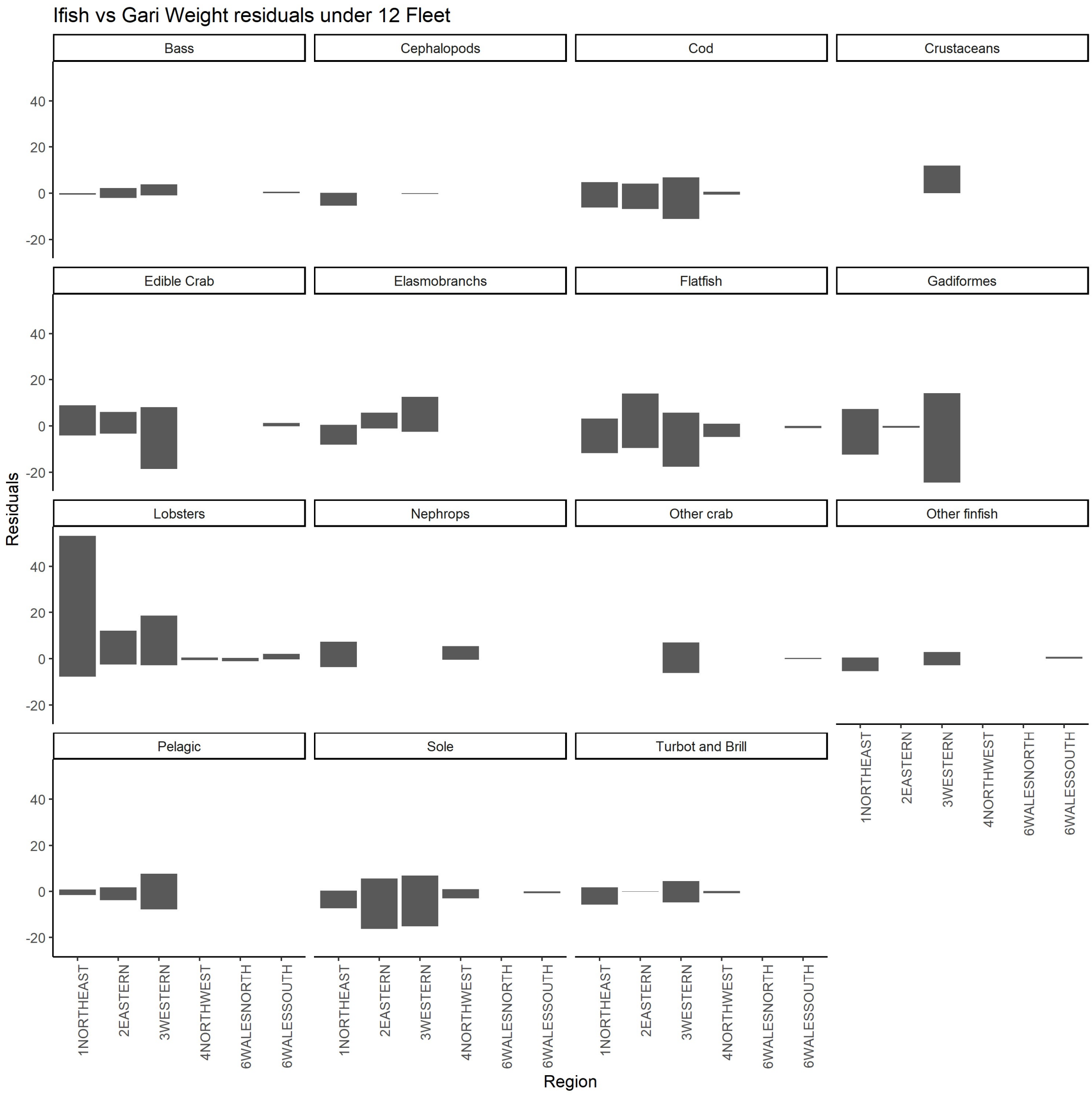
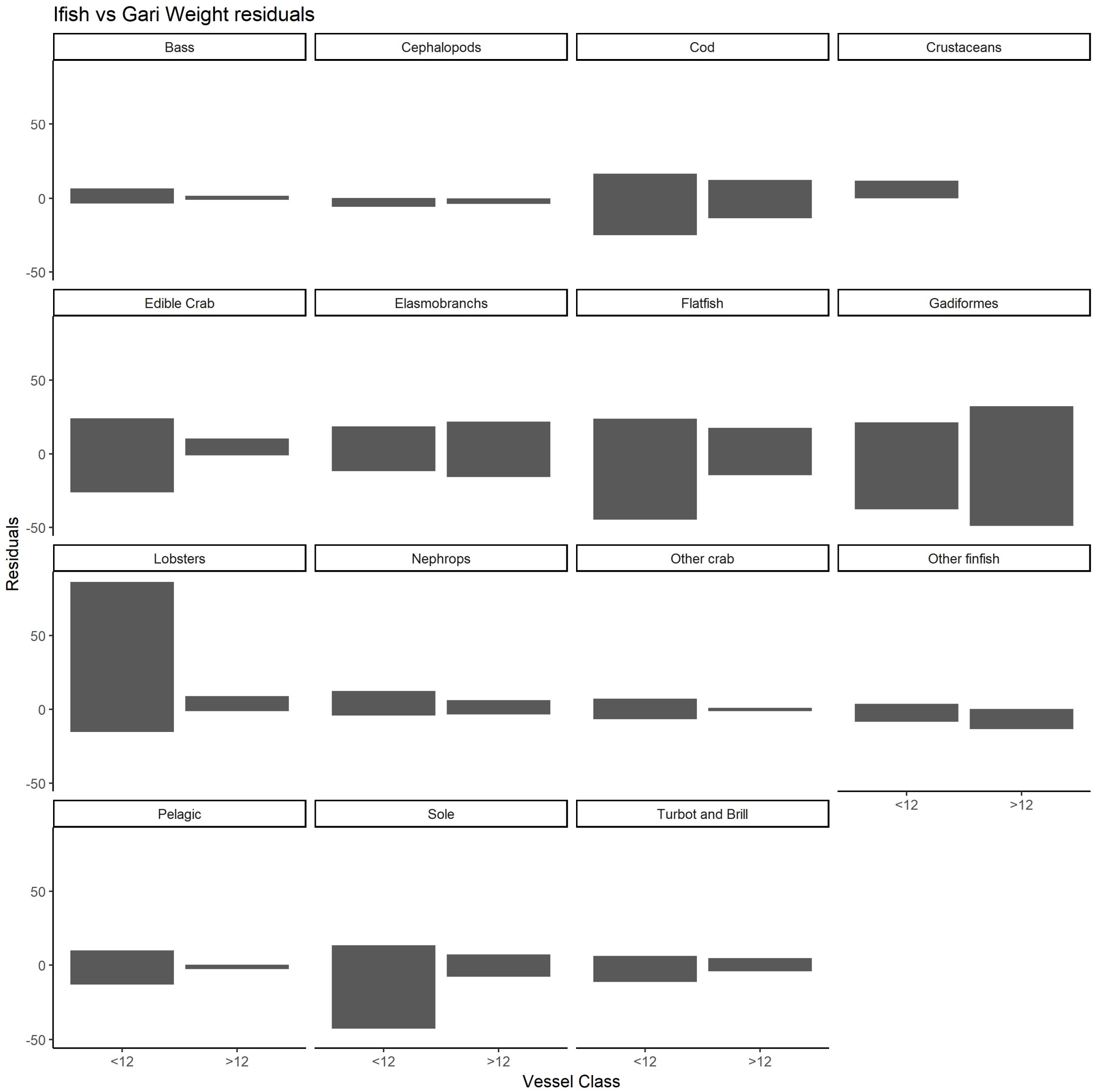

Ifish vs Gari Weight residuals under 12 Fleet
Bass
Cephalopods
Cod
Crustaceans
Edible Crab
Elasmobranchs
Flatfish
Gadiformes
Lobsters
Nephrops
Other crab
Other finfish
Pelagic
Sole
Turbot and Brill
Residuals
40
20
0
-20
1NORTHEAST
2EASTERN
3WESTERN
4NORTHWEST
6WALESNORTH
6WALESSOUTH
Region

Figure 12(b)



Conclusions

English and Welsh small scale fisheries, defined by vessel size, are often geographically distinct from other fisheries. Although small scale, the landings and value of small scale fisheries by region in the UK are not insignificant. The range of species important to these fleets are not necessarily the same as the large scale fisheries. This could be the consequence of management measures limiting access to inshore fisheries for larger vessels as well as limited quota for small scale vessels.

There are a significant number of registered vessels in the small scale fleet that do not report any fishing activity. This inactivity could be true zeros but some could be down to loopholes in the Control Regulation which puts thresholds on what data has to be recorded. There are significant differences in the same data recorded for these fisheries by independent methods which supports the idea that current reporting procedures and the control regulation is insufficient to capture and guarantee the mandatory activity and landings information in reasonable detail for small scale fisheries although UK control agencies are introducing new technological measures to improve this.

Tighter control regulations reducing the number of exemptions from reporting activity and catches, and the intended improvements to the reporting of landings and the spatial activity of the small scale fleet should help resolve some of the mismatches highlighted in this brief analysis. Improved control data will also improve the biological information collected. Either by improving the confidence in the meta data recorded for the landing sampled but also in the sampling design itself - allowing the programme coordinators to assess potential biases and allocate sampling effort to improve the coverage and reliability of the biological data.

References

Carpi, P., Searle, A., van der Kooij, J., 2018. Sardine Fisher Self Sampling. Lowestoft, Fisheries Science Partnership Report **52**.

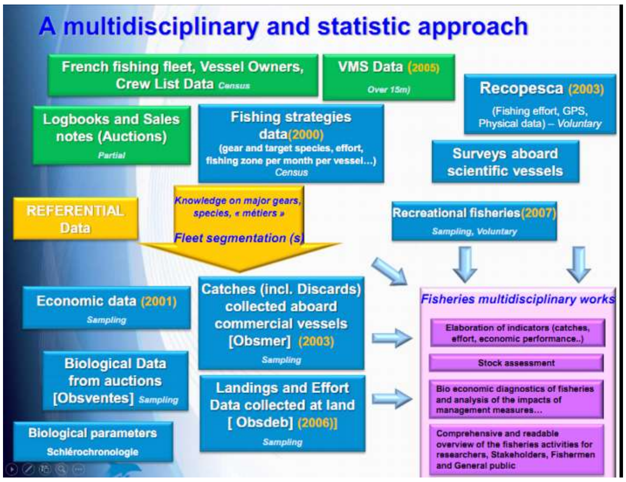
Elson, J., Firmin, C., Addison, J., Curtis, H., Longini, E., Edmonds, M., 2010. Environmentally Responsible Fisheries: Project Report. Lowestoft, Cefas Defra Contract C6875.

Mangi, S., Ribeiro Santos, A., Catchpole, T., 2016. Under 10 metre sampling project: For the Marine Management Organisation (MMO). Lowestoft, Cefas Defra Contract C3375.

Rodríguez-Climent, S., Campanella, F., Brown, D., Reeve, C.,Carpi, P., Silva, J., van der Kooij, J., in prep. Sardine and Sprat Fisher self sampling. Fisheries Science Partnership Report **XX**.

French case study (IFREMER)

Since 2000, Ifremer has implemented a Fisheries Information System *(FIS)*, a permanent, operational and multidisciplinary national monitoring network for the observation of marine resources and their uses, allowing an integrated and comprehensive view of fishery systems including biological, technical, environmental and economical components *(Leblond et al. 2008[11])*. The FIS covers all the French fisheries, including small-scale and overseas fisheries.



The process to assess the French North and Atlantic seas small scale fleet' fishing activity variables (fishing effort and landings per species) constitute a full part of this system, he is described hereunder.

Characterization of the French North and Atlantic seas small-scale fleet

More than 2700 active vessels (in 2017) build the French North and Atlantic seas (NAs) fleet for more than 450 000t landed, valued for more than 1 billion €. Vessels forming this fleet range in length from less than 4 meters to more than 80 meters.

75% of this total fleet vessels constitute the French NAs small scale fleet (SSF, here defined as less than 12 meters length vessels) which represent more than 2000 active vessels for more than 100 000t landed, valued for more than 250 million €. French NAs SSF is divided in one third less than 8 meters length vessels, one third 8 to 10 meters and one third 10 to 12 meters.

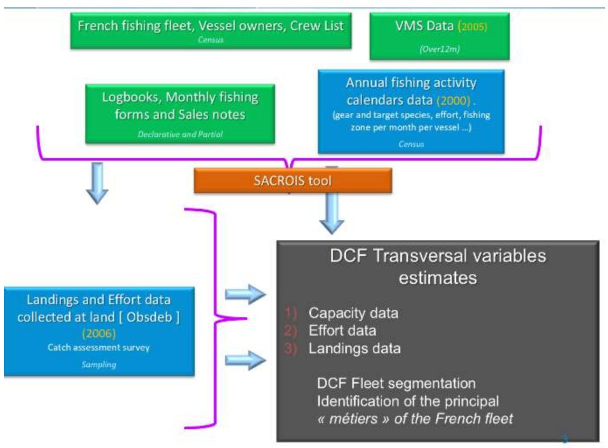
[11] Leblond Emilie et al. (2008). The Fisheries Information System of Ifremer: a multidisciplinary monitoring network and an integrated approach for the assessment of French fisheries, including small-scale fisheries. ICES 2008 Annual Science Conference, 22-26 september 2008, Halifax, Canada. http://archimer.ifremer.fr/doc/00059/17002/

French NAs SSF is a polyvalent fleet practicing a large diversity of “métiers” from diving to dredge, also nets, pots, lines and longlines, kelp fisheries, glass eel fishing, etc. and consequently present a large diversity of species landed. French NAs SSF fishing activity is mainly concentrated in the coastal area (3-12 miles boundaries).

More information on this fleet could be found in the 2017 fishing activity synthesis available on the following Ifremer Fisheries Information System web pages: https://sih.ifremer.fr/content/download/31866/217019/file/Mer%20du%20Nord%20-%20Manche%20-%20Atlantique%202017.pdf

The large diversity and polyvalence observed for this fleet introduce challenges for the fishing activity data collection and to assess quality fishing activity variables estimates.

Fishing activity’ data collection methodology and main objectives of the process



The above fishing activity' data global process applies in all French fishing activity regions with the following main objectives allocated: estimate capacity, fishing effort and landings by species. It is completed with specific sampling program for biological data (discards, length and age distribution, maturity, etc.) not described here.

Data could be collected under a census or a sampling approach depending of the regions/fleets and based on the declarative data coverage observed. In NAs, fishing activity data are exclusively collected under a census approach (no sampling data).

Data taken into account are the following:

1) French fishing fleet register. Reference file about the EU vessels with their technical characteristics. Statutory fishing gear often misinformed. No data on fishing effort, landings by species or fishing area.

2) Sales notes. Available for all the species' landings sold through the auction market; data incomplete as there is no obligation to sell landings through auction market. Sales data by species in volume and value. Fishing gear information optional. No data on fishing effort (except number of sales) or fishing area (except FAO zone in some cases).

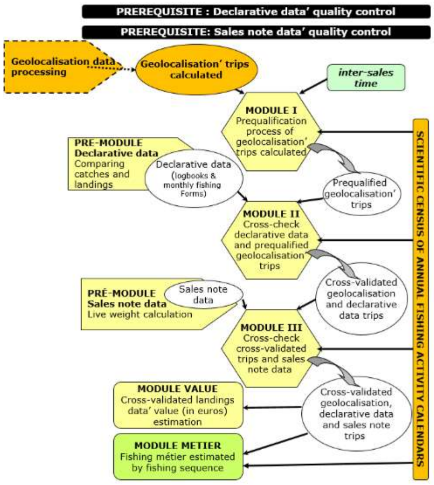
3) EU logbooks. For the 10 to 12 meters length vessels, EU control regulation applies obliging them to keep, fulfil and submit fishing logbooks. Fishing effort and landings (and discards if any) by species declared by trip and fishing gear (mesh size, dimension)/fishing area/fishing harbour/day. Declarative data which has to be validated and qualified. No data on value and fishing area frequently declared at an aggregated level.

4) Monthly declarative fishing forms. For the less than 10 meters length vessels (with no logbooks requirement), there is a national requirement to fill in monthly declarative fishing forms adapted to their special features. Fishing effort and landings (and discards if any) by species declared by day and fishing gear (mesh size, dimension)/fishing area/fishing harbour. Declarative data which has to be validated and qualified. No data on value.

5) Geolocalisation data (including VMS data). For the <12m' vessels equipped with geolocalisation devices, their data are also considered. Accordingly, potential generalization of vessels' geolocalisation will be taken into account as soon as vessels will be equipped. Fishing trips by vessel estimation with precise fishing area and fishing effort calculation. No data on catches by species and fishing gear.

6) Scientific census of annual fishing activity calendars data (see below for details).

Based on these different declarative data, the definition of all the fishing trips (including fishing effort, landings by species…) of the NAs French SSF fleet is based on a cross-validation tool: SACROIS which aim to provide the best possible fishing statistics data.



SACROIS[12] is a cross-validation tool for the fisheries statistics, cross-checking data from different declarative sources, as demanded in article 145 of the EU control Regulation. The application is crossing information, at the most disaggregated level, in order to build a dataset compiling the most accurate and complete information for each individual fishing trip. The application verifies and controls the different sources of data, with the objective of displaying validated and qualified landings per species and effort data series. The application compile all of these data into a single, verified and consistency-controlled data flow. Qualification of the data flow produced is emphasised and SACROIS tool provides also indicators about data quality and completeness (see below).

Coverage of the fleet

Quality and completeness of the available declarative data compiled by the SACROIS tool is analysed regularly. For vessels/fleets for which such data are judged insufficient, in term of coverage and/or precision, to estimate the fishing activity variables, alternative methodologies could be applied.

Annual fishing activity calendars census survey forms the foundation to assess quality and completeness of the available declarative data. SACROIS algorithm take also them into account to enhance the declarative data flow notably in terms of “métiers”/gears and fishing area.

They constitute one of the originalities of the FIS and consist in a comprehensive collection of vessels annual fishing activity calendars aiming at characterizing the inactivity or activity of the vessels each month of the year and, in the latter case, the métiers practiced (use of a gear to target one or several species) and the main fishing areas *(Berthou et al., 2008[13])*. This survey covers all the French fishing fleets *(exhaustive characterization of the national fishing fleet register)* and provides minimum but exhaustive information on the vessels, giving structural information of the fisheries surveyed. The

[12] Demanèche et al. 07/2013 : Projet SACROIS "IFREMER/DPMA" V3.2.5 (http://sih.ifremer.fr/Description-des-donnees/Les-donnees-estimees/SACROIS)

[13] Berthou Patrick et al. (2008). From fleet census to sampling schemes: an original collection of data on fishing activity for the assessment of the French fisheries. ICES 2008 Annual Science Conference, 22-26 september 2008, HALIFAX, CANADA. http://archimer.ifremer.fr/doc/00059/16996/

objective is to have a complete picture of the whole fleet in terms of monthly fishing activity schedules indicating notably the main fishing grounds and métiers operated by the vessels.

Forms used for this fleet monitoring procedure are the following:

Annexe 1

FISHING FLEET ACTIVITY CENSUS 2007 Individual annual fishing calendar

Registration Code	Starting date	Ending date	Vessel name	District Name	Port Name	Loa	Tonnage	Power (kW)	Owner code and name	EU main gear code and subsidiary gear code	Year building

							Métier 1						Métier 2						Métier 3						Métier 4						Métier 5					
Month	District	Port	Owner	Crew	Das	FD	Métier	O	AREA 1	R	AREA 2	R	Métier	0	AREA 1	R	AREA 2	R	Métier	O	AREA 1	R	AREA 2	R	Métier	0	AREA 1	R	AREA 2	R	Métier	O	AREA 1	R	AREA 2	R
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DAS = NB days at sea during the month / FD = NB fishing days / O = Origin of information (I = from Interview, L = from Logbook analysis) R = Fishing range of operation :Lagoon, Inshore, Mixed, ,Offshore

Reliability of information
❑ Direct
❑ Estimation
❑ Indirect

Activity Evolution	2006	2007
NB days at sea / year		
NB fishing days / year		
NB motor hours / year		

Panel	Owner data : address phone
Would you agree to participate an another enquiry, belong to the Panel ?	
Yes ☐ No ☐	

Métiers in logbooks or fishing forms All ☐ Some ☐ (A) *No* ☐

First selling of auction ☐ All through auction market ☐ Partly through auction ☐ (B) Totally

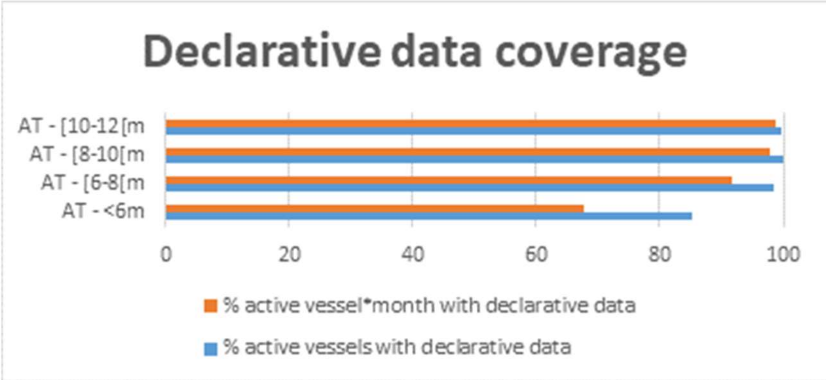
landings reliab : Y ☐ N ☐ NoAdjud ☐
Welc Quality : + ☐ = ☐ - ☐ NoAdjud

Whole landings ☐ (A + B)

Species completely sold through auction market : .... / .... / .... / .... / ....
Species completely sold out auction market : .... / .... / .... / .... / ....

The collection of the calendars is carried out by the observers' network of the FIS in the beginning of the year N+1 for the previous year N. Observers' task consist in monitoring a selected list of vessels for which they have an expert' knowledge. They comply with reference tables especially a list of national métiers. Calendars are mostly built based on an expert' analysis of the different sources of declarative data available by vessel. Based on the expertise of the observers, fishing activity calendars are easy to document very precisely for vessels with good quality declarative data available. Unfortunately, these data are not exhaustive for all the active vessels (and their reliability sometimes difficult to assess) and for these vessels, the annual fishing activity calendars are filled in, specified and completed through direct (fishermen or his wife) and indirect (local fishing network) observers' interviews. Good knowledge of the vessels' activity and close relationship between fishermen and the observers are key elements to obtain quality information. It is particularly instructive for the small-scale fleets where catches and effort data are regularly incomplete.

Annual fishing activity calendars survey provide input each year for, by example, the typological classifications of vessels by fleet, the complete description of their fishing activity or the definition of efficient sampling plans to structure the routine data collection. They are also used to assess the completeness, reliability, accuracy and pertinence of the declarative data available. Incompleteness' indicators are based on a comparison of the declarative data (SACROIS data) with the exhaustive annual fishing activity calendars.



For the French NAs SSF, declarative data coverage' indicators are quite good and data is evaluated as mostly complete except for the less than 6 meters fleet (less than 70% of the month) and some specific fleets like "glass eel fishing" for example.

Fishing activity variables estimation methodology

For fleets/regions, where such indicators conclude that declarative data available could be assessed as incomplete and imprecise and therefore as insufficient to meet the end-users needs (e.g. DCF requirements), two methods are currently used (depending of the fleets/regions) to rectify the fishing activity estimates calculate from the SACROIS data: 1) catch assessment complementary survey or 2) re-evaluation of the SACROIS data on the basis of the exhaustive annual fishing activity calendars survey.

Catch assessment survey (spatio-temporal on-site sampling) are used mainly to calculate the fishing activity estimates of the French overseas small-scale fleet. For them, they replace the first estimates calculate from the SACROIS data.

Re-evaluation methodologies are applied for fleets/regions where declarative data is still incomplete but sufficient to represent the diversity of the fishing activity practices observed (assessment of data quality/representativeness concluded that declarative data is still incomplete but cover all the fishing area, the "métiers"/gears…, integrate all the different parts/types of fishing activity taking place). In this context a methodology, based on a re-evaluation of the available declarative data scaled to the annual fishing activity calendars survey, has been developed to elevate/re-assess fishing activity' estimates in order to represent the reality of the total fishing activity of the fleet/region considered. An empiric coefficient of re-evaluation is defined by métier based on a comparison of the comprehensive fishing activity calendars survey and the available declarative data:

$$\begin{cases} \tau_m = \dfrac{\textit{number of months in Activity calendars}}{\textit{number of months in declarative data}} \\ \tau_d = \dfrac{\textit{number of days at sea in Activity calendars}}{\textit{number of days at sea in declarative data}} \end{cases} \rightarrow \tau = \dfrac{\tau_m + \dfrac{{\tau_d}^2}{\tau_m}}{1 + \dfrac{\tau_d}{\tau_m}}$$

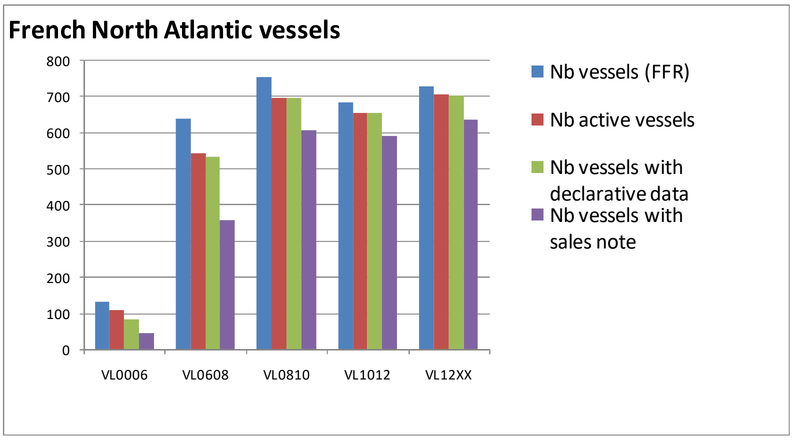
The coefficient τ has been defined after an optimization analysis and is based on two basic coefficients, the first one τm comparing the number of month for the métier observed in the annual fishing activity calendars and the number of month for the métier available in the declarative data, the second one τd comparing the number of days at sea in the two data sources.

For a given métier, based on this coefficient and fishing activity estimates coming directly from the SACROIS data, total fishing effort *(number of fishing trips, fishing effort)* and total landings by species could be estimated. The method is then embedded in a probabilistic framework in order to estimate confidence intervals of the re-evaluated indicators. A probability that a fishing trip is declared has been modeled following a probabilistic Bernouilli experiment law scaled to the coefficient of re-evaluation observed for the métier. Imprecision around this probabilistic law is then fixed arbitrarily at 10% to construct confidence intervals for the re-evaluated indicators.

SACROIS fishing activity estimates calculated (and re-evaluated if needed) enable then the calculation of all the fishing activity variables needed for the fleet/region considered. SACROIS data are available trip by trip and allow the calculation of the estimates at any resolution (minimum the trip) asked. SACROIS data re-evaluated estimates are calculated by quarter/month, metier and could be distributed by fishing area if needed.

Comparison of the data flows

Comparison of the different data flows conclude that one vessel without any declarative data (e.g. SACROIS data) is not inevitably an inactive vessel in French case study and that cross-validation method as SACROIS tool constitute an useful way to better addressed the reality of the total fishing activity in used in the region/fleet considered.



This is especially true considering the smallest vessels and especially in case of census type data collection based mainly/exclusively on sales note (see figure below).

Vessel length	% active vessels based on census fishing activity calendars	inclusive declarative data	sales note data
VL0006	83%	64%	43%
VL0608	85%	84%	66%
VL0810	92%	92%	87%
VL1012	96%	96%	90%
VL12XX	97%	97%	90%

Same conclusions have been produced regarding the species composition which could, for its part, benefit from additional biological data sampling.

Conclusion

French case study highlights the following main conclusions.

1) The **need** and importance to **calculate good quality estimates** of the **SSF fishing activity variables** in terms of fishing effort, volume and value of catches by species as minimum requirement of data to answer the different ongoing regulations, to ensure sustainable and responsible fisheries development and governance and as SSF could be, in certain area/cases, a major concern for stock assessment, fishery spatial management, socio-economic issues…

2) SSF present some specific features that distinguish them from large scale fleets, e.g.: polyvalent, multi-gear/multi-species, high spatial distribution/heterogeneity/seasonality, part-time/full-time activity, frequent direct sales… which introduces challenges for the fishing activity data collection and to assess good quality fishing activity variables estimates. **SSF have to be monitored differently by a census or a sampling approach adapted to their specific features.** For example, in case of a census type data collection approach it has been concluded that **EU logbooks are not suitable, not well adapted** to the SSF characteristics and special features and that **adapted declarative forms have to be used** (e.g. monthly fishing forms for the French case). Same issues will arise with e-declaration, e-logbooks will be not adapted to small scale fleets when dedicated app could meet the needs. Same issue apply for the framework of references (gears, métiers, fishing area, species…) used to monitor this fleet which must be also adapted to their specific features.

3) Census methods depend on self-reporting of data by fishers, reporting obligation regulation, coverage of sales note, equipment of the vessels with geolocalisation devices, etc. **Quality issues are related to coverage of the data and their accuracy/reliability. It has to be evaluated regularly through validation scheme.**

4) **Assessment of the coverage/completeness and the quality/reliability representativeness/precision of the declarative fishing activity data reached by a census type data collection must be done regularly** and **require a specific attention/analysis** in order to provide quality fishing activity estimates. This is particularly true for **small scale fleets** (even more for the smallest vessels) and **in case of census type approach based mainly/exclusively on sales note**.

5) **Sales note** could be used to improve estimates (complementary data, better species composition and information on value) but **are insufficient** (incomplete especially for SSF with significant direct sales, no specific fishing effort, no fishing gear neither fishing area information). Regarding species composition, potential direct sales contribute particularly to define a truncated view of SSF landings, especially for high-value species.

6) At this stage potential exemptions (e.g. EU control regulation exemption of <10m vessels from mandatory EU logbook completion, and allowance under the regulation to dispose of small landings and discards without documentation ; less than 50kg of live-weight equivalent in volume for any species landed) has to be taken into account. The **threshold of 50kg** constitute a **crucial issue for small-scale fleets** and contribute particularly to the truncated view addressed by the declarative data compared with the reality of the total fishing activity of the fleet/region considered. **Removal of such thresholds should be considered in order to improve fishing activity variables estimates, especially for small scale fleets.**

7) **New technologies** (in particular geolocalisation data) **constitute a significant opportunity to improve SSF monitoring and data collection**. French case study demonstrated it comparing vessels equipped or not with geolocalisation devices. Geolocalisation data are useful to assess the completeness/coverage of the declarative data available and/or to enhance available data regarding fishing effort and spatial information. Concomitantly, technological improvement should allow to have access to low-cost equipment.

8) In this context, there is a great value to develop a **cross-validation tool** (e.g. SACROIS tool in French case study) **to enhance the different data flows** (e.g. better spatial information taking into account geolocalisation data, precise information on gear/mesh size/dimension in EU logbooks or declarative forms, better species composition and information on value in sales note data…) and **to supplement them** in case of lack of data declared in one of them (concatenation/complementation of the different data flows).

9) To improve the estimates, France has developed an **exhaustive monitoring survey of the fleet** aiming at characterizing the inactivity or activity of the vessels each month of the year and, in the latter case, the métier practiced and the main fishing areas. This type of survey **is particularly useful to assess the completeness/coverage of the available declarative data by fleet/region** in order to evaluate if data are sufficient/insufficient to meet the needs. For which fleet/region the declarative data is sufficient and for which is not requiring developing alternative methodologies to calculate good quality estimates (e.g. catch assessment survey, re-evaluation methodology…). It is also **useful to assess the quality/representativeness of the data available** in terms of fishing area, fishing gear, métiers, etc. In France, annual fishing activity calendars are also used **to enhance declarative data** on gears, métiers, fishing area (limiting the misreporting) based on the observers expertise on fishing activities laid out in the calendars (especially useful also to estimate/validate the fishing gear/métier practiced by the vessel).

10) Finally, declarative data should benefit from comparison with all the other data available (e.g. improving species composition by comparison with biological data sampling).

Portugal case study (IPMA)

Characterization of the SSF

The Portuguese small scale fishing fleet, SSF, (vessels with Length overall, LOA, lower or equal than 12m) here described is restricted to the situation of the fleet in Portugal mainland on December 31, 2017 and registered at 32 ports of Portugal mainland. The SSF fleet is classified in two segments: LOA ≤ 9 m ("LOCAL" fleet) and LOA]9,12 m[("COASTAL" fleet). The fishing vessels belonging to the "LOCAL" fleet have a main operational area within 1 - 3 nmi; the fishing vessels with Loa]9,12 m[may operate in an area outside 1 nmi if GT < 100 or outside 6 nmi if GT >100.

In 31 December 2017 there were 6716 boats registered in mainland Portugal, of which 6147 (92%) belong to the SSF fleet. However, not all of them were active, i.e., engaged in fishing. In fact, just 3190 vessels had an active license in 2017. Among these, 2818 vessels (~ 88%) belong to the SSF fleet, of which 2649 vessels had LOA ≤ 9 m (94%) and 169 vessels had LOA]9,12 m[(6%).

The "LOCAL" fleet is polyvalent, i.e. multi-species and multi-gear fishery, composed of small traditional vessels most with less than 5 GT. It is important to note that despite SSF represented 88% of the Portuguese fishing fleet, the SSF fleet accounted for less than 11% of total GT and 40% of total kW. The SSF vessels usually operate within the 3 nmi at fishing grounds with depths ranging between 3 and 60 m. Usually these vessels are licensed to use several different gear types throughout the year, such as long-lines, nets, traps and pots.

Vessels belonging to the "COASTAL" fleet operate outside the 1 nmi and besides including multi-species and multi-gear vessels, purse seiners and trawlers also belong to this fleet.

Despite most of SSF vessels have commonly more than one fishing gear license, in the EU fleet register DataBase (http://ec.europa.eu/fisheries/fleet/index.cfm) only one main fishing gear licence is assigned to each SSF vessel.

Figure 1 presents the number of vessels by main fishing gear licence active in 31 December 2017 and by Portuguese NUTS II (Fig. 2). In all NUTS, the majority of SSF vessels, both "LOCAL" (78%) and "COASTAL" (47%) segments, have nets (GTR-trammel nets, GNS-gill nets, GND-drift nets) as the main fishing gear licence. Vessels with traps and pots (FPO-traps and pots) as a main fishing licence represent 9% of the SSF fleet, handlines and longlines 8%, dredges 3.5%, seines 3% and trawls less than 1%.

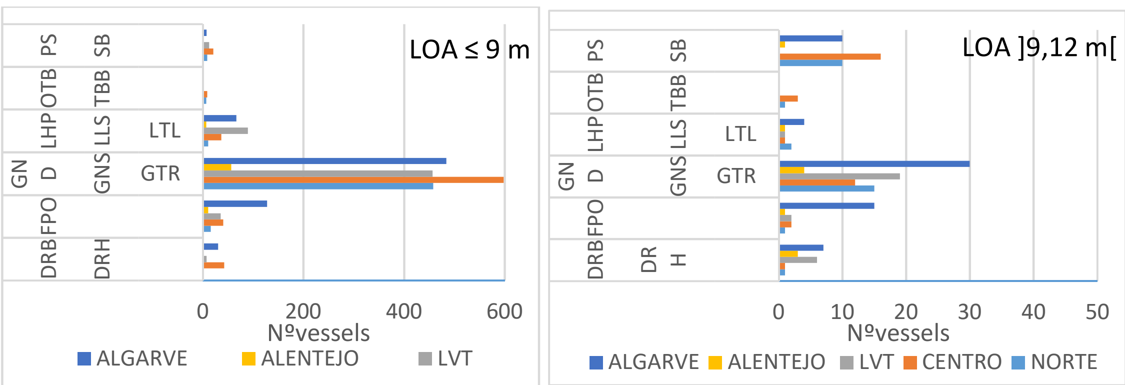


Figure 1. Number of vessels by groups of main fishing gear active licences in 31 December 2017 and by NUTS II (see Fig.2). DRB-dredges, DRH-hand dredges, PS-purse seine, SB, beach seine, OTB-bottom trawl, TBB-beam trawl, LHP-hand and pole-lines, LLS-set longlines, LTL-trolling longlines, GTR-trammel nets, GNS-gill nets, GND-drift nets, FPO-traps and pots.

Figure 2. Portugal mainland NUTS II

(https://www.google.com/search?q=PORTUGAL+MAIN+NUTS+II&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj-1t24sPLhAhVFPBoKHSwhAvsQ_AUIDigB&biw=1920&bih=937#imgrc=gfhY17Fi4oGLzM:.)

SSF "Local" and "Coastal" fleet landings and main species

In 2017 a total of 13594 and 7149 tons of fishery resources were landed in Portugal mainland by the SSF "LOCAL" and "COASTAL" fleets, respectively (Tab. 1). These landings corresponded to values of 45 248 M€ and 20 642 M€, respectively. In 2016 a total of 11 484 and 9 125 tons were landed in mainland Portugal by the SSF "LOCAL" and "COASTAL" fleets respectively (Table 1).

The most important species landed by the SSF "LOCAL" fleet were *Cerastoderma edule*, *Scomber japonicus*, *Octopus vulgaris*, *Sepia officinalis*, *Engraulis encrasicolus*, representing 21%, 21%, 15%, 4% and 4% of total landings in weight. In terms of value the most important species were the *Cerastoderma edule*, *Scomber japonicus* and the *Octopus vulgaris* accounting for 6%, 6% and 4% of total value of landings, respectively.

In 2017, the most important species landed SSF "COASTAL" fleet were *Scomber japonicus*, *Octopus vulgaris*, *Trachurus trachurus*, *Sardina pilchardus* (Table 2). In terms of value the most important species were the *Engraulis encrasicolus*, *Scomber japonicus*, *Octopus vulgaris* and *Trachurus trachurus* accounting for 7%, 4%, 4% and 4% of total value of landings, respectively.

Table 1 – 2017 (upper) and 2016 (lower) SSF Total landed weight discriminated by “Local” and “Costal” segments and by NUTSII.

TOTAL LANDED WEIGHT BY NUTS II 2017	**LOA < 9m (ton)**	**LOA]9, 12 m[(ton)**	**TOTAL SSF (ton)**
NORTE	1273	1820	3093
CENTRO	5120	2374	7494
LVT	4820	1258	6078
ALENTEJO	449	90	593
ALGARVE	1932	1606	3538
TOTAL	13594	7148	2074

TOTAL LANDED WEIGHT BY NUTS II 2016	**LOA < 9m (ton)**	**LOA]9, 12 m[(ton)**	**TOTAL SSF (ton)**
NORTE	1441	2867	4308
CENTRO	3472	2361	5833
LVT	4820	1409	6229
ALENTEJO	3603	98	3701
ALGARVE	2454	2389	4843
TOTAL	11484	9125	20609

Table 2. Portugal Mainland - Top ten species landed in weight by the "Local" and "Costal" segments in 2017 and in 2016.

2017		2016	
"LOCAL" SSF	"COASTAL" SSF	"LOCAL" SSF	"COASTAL" SSF
Cerastoderma edule	*Scomber japonicus*	*Octopus vulgaris*	*Scomber japonicus*
Scomber japonicus	*Octopus vulgaris*	*Scomber japonicus*	*Octopus vulgaris*
Octopus vulgaris	*Trachurus trachurus*	*Cerastoderma edule*	*Sardina pilchardus*
Sepia officinalis	*Sardina pilchardus*	*Sepia officinalis*	*Engraulis encrasicolus*
Engraulis encrasicolus	*Spisula solida*	*Engraulis encrasicolus*	*Trachurus trachurus*
Mytilus spp	*Callista chione*	*Trachurus trachurus*	*Spisula solida*
Trachurus trachurus	*Dicologlossa cuneata*	*Argyrosomus regius*	*Callista chione*
Conger conger	*Conger conger*	*Mytilus spp*	*Liza ramada*
Dicentrarchus labrax	*Ensis síliqua*	*Dicentrarchus labrax*	*Conger conger*
Trisopterus luscus	*Scomber japonicus*	*Sardina pilchardus*	*Trisopterus luscus*

Main objectives of the sampling

In Portugal mainland, the developed sampling programs on SSF fisheries have been mainly developed under specific scientific projects. In general, their main aim were to identify the different *métiers* among the SSF fisheries which involve the discrimination of the spatial identification of the main fishing grounds and respective catches associated with fishing gears.

However, given the spatial and temporal variability and heterogeneity of the SSF fishing fleets along the Portuguese continental coast associated with different *modi operandi* of fishing operations and given the legal Portuguese framework to assign fishing licenses the characterization of SSF fisheries and their landings are not fully achieved yet.

Coverage of the fleet

Under the Portuguese DCF monitoring program the sampling of SSF segment is included. The sampling strategy adopted for SSF is the same for the other fleets and can be consulted DCF Portuguese sampling program document (https://www.dgrm.mm.gov.pt/documents/20143/124662/PNRD_+2017_2019_texto+%282%29.pdf/1cb29ca5-c3f9-ae50-87b0-db119466e9a8). The sampling program adopted for SSF include the collection of landing information from landings at several fishing landing ports, fishing gear and fishery resources and its main objective is the estimation of length structure of the main exploited resources.

The DCF data analysis on SSF, here presented, covers the period from 2009 to 2016. Table 3 presents the number of different fishing vessels sampled by landing port and by year for the two fleets “LOCAL” and “COASTAL”.

Table 3 – Number of different vessels belonging to “LOCAL” (upper) and “COASTAL” (lower) fleets that landed in each port in each year from 2009 to 2016.

Region	Landing Port	2009	2010	2011	2012	2013	2014	2015	2016
N	Aveiro	3	4	8	4	1	11	14	6
N	Figueira da Foz	1		1	1	1	5	7	8
N	Matosinhos	10	10	13	15	12	8	11	7
N	Póvoa de Varzim	6	9	7	12	10	8	8	8
N	Viana do Castelo						8	6	6
C	Costa da Caparica						4	2	4
C	Nazaré						2	6	7
C	Peniche	12	13	11	15	11	21	25	23
C	Sesimbra	6	9	13	10	9	9	9	16
C	Setúbal	3	3	7	5	12	9	7	8
C	Sines	28	24	28	32	30	18	5	5
S	Fuzeta						2	4	
S	Lagos			1			1	1	2
S	Olhão	1	3	21	28	33	17	8	14
S	Portimão			1			5	8	8
S	Quarteira						7	8	11
S	Sagres	1	1				3	6	7
S	Santa Luzia								2
S	Vila Real Sto. António						2	1	

Region	Landing Port	2009	2010	2011	2012	2013	2014	2015	2016
N	Aveiro	1		2		2	5	5	2
N	Figueira da Foz	1	1	3		1	1	2	1
N	Matosinhos	16	9	9	9	6	7	6	12
N	Póvoa de Varzim		2	2	1				1
N	Viana do Castelo							3	2
C	Costa da Caparica							2	1
C	Nazaré							4	1
C	Peniche	20	21	25	25	27	29	30	28

C	Sesimbra		5	4	3	8	5	5	3
C	Setúbal	2	1	3	1	1	3	4	2
C	Sines	10	8	9	6	7	6	2	2
S	Fuzeta						5	2	1
S	Lagos						1	2	
S	Olhão	2	1	2	10	6	8	5	5
S	Portimão	3		1	1	2	6	5	4
S	Quarteira						5	4	4
S	Sagres		1				2		1
S	Santa Luzia								2
S	Vila Real Sto. António	1			1			1	

Table 4 presents the number of fishing trips sampled by landing port and by year for the “LOCAL” and “COSTAL” fleets.

Table 4 – Number of sampled trips belonging to “LOCAL” (upper) and “COASTAL” (lower) fleets that landed in each port in each year from 2009 to 2016

Region	Landing Port	2009	2010	2011	2012	2013	2014	2015	2016
N	Aveiro	4	4	8	5	1	12	21	8
N	Figueira da Foz	1		2	1	1	8	8	14
N	Matosinhos	18	17	19	25	22	13	16	8
N	Póvoa de Varzim	7	15	9	21	17	13	15	13
N	Viana do Castelo						10	8	8
C	Costa da Caparica						4	4	6
C	Nazaré						2	10	7
C	Peniche	16	25	22	24	23	34	36	33
C	Sesimbra	7	14	15	11	12	11	11	24
C	Setúbal	3	3	8	6	16	10	8	8
C	Sines	84	51	62	58	67	36	8	7
S	Fuzeta						3	4	
S	Lagos			1			1	1	2
S	Olhão	1	3	31	41	63	20	11	16
S	Portimão			1			8	10	9
S	Quarteira						7	8	11

S	Sagres	1	1				3	11	10
S	Santa Luzia								2
S	Vila Real Sto. António						2	1	

Region	**Landing Port**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
N	Aveiro	2		2		3	5	8	3
N	Figueira da Foz	1	1	3		2	4	3	4
N	Matosinhos	23	18	19	20	20	16	14	18
N	Póvoa de Varzim		2	7	1				1
N	Viana do Castelo							3	3
C	Costa da Caparica							2	1
C	Nazaré							7	1
C	Peniche	45	49	55	63	71	68	61	66
C	Sesimbra		6	5	6	11	5	8	6
C	Setúbal	2	1	4	1	1	3	4	3
C	Sines	59	32	20	14	29	12	3	4
S	Fuzeta						7	3	2
S	Lagos						1	3	
S	Olhão	2	1	5	23	9	11	9	6
S	Portimão	3		4	5	2	7	9	4
S	Quarteira						6	6	5
S	Sagres		1				2		1
S	Santa Luzia								2
S	Vila Real Sto. António	2			1			1	

For 2016, the number of distinct vessels sampled at each landing port and the corresponding number of vessels that landed in the landing port is presented in Table 5.

Table 5 – Number of distinct vessels belonging to “LOCAL” (upper) and “COASTAL” (lower) fleets that were sampled at each landing port under DCF in 2016 (nvessels) and the corresponding number of distinct vessels (Nvessels)

that landed at each landing port .

Region	Landing Port	nvessels	Nvessels
N	Aveiro	6	169
N	Figueira da Foz	8	65
N	Matosinhos	7	83
N	Póvoa de Varzim	8	26
N	Viana do Castelo	6	68
C	Costa da Caparica	4	217
C	Nazaré	7	71
C	Peniche	23	159
C	Sesimbra	16	170
C	Setúbal	8	162
C	Sines	5	56
S	Fuzeta		67
S	Lagos	2	75
S	Olhão	14	149
S	Portimão	8	113
S	Quarteira	11	160
S	Sagres	7	74
S	Santa Luzia	2	36
S	Vila Real Sto. António		45

Region	Landing Port	nvessels	Nvessels
N	Aveiro	2	28
N	Figueira da Foz	1	16
N	Matosinhos	12	34
N	Póvoa de Varzim	1	13
N	Viana do Castelo	2	12
C	Costa da Caparica	1	11
C	Nazaré	1	14

C	Peniche	28	41
C	Sesimbra	3	22
C	Setúbal	2	34
C	Sines	2	8
S	Fuzeta	1	31
S	Lagos		12
S	Olhão	5	33
S	Portimão	4	27
S	Quarteira	4	36
S	Sagres	1	10
S	Santa Luzia	2	21

Comparing the number of vessels landed at each landing with the vessels sampled, it is evident that the level of coverage is very scarce. Deficiency is also evident on the sampling effort translated by the ratio of the number of trips sampled with the total number of trips by landing port (Table 6). Besides this generalized low level of sampling effort it is also evident a high variability on sampling effort among landing ports.

Table 6 – Number of sampled trips (ntrips), total number of trips (Ntrips) and sampling effort (f %) by landing port from where DCF sampling information is available to "LOCAL" (upper) and "COASTAL" fleets in 2016

Region	Landing Port	n trips	N trips	f %
N	Aveiro	8	11159	0,1%
N	Figueira da Foz	14	2943	0,5%
N	Matosinhos	8	2517	0,3%
N	Póvoa de Varzim	13	1304	1,0%
N	Viana do Castelo	8	1851	0,4%
C	Costa da Caparica	6	10612	0,1%
C	Nazaré	7	3782	0,2%
C	Peniche	33	8880	0,4%
C	Sesimbra	24	12416	0,2%
C	Setúbal	8	11566	0,1%
C	Sines	7	4591	0,2%
S	Fuzeta		2012	
S	Lagos	2	4133	0,0%
S	Olhão	16	7252	0,2%

S	Portimão	9	4930	0,2%
S	Quarteira	11	7738	0,1%
S	Sagres	10	4956	0,2%
S	Santa Luzia	2	1487	0,1%
S	Vila Real Sto. António		960	

Region	Landing Port	n trips	N trips	f %
N	Aveiro	3	834	0,4%
N	Figueira da Foz	4	402	1,0%
N	Matosinhos	18	1830	1,0%
N	Póvoa de Varzim	1	179	0,6%
N	Viana do Castelo	3	705	0,4%
C	Costa da Caparica	1	407	0,2%
C	Nazaré	1	804	0,1%
C	Peniche	66	3854	1,7%
C	Sesimbra	6	1888	0,3%
C	Setúbal	3	2935	0,1%
C	Sines	4	641	0,6%
S	Fuzeta	2	611	0,3%
S	Lagos		656	
S	Olhão	6	1687	0,4%
S	Portimão	4	1752	0,2%
S	Quarteira	5	1479	0,3%
S	Sagres	1	653	0,2%
S	Santa Luzia	2	784	0,3%
S	Vila Real Sto. António		142	

The number of sampled trips by fishing gear or by group of fishing gear is presented in Table 7. Trips sampled from landings derived from FPO are quite common in all the regions and for the two fleets. There is, however, a great variability on the number of trips sampled from static net gears, with highest numbers been registered for set gillnets (anchored) GNS.

Table 7 – Number of sampled trips (ntrips) in 2016 by EU GEAR and by region for "Local" (upper) and "Coastal" (lower) fleets in 2016

Region	ARTE_EU	n trips	Region	ARTE_EU	n trips
N	FPO_MOL_>=29_0_0	25	C	GNS_DEF_80/GTR/FPO	2
N	FPO_MOL_0_0_0	12	C	GNS_DEF_80/GTR_>=100	39
N	GNS_DEF_>=100_0_0	1	C	GNS_DEF_80-99/LLS_DEF_0_0	2
N	GNS_DEF_60/FPO_MOL	1	C	GNS_DEF_80-99_0_0	10
N	GNS_DEF_60/GTR/FPO	1	C	GTR_>=100/FPO_MOL	9
N	GNS_DEF_60-79_0_0	12	C	GTR_>=100/LLS_DEF_0_0	1
N	GNS_DEF_80/GTR/FPO	1	C	GTR_DEF_>=100_0_0	31
N	GNS_DEF_80/GTR_>=100	4	C	LHM_FIF_0_0_0	15
N	GNS_DEF_80-99/LLS_DEF_0_0	1	C	LLD_DEF/FPO_MOL	1
N	GNS_DEF_80-99_0_0	7	C	LLS_DEF_0_0_0	33
N	GTR_>=100/FPO_MOL	10	C	SB_SPF_>=0_0_0	1
N	GTR_>=100/LLS_DEF_0_0	7	S	DRB_MOL_30_0_0	1
N	GTR_DEF_>=100_0_0	87	S	FPO_MOL_0_0_0	60
N	LLS_DEF_0_0_0	9	S	GNS_DEF_>=100_0_0	1
N	PS_SPF_>=16_0_0	3	S	GNS_DEF_60/GNS_80	1
N	TBB_CRU_>=20_0_0	12	S	GNS_DEF_60/GTR_>=100	8
C	FPO_MOL_>=29_0_0	16	S	GNS_DEF_60-79_0_0	52
C	FPO_MOL_0_0_0	26	S	GNS_DEF_80/FPO_MOL	1
C	GNS_DEF_>=100_0_0	12	S	GNS_DEF_80/GTR_>=100	9
C	GNS_DEF_60/FPO_MOL	3	S	GNS_DEF_80-99/LLS_DEF_0_0	3
C	GNS_DEF_60/GNS_80	8	S	GNS_DEF_80-99_0_0	16
C	GNS_DEF_60/GTR/FPO	7	S	GTR_DEF_>=100_0_0	3
C	GNS_DEF_60/GTR_>=100	23	S	LHM_FIF_0_0_0	12
C	GNS_DEF_60-79_0_0	9	S	LLD_LPF_0_0_0	1
C	GNS_DEF_80/FPO_MOL	2	S	LLS_DEF_0_0_0	11

S	PS_SPF_>=16_0_0	3

Region	ARTE_EU	n trips
N	FPO_MOL_>=29_0_0	2
N	FPO_MOL_0_0_0	3
N	GNS_DEF_60/FPO_MOL	4
N	GNS_DEF_60/GTR/FPO	1
N	GNS_DEF_80/GTR/FPO	1
N	GTR_>=100/FPO_MOL	8
N	OTB_DEF_>=55_0_0	8
N	PS_SPF_>=16_0_0	5
N	TBB_CRU_>=20_0_0	11
C	FPO_MOL_>=29_0_0	13
C	FPO_MOL_0_0_0	8
C	GNS_DEF_60/FPO_MOL	1
C	GNS_DEF_60/GNS_80	3
C	GNS_DEF_60/GTR_>=100	10
C	GNS_DEF_60-79_0_0	1
C	GNS_DEF_80/FPO_MOL	4
C	GNS_DEF_80/GTR/FPO	1
C	GNS_DEF_80/GTR_>=100	2
C	GNS_DEF_80-99_0_0	4
C	GTR_>=100/FPO_MOL	5
C	GTR_>=100/LLS_DEF_0_0	2
C	GTR_DEF_>=100_0_0	11
C	LLS_DEF_0_0_0	15
C	OTB_DEF_>=55_0_0	24
C	PS_SPF_>=16_0_0	8
S	FPO_MOL_0_0_0	28

S	GNS_DEF_>=100_0_0	1
S	GNS_DEF_60-79_0_0	1
S	LLS_DEF_0_0_0	2
S	PS_SPF_>=16_0_0	4

The number of trips by species or higher scientific taxon (COD_FAO) sampled in 2016 under DCF are presented for the Portuguese “LOCAL” and “COASTAL” fleets (Table 8). The number of trips sampled are seldom higher than 2.

Table 8 – Number of sampled trips (ntrips) in 2016 by species (COD_FAO) and by region for “Local” (upper) and “Coastal” (lower) fleets in 2016. IN annex I the scientific name fo the COFD_FAO is given.

Region	COD_FAO	n trips	Region	COD_FAO	n trips	Region	COD_FAO	n trips	Region	COD_FAO	n trips
N	ANE	1	N	SLM	1	C	MMH	1	S	BSH	1
N	ASD	2	N	SOL	4	C	MUL	2	S	BSS	2
N	BIB	5	N	SOS	3	C	MUR	2	S	CET	2
N	BON	2	N	SPU	1	C	OAL	1	S	COE	1
N	BRB	3	N	SWA	4	C	OCC	6	S	CTB	3
N	BSS	4	N	SYC	1	C	RJC	3	S	CTC	5
N	CET	1	N	TRG	1	C	RJE	1	S	DIE	1
N	COE	4	N	TUR	2	C	RJM	2	S	FOR	1
N	CPR	1	N	WRA	3	C	RPG	2	S	HKE	4
N	CTC	2	C	ANK	1	C	SBA	3	S	MAS	1
N	FLE	4	C	BIB	3	C	SBG	4	S	MGA	1
N	GGU	2	C	BLL	1	C	SHR	1	S	MIA	4
N	GUU	3	C	BLU	1	C	SLM	2	S	MLR	3
N	HKE	2	C	BON	2	C	SOL	3	S	MUL	1
N	HOM	2	C	BRB	2	C	SOS	3	S	MUR	5
N	MGC	1	C	BSH	1	C	SPU	2	S	OCC	7
N	MLR	1	C	BSS	4	C	SQR	2	S	PAC	1
N	MUF	2	C	CET	1	C	STG	1	S	RPG	1
N	MUL	1	C	COE	3	C	SWA	3	S	SBA	3
N	MUR	1	C	CTB	6	C	SYC	2	S	SBG	2

N	OAL	1	C	CTC	4	C	THS	1	S	SCS	1
N	OCC	4	C	CTZ	1	C	TOE	1	S	SNQ	1
N	PLE	2	C	FPP	1	C	TRG	1	S	SOL	2
N	POL	1	C	GUN	1	C	TUR	1	S	SOS	2
N	QPH	1	C	HKE	3	C	USI	1	S	SQC	1
N	REG	1	C	HOM	3	C	YFM	1	S	SQR	3
N	RJE	2	C	JAA	1	S	BIB	2	S	SWA	2
N	RJU	1	C	MGA	1	S	BLL	1			
N	ROL	1	C	MGC	2	S	BLU	1			
N	SBA	1	C	MGR	4	S	BON	1			
N	SBG	1	C	MIA	2	S	BRB	2			

Sampling Estimation problems

Given the sampling effort applied to the Portuguese SSF it can unquestionable concluded that this level is clear insufficient to attain reasonable precision levels of the DCF objective to estimate the length structure of the main exploited resources by SSF.

Given the high number of vessels belonging the Portuguese SSF together with the diversity of the fishing gear used, even during the same fishing trip, it is concluded that the SSF sampling program needs to be revised. It is suggested that the main objectives of the DCF adopted to Portuguese SSF be re-addressed and the level of sampling effort and the sampling strategy be set in light with national reality, priorities and budge available. There are still very important gaps about the SSF fleets, particularly in what concerns their spatial and temporal dynamics that hinder the construction of a new sampling plan for SSF.

CODE	SCIENTIFIC NAME	CODE	SCIENTIFIC NAME	CODE	SCIENTIFIC NAME	CODE	SCIENTIFIC NAME
ANE	Engraulis encrasicolus	GUM	Chelidonichthys obscurus	PLE	Pleuronectes platessa	SYC	Scyliorhinus canicula
ANK	Lophius budegassa	GUN	Trigla lyra	POL	Pollachius pollachius	TDQ	Todaropsis eblanae
ASD	Alosa alosa	GUR	Aspitrigla cuculus	QPH	Polybius henslowii	THS	Microchirus spp
BIB	Trisopterus luscus	GUU	Chelidonichthys lucerna	REG	Sebastes marinus	TOE	Torpedo spp
BLL	Scophthalmus rhombus	HKE	Merluccius merluccius	RJC	Raja clavata	TRG	Balistes capriscus
BLU	Pomatomus saltatrix	HOM	Trachurus trachurus	RJE	Raja microocellata	TUR	Psetta maxima
BOG	Boops boops	JAA	Trachurus picturatus	RJH	Raja brachyura	USI	Labrus mixtus
BON	Sarda sarda	JOD	Zeus faber	RJM	Raja montagui	WRA	Labridae (family)
BRB	Spondyliosoma cantharus	LDB	Lepidorhombus boscii	RJU	Raja undulata	YFM	Symphodus melops
BRF	Helicolenus dactylopterus	LIO	Necora puber	ROL	Gaidropsarus guttatus		
BSH	Prionace glauca	MAS	Scomber japonicus	RPG	Pagrus pagrus		
BSS	Dicentrarchus labrax	MGA	Liza aurata	SBA	Pagellus acarne		
BXD	Beryx decadactylus	MGC	Liza ramada	SBG	Sparus aurata		
CET	Dicologlossa cuneata	MGR	Argyrosomus regius	SCR	Maja squinado		
CIL	CYL	MIA	Microchirus azevia	SCS	Scorpaena spp		
COE	Conger conger	MKG	Microchirus variegatus	SFS	Lepidopus caudatus		
CPR	Palaemon serratus	MLR	Chelon labrosus	SHR	Diplodus puntazzo		
CTB	Diplodus vulgaris	MMH	Muraena helena	SLM	Sarpa salpa		
CTC	Sepia officinalis	MON	Lophius piscatorius	SNQ	Scorpaena notata		
CTZ	Chelidonichthys lastoviza	MUF	Mugil cephalus	SOL	Solea solea		
DIE	Dionda episcopa	MUL	Mugilidae(familia)	SOS	Pegusa lascaris		
EOI	Eledone cirrhosa	MUR	Mullus surmuletus	SPU	Dicentrarchus punctatus		
FLE	Platichthys flesus	OAL	Solea senegalensis	SQC	Loligo spp		
FOR	Phycis phycis	OCC	Octopus vulgaris	SQR	Loligo vulgaris		
FPP	Sander lucioperca	PAC	Pagellus erythrinus	STG	Cynoscion regalis		

GGU	Gaidropsarus vulgaris	PIL	Sardina pilchardus	SWA	Diplodus sargus	

Suplementary Material. Matrix evaluation of different methodologies used to collect SSF data.

Considering the methodologies identified to collect data of the SSF, the experts involved in this WP, created a Matrix to evaluate the potential use of them considering the quality of the data obtained but also the cost of implementing these methodologies.

Summarizing, on the one hand, in one column, all the methodologies used are identified. On the other hand, the variables to be collected taking into account main end-users needs are identified (e.g. effort, landings, discards, PETS etc.). As mentioned before, considering the quality of the data collected and the cost of it, each methodology is evaluated, and three main cons & pros are also highlighted.

The main objective of this matrix is to provide a useful tool for different RCGs when SSF data collection is discussed. It could provide some guidelines about the methodology to be used once the end-users needs are identified. Depending on the information needed, its quality, resolution etc. different alternatives should be considered, without forgetting the cost of its implementation.

The Matrix created after scoring the methodologies considered is shown below.

0	€
2	€€
3	€€€
4	€€€€
5	€€€€€

	Quality and Costs to be considered		Population	Effort							Landings				Discards			PETS				Cost(€,€€,€€€,€€€€,€€€€€)	*for collecting data on SSF vessels*
	Methodology	**Control Regulation**	**Active/Inactive Vessels**	**Days at sea**	**Number Trips**	**Fishing effort (hours, fishing days)**	**Fishing area**	**Gear used**	**Gear parameters (mesh size, number hooks)**	**Species composition**	**Quantity**	**Value (euros)**	**Biological (length, age)**	**Species composition**	**Quantity**	**Biological (length, age)**	**Species composition**	**Quantity**	**Biological (length,age, genetics)**		**Relative costs**	**Effectiveness**
VMS		No (except for >=12m vessels)	4	4	4	4	4	2	2	1	1	1	1	1	1	1	1	1	1	3	€€€	2
Alternative GPS	AIS	No	4	4	4	3	4	3	2	1	1	1	1	1	1	1	1	1	1	2	€	3
	Realtime trackers/iVMS	No	4	4	4	4	4	3	2	1	1	1	1	1	1	1	1	1	1	2.6	€€	4
Surveys	Fishermens diarys	No	4	3	3	3	4	4	4	3	3	2	2	3	3	2	3	3	2	3	€€€	3
	Interviews/Questionaires	No	4	3	3	3	3	3	4	2	2	3	1	2	2	1	2	2	1	3	€€€	3
Declarative forms	Electronic/Tablets/Apps	No	4	4	4	3	3	4	4	4	4	3	2	3	3	2	3	3	2	3.6	€€€€€	3
	Paper (Coastal logbooks)	No	4	3	3	3	3	3	3	3	3	2	2	3	3	2	2	2	2	3.2	€€€€	3
	Landings declaration/recei	No	4	3	3	3	3	3	2	4	4	3	2	2	2	2	2	2	2	3.6	€€€€€	4
Sampling programme	Auction	No	3	2	2	2	2	3	2	4	4	3	4	2	2	2	2	2	2	3.4	€€€€	4
	Onboard Observer	No	3	3	3	3	3	3	3	4	4	3	4	4	4	4	4	4	4	3.4	€€€€	4
	Onsite surveys	No	4	3	3	3	3	4	3	4	4	3	4	3	3	3	3	3	3	3.4	€€€€	4
	Reference fleets	No	3	3	3	3	4	4	4	4	4	3	3	4	4	3	4	4	3	3	€€€	4
	Self sampling	No	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	2.8	€€€	3
New technology	CCTV	No	4	3	3	3	3	4	4	3	3	1	2	3	3	2	4	4	2	3.333333333	€€€€	3
	Drones	No	4	2	2	2	3	3	2	2	2	1	2	2	2	2	2	2	2	3	€€€	3
Logbook and landing declaration		No (except for >=10m vessels)	4	4	4	3	3	4	3	4	4	2	2	2	2	2	2	2	2	3.333333333	€€€€	4
Sales notes		Yes	4	3	3	2	2	3	2	4	4	4	2	2	2	1	1	1	1	2	€	3
Transport documents		Yes	3	2	3	2	2	2	2	3	4	2	1	2	2	1	1	1	1	2.6	€€	2

Good
Adequate
Possible
Not applicable

Furthermore, the Strengths and Weakness of each methodology were analyzed.

Geospatial data

There are several devices to collect geospatial data for the SSF which could improve the knowledge about the effort realized by this fleet. These devices are considered below.

VMS

Currently at EU level, only vessels equal or above 12 meters overall length are obliged to have installed the VMS device under the Control regulation. However, the option to install it in vessels under this total length was considered considering the strengths and weakness.

- **Strengths**

Main strength of this device is that is an automated system and it cannot be switch off. On the other hand, with the information collected, active vessels versus inactive vessels could be identified, a very relevant issue in the case of the SSF. Based on different algorithms used currently for the large-scale fleet it would be quite easy to estimate different effort variables (trips, days at sea, number of hauls etc.). Gear used and main fishing grounds could be also identified.

- **Weakness**

The cost of this device is the main weakness of this device. The signal is got through satellite and this system is very expensive for the SSF. The system also requires sufficient power and vessels super structures. Furthermore, the ping interval resolution (1 or 2 hours) is not enough precise for the SSF.

AIS

Automatic Identification System (AIS) class A is mandatory for vessels with total length equal or higher than 15 meters. However, the class B is used for vessels under that length although in this case is voluntary based.

- **Strengths**

The information collected from this device is similar to the ones obtained from the VMS but in higher ping interval resolution which allows to make high resolution analysis to obtain the effort information needed for the SSF. Furthermore, the data is collected by receivers and not by satellite which reduces the cost considerably.

- **Weakness**

This device installation is voluntary, and this requires an important effort and collaboration with skippers to convince them to install it and to maintain the device switched on, as it´s quite easy to switch it off. There could be some limitation in the reception of the data in some areas depending on the geography. Furthermore, the high amount of data collected needs to develop large databases and the processing of the data could be also important. Finally, the data is not confidential which increases the difficulties in convincing the skippers to install this device, as they can be identified while they´re fishing.

Realtime trackers (iVMS, GPS etc.)

There are several real time trackers that have been started to install in the SSF. The information collected is the same as the previous devices, especially with the AIS Band also the strengthens and the weaknesses. The main difference is that in this case, although the installation of the device is again volunteer, the information is confidential as it is collected by the scientist involved in the studies.

Surveys

This methodology is used quite often to collect information about the SSF. As in the previous section several alternatives are considered, and strength and weakness analyzed.

Fisher's diaries

- **Strengths**

When skippers implication is important good information could be obtained from all variables. Good source for catch and economic data and also some information about the gears used and effort data could be obtained. It could be a useful methodology to characterize the SSF. It also increases confidence and communication between skippers and researchers.

- **Weakness**

The information obtained is coming from skippers and it could be difficult to ascertain the quality of the data. This means that a high implication of skippers is needed as it´s not mandatory to fill these diarys. Furthermore, the information must be introduced manually in the data bases that needs important human effort. There could be errors of interpretation and transcription errors in this process with some effects in the quality of the data.

Interviews/questionnaires

- **Strengths**

It could be a good methodology to get a general overview of the fleet activity. It could be used to check other data collected and if the interview is conducted at the same time as landing a double cross check could be done to compare official data from that landing and the information collected during the interview. As in the case of the diarys, this cooperation with the industry, increases confidence and communication between skippers and researchers.

- **Weakness**

Only a subsample of the total population could be covered and the effort on human resources could be important because it´s time consuming. The information collected is qualitative and the data obtained is usually of lower resolution an highly dependent of the fishermen trustworthy.

Declarative forms

Electronic/tablets/apps

- **Strengths**

It can provide in a simple and effective way of capturing activity and catch data without using and with limited keyed data entry. This reduces the processing cost and the information can be uploaded to the data bases directly. The coverage of the fleet could also be high, and the data collected is also confidential.

- **Weakness**

Cost could be high and the installation difficult depending on the vessel characteristics. Depends on the self-will of the fishermen to enter the process and the quality of the data also depends of them and that´s why some quality checks will be needed. In the long term it could be difficult to maintain the skippers motivated to provide the data.

Paper (Coastal logbooks)

Logbook system is mandatory at EU level under the Control Regulation for vessels equals or above ten meters total length. However, adapted coastal logbooks adapted are used for vessels under 10 meters.

- **Strengths**

Provides catch composition and effort information at the resolution defined by scientist. The coverage of the fleet could be high, and the information obtained is by vessel. Inactive from active vessels are also are known.

- **Weakness**

The data collected must be introduced manually and depending on the size of the fleet and the information required the cost is high. The data quality and reliability need to be cross checked with other methodologies as the information provided again depend on skippers implication and it´s common to get imprecise information in the catch composition due to difficulties in identifying the correct species, aggregating catches at low taxonomic levels etc. As it´s no t mandatory some incentives are needed for skippers to maintain them involved in the long term.

Landings declaration/receipts

Not to be confused with the official logbooks and sale notes mandatory under the Control Regulation. Although similar these are adapted specially for the under 10 meters segment fleet. The strengths and weaknesses are quite similar to the adapted coastal logbook, where information of the catch composition could be obtained. However, the resolution of the data is lower specially for the effort variables.

Sampling programmes

Auction

- **Strengths**

A complete view of the fleet activity is obtained. Relevant source for size and biological data from multiple landings required for assessment. The number of landings present could be representative of all the fishing activity in the area. It also provides a good opportunity to calibrate the landings of species or species groups recorded by the industry when scientific names aren´t used or aren´t used correctly.

- **Weakness**

In the case of the SSF, auctions might not be the only outlets or primary outlets for SSF fleets. This could skew the sampling towards the landings of the larger vessels. The coverage is only of the vessels sampled. Effort is assumed and fishing area is not always detailed. Finally, high human resources are needed to maintain the programmes.

Onboard Observer

- **Strengths**

It´s the only alternative source for a direct observation of fishing effort and gear on individual trips, and size and biological data from all catch components. The quality of the data collected is high quality data. Depending on the scheme, irrespective of the biological data collected the number of trips sampled could be representative of all the fishing activity in that area. Other data such as environmental data could be obtained.

- **Weakness**

It´s a relative expensive programme. In the SSF due to safety reason not all fleet segments are able to be monitored using scientific observers, and sampling is often skewed to larger vessels. The observer effect is also an important point to be considered.

Onsite surveys

Similar programme to the previous one. It can provide an independent direct observation of active vessels and their landings which can be used as a check for the other sources of information. It can be used for QA of other data sources. It could also provide an additional source for biological data with sufficient cooperation from the industry. However, as in the observers programmes, the cost is relatively high, and in the case of the SSF a good coverage is needed to provide reasonable estimates. If it´s not the case, the overall view of the SSF activity is not provided.

Reference fleet

- **Strengths**

Complete activity of the vessels selected is obtained with good information on catch composition, effort collected if observers are also onboard. Reduces the “inefficiencies” of random vessels selection and refusal rates. It should be considered as a potential programme to solve some specific issues as monitoring “rare” metiers, seasonal fisheries etc. Intensive dialogue with the same fisherman over the sampling period could improve understandings and relationships in some areas.

- **Weakness**

Relatively expensive as one event is sampled in real time. Sampling often skewed towards the larger vessels that can safely accommodate an observer in the SSF. The number of vessels (sampling rate) needed for a reliable/representative 'reference fleet' (representative of the diversity of fishing) need to be assessed carefully and then funded. Need to test the assumption that the reference fleet is representative of what the unsampled fleet are doing. Finally, data quality and reliability might be assessed and qualified.

Self-sampling

- **Strengths**

It´s a relatively cheaper than an observer programme if the crew bring back samples of the different components of the catch. If well designed may constitute a source of data for most of variables under interest and it may guarantee a well coverage of SSF. Can be used for small vessels unable to take observers onboard.

- **Weakness**

It´s highly dependent on fisherman self-will to participate and to maintain the process and requires cross-checking mechanism to validate the data. In many cases some incentives should be provide to fishermen and administrative effort is needed to maintain this programme. Some training to the crew is also sometimes required related with sampling issues.

New technology

CCTV

- **Strengths**

It has been shown to be effective in capturing realtime effort and activity, catch and size data from all components of the catch. Its´s often used in discards and PETS species monitoring programmes. In the case of the SSF it could be used for vessel not able to take onboard observers.

- **Weakness**

It could be expensive to set up, hardware (+ replacements) and training for multiple vessels. In some fisheries there could be difficulties in species identification. It needs a lot of time and human resources to analyse the images, although this is improving with the algorithms created for this purpose. Maintenance and development of the (large) database and (efficient with important computing power) process tools to be provided. Finally, could some resistance from the fishermen to install cameras onboard. In the majority of the cases some incentives are needed for the fishermen.

Drones

- **Strengths**

Remote and totally independent of the fishing activity. It can be effective in certain areas (coastal lagoons, estuaries) and for certain fisheries (e.g. bivalve harvesting). Some information on fishing activity (number of active vessels, fishing areas) could be observed.

- **Weakness**

Could be expensive to set up, hardware (+ replacements), training and video processing. The fishing area covered could be scarce due to the low autonomy of the drone.

Annex 5.2 Progress, challenges, and data gaps: towards standardisation of electronic reporting in small scale fisheries in Europe

Introduction

Electronic Recording and Reporting Systems (ERS) are used to report, process, store and send fisheries data, such as catches, landings and positional information from fishing vessels to relevant stakeholders. In Large Scale Fisheries (LSFs), the introduction of Vessel Monitoring Systems (VMS) and Automated Identification Systems (AIS) have resulted in increased reporting of fishing vessel positional data at finer temporal and spatial scales than previously possible. Electronic catch reporting with e-logbooks is another widely used system, where catches are entered by the skipper into an electronic logbook system and transmitted to control authorities (James et al., 2019). Coupling the positional data with the e-log system has been used to produce fine-scale maps of catch and effort (Gerritsen and Lordan, 2011; Hintzen et al., 2012; Russo et al., 2014), to identify main fishing grounds (Jennings and Lee, 2012; Le Guyader et al., 2017); monitoring of compliance to regulations (McCauley et al., 2016), and estimate distribution of impact on marine habitats (Stelzenmuller et al., 2008; Gerritsen et al., 2013).

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

Small Scale Fisheries (SSF) in Europe are generally exempt from reporting requirements using these technologies. While there is no common definition of SSFs in Europe, common characteristics of SSF vessels are that they are mostly smaller, their fishing grounds are located closer to shore, and they are predominantly using passive gears (Guyader et al., 2013). Vessels from 10 – 12 metres are required to fill in a paper logbook and vessels above or equal to 12 meters, electronic logbooks, but vessels under 10 m generally have no obligation under the Control Regulation (Regulation (EU) No 1224/2009 of 20 November 2009 and Commission Implementing Regulation (EU) No 404/2011 of 8 April 2011) to supply EU logbooks (ICES, 2017). However, this sector of the SSF corresponds to ~80% of the total number of vessels in the fishing fleet (European Commision, 2018). Due to the great number of SSF vessels , the lack of resources directed at data collection, and the often dispersed and remote nature of SSF fleets, catch and effort data are challenging to collect for this sector (Salas et al., 2007; Stewart et al., 2010). Increased recognition of ecological impacts from SSF to abundances and biomass of target (Ruttenberg, 2001; Hawkins and Roberts, 2004) and non-target species (McClanahan et al., 1996; D'agrosa et al., 2000) and the development of innovative low-cost technologies for collecting data have prompted pilot trials and initiatives for electronic reporting in SSF worldwide.

This study addresses the increasing need for a strategic approach to the collection of data via ERS in SSFs in Europe. The aim of this research was to determine 1) what electronic reporting systems are available, device specifications and the type of data collected 2) identify relevant case studies, their spatial extent and the proportion of SSF fleets having used/using ERS, 3) how data requirements and data derived via electronic reporting align and 4) develop recommendations for future data collection protocols for SSFs. A review of electronic reporting systems in the North Sea and north east Atlantic was conducted focusing on the different systems available, and whether and how these data were currently incorporated into management. We highlight strengths, weaknesses, opportunities and threats by examining stakeholder experiences and develop recommendations for future data collection protocols for SSF.

Methods

Overview of available systems

To review ERSs that can be installed on small-scale vessels manufacturers of systems currently available on the commercial market were interviewed. Initially, a list of manufacturers was drafted from Google searches using a combination of keywords: electronic reporting, electronic monitoring, recording, electronic, VMS, AIS, fishing, small scale fisheries, GPS, tracking, iVMS. Listed manufacturers were then circulated and reviewed within the project coordination team and the list further expanded on through recommendations and available online case studies. Attendance at the 9th International Fisheries Observer and Monitoring Conference (IFOMC 11-15th June 2018), Vigo, Spain by project team members raised awareness of other manufacturers. After further review, 15 manufacturers were contacted and all replied to the request to participate in an online or telephone interview about their systems (see list of contacted manufacturers and the interview used in Supplementary Material 1, and Supplementary Material 2, respectively). The interviews were conducted on a semi-structured basis. A written record of the interview narrative was supplied to the interviewees who were requested to confirm the nature of their responses, amend any factual errors and confirm whether they were content for the corrected survey narrative to be used for further analysis. After initial communications regarding interview content, three companies did not respond to any subsequent correspondence and one company did not reply to requests for their consent post-interview. A total of 11 consented interviews discussing 15 systems were conducted and included in the review, two manufacturers chose to remain anonymous and are referred to as Anon. 1 and Anon. 2. All costings, where appropriate, have been converted into EUR at the current exchange rate at the time of writing. Each interview lasted up to one hour. The survey structure, content and process was formally approved by the University of St Andrews research ethics committee.

Identification of case studies using electronic reporting

Under Work Package 5 of the fishPi2 project (MARE/2016/22) a review of ERS that have or are being used to collect fishery dependent data from SSF up to the point of landing has been conducted. Many of these cases are pilot scale trials which have not been formally published in peer reviewed or grey literature. As such, fishPi2 partner institutions were canvassed to provide contact information relevant to electronic systems and processes that were being used to collect SSF data in their Member State, and the type of data recorded (i.e. positional, catch, effort). Methods could range from e-logbooks, on-board trackers and closed-circuit television (CCTV) systems to mobile phone/tablet applications. Once the relevant expert in those trials had been identified, an online or telephone interview (Supp.

Mat. 3) was conducted. The interview consisted of questions on the study rationale, specific characteristics of the fleet, fisher's uptake, the spatial distribution of fleets equipped with ERS, how the data acquired could be aligned with data requirements, and a Strength, Weakness, Opportunities, Threats (SWOT) analysis.

To map the extent or distribution of the fleets involved in electronic reporting trials stakeholders were asked to define where the fleets operated. Answers included, for example, ICES rectangles, coastal limits such as the 6NM assigned for inshore fisheries, or specific towns or points on the coast. To standardise answers ICES statistical rectangles were used to map the fleets' distribution and were then sent to interviewee for verification that the area covered was representative. This is likely to have resulted in an overestimation of the extent of where the fleets operated but provides an overview of the geographic distribution of such trials.

To assess how data requirements and data derived via electronic reporting align we focused on the list of transversal variables (Sup. Mat. 4) identified by the ICES Working Group on Commercial Catches (WGCATCH) to be collected for vessels <10 m length (ICES, 2017). This decision was taken as the <10 m fleet represents ~80% of the total number of vessels in the EU and these vessels have no obligation under the Control Regulation (Regulation (EU) No 1224/2009 of 20 November 2009 and Commission Implementing Regulation (EU) No 404/2011 of 8 April 2011) to supply EU logbooks. Furthermore, there is no legal requirement or no standardised way to collect positional data, to inform marine spatial planning.

The final collection of questions posed to stakeholders related to their experiences with the trialled equipment and opinions on ERS in general. This information was used to inform the SWOT analysis. The SWOT analysis technique is used to indicate current constraints and future possibilities of a given system, in our case ERS for monitoring and management in SSF across the North Sea and north-east Atlantic. It is often used for strategic planning with businesses by assessing internal and external factors that may impact a system and analysing its resources and capabilities (Pickton and Wright, 1998).

Results

Overview of available systems

Eleven interviews were conducted with manufacturers of systems that recorded information on vessel position, catch and/or effort and biological data, and included questions about the general specifications of each system. Eight ERS feature in the described case studies in this review (Table 1).

Table 1. List of manufacturers interviewed and their ERS

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

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

System features

Physical dimensions of systems varied from 10.0 x 10.0 x 3.0 cm to 42.6 x 29.0 x 16.0 cm. Two manufacturers explicitly stated their systems could not be installed outside of the wheelhouse. Only Anon.1 relies on its solar panel to supply its power, all other systems connect to the vessels own power supply. A back-up power supply if the main engine fails, was incorporated in a total of 7 systems, five using internal batteries with power duration ranging from 10 minutes to one week, two had a solar panel. Anti-tampering and security features were automatically included on eight systems and three Apps, and included case-opening alerts, login details and unique seals.

The costs of systems varied depending on their intended purpose, with many noting the price may change if further features were needed i.e. satellite communications or connected cameras. Costs for eight of the commercially available onboard systems ranged from 88 - 5260 EUR (excluding additional modifications). The five Apps currently being used in global SSF trials are free to the fishers, Vericatch could not provide a price without further specification. The SIFIDS, Vericatch and WWF's App are currently only available on Android, other Apps can be installed on both Android and IOS platforms.

For the system user to view their own data, five ERS systems relied on users paying a regular fee with only Anchorlab disclosing the cost to the fisher to access data being 14 EUR per month. Running and marginal costs were disclosed by four manufacturers as monthly costs (range 10 – 131 EUR) and mentioned by a further three without prices. When asked "do you offer or require payment for your data collection/processing software/service to be used?" and "if yes, what is the cost?", only Anchor Lab specified their costs at 3,000 – 4,000 EUR per year. Four systems, including two Apps, include additional costs for processing but were not released.

Type of data collected

Positional information

The majority of the devices and Apps described above report their data to the developer or manufacturer's server via mobile telephone GPRS/GSM connection and will function across a range of available mobile networks. All fifteen systems were capable of recording vessel position whilst at sea, and were fitted with Global Navigation Satellite System (GNSS) receivers. In three systems, positional data was transmitted using satellite connection whilst six used General Packet Radio Service (GPRS) and General System for Mobile communications (GSM) mobile telephone technology to transmit data. The remaining six were mobile phone applications (Apps) that used GPRS/GSM communications to transmit data. The reporting of position data back to the host database ranged from 1 to 30 minutes, with the exceptions being one hard-drive only system that must be posted (Observe hardware - Archipelago), one portside Wi-Fi system (reports when vessel is back in port) and three non-logging Apps (only records the beginning and end of a fishing event). Reporting real-time/near-real time was not possible in ten systems when cellular network coverage was unavailable, data would then be forwarded when reconnected. The logging frequency could be updated remotely by the developers in 80% of the systems.

Positional accuracy ranged from 2 m to 15 m for the dedicated GNSS systems. Mobile phone GNSS positional accuracy is dependent on the model of phone; however, stated accuracy ranged from 10 m to 15 m. All dedicated GNSS receiver systems and three Apps continuously logged the vessels position at sea with default position logging frequencies ranging from every 0.5 seconds to 5 minutes, the remaining three Apps logged only when fishing began and ended as indicated by the fisher. Only five systems could be customised to vary the logging frequency with vessel speed, i.e. every 30 seconds when steaming versus every 5 minutes when stationary.

All data collected was accessible to the appropriate authority level and fishers, except one stating fishers could only access all their own data online if requested or permitted by the system controller. Fishers and regulators with appropriate permissions can then interrogate the vessel track data as required. In some cases, the data is transferred to the regulator's server and database.

Catch data

Collecting aspects of catch data is a key feature in 7 ERSs, four on-board systems and three Apps, including the unique iCatch App only recording the bycatch and discarding of spurdogs *Squalus acanthias* (Supplementary Material 7). Two other systems (Anon 2. And Vericatch) highlighted their ERS systems are configurable to record catch data but had not been designed to collect a pre-determined cohort of catch data. SRT's trial system consisted of fishers either using a port-side computer or a mobile device connects to the Automatic Identification System (AIS) transceiver to record their catch data. The SRT set-up and the catch recording App all require the manual input of data such species, weight or numbers, thus accuracy is often dependent on the fisher. Data collected through on-board systems could also be done by stills, video, a 2D laser-camera scanner recording the catch passed underneath. The catch 2D laser-camera system developed for the SIFIDS project by Seascope Ltd. is designed to determine, species (lobster *Homarus gammarus* or crab *Cancer pagurus*), sex and size of each animal using machine learning for automated classification and to improve the accuracy of the system which, at the time of writing, is at 95% accuracy for species identification.

Biological data, such as length and sex of individuals was featured in three systems (Electronic Eye, Observe and OBCDCS). The recording of Protected, Endangered, Threatened Species (PETS) in the catch was only featured in the SIFIDS App and SRTs mobile/port-side system. All systems could provide a spatio-temporal reference for the catch data.

Effort data

Days fishing and gear time fishing can be recorded by 13 of the 15 reviewed systems, 12 of which can record the duration of fishing events either through manual input (mobile phone or computer) or when connected to on-board sensors via Bluetooth or hard-wired ports (i.e. RFID tag readers, hydraulics sensors, pressure sensors). Sensors also provide data on the amount of gear deployed for three onboard systems and can be recorded by four Apps. Two Apps include gear length and another records gear size. Electronic Eye and Anon.2 systems collected image data and had to be later analysed to determine when gear was being deployed. All systems provide a spatio-temporal reference for the effort data.

Overview of main case studies identified using electronic reporting in the North Sea and north east Atlantic

We conducted 14 interviews comprising 12 institutions in 9 countries (Table 2). Eight of these case studies are ongoing, five were completed and one is about to start. Below there is a brief description of each of these case studies.

Table 2. Description of main case studies identified via interviews, with a list of interviewees and their affiliations.

Case study ID	Case study	Interviewee	Institution	Country	Ongoing trial?
A	**MOFI App**	Uwe Krumme	Thuenen Institute of Baltic Sea Fisheries (Thünen-OF)	Germany	No
B	**Bivalves**	Miguel Gaspar	Instituto Português do Mar e da Atmosfera (IPMA)	Portugal	Yes
C	**Bycatch marine mammals**	Lotte Kindt-Larsen	Technical University of Denmark (DTU)	Denmark	Yes
D	**Fishers data collection**	Grant Course	Seascope Fisheries Research	Scotland	No
E	**Razor clam electrofishing**	Norman Fletcher	Fully Documented Fisheries Unit. Marine Scotland	Scotland	Yes
F	**AIS tablet**	Estanis Mugerza	AZTI Tecnalia	Spain	Yes
G	**Bivalve dredging**	Pernille Nielsen	Technical University of Denmark (DTU)	Denmark	Yes
H	**Cod bycatch**	Bram Couperus	Wageningen University & Research (WUR)	Netherlands	No
I	**Green box**	Candelaria Burgos Cantos	Instituto Español de Oceanografía (IEO)	Spain	Yes
J	**Razor clam dredging**	Oliver Tully	Marine Institute	Ireland	Yes
K	**Environmentally Responsible finfish Fisheries**	Jon Elson	Centre for Environment, Fisheries and Aquaculture Science (CEFAS)	England	No
L	**Spurdog bycatch App**	Rose Nicholson	Centre for Environment, Fisheries and Aquaculture Science (CEFAS)	England	Yes
M	**Mixed fleet catch and position**	James Doughty	Coastal PO	England	To be approved
N	**AIS on static gear fleet**	Mark James	Scottish Oceans Institute (SOI)	Scotland	No

A. Mobile application for gillnet fishery targeting cod, Germany

A mobile application developed by Thünen-OF and Anchor Lab, called MOFI was used during the spawning closure for cod from February – March 2018. The fishery is not allowed in waters deeper than 20 m because these are the main spawning depths for cod. During this two-month closure, all fishing activities are prohibited except for vessels <12 m length if they were able to document that they were fishing in areas shallower than 20 m using MOFI. About 90 fishers used the App to report their fishing location, data were sent to Anchor Lab and from them to the Control Agency in Germany. This trial allowed small scale fishing vessels access to fishing grounds that would have otherwise been closed.

B. Positional data for the bivalve dredge fishery in Portugal

A real time tracking device was developed with a Portuguese enterprise (Robot) to improve the knowledge on the distribution of fishing effort for the bivalve dredge fishery. The < 14 m vessels operate mostly within 3 NM of the Portuguese coast, although some go out to 6 NM. The use of this device is mandatory for the whole dredge fleet. The data are being used to assist management by the Instituto Português do Mar e da Atmosfera (IPMA), with timely advice on areas to be closed for fishing, to monitor fisher's compliance to area closures, and to estimate fishing effort and its effect on bivalve populations.

C. Electronic Monitoring with CCTV systems to monitor bycatch, Denmark

Remote electronic monitoring systems (from Anchor Lab and Archipelago) are used in the cod and flatfish gillnet fishery to monitor bycatch of seabirds and marine mammals. Systems were installed on the vessels, ranging from 9-12 m, operating mainly in the Skaagarat Sea out to 6NM. The data is being used by Technical University of Denmark (DTU) to predict bycatch rates or chance of bycatch for harbour porpoises and communicated to government. It is also being used to provide information for the Natura 2020 areas.

D. Electronic monitoring with CCTV systems, Scotland

Remote electronic systems (from Archipelago) were used in 11 vessels < 12 m operating on the west coast of Scotland. Nine vessels targeted crabs and lobsters using traps, one vessel targeted scallops using dredges and one vessel targeted langoustines using a bottom trawl. These were mainly pilot trials to assess the feasibility of using electronic monitoring technology on small scale fishing vessels and to train the fishers to collect data for stock assessment purposes (using electronic callipers to measure the catch). The data were used by Seascope to compare the data collected by fishermen against that collected by video recordings from electronic systems (Course et al., 2015).

E. Positional data and gear sensor, electro-fishery for razor clams, Scotland

Electrofishing for razor clams is currently under trial in Scotland. Thus far 28 vessels have been given access to this fishery, out of which 22 have been fitted with a tracker system (black box R2 –Anchor Lab that records position and has gear sensors) and 6 still have to fit the mandatory electronic reporting system. The vessels range from 6 – 13 m but are mostly 8-9 m long. Data are being used by the Fully Documented Fishery Unit, Marine Scotland, to ensure that vessels are fishing in waters that have been classified by Food Standards Scotland within designated areas and to inform policy to develop terms and conditions for fishery. The designated areas are located mainly on the west coast, although there is one on the east coast of Scotland.

F. Positional data (AIS) and tablet, multispecies fishery, Basque Country, Spain

The multispecies small scale fleet in the Basque Country consists of 70 vessels <15 m length. The main species targeted are hake, mackerel, red mullets, anglerfish, sole, rays, seabass, and cephalopods and the main gears used are gill and trammel nets in addition to traps, long-lines and handlines. They operate mainly in Basque inshore waters out to 6NM. Forty-five of these have AIS devices (Class B transponders) are installed to report positional data, and ten are using tablets (developed by Sumelco) to report catch data. AIS data is being used by AZTI tecnalia to assess fleet effort and the data from the tablet is being compared to log-books and sale notes and used for stock assessment.

G. Positional data and gear sensor, dredge bivalve fishery, Denmark

Dredgers operating in Danish coastal waters are required to have a black box (Anchor Lab) installed to report their fishing locations to Government. The vessels (~50 to date with system) range between 10-20 m, target mainly blue mussels, cockles and European flat oysters. The electronic systems were initially required if fishing inside Natura 2000 sites but is now required for vessels fishing either inside or outside Natura 2000 sites. The data is being used by Technical University of Denmark (DTU) to assess the level of impact on an area. Only 15% cumulative impact is accepted over the regeneration time of an ecosystem component (i.e. seagrass, macroalgae).

H. Electronic Monitoring with CCTV systems, cod fishery, Netherlands

Remote electronic monitoring systems (from Archipelago) were used in the cod (and brill, turbot, plaice, flounder) trammel and gillnet fishery to estimate number of harbour porpoises being caught. Systems were installed on ten vessels which were mostly <10 m long. The data were used by Wageningen University and Research (WUR) to report to government on bycatch rates.

I. Positional data, inshore fisheries, Andalucia, Spain

Since 2004 the Andalusian Regional Government have installed their own positional reporting system on SSF vessels, called SLSEPA ("Sistema de Localización y Seguimiento de Embarcaciones Pesqueras Andaluzas", or "green box"). Since 2015, the installation of this system is mandatory for inshore vessels (<15 m) using gillnets, dredges and traps with home port in Andalucia. The Andalusian Regional Government and the Instituto Español de Oceanografía (IEO) use the data to calculate Catch Per Unit Effort to inform stock assessments by ICES. Additionally, the systems improve safety at sea, control fishing activities and improve the monitoring and assessment of fishery resources.

J. Positional data for the small scale fleet targeting razor clam, Ireland

There is a legal requirement for the Irish razor clam fishery to use an inshore Vessel Monitoring System (iVMS, from AST and Succorfish) to report their position. All vessels participating in this fishery (80) are currently equipped with this system. Vessels are generally < 12 m length and use hydraulic dredges.

Vessel positions are used by the Marine Institute to define fishing locations. If fishing outside designated areas is detected the Control Authority can issue a warning. The data is currently used for controlling position with reference to geo-fences or production areas and to control the number of vessels.

K. Positional data for a finfish fishery, England

In 2008, “VMS-Lite“ (AST-MSL) was fitted to 31 under-10 m vessels targeting finfish in three regions of England up to 12 NM, recording their position every 15 minutes; the northeast coast centred around Hartlepool, off the east coast centred around Lowestoft and in the Thames Estuary. The aim was to quantify the biological and economic impacts of the fleet when vessels were granted the right to fish without quota restrictions, other than minimum landing size and conservation measures. The electronic positional and speed data was linked to manually recorded catch log-books providing detailed information on the distribution of the fleet’s fishing effort. Data demonstrated the vessels had significant catch capacity when quota restrictions were removed and that in the absence of a logbook, positional data combined with a record of gear used, targeted species and daily landings records could offer a good estimate of fishing effort. Data was collected solely for CEFAS research purposes.

L. Positional and bycatch data for a mixed fishery, spurdog discards in England

In June 2018, the iCATCH catch recording mobile phone App and aVMS (AST-MSL) was set-up on five under 10 m longline vessels in Lowestoft, England. Two participating vessels have an additional electronic monitoring system fitted on-board by either Archipelago or Anchor Lab. The CEFAS project works with a mixed fishery and aims to electronically monitor spurdog bycatch and discard by the inshore fleet. iCATCH allows the fisher to record time spent fishing and quantity of gear used whilst then recording their catch and bycatch, the installed EM systems collect biological data on any spurdogs caught. The trial is gathering data to inform future spurdog management in longlining as there is no current legislation.

M. Positional and catch data for a mixed fleet, England

Coastal PO have proposed to the Maritime Management Organisation a quota flexible trial with vessel tracking and daily catch electronic reports from a 28 <10 m mixed-fishery fleet in Hastings. The data would feed into SSF management systems to facilitate compliance requirements of a producer organisation for the landing declaration and monthly catch limits of SSFs. The proposed trial would potentially use AST-MSL’s aVMS and SnapitHD’s solarVMS for positional information. Catch records would be produced by iCATCH mobile phone application. Trial data will be used to help Coastal PO demonstrate the capability of the tested equipment and systems to deliver the Producer Organisations legal obligations (CFP and Common Organisation of the Markets of Fishery and Aquaculture Products (CMO)).

N. Positional data for inshore static gear fleet, Scotland

From June 2014 to July 2015 274 AIS Class B Automatic Identification System (AIS) transceiver units were fitted to 274 vessels representing a cross section of the under 12 m, inshore static gear Scottish fishing fleet targeting non-quota crabs, lobsters and langoustine (*Nephrops norvegicus)* (Anon, 2015). This study assessed the potential of using AIS technology to track fishing vessels, identifying fishing areas, and gain a better understanding of AIS coverage around the coast of Scotland. The willingness of the fishing industry to accept AIS onto their vessels was also assessed. The conclusion was that whilst AIS was a useful tool, there are challenges with respect to coverage due to complex coastal topography blocking transmission, the distribution of base station receivers, the quality of the data provided by those receivers and ultimately the willingness of fishers to adopt a technology that openly broadcasts their position to other fishers.

Other trials

Several other trials of electronic reporting systems were identified but are not reported here in detail as the information available was insufficient. We include them here in overview but they are not included in the analyses below. Knowledge of these trials were obtained partially from interviews but also from grey literature.

In Portugal, IPMA is trialling passive trackers to collect positional data in about 10 vessels per gear in several fisheries such as: octopus and cuttlefish traps; seine fishing for sardine; fish traps for sea bass and sea bream; longlines for fish and sea bream; gillnets for several fish; trammel nets for sole and cuttlefish; tangle nets for sole; nets for shrimp; dredges for bivalves.

In Germany, a feasibility study using Remote Electronic Monitoring (CCTV systems) is currently being trialled by researchers at the Thuenen Institute of Baltic Sea Fisheries (Thünen-OF) in 3 vessels targeting herring, cod and eel using gillnets and longlines.

In Denmark, a video camera connected to a battery was tested by the Swedish University of Agricultural Sciences (SLU) in 3 vessels targeting mainly lumpfish and cod using gillnets to report bycatch rates of harbour porpoise.

In Ireland, positional records have been collected from about 60 vessels targeting crabs (*Cancer pagurus, Necora puber*) and lobsters (*Homarus gammarus*) using pots and traps and in 3 vessels in the spiny lobster fishery using static nets/gillnets.

In France, for some species (Common sole (*Solea solea*)) in the East Channel (ICES VII d) and in the Bay of Biscay (ICES VIIIa and b) and scallop (*Pecten maximus*), vessels smaller than 12 metres are required to install a VMS equipment (DGMARE, 2018).

Analyses of case studies

Rationale of case studies

The majority of case studies (9 out of 14) aimed to obtain positional records for spatial control and safety in the SSF (Table 3). The second rationale for using electronic reporting systems in SSF was to obtain bycatch data using CCTV systems. One trial looked at the feasibility of using fisher derived data collection for stock assessment and the other used electronic positional records to help locate and quantify the size of impact SSFs had when quota for targeted species was removed (Table 3).

Table 3. Case study rationale for the use of electronic systems in SSFs

Case study ID	Title	Study rationale	Category
A	**MOFI App**	Allow smaller vessels to fish in selected areas during a spawning closure for cod	positional records for spatial control
B	**Bivalves**	For dynamic management - timely closure or opening of areas to fishing	positional records for spatial control
C	**Bycatch marine mammals**	To monitor bycatch of seabirds and marine mammals on small scale gillnetters	assess bycatch
D	**Fishers data collection**	To trial electronic technology on-board of SSF vessels and train fishers to collect data for stock assessments purposes	feasibility study fisher's derived data collection
E	**Razor clam electrofishing**	To ensure that vessels are fishing within classified waters – no electrofishing is to occur outside these designated areas	positional records for spatial control
F	**AIS tablet**	Basque fisheries management team collect AIS data to look at effort. Catch data from project via the App is compared to log books for stock assessment	positional records for effort and catch data
G	**Bivalve dredging**	Gather positional data in order to fish inside Natura 2000 sites	positional records for spatial control
H	**Cod bycatch**	To estimate number of harbour porpoises being caught in gillnet fisheries.	assess bycatch
I	**Green box**	Safety at sea, control fishing activity, and improve the monitoring and assessment of fisheries resources	positional records for spatial control and safety
J	**Razor clam dredging**	Controlling position in reference to geo-fences or production areas and to control the numbers of vessels	positional records for spatial control
K	**Environmentally Responsible finfish Fisheries**	Gather positional data on vessels targeting finfish when quota restrictions were removed to quantify the biological and economic footprint of vessels when linked to sale notes from buyers	feasibility study
L	**Spurdog bycatch App**	To electronically record Spurdog bycatch by small-scale vessels along with associated GPS track	assess bycatch

Case study ID	Title	Study rationale	Category
M	**Mixed fleet catch and position**	A proposed trial to the MMO to electronically gather positional and catch data on SSFs	positional and catch data
N	**AIS on static gear fleet**	Establishing the location of offshore fishing activities within Scottish inshore areas	positional records for control

Characteristics of fishing fleets using electronic reporting systems

ERS were trialled in several different fishing fleets, but have mainly been used in vessels using dredges (7 case studies), and gillnets (6 studies), followed by pots and traps, longlines and handlines, bottom trawlers, trammel nets and diving (Figure 1, Supplementary Material 5). The main target species pursued by vessels equipped with ERS were cod and bivalves, followed by a mix of inshore fish, crabs and lobsters and skates and rays (Figure 2, Supplementary Material 5). The overall length of the vessels was less than 12 m (10 out of 14 case studies) and mostly less than 15 m.

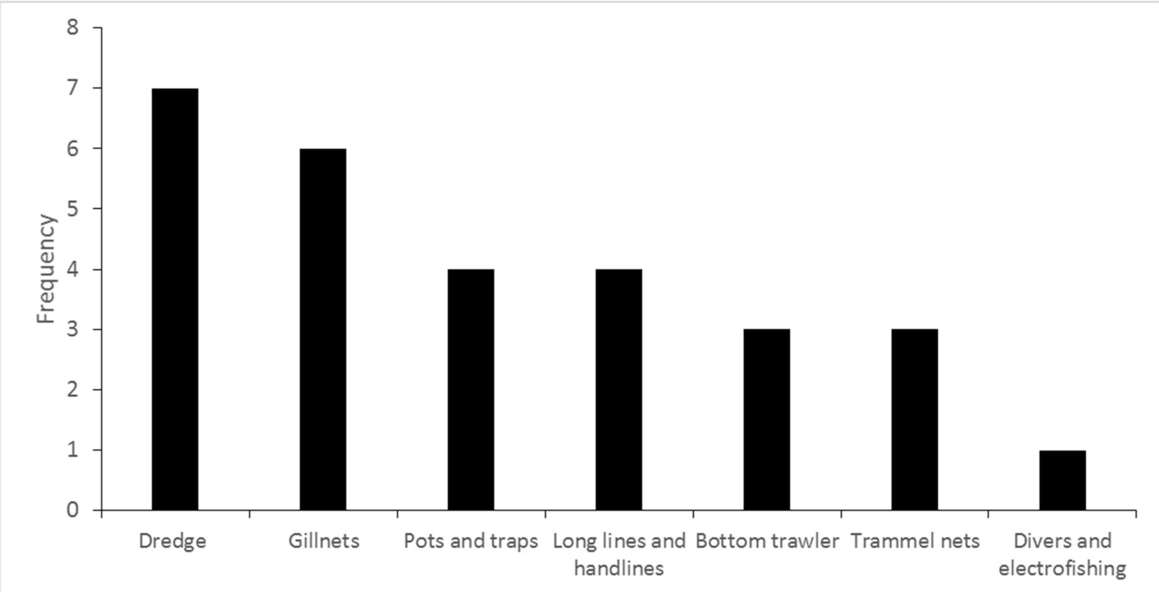


Fig. 1. Frequency of each fishing gear used in fleets equipped with ERS in SSFs.

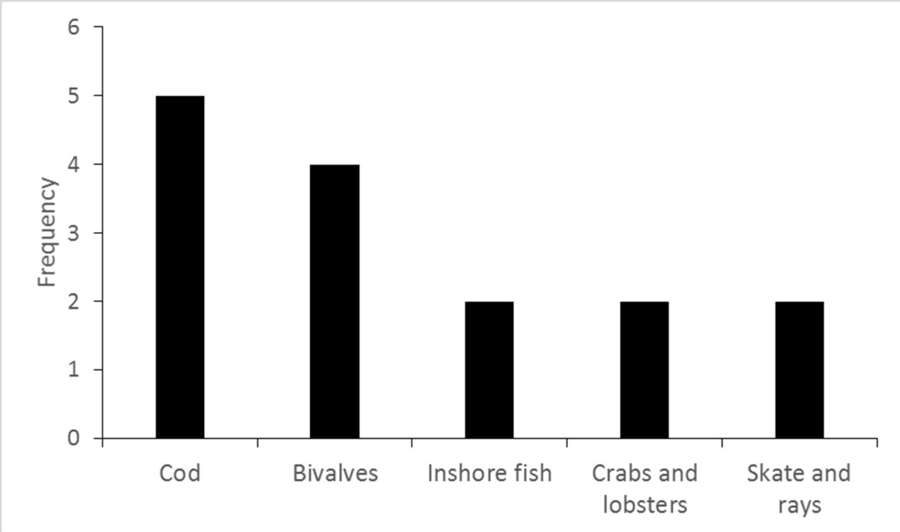


Fig. 2. Frequency of each species targeted in fleets equipped with ERS in SSFs.

The proportion of vessels equipped with ERS in each fleet varied greatly. Fleets targeting bivalves (4 case studies) using dredges (3) and electrofishing followed by divers (1) had full coverage of the fleet as the use of electronic reporting systems was mandatory (Supplementary Material 5). In Andalucía, Spain, all inshore vessels using gillnets, dredges and traps were equipped with an ERS. The use of ER was also mandatory for a fleet targeting cod with gillnets and trammel nets (Case study H, see Table 3), for which only 10 vessels that were randomly selected were required to use the ERS and another fleet targeting cod where about a quarter of all vessels used the system if they wanted to be active during a fishing closure (Case study A, see Table 3). In some cases full (or almost full) fleet coverage was achieved in case studies where the use of ERS was not mandatory. This included a small scale fishery in England that targeted mixed stock with quota, and the Basque inshore fishing fleet which targeted several different target species. The Scottish AIS case study equipped 274 (about 18% of the small scale fleet using traps and pots) with systems. The other 4 case studies (Case studies C, D, H, L) for which the use of ERS was voluntary equipped only a number of vessels (< 12 vessels). The main manufacturers involved in the case studies were Anchor Lab, Archipelago and AST.

SSF fishers and ER systems

The general perception among the stakeholders interviewed was that the uptake of the equipment was initially slow, but became readily accepted with time as they understood the benefits for the fishery. In three case studies, increased quota or financial incentives had to be offered to fishers. Clear communication between government control agencies, scientists and fishers was necessary to guarantee success in case studies. Fishers usually did not have to pay for the ERS (12 out of 14 case studies), even if the system was mandatory for seven case studies (A, B, E, G, H, I, J), except for 2 studies (F and H) where they had to pay for the hardware but not for the analysis or ongoing software costs.

In general, fishers respond more positively to ERS when exposed to external pressures such as the requirement to provide information on historic use of fishing grounds to support challenges to spatial restrictions that result from competing uses of marine space such as; marine renewable energy development, aquaculture development, and the establishment of Marine Protected Areas. In areas where gear conflict is high, fishers have also responded positively to ERS which can be used to mark their gear or fishing track to help reduce the potential for loss of gear or indeed provide proof that their vessel was not responsible for alleged gear damage or removal. Similarly, some fishers are happy to have ERS that provides evidence that they are fishing legally and not in restricted areas. When linked to traceability schemes, ERS can also be viewed positively by fishers if it results in measurable benefits to their businesses. Most fishers are sensitive to their fishing tracks and locations being visible to other fishers but recognise the increasing need to improve the management of small scale fisheries at finer spatial and temporal scales. The cost and complexity of some ERS systems and processes has limited their widespread adoption and durability. Approaches to the use of ERS have also been fragmented and limited in scope – often focused on the needs of compliance and enforcement rather than better management, increased efficiency and business advantage.

Spatial coverage of electronic reporting systems in small scale fishing fleets

Several trials using electronic systems for data collection in SSFs have been conducted in the North Sea and the north east Atlantic EU waters (Figure 3). Each case study's spatial extent is represented by coloured ICES statistical rectangles, as confirmed by each stakeholder. Either pilot trials or currently running monitoring programs for SSF fleets have been conducted in 8 Member States.

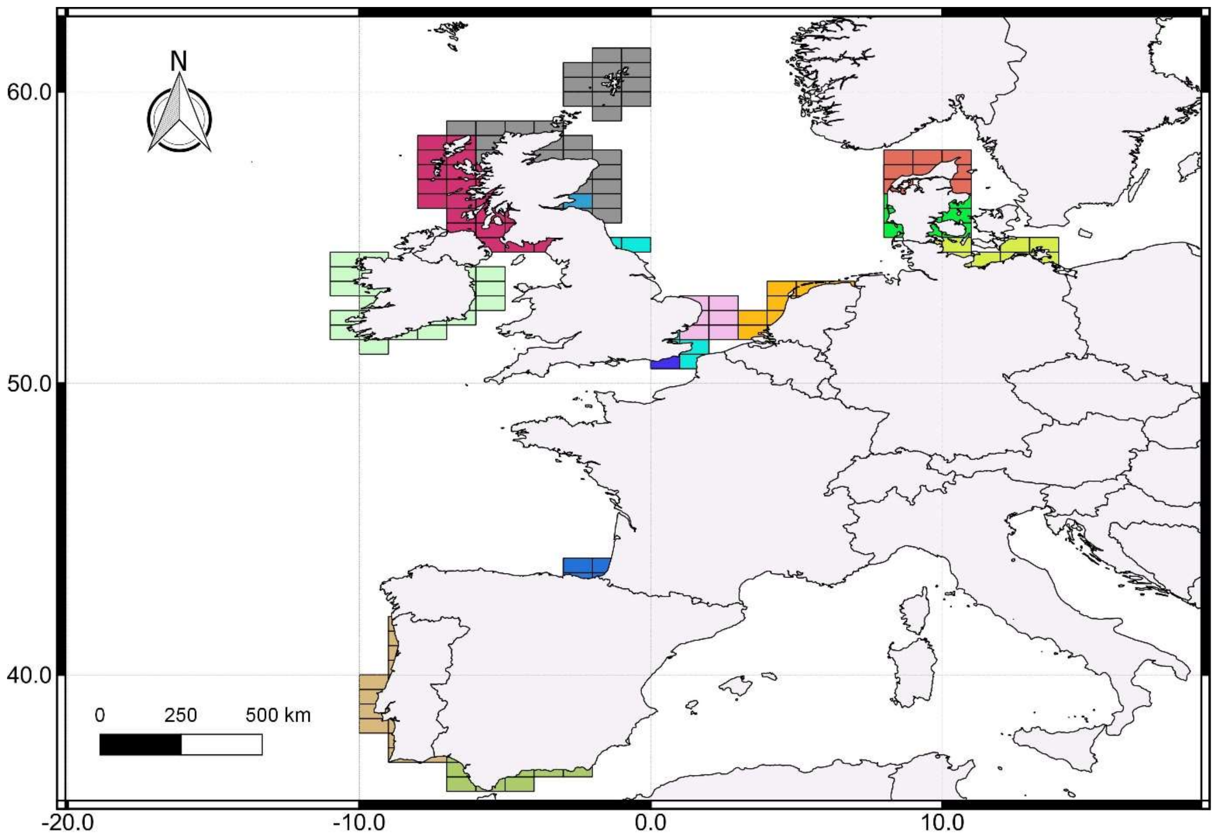


Fig. 3. Map showing the current use of e-reporting systems in North Sea and North East Atlantic EU waters for SSF.

Meeting data requirements for the small-scale fleet <10 m

Effort data

In all 14 interviewed case studies, time spent fishing is being or have been directly electronically recorded or could be derived from other on-board equipment from which number of trips, days at sea, fishing days, and number of fishing vessels can be calculated. Gear soak times were recorded directly by ERS by connections to gear sensors (case studies E, G, I, J and M) or were input by the fishers in trials that included an App or tablet (case studies A, F, L, M). Indirect methods included interpretation of gear RFID tag readings and analysis of vessel speed (case studies B, C, D and I). Logging quantity of gear used per fishing trip was mentioned in nine case studies (case studies A, B, C, D, F, H, J, L, and M), eight of which included gear length (the EFF Scottish study only focussed on pots and traps, for which length is not usually measured).

Landings data

Live weight of landings was reported in three studies (case study F, L, and M), via a mobile phone App. No studies recorded the value of landings totals and per species or price per species electronically.

Biological, discard and bycatch data

Length of the catch was stated to be recorded in two case studies (case study C, D) from video analysis. Case study D also included sexing from video analysis.
The composition of the discarded catch (species in numbers and weight) was recorded in a total of five studies through either video analysis (C and D) or inputted into an App (F, L, M), the English spurdog discard trial (case study L) includes Spurdog weight as a species-specific category. Bycatch and interaction with PETS were both included in four studies (C, D, F, H), focusing mainly on species and number of seabirds, marine mammals (harbour porpoise), skates and rays (case study C). All case studies which recorded either catch, biological, discard or bycatch data offered electronic temporal and spatial data is associated with the data.

Overall discussion of strengths, weaknesses, opportunities and threats of using ERS for monitoring and management of SSF

Strengths and opportunities

A key aspect to ERS for monitoring SSF is their reliability to log and report all collected data. In the 14 case studies, thirteen agreed that the devices were reliable for delivering their intended data outputs. Compared to traditional data recording methods such as manual logbooks, 13 scientists agreed ERS offered a more robust approach to collecting the same data. Improved time-efficiency and/or data accuracy were both mentioned by seven interviewees each. More detail, saving money and the technology's suitability for the trial were other stated benefits of ERS in 6, 2 and 1 case studies respectively. Indeed, ERS is now being used to assist current management decisions in four Member States through mandatory requirements of ERS use on some SSFs; all vessels in the Portuguese bivalve dredge fishery, all vessels in the Danish bivalve dredge fishery, all vessels <15 m in the Andalusian coastal waters, and for all Irish razor clam fishers.

The use of ERS to monitor the position of vessels assisted in fishing effort calculations, informing stock assessments and marine spatial planning (i.e. monitoring if vessels were fishing inside closed areas). Vessels that volunteered to participate in five case studies are informing management too; the German MOFI app, Danish marine mammal bycatch, Netherlands cod bycatch, Scottish razor clam electrofishing and Spanish AIS tablet trial. The monitoring of spatio-temporal fishing activities is helping to improve upon previous bycatch estimates which in turn has permitted management to focus effective control measures upon fishing activities in specific areas, for example, to protect cod spawning grounds from unsustainable fishing and highlight areas for future Natura 2020 designation. Three case studies stated that although the trial outputs were not being used for current management decisions at the time of interview the data collected was used to help draft future management plans.

Factors which make electronic reporting an appealing system for future management were highlighted by all interviewees. The most popular examples given were improved ability to locate fishing grounds, calculate fishing effort and the increased quantity of data. Other answers included ERS use to designate or protect established MPAs/conservation zones/closed areas, the improvement data accuracy and to improve the public's perception of fishing (Sup. Material 7).

A further strength with ERS is the ease of sharing data to all interested stakeholders, in six cases fishers were granted free access to their own data providing the opportunity for them to see the data they helped gather. Depending on the trial fishers could see a record of their vessel's spatio-temporal data, catch and/or effort data. Providing information back to fishers offers the chance to build relations with the organisation(s) implementing ERS as many fishers have often not had feedback before or the chance to visualise their own impact. A total of five trials were facilitated by the member states' government and research institute, enabling researchers and management to both benefit from the data received. In only two cases was the data accessible to government only.

Weaknesses and threats

A weakness to ERS covered in this study is the absence of integration of the data collected by reporting to statutory databases, the Danish bivalve fishery and <15 m Andalusian vessels are the only legally required ERS case studies to do so. In total, nine of the fourteen interviewees who reported case studies did not have a direct link between the system used for the case study and a statutory database. A consequence for management using commercial ERS manufacturers is data can only be processed by the manufacturer's internal systems and/or analytical software, which must be paid for. Thus, manufacturers can become an 'intermediary' between vessel data and management as shown in the both the Irish and Scottish Razor clam case studies. The fragmentation of ERS data collection and the lack of continuity between the collection of these data and statutory of common databases that could be used for fisheries compliance and management purposes is a significant weakness. The lack of clear guidance on the requirements and technical specifications for ERS in SSF across the EU or at Member State level is a concern expressed by interviewees from the United Kingdom, Denmark, Spain and the Netherlands.

Although there was a general consensus among interviewees that ERS offers benefits to fisheries management if implemented effectively, the principle of using ERS is not universally welcomed by fishers, many of whom regard this technology as intrusive and unnecessary. The need for ERS and what its use entails for the fishers has, in some cases, not been properly communicated by those trying to trial or implement ERS. In the absence of legislative pressure, it is unlikely that fishers will voluntarily install and use ERS. Privacy of data remains a significant concern for many fishers who consider their fishing activity and more specifically fishing locations to be commercially sensitive information that should not be shared. The price of equipment was also said to be a contributing factor to limiting the uptake of ERS.

From a management perspective, two interviewees noted that ERS can also result in more time being spent analysing data, particularly where for compliance purposes these data needed to be cross referenced with sales notes. Furthermore, six trials highlighted various technical issues with their ERS, such as loss of GNSS signal, power supply inconsistences, device breakdowns and miscommunications with manufacturers causing further delays. With respect to the use of AIS (Class B), the ability of fishers to turn off or operate the AIS in silent mode is an additional confounding factor.

Recommendations for a standardised approach to data collection

There is a need to take a broad view of the diverse drivers and potential solutions for delivering ERS across EU SSF. Some common themes emerge around the need to collect data that can be used for compliance, stock assessment, fisheries management and marine planning. Compliance and stock assessment are principally driven by statutory requirements. Fisheries management can be viewed more broadly and has more obvious benefits to the fishers themselves where it leads to greater operational flexibility, fairer or more transparent access to fishing grounds or economic return for example. Marine Planning increasingly requires the users of the marine environment to be able to demonstrate and to some extent justify their use of marine space. SSF are one of many users of our coastal waters, and fishers will need to collect data that can be used to support their case for continued use of this resource in the face of competing demands such as Marine Protected Areas and marine renewable energy developments for example.

ERS falls into a number of categories, summarised below:

- The use of GNSS usually coupled to GPRS/GSM or satellite communications to capture and transmit temporal and spatial data which can be used to track vessel movement (in near real time if required), infer where fishing is taking place and potentially be used to estimate the amount of gear deployed and the time the gear is actively fishing.
- Gear sensors such as hydraulic sensors, and RFID tags which are used to identify when gear is being shot or hauled and to identify individual pieces of gear.
- CCTV or similar video monitoring equipment designed to provide a visual record of gear use, and fishing practices. The use of artificial intelligence and machine learning is extending the use of both moving and static image capture by allowing computers to automatically detect, enumerate and measure catch and bycatch.

- Increasingly, Apps on mobile devices such as phones or tablets are being used to allow fishers to record catch or bycatch data at sea. Some of these Apps are also linked to GNSS providing a temporal and spatial reference for the catch or bycatch data. Connections via GPRS/GSM also permits the real time reporting of these data.
- Other technology has either been developed or is in development to facilitate fishers to collect biological data to feed into stock assessment – these include, for example, electronic measuring callipers and tables, video and laser based recognition systems for automatically identifying species, sex and size of catch.

A framework for the use of ERS in SSF

Defining user requirements

In order to realise the full benefits of collecting ERS in SSF there is a need to recognise the data and type of outputs required by the range of users who can benefit from access to this information. The original fishPi project (DG MARE, 2016) identified a number of user groups for data derived from SSF and the original table is amended here to include fishers (see Table 4). For fishers, ERS can provide data to help them improve the efficiency and demonstrate the sustainability of their businesses. Fisheries managers will have access to spatially and temporally resolved data which they can use for much more targeted local and regional fisheries management measures. Marine planners and those involved in the regulation and licencing of marine activities will have data to underpin objective decision making. Researchers can also benefit from access to these data as they offer significant opportunities to develop better management tools and understanding of the sustainability of the fishery. Although fisheries compliance will also be better placed to enforce regulations based on ERS evidence this should perhaps not be promoted as the primary purpose for using this technology in SSF.

Table 4. Definition of potential end user groups for ERS data (modified from fishPi, DG MARE, 2016).

End User	**End user sub groups**	**Use of SSF data**
Industry	Skippers and vessel owners	Inform fishing activities and use data to improve efficiency, profitability and sustainability.
	Supply change actors (buyers/processors/local authorities)	Skippers/vessel owners give other supply chain actors, access to data to streamline transactions and reduce costs.
	Accreditation bodies	Data useful for traceability, provenance and accreditation specific verification.
	ICES expert assessment WG	
	ICES WGCATCH	Documents national fishery sampling schemes, establishes best practice and guidelines on sampling and estimation procedures, and provides advice on other uses of fishery data.
	ICES WGRFS	Planning and coordination of marine recreational fishery data collection for stock assessment purposes.

End User	End user sub groups	Use of SSF data
Other RMFO (ICCAT, NAFO, NEAFC)	ICES PGDATA	To understand the quality of datasets and to use them as effectively as possible, and to employ objective ways to identify and prioritise data needs
	Expert assessment and ecosystem WG	
European Commission	End user sub groups DGMARE & DG Environment	Use of SSF data
		Implementation of MSFD; achievement of GES with good management of recreational as well as small scale fishery impacts. Implementation of CE 812/2004, Birds Directive, Habitats Directive
	STECF	Inclusion of data collection in the EU MAP
International Organizations	FAO, OSPAR, ASCOBANS, ACAP, IWC	Identifying threats, recommending action plans, implementation of different agreements
Regional Coordination Groups	RCGs for each region	Coordination and cost-effectiveness of fisheries data collection within regions (if included in EU-MAP). Finding the balance between regional and national data needs
National Governments and regional fisheries authorities within countries		Developing policy positions on management that reflects the ecosystem aspects of sustainable development in coastal regions and spatial planning such as MCZs. Meeting international agreed responsibilities
Scientific community in general.	Universities; Govt. departments; other Institutes	Scientists interested in small scale fisheries and their impact in the coastal ecosystems. Interactions with other uses of the sea
		Data for publication
Representative bodies for International and national commercial fisheries.	Commercial fishermen's organisations and federations.	Policy developments in relation to small scale fisheries and their impact in the coastal ecosystems. Interactions with other uses of the sea
Recreational fisheries bodies	Recreational fishermen's organisations and federations (EAA, Angling Trust)	Developing best practices

End User	End user sub groups	Use of SSF data
Advisory Councils	e.g. North Western Waters AC; North Sea AC	Policy developments in relation to small scale fisheries and their impact in the coastal ecosystems. Interactions with other uses of the sea.
Marine Planners	Local Authorities and Marine Planning Related bodies	Data required to inform planning decisions in coastal waters e.g. aquaculture developments, marine renewable energy developments, designation of Marine Protected Areas etc.
Marine NGOs	Birdlife international, WWF, GREENPEACE,	Policy developments in relation to small scale fisheries and their impact in the coastal ecosystems. Interactions with other uses of the sea.

Defining the level of ERS required

The level of ERS required for any given fleet segment could potentially be defined on a risk basis which would encourage a proportionate approach. For example, it could be argued that for the majority of static gear vessels operating in non-sensitive areas using relatively benign gear types (such as pots, traps and creels) spatio-temporal data of appropriate resolution is all that is required. This means a GNSS system coupled to GPRS/GSM communications reporting positions at a frequency sufficient to accurately infer where fishing is taking place, how much gear is potentially deployed and the duration of that deployment. These data coupled to daily or perhaps weekly reporting of catch (electronically if possible) would provide fisheries management and marine planning relevant data, together with sufficient data to inform compliance – and indicate whether further ERS technology might be required if the vessel appears to be non-compliant. This might, for example, include a combination of gear sensors which coupled to spatial and temporal evidence provide sufficient confidence for compliance. For vessels using higher impact gears with respect to: benthic impacts; bycatch; vessels subject to specific gear or temporal or spatial restrictions, the addition of video monitoring may be required.

If conceptualised around “environmental sustainability” for example and the risks posed, it is possible to construct scenarios for the levels of ERS required to minimise or mitigate these risks for each of the recognised user groups (see Table: 5 adapted from SIFIDS). In principle, it should be possible to use some form of expert elicitation to define and score a risk matrix similar to the hypothetical example provided in Table 5. As a minimum, all SSFs should be able to provide accurate and timely reports of what they have caught, what they land and where they fished for a defined catch. These data can be derived from a GNSS vessel track of appropriate resolution and some form of catch reporting using an App for example. The GNSS track can, for many fishing activities, be used to statistically infer when and where fishing is taking place, the amount of gear being deployed, the soak time and area fished (Mendo et al. 2019 in press). Where fishing activity is deemed to be more risk sensitive, additional evidence of fishing activity could be derived from the addition of gear sensors which detect when gear is being deployed or hauled, such as hydraulic or electromechanical winch sensors (e.g. Table 5). For vessels considered to be in the high risk category or required to collect direct evidence of fishing activities for operational or compliance purposes, in addition to the above data sources, a camera system may also be required. Whether data reporting needs to be near real time or can be delayed on a store and forward basis is also something that can be taken into account in the risk assessment process.

Figure 4 is a graphical representation of the way that a hypothetical SSF fleet might be divided into different risk categories, data evidence requirements and hence the type of ERS needed. For many SSF using static gears with limited bycatch in non-sensitive areas, it would seem likely that the only requirement for ERS would be track and catch data.

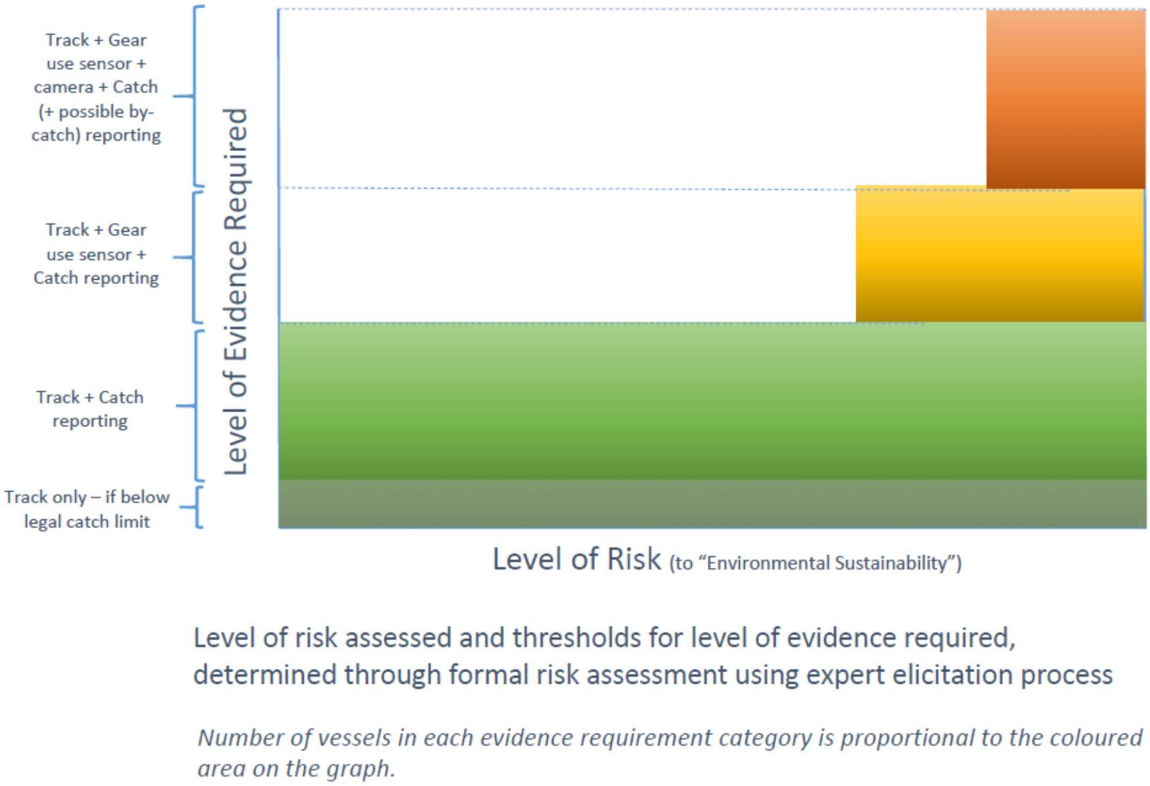


Fig. 4 Breakdown of ERS that could be distributed across an SSF fleet based on an assessment of risk (adapted from SIFIDS Project).

Table 5: A hypothetical example of a risk matrix to inform the level of ERS reporting required (developed for the SIFIDS project). Consequence (A) ranges from 1 (mild) to 5 (severe) and likelihood (B) ranges from 1 (low) to 5 (high). GNSS – Spatio-temporal data; GS – Gear sensor(s); C-IP Video camera

Risk Category (Environmental sustainability)	**Consequence (A)**	**Likelihood (B)**	**Details**	**Risk Consequences**	**Joint Risk (A*B)**	**Level of Evidence**
Dredging	5	4	Mobile gear in contact with or in close proximity to the seabed	Damage to the seabed and/or associated fauna/flora/high levels of by-catch	20	GNSS + GS + C
Electric fishing	5	4	Mobile gear in contact with or in close proximity to the seabed. Insufficient information to assess potential environmental impacts.	Possible damage to the seabed and/or associated fauna/flora/high levels of by-catch	20	GNSS + GS + C
Benthic trawling	4	4	Mobile gear in contact with or in close proximity to the seabed	Damage to the seabed and/or associated fauna/flora/ high levels of by-catch	16	GNSS + GS
Pelagic trawling	4	3	Mobile gear not in contact with the seabed	Bycatch of mobile PETS	12	GNSS + GS
Static nets	4	2	Static gear suspended in water column	Possible localised damage to seabed and bycatch of mobile PETS	8	GNSS
Pots/traps in strings	2	3	Static gear strung together and in contact with the sea bed	Possible localised damage to seabed and entanglement with mobile PETS	6	GNSS
Pots/traps singles	2	2	Static gear deployed individually in contact with the seabed	Possible entanglement with mobile PETS	4	GNSS
Long line	3	3	Static gear with multiple hooks on suspended line	Possible by catch and entanglement of mobile PETS	9	GNSS
Commercial Rod and line	2	1	Single or multiple hooks suspended from a fishing rod – static or trawled	Possible by catch of PETS	2	GNSS
Diver hand caught	2	2	Diver collecting shellfish by hand from the seabed	Possible localised overfishing	4	GNSS
Risk Category (spatial restriction)	**Consequence (A)**	**Likelihood (B)**	**Details**	**Risk Consequences**	**Joint Risk (A*B)**	**Level of Evidence**
Entering a restricted area	4	3	Accidental or deliberate infringement of an area where fishing is prohibited	Possible damage to habitats, PETS, infrastructure + potential for fishers to be implicated in illegal activity	12	GNSS + GS

Fishing in a restricted area	5	2	Accidental or deliberate fishing in a prohibited area	Possible damage to habitats, PETS, infrastructure + potential for fishers to be implicated in illegal activity	10	GNSS + GS
Other considerations						
Gear conflict	5	2	Mobile and static gear fisheries prosecuting the same area at the same time	Accidental or deliberate loss of static fishing gear. Denial of legitimate mobile fishing opportunities.	10	GNSS + GS
Previous history of non-compliance in sector/fleet	4	5	Any breaches in compliance with respect to Gear Type, Location or Time restriction or Catch/By-catch/Discarding	Lower risk categories for gear type, use, location, time or nature of catch or discarding becomes higher risk because a significant proportion of the fleet is non-compliant	20	GNSS + GS + C

Defining the Integrated data system

Future data collection schemes must provide more streamlined means of data acquisition (largely automated) and leverage the full power of relatively low-cost mobile communications technologies and sensors. This same technology is also capable of requesting and receiving bespoke feedback from acquired fishery dependent data collection coupled to a range of complementary data sources (e.g. weather, markets and prices, alerts and notifications). This feedback loop to fishers and other non-statutory data users could fundamentally change the dynamics of fisheries data collection and use, whilst improving and augmenting the fisheries dependent data flow required for statutory purposes. The Scottish Inshore Fisheries Integrated Data System (SIFIDS) project has been developing systems and processes based on these principles for data collection, analysis and reporting (see Figure 5).

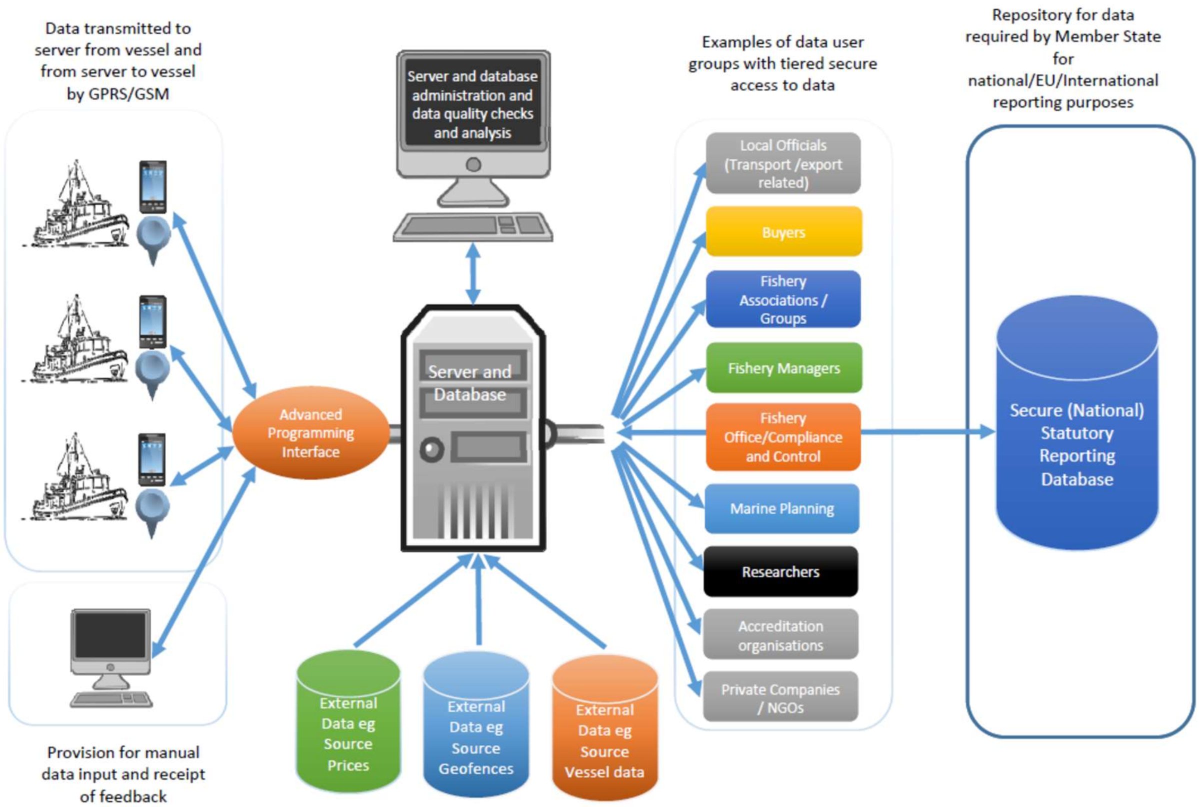


Fig. 5 Hypothetical data flow scenario for ERS for SSF (adapted from SIFIDS Project).

ERS and catch data from SSF are transmitted via GPRS/GSM to a relational database (Fig. 5). An Advanced Programming Interface is made available to allow a variety of different devices to communicate with the database provided they deliver data in the correct format and with the necessary security protocols. The database could be "owned" by the industry, a combination of industry and Government or an independent third party. The database would require some form of administration for update and maintenance, but most error checking, data quality checks and routine analytical procedures could be automated. The data provided from each vessel can only be viewed by those who either require access for statutory purposes or those that the fisher (owner of the data) elects to give access to. Fishers (data owners) can receive feedback through Apps developed for mobile devices (phone/tablet) in the form of reports related to catch, track, fishing effort, alerts and notices etc. Agreed, tiered access to the database by different user groups can also be established whereby data aggregated at different levels can be made available to meet the requirements of these user groups. Any statutory data such as catch or track data needed for compliance purposes could be routed to the necessary Government/National databases with verification/input from the regulating/control authorities (e.g. Fishery Offices). The data ownership and database operational model suggested in this scenario respects the confidentiality of fisher derived data, whilst making data necessary for compliance and statutory reporting purposes available to those that require it. Value can be added to the data by processing it into "products" useful to the fishers, associated supply chain actors, fisheries managers, and marine planners for example. Keeping the primary database outside of Government or public systems could offer greater operational flexibility and, from a Government perspective potentially offer greater security against cyber-attack as data transfer from the primary database to the Government database could be via a single fixed Internet Protocol (IP) address. The primary database will need to accept data from a large number of external devices via the mobile telephone network. In this approach, the use of AIS data has been omitted as there are some technical and operational aspects of the use of AIS (Class B in particular) that suggest that it may not be optimal for use in all SSFs (James et al., 2018). Notwithstanding these caveats, AIS data can easily be harvested and incorporated into the proposed data structures and analyses.

Guidelines for data collection

System specification for collecting positional data

Suggested minimum technical specifications for a basic ERS for SSF:

- GNSS receiver with the capacity to receive positional data from at least two relevant satellite constellations (e.g. GPS and GLONASS). The ideal GNSS receiver should combine dependable precision with reliable accuracy. Most GNSS devices will report position, speed and heading.
- GPRS/GSM should cover 2G, 3G and 4G networks, with it in mind that 2G and some 3G networks are being deprecated in some areas. Multi-network SIM capability may also be advisable where network coverage is patchy.
- On-board internal memory sufficient to store spatio-temporal data for a specified minimum number of records – this will be based on the operational characteristics of the fleet.
- Battery capable of powering the device for a specified minimum period in the absence of external power supply – the endurance of the backup battery will be a function of the required reporting frequency of the device and hence the operational characteristics of the fleet.
- A power supply derived from the vessel or from another source (such as solar PV).
- The device as a whole should be at least IP67 rated and tamper proof/evident.

From an operational perspective:

- The ERS device should report the unique vessel and ERS device identification together with position, speed and heading.
- The device should be remotely configurable – this is to say that the frequency with which spatio-temporal records from the GNSS are recorded can be amended without the need of an

engineer present. In addition, the frequency with which the recorded GNSS data is transmitted should also be configurable.

- When GPRS/GSM network connections are unavailable, the device must automatically store the GNSS data and forward these data when a network connection is restored. In addition, the device should report the quality of the GNSS record (i.e. the number of satellites used to define the position of the vessel) and hence the accuracy and precision of the position reported.
- The status of the power supply and internal battery should also be reported, and an alert should be given when the power supply is interrupted.
- The data transmitted via GPRS/GSM is directed from the network provider to a designated server which generally under the control of the ERS device supplier or manufacturer.
- Tiered access to these data for regulators and control authorities is likely to be necessary and this could be achieved either through direct access to the ERS database or through data being transferred via an Advanced Programming Interface (API) to a regulatory or control database.
- Fishers should be able to interrogate their own data – preferably in format that is easy for them to understand and on platforms such as mobile or tablet that are easily accessible to them.
- Where these data could be used to inform other fisheries management, marine planning or perhaps traceability and provenance measure consideration of the capacity to utilise these data should be included in the operational model.
-

GNSS position reporting frequency

Research being conducted as part of the SIFIDS project (https://www.masts.ac.uk/research/emff-sifids-project/) strongly suggests that vessel track data when recorded with sufficient resolution and modelled against known fishing practices with different gear types, can be used to accurately predict when and where fishing gear is deployed. It may also provide reasonable estimates of the amount of gear deployed. Further work is required to validate this approach, but in principle, results thus far suggest that using a reporting (polling) frequency of approximately 60 seconds fishing activity with static gears (pots and traps) can be identified and quantified within given levels of statistical confidence (Mendo et al, 2019, in press). It should be possible to automatically interrogate large volumes of vessel track data (in near real time if required) to provide automated reports and alerts that could be fed back to regulators and control authorities as well as the fishers themselves (via a mobile phone App for example).

Spatial reporting requirements

All forms of GNSS reporting offer the potential for the collection of highly spatially and temporally resolved data with many systems offering accuracy to 10 m. A clear rational for the resolution of data required should be agreed across relevant stakeholders (beyond fisheries compliance only) before widespread deployment of vessel tracking. By so doing, relevant data can be collected at sufficient resolution to be meaningful to those stakeholders. Statistically quantifying these requirements can also help place rational limits on the amount of data needed, thus minimising data transmission, processing and storage costs.

Catch reporting

The development of App based systems to facilitate fishers inputting catch (and bycatch) data to mobile devices is likely to increase significantly, increasing the frequency and potentially the quality of catch reporting. However, the development and rollout of these systems and processes must involve fishers and recognise that many are still averse to the use of this technology, preferring to use paper based reporting systems. Both the sophistication and growth of these mobile technologies and processes offers the potential to link temporal and spatial fishing activity data to catch data at high resolution. There is an established and very large consumer market for vehicle and transport logistics uses. Much of this technology is perfectly adaptable to use on SSSF and capable of meeting the specification outlined above. Apps can be developed relatively cheaply and there are an increasing number of open source solutions available that could be adapted for use with SSF. This has implications for fisheries compliance, management, planning and marketing. Opportunities to develop chain of custody, provenance and quality checks could be expanded cost effectively across SSF fleet segments.

Gear sensors and video monitoring

Vessels using high impact gear and or operating in a manner deemed to be sensitive will require additional forms of electronic remote monitoring to both ensure and provide evidence of compliance. This is likely to involve a combination of gear sensors such as hydraulic pressure sensors on winches and cameras positioned to observe deck operations, specific aspects of gear use, catch, bycatch and discarding. Thus far, the majority of trials using these systems have taken place using the more “high end” vessel monitoring systems adapted from the larger scale capture fishery. As a result, these systems tend to be quite expensive and require specialist knowledge to fit and operate from a compliance perspective. However, technical advances and the widespread use of video surveillance across the consumer market has driven down costs and increased the feasibility of deploying these technologies on SSF. The ability to interrogate these systems remotely and transmit video data over mobile telephone networks at reasonable resolution and costs has opened new opportunities to monitor SSF. The increasing use of Artificial Intelligence (AI) and machine learning to automatically interrogate video images is also accelerating and will inevitably feature in SSF video monitoring systems. Work is still required to adapt the existing and rapidly developing consumer level video systems to make them fit for more widespread and affordable use in SSF but this is beginning to occur. This technology and associated software will make full electronic monitoring of SSF increasingly feasible.

Biological data collection

As with vessel monitoring, a range of technologies are now being developed to facilitate verifiable on-board sampling and the semi or fully automated collection of biological data. This includes trials with electronic callipers and measuring tables designed to record dimensions. Bluetooth enabled callipers with additional functionality have also been trialled which allow the person taking the measurement to also record species and sex. Data can be collected via a tablet or other mobile device and transmitted directly to the relevant database.

Video technology coupled to AI and machine learning is also advancing rapidly and may provide rapid and automated ways of capturing biological data. A laser-video based system being developed as part of the SIFIDS project is capable of rapidly and automatically imaging lobsters and crabs identifying the species, determining sex and size. The equipment being tested is designed to operate on the deck of a 12 m or under fishing vessel. The ambition being to establish a SSF reference fleet in Scotland which would provide data of sufficient quality and veracity to feed into stock assessments. Numerous other frameworks and systems for the automated capture of fisheries relevant data are being developed (e.g. VIAME - http://www.viametoolkit.org/) but few are currently used routinely for operational purposes.

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Supplementary material 1. Manufacturers contacted and successfully interviewed

Company	**Accepted to interview in email correspondence**	**Interviewed**	**Consent form and verified interview received**
Anon 1.	⍰	⍰	⍰
Anchor Lab	⍰	⍰	⍰
Vericatch	⍰	⍰	⍰
Sat Link	⍰	no reply after initial acceptance	
Pelagic Data Solutions	⍰	⍰	consent was not received
Archipelago	⍰	⍰	⍰
Marine Instruments	⍰	⍰	⍰
WWF	⍰	⍰	⍰
AST Marine Science Limited	⍰	⍰	⍰
SRT Marine Systems plc	⍰	⍰	⍰
Anon 2.	⍰	⍰	⍰
BlueTraker	⍰	no reply after initial acceptance	
E-Catch	⍰	no reply after initial acceptance	
Seascope Fisheries Research Ltd	⍰	⍰	⍰
University of St Andrews	⍰	⍰	⍰

Supplementary material 2. Questionnaire to manufacturers – WP5 Fishpi2

DATE OF INTERVIEW:

LOCATION OF INTERVIEW:

- ☐ skype
- ☐ telephone

INTERVIEWER:

INTERVIEWEE:

COMPANY:

PRODUCT(S):

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1. What is your role within the company associated with the device?
2. How long has this company been operating for?
3. We have identified, *product name*, is a device which could be used to electronically monitor the:
    a. Position;
    b. Catch; or
    c. Fishing effort
    d. *Anything else?*

    of an inshore, small-scale fishing vessel.
4. How do you obtain the data for the above aspects from the device? *I.e. mobile phone link (if yes, 2G,3G or 4G or all?), satellite, hard-drive?*
5. Is there a case study where this product has been used or is currently used in an inshore, small-scale fishery? i.e. *How many vessels/skippers are using it, target species, gear, vessel size*
6. Was this device made following outlined pre-existing specifications? *i.e. governmental vessel monitoring product requirements or from previous research trial recommendations*
7. Is this product approved by any fishery management groups/organisations to provide data to assist management decisions? *i.e. NGOs or governmental fishery departments*
8. Is there a publicly available technical specification for this device that outlines the answers to this interview questions? *i.e. is there an accessible brochure? Does it have to be requested?*
    a. If publicly available, link:

QUESTIONS ON POSITIONAL DATA (*if applicable)*

1. Can you please tell us how your device records the vessel's position? *i.e. AIS (class A or B) or GPS (GNSS (global navigation satellite system)) etc*
    a. What is the accuracy of the recorded positional data? *i.e. +/- 10m*
    b. Is there just one positional logger? i.e. *To provide redundancy*
2. What is the logging frequency of the device? *i.e. the frequency the position is captured*
3. What is the reporting frequency of the device? *i.e. the frequency the logged position data is sent to the data base*
    a. Are you able to modify the logging or reporting frequency remotely, through software if required? *i.e. a member of staff does not have to physically visit to do an update*
    b. Can reporting frequency be altered by the skipper?
    c. Can the logging frequency change with vessel speed? *i.e. every 10 seconds when steaming Vs 30 seconds when moored*
4. Are there geographical areas where your device may not have sufficient coverage to 'ping' the vessels position to the server in real-time or near to real-time?
5. What is the storage capacity of the device, if it is out of coverage? *i.e. up to 2000 positional data points*
6. Is the device connected to an online mapping system that the device owner can use? *i.e. a mobile phone app to review their track or a website map plotter*
    a. Can others see the vessels tracks? *i.e. could government fishery management teams see where device owners are fishing*

CATCH DATA (*if applicable)*

1. Can you please tell us what information on the catch is collected through your product? *i.e. catch landed or discarded, animal numbers or weight*
2. Was it designed for a specific fishery? *I.e. shellfish or fish? Small-scale or pelagic*
3. How does your device electronically record catch data for a vessel? *I.e. stills, video, shipper, weights*
    a. What is the accuracy of the recorded catch by your device? *i.e. +/- 10 kg if weight, accuracy at IDing if applicable*
4. Does the device record any biological data*? i.e. individual length, sex*
    a. What is the accuracy of biological data? *i.e. +/- 10 cm*
5. Are bycatch electronically recorded by your device? *i.e. weight, species, numbers*
    a. What is the accuracy of recorded bycatch or discarded data*? i.e. +/- 10 kg*
6. Can the device log any interaction with Protected, Endangered or Threatened species?
7. Is the data collected geo-tagged? *i.e. can this data be linked to a/the GPS track?*

EFFORT DATA (*if applicable)*

8. Can you please tell us what information your device collects regarding fishing effort? *i.e. time spent fishing, when gear was released, when gear was hauled, quantity of gear used*
9. How does your device electronically record effort?
    a. Does the device use sensors to record effort? *i.e. movement sensors, RFID tags or pressure sensors*
    b. Does the user have to manually input what they have done? *i.e. a mobile phone application*
10. Is the collected data geo-tagged? *i.e. can this data be linked to a/the GPS track?*

GENERAL DEVICE FEATURES

1. What is the physical size of the device or phone requirements if an App?
    a. Where can it be fitted in the vessel?
2. Can the device connect to vessel's main power supply?
    a. How much power does the device draw from the vessel's main power supply?
3. Can the device use other sources of power? *i.e. batteries, solar panel*
    a. If yes, please specify duration of alternative power supply
4. What is the warranty for the device?
    a. What is the IP rating of the device? *Ingress Protection Rating, classifies the degrees of protection against both solids and liquids in electrical enclosures.* ***IP67*** *equipment is the most commonly found in the connectivity market. It is 100% protected against solid objects like dust and sand, and it has been tested to work for at least 30 minutes while under 15cm to 1m of water.*
5. Does the device come with any anti-tampering features? *i.e. alarms, mobile notification*
6. What is the fixed cost of the device per SMALL-SCALE VESSEL (<12m) l? *i.e. the one off purchase cost of the device(s) OR the minimum cost to lease if applicable*
    a. Does this price allow the user to see the data that was collect on their vessel?
7. What are the marginal costs for the device per vessel? *i.e. renting, maintenance*
8. Do you offer or require payment for your data collection/processing software/service to be used?
    a. *If yes,* what is the cost of this
9. Who owns the data?

End of interview

Supplementary material 3. Questionnaire to stakeholders (government/institutes using ERS to collect small-scale fisheries data)

Date of interview:
Location of interview:

- ☐ skype
- ☐ telephone

Interviewer:
Interviewee:
Organisation:
Country:

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1. Which small scale fisheries (SSFs) are using or have used electronic data collecting systems in your country? *i.e. scallop dredge fishery in Scotland*
2. Are there any legal requirements / specifications for electronic systems in SSFs to satisfy governmental bodies/ local fishery management group? (example MMO website)

INFORMATION ON CASE STUDIES (fill one table and answer the following questions for each fishery)

Fishery descriptors:	Comments
Targeted species *i.e. scallops*	
Total number of vessels in this fleet (with and without system)	
Area covered (km^2) (could circle in map, send coordinates, shapefile?	
Gear used *(level 4 - in 2009-12-18_Commission Decision_93)*	
Overall length of vessels in fleet (<10, 10-12, >12-15?)	
Purpose of the study	

SYSTEM DESCRIPTION:

1. Manufacturer's or company name (who developed the system):
2. Product name:
3. Does the system link into a database that is used for statutory purposes? *i.e. a database used for compliance*
4. Who has access to the data collected? *i.e. manufacturers, research institute, government or fishermen*

5. Who owns the data? *i.e. manufacturers, research institute, government or fishermen*
6. Are there any estimates of running costs- fixed costs (independent of # vessels) and marginal costs (cost for transmitting data/storing data/company fees/accessing data?)
7. Does the device record the vessel's track and at what interval? *i.e. AIS (class A or B) or GPS (GNSS (global navigation satellite system)) etc*
8. Were the devices reliable? Is there a report of reliability of the device?

MEETING DATA REQUIREMENTS [14]

Could/can the system provide information on the following for <u>this case study</u>:

1. **EFFORT DATA (*if applicable)***

	Y/N	More info
Number of trips		
Days at sea		
Fishing days		
Number of vessels active		
Vessel time spent fishing		
Gear soaking time		
Gear quantities		
Gear length		
Can you get the position of the fishing activities? *i.e. can this data be linked to a/the GPS track?*		

2. **CATCH DATA (*if applicable)***

[14] Taken from the ICES WGCATCH report 2016, Table A11.2, "Proposed list of transversal variables to be collected for vessels without logbooks requirement (LOA<10 meters)"

	Y/N	More info
Value of landings totals and per species *i.e. euros*		
Live weight of landings *(tons)*		
Prices by species *i.e. euro/kg*		
biological data*? i.e. individual length, sex*		
Discards? *i.e. weight, species*		
Bycatch *i.e. weight, species, numbers*		
Any interaction with Protected, Endangered or Threatened species?		
Can you get the position for any of these data? *i.e. can this data be linked to a/the GPS track?*		

MANAGEMENT SUPPORT:

1. Are the data collected by e- systems being used to assist current management decisions?
2. Have you identified any factors that are hindering the use of e- systems for fisheries management?
3. Have you identified any opportunities by which using electronic systems will help SSF management in the future?
4. Have you found that collecting data on SSFs has been more time-efficient/robust? Precise?

FISHERS AND SYSTEMS:

1. Is fisher's use mandatory or voluntary?
2. Does the fisher have to buy the required equipment themselves? / pay for the ongoing costs?
3. How did the fishers uptake the equipment? i.e. *readily accepted, considered a burden? Any evidence to support statements?*

If you are able to provide information on any case studies, would you be able to provide us with a copy of any relevant reports that were produced related to the study

Supplementary Material 4. List of transversal variables to be collected for vessels without logbooks requirement (LOA<10 meters) (Taken from ICES, 2017)

HEADING	VARIABLE	UNIT	DESCRIPTION	COVERAGE	ACTIVITY SEGMENTATION	REFERENCE PERIOD
Capacity	Number of vessels	Number	Total number of vessels	Community Fishing Fleet Register	Fleet segment	
	GT	Number	Total GT of the vessels in the segment	Community Fishing Fleet Register	Fleet segment	
	kW	Number	Total kW of the vessels in the segment	Community Fishing Fleet Register	Fleet segment	
	Vessel Age	Number	Average AGE of the vessels in the segment	Community Fishing Fleet Register	Fleet segment	
Effort	Number of trips	Number		Active vessels	Fleet segment and gear (level 3)	Quarterly
	Days at sea	Day		Active vessels	Fleet segment and gear (level 3)	Quarterly
	Fishing days	Day		Active vessels	Fleet segment and gear (level 3)	Quarterly
	Number of vessels	Number		Active vessels	Fleet segment and gear (level 3)	Quarterly
Landings	Value of landings totals and per species	Euro	Value of landings total and per species	Active vessels	Fleet segment and gear (level 3)	Quarterly
	Live weight of landings	Tons	Live weight of landings in kg total and per species.	Active vessels	Fleet segment and gear (level 3)	Quarterly
	Prices by species	Euro/kg	Price per kg of species landed	Active vessels	Fleet segment and gear (level 3)	Quarterly

Supplementary Material 5. Characteristics of fisheries Characteristics of fishing fleets using electronic reporting systems. Case study letters refer to case study ID shown in Table 3, main text.

	Case study													
Fishery characteristics	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
Main targeted species	cod	*Several bivalves*	Cod, plaice	crabs, lobster, scallop, langoustine	Razor clam	Hake, mackerel, red mullets, anglerfish, sole, rays, seabass, Sparidae spp. and cephalopods	Blue mussels and cockles	Cod, brill, turbot, plaice, flounder, sole	Most inshore fisheries	razor clam	sole, skate, cod, bass, *langoustine*	Thornback, blonde, and spotted ray, bass, cod	mixed fishery of primarily quota stocks	crabs, lobsters and langoustines
Vessels in fleet with system	~90 out of 400	all vessels in fleet=83	10	11 out of 1500	all vessels in fleet=22	55 out of 70	all vessels in fleet=55*	10 out of 90	1073 out of 1384*	all vessels in fleet=80	9, 10 and 12 vessels respectively in each of the three fleets studied (Hartlepool, Lowestoft and Thames)	5 vessels	28/28	274 out of 1522
Geographical area where fleet operates	German territory	Portugal – mostly within 3 NM, some out to 6NM	Skaagarat Sea – out to 6 NM	West of Scotland	11 designated areas in Scotland. Inshore fishing generally within 0.5 miles of coast.	Basque inshore waters out to 6 nmiles	Danish coastal waters	ICES IVC: 32F3 32F4 33F3 33F4 34F4	Andalucia, Spain	East, South and South West of Ireland	Hartlepool, Lowestoft and Thames region	Southern North Sea (1.5-2.5 degrees East and 51.5-53.5 degrees North)	12 NM from Hastings coastline, England	Scottish inshore waters
Gear used	Gillnets	Dredge	Bottom gillnets	Pots and traps for crabs, velvets and lobster, dredge for scallops, bottom trawler for langoustines	Divers and electrofishing	Multi-gear – mostly gill and trammel nets but also traps, long lines and handlines	Dredges	Trammel nets and gillnets	Gillnets, dredges, traps	Hydraulic dredges	Bottom otter trawl, multi rig trawl, bottom pair trawl, set longlines, pots and traps, trammel nets, set gill nets, drift nets, dredge	Longliners	Multi-gear	pots and traps, line, bottom trawls, dredges
Overall length of vessels in fleet	<12 m	Local and coastal < 14 m	9-12 m	< 12 m	6-13 m but most in 8-9 m range.	<15 m	10 – 20 m	Most of them < 10 m, rest 10-12 m and 12-15 m	<15 m	<12 m	<10 m	<10 m	<10 m	<12 m
Type of system used (manufacturer/company)	MOFI App (Anchor lab)	Real time tracker (Robot)	REM (Anchorlab)	REM (Archipelago)	R2 system black box (Anchorlab)	AIS and tablet	R2 system black box (Anchorlab)	REM (Archipelago)	Green box	iVMS and gear sensor (AST, Succorfish and IDS monitoring)	“VMS Lite” (AST-MSL)	iCatch App and AVMS (AST-MSL)	AST MSL and Snapit HD, other companies may be considered	AIS (Succorfish)
type of data collected? - position, effort,catch, bycatch, PET	position, effort	position, effort	position, effort, biological data, bycatch, PET	position, effort, biological data	position, effort	position,effort and catch	position, effort	position, effort, bycatch	position, effort	position, effort	position, effort	position, discards	position, effort, catch, discards	position

- Values taken from outcomes of the Workshop of Digital Tools for Small-Scale Fisheries. https://ec.europa.eu/fisheries/press/outcomes-workshop-digital-tools-small-scale-fisheries-brussels-4-5-december-2018_en

Supplementary Material 6

	Case study													
EFFORT DATA	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
Number of trips	Y	Y	Y	Y	Y	Y - The user selects when they leave the port	Y	Y	Y	Y	Y	Y	Y	Y
Days at sea	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fishing days	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y - by app	Y	Y - From speed between points and track shape
Number of vessels active	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Vessel time spent fishing	Y	Y - From speed tracks	Y	Y	Y	Y	Y	Y - Derived from speed and use of hydraulic sensor on winch	Y	Y - Infer fishing activities from speed, but starting to look at sensors to identify when gear is shot/hauled.	Y	Y	Y - From App	Y
Gear soaking time	Y	Y - Derived via time spent towing. Recording data at 30s-1min so estimation is very reliable.	Y	Y - Only with interpretation of the RFID trial data	Y - Electrode operation time	Y - When gear is shot/hauled via tablet	Y - Estimated from sensor registering any winch activity (shooting/hauling).	Y	Y - If no sensors the activity is derived from speed, course and duration	Y - If sensor is absent then no signal	N	Y - by app	Y - When gear shot/hauled and lat and long	N
Gear quantities	Y	Y - Derived from length of net and track	Y	Y - Only with interpretation of the RFID trial data	N	Y -Number of nets and hooks	N - Can get from E-Logbook	Y	N	Y	N	Y - by app	Y - by app	N
Gear length	Y	Y	Y	N/A	N	Y	N - Can get from E-Logbook	Y	N	Y - For dredges estimate hauled path, for pots and nets estimate length of string	N	Y	Y - by app	N
Can you get the position of the fishing activities?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Supplementary Material 7. Stakeholders answers to the questions regarding the collection of catch data during their case study, yes (Y) and no (N) along with any additional information is included

	Case study													
Catch Data	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
Value of landings totals and per species *i.e. euros*	N	N	N	N	N	N	N	N	N	N - Not collected but aiming to couple e-logbooks with i-VMS	N	N	N	N
Live weight of landings *(tons)*	N	N	N	N	N	Y	N - ONLY MANUAL LOGBOOK	N	N	N	N	Y	Y - By app	N
Prices by species *i.e. euro/kg*	N	N	N	N	N	N	N - ONLY MANUAL LOGBOOK	N	N	N	N	N	N	N
Biological data? *i.e. individual length, sex*	N	N	Y - for fish length from video	Y - Estimates of accuracy of assessment of sex and length in EFF report	N	N	N	N	N	N	N	N	N	N
Discards? *i.e. weight, species*	N	N	Y	Y - species, sex and counts from videos	N	Y - By app	N	N	N	N	N	Y - By app	Y - By app	N
Bycatch *i.e. weight, species, numbers*	N	N	Y - Species numbers (seabirds, marine mammals), seabird sex from video	Y - Could be derived from video observations	N	Y - Species of seabirds	N	Y - Number of harbour porpoise, estimating bycatch rate	N	N	N	N	N	N

Any interaction with Protected, Endangered or Threatened species (PETS)?	N	N	Y - Marine mammals, skates and rays	Y - Could be derived from video observations	N	Y - Number caught	N	Y - harbour porpoise	N	N	N	N	N	N
Can the device provide the position for any of these data?	N	N	Y - Match video data with GPS data	Y - Could add comment in system to link data to a position	N	Y -When hauling	N	Y	N	N	N	Y	Y	N

Supplementary Material 8. Case study SWOT Analysis

	Case study													
SWOT	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
Strength														
Were the devices reliable? Is there a report of reliability of the device?	Y	Y	Y - But fishers can cheat system	Y - Some breakdowns	Y	Y	Y - GPS issues	Y - Power issues	Y	Y (Succorfish) and N (some AST-MSL)	Y - Supplier and power issues	Y - Installing issues	Y	N - Supplier and power issues
Have you found that collecting data on SSFs has been more time-efficient/robust? Precise? *i.e. compared with alternative methods (e.g non-electronic) to gather same type of information*	Y - Time, accuracy, more detail	Y - Time, accuracy	Y - More detail	Y - Saves money, more detail	Y - Time, accuracy, saves money	Y - Accuracy,more detail	Y/N - Time	Y - More detail produced	Y, accuracy, applicable	N/A	Y - More detail, and N - Time	Y - Time, accuracy	Y - Time	Y - Time, accuracy
Weakness														
Are there any legal requirements / specifications for electronic systems in SSF to satisfy governmental bodies/ local fishery management group? (example MMO website)	N - Volunteers and projects only	Y - Dredges, real-time positional systems, only research	Don't know	N	N- Volunteers and projects only	In the future	Y - Bivalve fishers, positional systems	N	Y - Postional information for all <15 m	Y - Razor clam fishery	N	N	N	N, but yes for >10 m vessels
Does the system link into a database that is used for statutory purposes? *i.e. a database used for compliance*	Y - Data goes via Anchor Lab	N - Database being developed	N	N	Y - GPS, speed, generator use	N	Y	N	Y	N	N - data held on manufacturers system, accessed by research institute	N	Y	N
Opportunities														
Who has access to the data collected? i.e. manufacturers, research institute, government or fishermen - if fishers have access	Government	Government (IMPA)	Fishers and research institute (DTU)	Research Institute (Seascope), Government (Marine Scotland)	Government (Marine Scotland Science), fishers	Research Institute (AZTI), government	Governmen t and research institute (DTU)	Research institute (WUR)	Andalusian Regional Government, research institute (Instituto Español de Oceanografía)	Research institute (Marine Institute), some fishers, government(C ontrol Authority)	Government (CEFAS), fishers	Government (CEFAS), fishers	Fishers, government (CEFAS), Coastal PO	Research institute (USTAN), fishers, AIS data is public
Are the data collected by e-systems being used to assist current management decisions? (e.g. fleet interactions, marine spatial planning, spatial distribution, stock assessment, bycatch reduction, quantification, protected endangered species) Please elaborate the outcomes of the trial.	Y - RESTRICTED COD FISHING IN 2018, MOFI APP HAD TO BE USED WHEN FISHING	Y - PROVIDES MONITORIN G ON FLEET POSITION, CALCULATIO NS ON FISHING EFFORT	Y - BYCATCH CALCULATIO NS, INFORM GOVERNMEN T PLANS, NATURA 2020 DATA	N - FEEDER PROJECT TO BIGGER PROJECT TO HELP MANAGEMEN T	Y - DATA INFORMS POLICY AND CONDITIONS FOR FISHERY, ASSISTS MONITORING OF FLEET, DATA FORWARDED TO FOOD STANDARDS SCOTLAND	Y - CALCULATIONS OF FLEET EFFORT, PROJECT CATCH APP DATACOMPARE D TO LOGBOOKS AND SALE NOTES FOR STOCK ASSESSMENTS	Y - MARINE SPATIAL PLANNING TO PROTECT MARINE FEATURES	Y -BYATCH CALCULATIONS , INFORM GOVERNMENT DECISIONS.	Y - CALCULATIO NS OF FLEET EFFORT, INFORM STOCK ASSESSMENT S	Y - OFFERS MONITORING OF FISHING POSITION	N	N - FOR FUTURE MANAGEMEN T OF FLEET AND SPURDOGS	N, FOR FUTURE MANAGEMENT OF FLEET	N

Have you identified any opportunities by which using electronic systems will help SSF management in the future?	Yes, LOCATE FISHING GROUND, HELP DESIGNATE OR PROTECT ESTABLISHED MPA/CONSERVATION ZONES/CLOSED AREAS	Yes, LOCATION OF FISHING GROUNDS, CALCULATION OF FISHING EFFORT	Yes, FLEXIBLE AND REPRESENTATIVE MANAGEMENT	Yes, INSENTIVE TO FISH RESPONSIBLY, COMPLIANCE, STOCK MANAGEMENT	Yes, INCREASED DATA ACCURACY, COMPLIANCE, RESOLVES INFLEET CONFLICT	yes, INCREASED DATA ACCURACY	Yes, HELP DESIGNATE OR PROTECT ESTABLISHED MPA/CONSERVATION ZONES/CLOSED AREAS, FISHING BEHAVIOUR ANALYSIS, PUBLIC	Yes, MORE DATA, AI, CALCULATE EFFORT OF FLEET	Yes, INCREASED DATA ACCURACY, CALCULATE EFFORT	Yes, SPATIAL MANAGEMENT, CALCULATE EFFORT OF FLEET, CATCH RATE, FISHING BEHAVIOUR ANALYSIS	Yes, PUBLIC IMAGE, SAVE TIME, SAVE MONEY	Yes, ALERT FISHERS DIRECTLY, PETS DATA, LOCATE FISHING GROUNDS	Yes, MORE DATA, INDIVIDUAL QUOTA LIMIT TRIAL, HELP PREVENT DISCARDING	Yes, MORE DATA, ASSIST MANAGEMENT
Threats														
Have you identified any factors that are hindering the use of e-systems for fisheries management? i.e. lack of acceptance in the small-scale fishers communities	DEADLINES, POOR COMMUNICATION BETWEEN MANAGEMENT AND FISHERS, NO TEST PHASE , PRIVACY CONCERNS	PRIVACY CONCERNS, LACK OF WANTING CONTROL FROM DATA GATHERED	FISHERS RELUCTANCE, EQUIPMENT COSTS, INSTALLATION DIFFICULTIES	COMPLIANCE AND MANAGEMENT RELUCTANCE TO ENFORCE, BREXIT	YES, FISHERS RELUCTANCE AND SYSTEM INFLEXIBILITY	AIS CAN BE TURNED OFF	N	EQUIPMENT COSTS, CONCERNS ABOUT PRIVACY, LACK OF COMMUNICATION BETWEEN MANAGEMENT AND FISHERS	N	N	LACK OF INCENTIVE FOR FISHERS, PRIVACY CONCERNS, LACK OF TRUST IN MANAGEMENT, FISHERS RELUCTANCE	FISHERS RELUCTANCE, INCONSISTENT POWER SYSTEMS ON BOATS	FISHERS RELUCTANCE, MANAGEMENT STRATEGIES ARE NOT REPRESENTATIVE	AIS CAN BE TURNED OFF, PRIVACY CONCERNS, TRANSMISSION FREQUENCY

Supplementary material 9.

	Case study													
Fishers involvement	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
Is fisher's use of electronic methods of collecting data mandatory or voluntary?	M	M	V	V	M	V	M	M	M	M	V	V	V	V
Does the fisher have to buy the required equipment themselves / pay for the ongoing costs?	No	No	No	No	Yes, hardware and sim card. Marine Scotland pays for analysis/server software	No	Yes, fishers pay for sensor, system and installation. Ministry pays for ongoing costs such as data transfer and server	No	No	No	No	No	To be decided	No
How did the fishers uptake the equipment? i.e. readily accepted, considered a burden? Any evidence to support statements?	Considered it a burden and controlled, reluctance due to poor communica tion, not used to technology	Most fine - some considered it a burden. Disconnecti ng equipment meant a fine and fishing ban	Most fine - felt like researchers and cooperated, some need motivation, others refused	Readily accepted due to financial incentives	No choice - fishers had to have trackers to meet requirements to fish	Most fine - AIS and tablet easy to use, flexible to record activities for management, issues with AIS being public information	Reluctance at start due to threat of punishment, accepted more now due areas being opened and fishers having personal activity records	Relutance at start due to process, participatio n secured due to promise of increased quota	Most fine, some considered it a burden	Relutance from fishers at start, accepted more now due to fishing having personal activity records	Readily accepted as trail allowed quota free fishing. Fustrated when equipment broke as fishers were not allowed to fish	Readily accepted	Readily accepted	Readily accepted, many requests for equipment, equipment still being used by some fishers post-trial

Supplementary Material 10.

	Mofi App	**Blackbox R2**	**WatchMan Pro**	**Electronic Eye**	**anon.1**	**Observe hardware, Interpret software**	**SRT - B300 AIS class transceiver**	**Guardian App**	**iCatch App**	**aVMS**	**SIFIDS App**	**OBCDCS**	**anon.2**	**Vericatch App**	**WWF App**
Recording method	GNSS via mobile phone	GNSS receiver	GNSS	GNSS	GNSS	GNSS	GNSS	GNSS via mobile phone	GNSS via mobile phone	GNSS	GNSS via mobile phone	GNSS	GNSS	GNSS via mobile phone	GNSS via mobile phone
Accuracy	15 m	~15 m	~2.5 m	~2.5 m	15 m	<2 m	5 m	10 m	10 m	2.5 m	10 m	3 m	5 m	10 m	10 m
logging freq.	1 min	10 sec	10 sec	10 sec	1 min	10 sec	5 min	1 min	n/a	5 min	30 sec	1 sec	0.5 sec	when fishing starts and ends	when fishing starts and ends
reporting freq.	15 min	15 min	1 min	3 hours	10 min	hard-drive	customisable	customisable	n/a	customisable	30 mins	5 min	when connected to port wifi	n/a	n/a
remote modifcation of frequencies	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	n/a	Y
logging frequency change with speed	N	N	y	N	N	N	y	y	N	Y	N	N	Y	n/a	N
limitations to real-time reporting	out of cellular network coverage	out of cellular network coverage	out of cellular network coverage	None	None	None	radio frequency can be blocked	out of cellular network coverage	n/a	out of cellular network coverage	out of cellular network coverage	out of cellular network coverage	out of cellular network coverage	out of cellular network coverage	out of cellular network coverage
storage capacity of positional records	device dependent	40,000,000 positional points	3 months of data	12 months	n/a	1 terabyte	90 days	Y	n/a	30 days	device dependent	1 T Byte	64 G Bytes	device dependent	device dependent
capacity to forward stored position records	Y	Y	Y	n/a	n/a	N	Y	phone dependant	phone dependant	Y	Y	Y	Y	Y	Y

Supplementary Material 11

	Mofi App	Blackbox R2	WatchMan Pro	Electronic Eye	anon.1	Observe hardware, Interpret software	SRT - B300 AIS class transceiver	Guardian App	iCatch App	aVMS	SIFIDS App	OBCDCS	anon.2	Vericatch App	WWF App
Aspects of catch recorded	n/a	n/a	n/a	catch (numbers, species)	n/a	catch (numbers, species)	catch (number, species, date landed, location and time of catch)	n/a	bycatch (species, weight), bait, trawl depth	n/a	catch (number, species, date landed, location and date of catch, discards)	catch (number, species)	all - configurable	all - configurable	catch (species, number, bycatch)
method of recording	n/a	n/a	n/a	stills	n/a	video	in-port computer, mobile phone application	n/a	stills and manual input	n/a	manual input	onboard scanner	video and app	manual input	manual input
Accuracy of recording method	n/a	n/a	n/a	human error using software	n/a	human error using INTERPRET software	human error using software	n/a	human error inputting	n/a	human error inputting	95%	human error using software	human error inputting	human error inputting
Biological information	n/a	n/a	n/a	Y	n/a	length	N	n/a	N	n/a	N	sex and size	N	can be included	N
Accuracy of biological information	n/a	n/a	n/a	human error	n/a	<5 cm for length when using INTERPRET software	N	n/a	n/a	n/a	n/a	tbc	n/a	human error	n/a
Recordings of Protected, Endangered or Threatened species interactions	n/a	n/a	n/a	Y	n/a	Y	Y	n/a	N	n/a	Y	n/a	can be included	can be included	n/a
Are records geo-tagged?	n/a	n/a	n/a	Y	Y - If connected to other system	Y	Y	n/a	Y	n/a	Y	Y	Y	Y	Y

Supplementary material 12.

	Mofi App	Blackbox R2	WatchMan Pro	Electronic Eye	anon.1	Observe hardware, Interpret software	SRT - B300 AIS class transceiver	Guardian App	iCatch App	aVMS	SIFIDS App	OBCDCS	anon.2	Vericatch App	WWF App
Aspects of effort recorded	gear time fishing, fishing days	gear time fishing, fishing days	gear time fishing, fishing days	gear time fishing, fishing days	gear time fishing, number of gear deployed	gear time fishing, fishing days	gear time fishing, fishing days	n/a	gear fishing time, days fishing, number and length of gear	n/a	days fishing, number and size of gear	gear time fishing, fishing days, number of gear	gear time fishing, fishing days, number of gear	gear time fishing, fishing days, number, size and length of gear	gear time fishing, fishing days number of gear
method of electronic recording	manual input	4 gear sensor ports (i.e. electric current or hydraulic)	RFID (i.e. winch, hydaulics)	stills, gear sensors (i.e. winch, hydraulics)	gear sensors, RFID tags	gear sensors (i.e.movem ent sensors, proximity, pressure), cameras	manual input	n/a	manual input	n/a	manual input	RFID tags, inductive sensor	mobile phone App, video and onboard gear sensors (i.e. RFID tag readers and hydralics)	manual input, app connected to sensors (i.e. RFID tag readers, bluetooth calipers)	manual input
Are records geo-tagged?	Y	Y	Y	Y	Y	Y	Y	n/a	Y	n/a	Y	Y	Y	Y	Y

Supplementary Material 13 N/P = NOT PROVIDED

	Mofi App	Blackbox R2	WatchMan Pro	Electronic Eye	anon.1	Observe hardware, Interpret software	SRT - B300 AIS class transceiver	Guardian App	iCatch App	aVMS	SIFIDS App	OBCDCS	anon.2	Vericatch App	WWF App
Size of device (cm)	mobile phone	12.8 x 20.0 x 5.8	10 x 15 x 17.5	39.0 x 49.0 , camera: 15.7 x 32.1 x 15.2	25.6 x 12.5 x 2.7	30.5 x 30.5 x 8.5	10 x 10 x 3	mobile phone	mobile phone	25.5 x 24.0 x 14.0	mobile phone - Android only	42.6 x 29.0 x 16.0	17.1 x 12.1 x 5.5	mobile phone - Android only	mobile phone - Android only
fitting position on vessel	n/a	inside wheelhouse	outside wheelhouse	outside the wheelhouse	outslide wheelhouse	inside wheelhouse	outside wheelhouse	n/a	n/a	outside wheelhouse	n/a	outside and inside wheelhouse	outside and inside wheelhouse	n/a	n/a
Connection to vessel's main power supply	n/a	Y	Y	Y	N	Y	Y	n/a	n/a	n/a	n/a	Y	Y	n/a	n/a
Power consumption	n/a	<1 Watt	<4.8 Watt	<15 Watt	N	120 Watt	1mAh	n/a	n/a	n/a	n/a	1.5 Amps at 12 volts	180 mAMPs	n/a	n/a
Other power sources	n/a	N	Batteries	batteries	solar panel and battery	batteries	batteries	n/a	n/a	solar panel	n/a	N	solar	n/a	n/a
Duration of alternative power supply	n/a	N	1 week	72 hours	2 weeks	10 minutes	dependant on battery	n/a	n/a	n/a	n/a	n/a	2.5 days	n/a	n/a
Warranty for device	phone dependant	2 years	12-24 months	12-24 months	3 years	n/a	10 years	phone dependant	phone dependant	2 year	phone dependant	1 year	3 years with yearly mainenance checks	phone dependant	phone dependant
Ip rating	phone dependant	none	67	68	67	n/a	66&67	phone dependant	phone dependant	68	phone dependant	not rated yet	65	phone dependant	phone dependant
anti-tampering features	password for wesbite server	case opening sensor, passwords for website server	case opening sensor	case opening sensor	online notifications	locked device, username and password for INTERPRET software	encryption, anti-tampering alarms	username and password for App	username and password for App	unique seals, transmission of shore side alarm	phone dependant	password protected and lockable	N	phone dependant, app and website password	website password

Fixed price of device	Free to download	2 000 EUR	600 EUR	2500 EUR	1875 NZD	6007 USD	100 USD (400-1500 USD for further configuration)	free to fisher	free to fisher	n/a	free to fisher	2 000 GBP	2000 USD	n/a	free to fisher
does the user have to pay to see their data?	Y - 14 EUR for fishers	Y - 14 EUR for fishers per month	N	N/P	N	Y	Y	N	N/P	Y	N	N	N	N	N
Marginal costs (renting, maintenance)	0	18 EUR per month	10 EUR per month after first year	none - unless satelitte communica tion is opted for	60 NZD per month	cost not specified for imagery analysis software	0	0	0	airtime price	0	0	150 USD	monthly fee	0

Annex 5.3 - Standardize Workflow to analyse Automatic Identification System AIS (geospatial)/Sale notes data.

Introduction

The use of VMS (Vessel Monitoring System) devices was implemented by European law for vessels over 24 m in year 2000 (EC 1489/97 and 686/97), for vessels over 18 m in 2004 (EC 2244/2003) and for vessels over 15 m in year 2005 (EC 2244/2003). Since 2012, EU vessels over 12 m are obliged to have VMS, with a possible exemption for vessels under 15 meters operating within the territorial waters of the flag Member State (EC 1224/2009). This has allowed fisheries scientists to take into account the fine-scale spatial and temporal dimensions of commercial fisheries data, which can be applied to a variety of fields, such as the description of the spatial distribution of fishing effort and catches (e.g. Rijnsdorp et al., 1998; Murawski et al., 2005; Fonseca et al., 2008; Lee et al., 2010, Gerritsen and Lordan 2010); the estimation of the impact of trawlers on the ecosystems (Eastwood et al., 2007; Stelzenmuller et al., 2008), or marine spatial planning (Campbell et al., 2014).

The SSF which are not affected by VMS obligations, have been traditionally left out of these types of analysis. However, publicly accessible vessel reporting systems such as AIS (Automatic Identification Systems), and ad-hoc voluntary geolocalization systems, have recently provide an alternative source of data that can be used to inform fisheries management and marine planning for SSF (James et al 2018). This is particularly important because the activity of SSF is taking place near the coast, with a significant fishing impact on some coastal fish resources and essential habitats, in an area where conflicts between competing users of marine space are increasing (Ehler and Douvere, 2017), and which host vulnerable fish resources and essential habitats.

AIS (class A) was introduced as mandatory for fishing vessels above 24 m from 31 May 2012, fishing vessels above 18 m from 31 May 2013 and from 31 May 2014 it was mandatory for all vessels above 15 m (EC 2002/59, EC 2011/15). However, many smaller vessels have AIS installed (often class B) voluntarily for security reasons. AIS geospatial data present special characteristics in comparison to VMS data, such as higher spatial and temporal resolution, positions very near to the coastline, or transmission problems due to complex coastal topography. As noted by James et al 2018, the challenges of storing, applying quality control filters, querying and mapping large volumes of positional data that are likely to be produced by the large number of SSF vessels in Europe have thus far not been adequately addressed. There is a need to develop procedures to manage and integrate vessel movement data sets and link these data with relevant effort metrics to inform fisheries management

In this section, fishPi 2 recommends a workflow adapted to SSF data, and make a summary of the main issues encountered when working with AIS and sales notes data in SSF, together with some conclusions and recommendations. Additionally, two CS are presented as examples of the results that can be obtained with this kind of data.

Workflow: proposed workflow to analyse AIS / Sales notes data

The objective of this section is to recommend a workflow to work with SSF geospatial and catch data. The list of steps should be adapted to the specific characteristics of the national data. In some cases, additional analysis may be needed, or some of the steps described here may not be relevant. It is a list of points recommended considering the whole process, including preparation of a convenient input format, data cleaning, analysis and production of results.

The workflow is based on the EFLALO and TACSAT data formats used by the R package VMStools (Hintzen et al. 2012). These formats build on work done and agreements made during previous EU funded scientific projects such as TECTAC, CAFÉ, AFRAME and "Development of tools for logbook and VMS data analysis (Mare 2008/10 Lot 2)" and are well known within the International Council for the Exploration of the Sea (ICES) community. A description of them can be found in the link: "https://github.com/nielshintzen/vmstools/releases/download/0.0/Exchange_EFLALO2_v2-1.doc".

The use of a standardized input data format is key to enhance regional cooperation as it makes sharing of data and developed code possible. TACSAT and EFALO formats have been widely used in fisheries geospatial analysis for off-shore fleets (Gerritsen and Lordan 2011). The TACSAT format was defined for VMS data, and all the required information is usually collected by other types of geospatial devices (AIS, GPS etc.). The EFLALO format is based on logbook data, and this can be a problem in the case of SSF under 10m for which logbooks are not available. In these cases, sales notes can be used by adapting some of the variables. The main required adjustments are detailed in the workflow.

Proposed workflow:

1. *Convert geospatial data into TACSAT format.*
   Geospatial devices used for SSF usually record the information required in this format (vessel id, position, time, speed and heading). The identification of the vessel is needed. In the case of AIS data, this can usually be done using the radio call sign (IRCS)

2. *Convert catch data into EFLALO format.*
   EFLALO format is based on logbook data, which can be a problem in the case of SSF under 10m for which logbooks are not available. In these cases, sales notes can be used just by adapting some of the variables. The main required adjustments are the following:

   a. In the case of SSF, trips are usually one day long and can be defined by the combination of vessel and landing date. The use of landing date instead of sales date is a potential issue, as a single trip may be sold in more than one day.
   b. Landing date can also be used as departure date and catch date.
   c. If landing date is not available, sales date can be used. In these cases, a correction may be needed to adjust selling and landing dates (i.e., +1 day)
   d. If there is no information on the landing time, default time can be inserted (e.g. starting at 2:00 and ending at 23:00)
   e. The gear can be estimated from landings compositions, vessel characteristics, licenses or other data sources available.

3. *Clean TACSAT files*
   a. Cleaning points in land: The function pointOnLand (VMStools) is very useful to identify points which are on land. However, the map provided with VMS tools is too coarse. A

higher resolution coastline is needed when working with SSF, as the small-scale fishery is often taking place close to the coast. A public coastline shapefile can be found at the EEA website (European Environmental Agency) https://www.eea.europa.eu/data-and-maps/data/eea-coastline-for-analysis-1

b. Cleaning points in harbour: The function pointInHarbour (VMStools) allows the removal of points which are too close to the harbour by setting a buffer zone around the position. A harbour position file is found in the VMStools package. It is important to check that the position of the harbours is accurate enough and also to test the size of the buffer zone.
c. Points out of the spatial range of the fleet.
d. Cleaning of effort: effort information is based on the time interval between two pings.
    i. Sometimes, the time interval between two points is much higher than expected and it can have a strong influence in our results. This can happen in the first ping of the day (due to the time difference with the previous ping) and also if there are missing data (transmission failures, misuse of the device, etc), and can be corrected using mean interval values.
    ii. It can also happen that for one trip there are very few pings with fishing activity (this is usually due to transmission failures). A threshold can be set, to remove those trips with very few pings

4. *Clean EFLALO files.*
    a. Check that departure dates are before arrival dates.
    b. Identify duplicate records based on trip id. This could happen if same trip lands in two different ports, in this case, it would be better to sum the two landings.

5. *Link TACSAT and EFLALO data.*

    This is a key point of the analysis. The trips defined in EFLALO are linked with geospatial data (TACSAT) using vessel and date information. This conform the basis in which the next steps are settled. Different options are available

    a. Use the mergeEflaloToTacast function from VMStools. It merges the TACASAT and EFLALO data based on the departure date and arrival date (from EFLALO) of a specific vessel.
    b. Ad-hoc function: This link can be also done with an ad-hoc function allowing more flexibility. For example, if there is not a direct link with vessel+landing date, the following dates may be tested with a loop to improve the link performance. This is relevant for SSF, as the selling is sometimes done some days after the landing takes place.

6. *Assignment of gear to TACSAT linked trips*

    This is important as it is the only way of assigning a gear to TACSAT data. Additionally, other trip-based information available in EFLALO files can be added.

7. *Identification of fishing pings:*

There are different ways to identify fishing activity:

a. In many cases, activity can be defined based on speed. Pings with registered speed below a threshold can usually be classified as fishing in the case of passive gears. For trawlers there will typically be two peaks in a speed profile: one at lower speed when fishing, and one at higher speed when steaming. The speed threshold may be different depending on the gear used and will need to be revised case by case
b. Other methods: Fishing activity can also be derived from TACSAT data using more sophisticated methods as statistical learning (Kroodsma et al. 2018, Thiebault et al 2018)

8. *Split catches among fishing positions*

   In this step, the catch coming from EFLALO is distributed among the geographical positions registered in TACSAT where fishing activity is assumed. Again, different options are available

   a. The function splitAmongPings (VMStools) is used for distributing the landings among the positions identified as fishing.
      i. Argument by="INTV" is used to distribute the landings relatively to the effort (time interval between the positions). If that is not specified, the landings will be distributed evenly between the number pings identified as fishing.
      ii. Argument "conserve" can be set to "FALSE", if we want to split only the catch corresponding to the linked trips, or "TRUE" if we want the whole catch to be split.
   b. Ad-hoc function: This splitting can be also done with an ad-hoc function allowing more flexibility. This can be relevant to test different allocation rules, as for example:
      i. In cases of a poor level of linked trips, we can use the combination of vessel+month+gear, to distribute the EFLALO catch among the corresponding pings.
      ii. The allocation of the total catch among linked trips (conserve=TRUE in the function splitAmongPings may also be done using different proportions/rules which may be adapted case by case.

9. *Summary statistics:*

   Due to the large amount of data being used in these kinds of analysis, and the varying quality of available data, it is important to evaluate the performance of the different transformations made, especially in steps 5 and 8. Some of the statistics that we found to be relevant to assess the quality and reliability of the analysis are the following:

   a. Number of pings with fishing activity each day/trip. This is useful to identify anomalous TACSAT trips due to transmission failures. It is important to remember that once TACSAT and EFLALO data are linked (step 5) the whole catch of each trip is distributed among the available pings. Therefore, a trip with very few fishing trips will concentrate all the catches on these pings.
   b. Performance of the trip-by-trip link:
      i. Number of trips from TACSAT/EFLALO which are linked.
      ii. Total kg from EFLALO which are linked

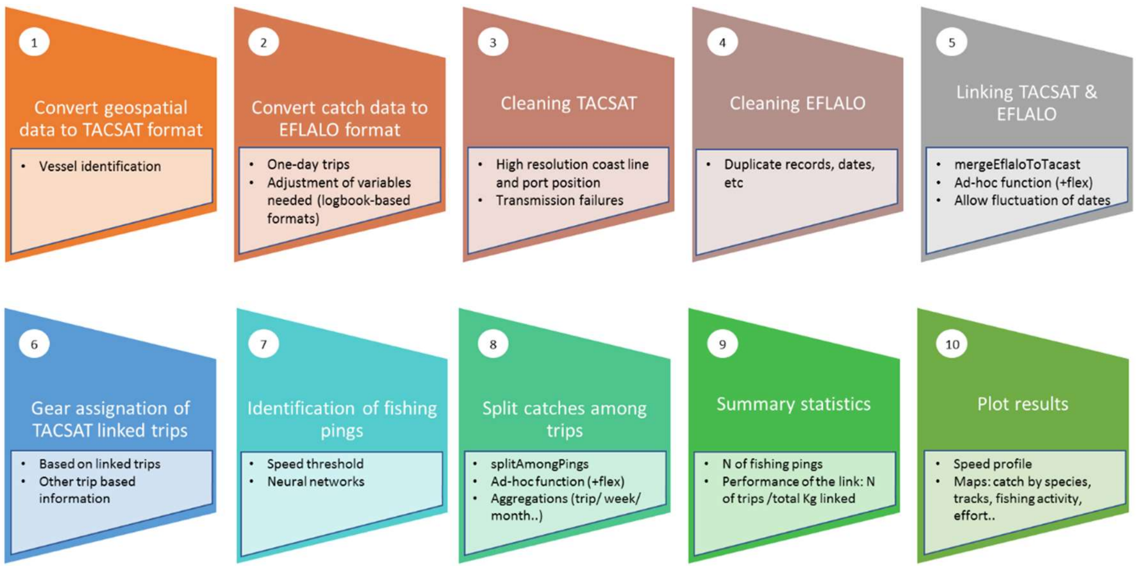
10. Plot results:

The plotting of the speed profile (speed vs time) gives also relevant information on how fishing activity is being discriminated

The main power of this kind of analysis is the ability of plotting variables at fine geographical scales. Some of the variables that can be mapped are:

a. Catches by species
b. Effort
c. Tracks
d. Fishing activity

The data were also aggregated to c-squares on 0.01 degrees resolution, rasterized and plotted in a leaflet, making it possible to zoom in on the fisheries.



Common issues found when analysing the AIS and sales notes data

AIS

It is important to be aware that while VMS data is with the purpose of fishing control, and not possible to switch off, the AIS data comes from a security system with the purpose to avoid collision between vessels. However, in the case of the small-scale fishery, VMS data is not available, and therefore it is tested if AIS data can provide information on the fishing activity. But it is important to keep the issues listed below in mind when working with and making conclusions based on these data.

- AIS is mandatory for fishing vessels above 15 meters (class A), but smaller vessels can have it voluntarily (class B). Real-time AIS positions of vessels are made public by e.g. marinetraffic.com. The signals can be picked up either by a land-based AIS station or by satellite if the vessel is far away from coasts.
- The AIS signal can be turned off manually. Some fishermen say that they turn off the AIS signal to keep good fishing grounds secret.
- There can be areas with bad AIS coverage, due to signals not reaching receivers due to e.g. topography
- The vessel ID is not part of the AIS data, so if coupling with other data sources like logbooks or sales notes, the vessel id has to be found another way. This can be through the radio call signal (IRCS), which is also part of the European fleet register. In some cases, the full radio call signal is not received, and the last digits might be missing. The vessels radio call code is not always updated in the fleet register.
- To filter points in harbours from the total AIS dataset, a buffer is created around harbour positions. In the case of small-scale fishery, vessels can be fishing close to the harbours, so the harbour points should be well defined, and the size of the buffer be considered, e.g. 500 meters.
- To filter points on land from the total AIS dataset, a good resolution coastline is necessary for small-scale fisheries, as the fishery can take place close to the coast. A high resolution coastline for Europe can be found at the EEA website (https://www.eea.europa.eu/data-and-maps/data/eea-coastline-for-analysis-1). The high-resolution coastline can make the R-script slow, and it is therefore recommended to cut the coastline polygon to the area that it relevant for the national small-scale fishery.
- Depending on the fisheries, the ping frequency might be an issue. For some fisheries, e.g. dredging, the fishing duration is only a few minutes.
- Sometimes there can be a variation in the ping frequency. This need to be considered when allocating of landings, therefore not distributing equally out on all positions with fishing activity, but taking the time interval between positions into consideration.

Sales notes data

- The day of the sales is not necessarily the same as the day of fishing. Therefore when merging with sales notes, the positions associated with the landings can be from the previous day. If data doesn't match directly by vessel-id and date, the landing date from the sales notes can be changed to the day before, or data might be aggregated by e.g. week.
- There can be fishing trips with no sales notes, e.g. where the landing is not sold through auctions, and therefore no sales note is available corresponding to an AIS trip.
- If combining AIS with sales notes, information on the fishing gear used is often missing, and have to be estimated based on data sources available.

Merged data

- The definition of a fishing trip in AIS data might be based on applying an algorithm to the AIS data, assessed visually, using the date (if the fishery conducted is day-trips) or using the logbook or sales notes information.

- When defining fishing activity vs. steaming for a position, it is normally based on a speed filter when working with VMS data. In ICES WGSFD 2018 (Working Group on Spatial Fisheries Data) (http://ices.dk/community/groups/Pages/WGSFD.aspx), speed filters applied to passive gears was investigated, with the conclusion that applying the speed filter is useful for locating fishing grounds.

Case study 1: Small Scale Fisheries in the Basque Country

Methodology

Vessels selected for this CS

Vessel selection. Vessel characteristics/small scale (very brief)

The vessels selected for this study were all the vessels included in the Spanish National fleet register census under the "minor gears" category and with a total length under 15 meters. In the case of the Basque Country this means around 70 vessels. These vessels are considered as SSF and their characteristics are very similar to the rest of the EU SSF fleet at EU level (multigear, fishing near the coastline, multispecies catches etc…). The installation of the devices was volunteer and although currently 80% of the fleet installed the AIS B, when this case study was carried out the number of vessels with AIS B was 24. However the results obtained here, could be extrapolated to the rest of the vessels.

Data source:

- Sales notes

Sales notes are available for all selected vessels landing in the Basque Country and can be considered as census data. They contain information on the vessel, landing port, landing date and species composition. The gear and metier are assigned with an algorithm based on the landing composition, information of the fleet register and logbook information when available. GNS and GTR were grouped in GXX as both gears are often deployed in the same trip. The main drawback of this source of information is the exemption to declare landings not exceeding 30kg, and the common practice of grouping similar species under a common commercial name. Additionally, a selling event not always correspond to a landing event: the catch of several fishing days can be grouped to be sold in one single day, and the catch of a single day can be split to be sold different days.

- AIS-B: short Description

AIS Class B transponders are designed to be used on marine small vessels and unlike the AIS class A, is not mandatory to have it installed. Each unit has a VHF Transmitter, two VHF receivers, one of which is multiplexed with the VHF Digital Selective Calling (DSC) Receiver, and a GPS active antenna. There are two categories of information transmitted by an AIS transceiver: Static and dynamic data.

The vessel's dynamic data, which includes location, Speed over Ground (SOG) and Course overground (COG), is calculated automatically using the installed AIS Antenna.

Static data is information about the vessel which must be programmed into the AIS transceiver. This includes:

- Maritime Mobile Service Identity (MMSI)
- Vessel name
- Vessel call sign (if available)
- Vessel type
- Vessel dimension

Data analysis

Sales notes and AIS data were converted to EFLALO and TACSAT format respectively, and checked for quality assurance following the workflow detailed above. Intervals higher than 30 min were identified as holes in the data transmission. Intervals higher than 5 min were set to 5 in order to avoid strong influential registers. Fishing activity was defined using a speed interval between 0.1 and 4 knots. Trips with less than 5 pings with fishing activity were removed to avoid highly influential registers.

TACSAT and EFALO trips were linked using an ad-hoc function based on the unique combination of vessel and day. In the cases where the matching was not direct, it was allowed the selling date to fluctuate from 0 to 4 days after the landing.

Catches were split among pings proportionally to the effort (interval). And three scenarios were tested:

1. By trip:
   Catches are split only in those trips which were linked (TACSAT & EFLALO)

2. By vessel + month + gear:
   Catches are split in those trips which were linked, and then, the total catch of the unique combination of "vessel + month + gear" (EFLALO) was split among all the trips linked for the same combination of "vessel + month and gear" (TACSAT). This is done to minimize the amount pf catches which could not be allocated.

3. The whole catch is split:
   The whole catch registered in the sales notes (EFLALO) is split, following the same proportions calculated in scenario 2 (By vessel + month + gear).

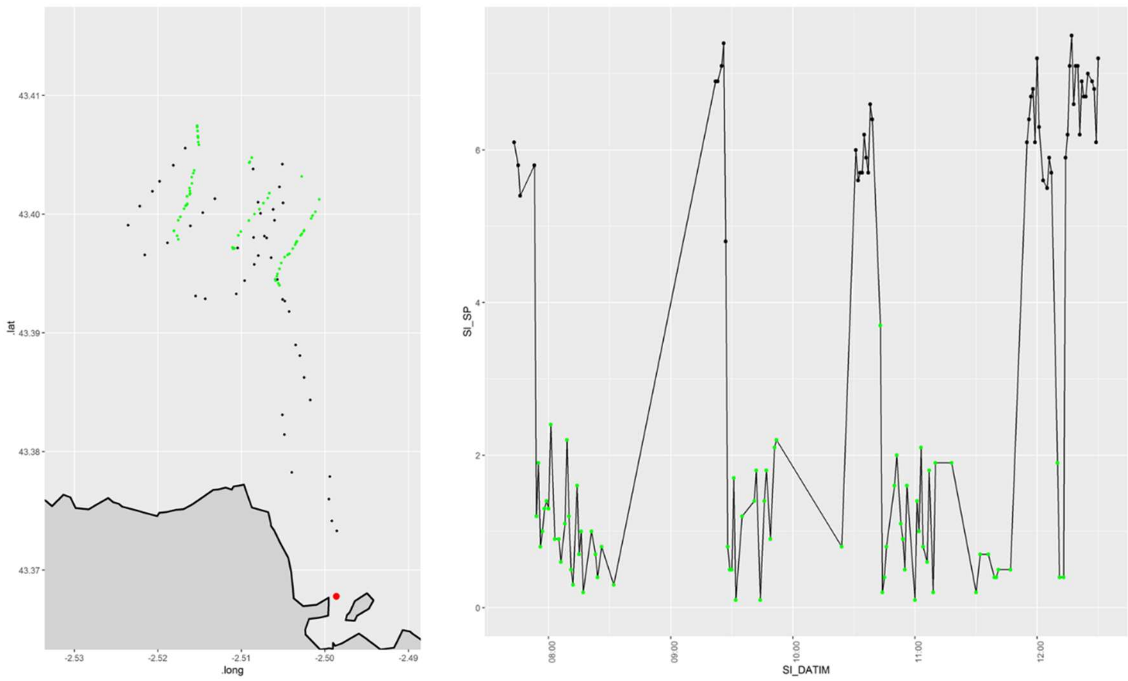
Results and discussion

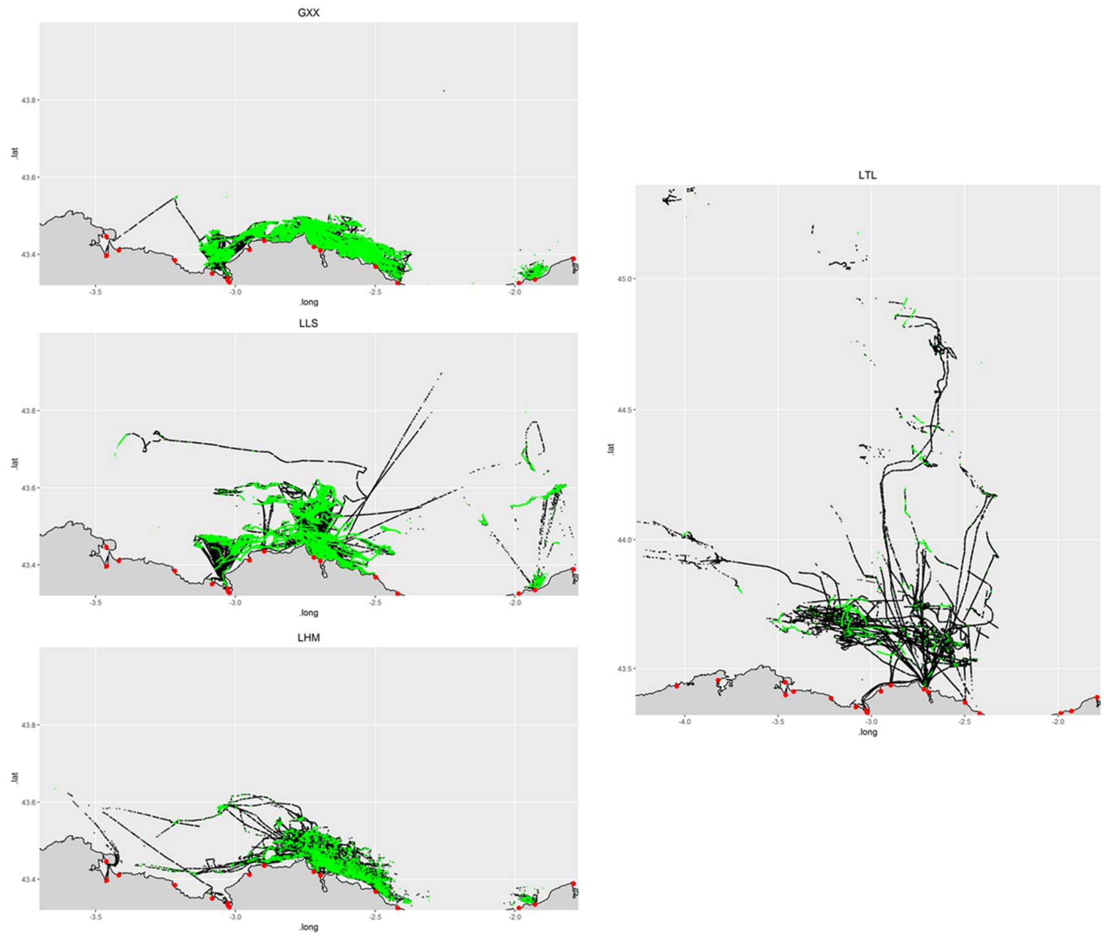
From 24 vessels with the AIS installed, we obtained geospatial data for 1949 trips, from which 1489 had some fishing activity and 1287 had more than 5 fishing pings. These were the ones used for the analysis (Table 10).

From all the trips presenting some fishing activity, 403 trips were identified to had at least one interval with more than 30 minutes from one ping to another. These holes were interpreted as transmission failures and they were corrected with mean interval time.

N Vessels	24
n Trips	1949
N Trips fishing	1489
N Trips fishing with hole	403
N Trips fishing with more than 5 pings	1287

Figure 23 shows an example of the pings registered for one single trip, highlighting the fishing trips in green. It illustrates how a simple method for defining fishing activity as the speed range can provide good results. Figure 24 shows the AIS pings per fishing gear.

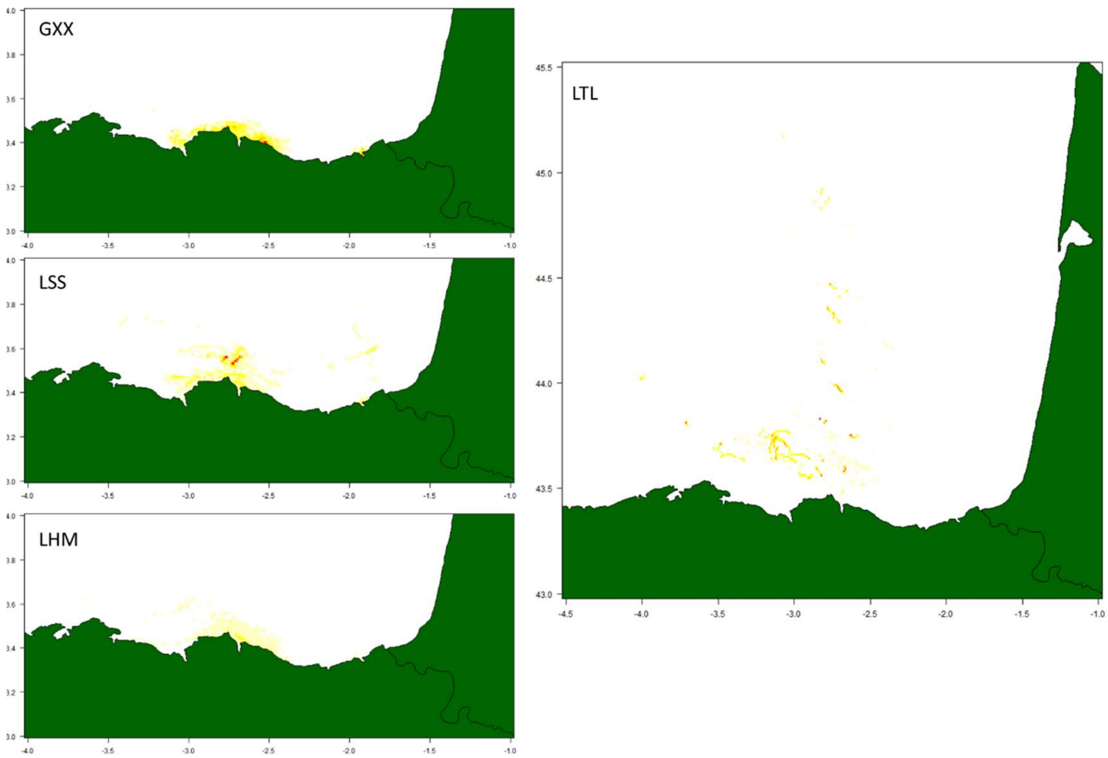


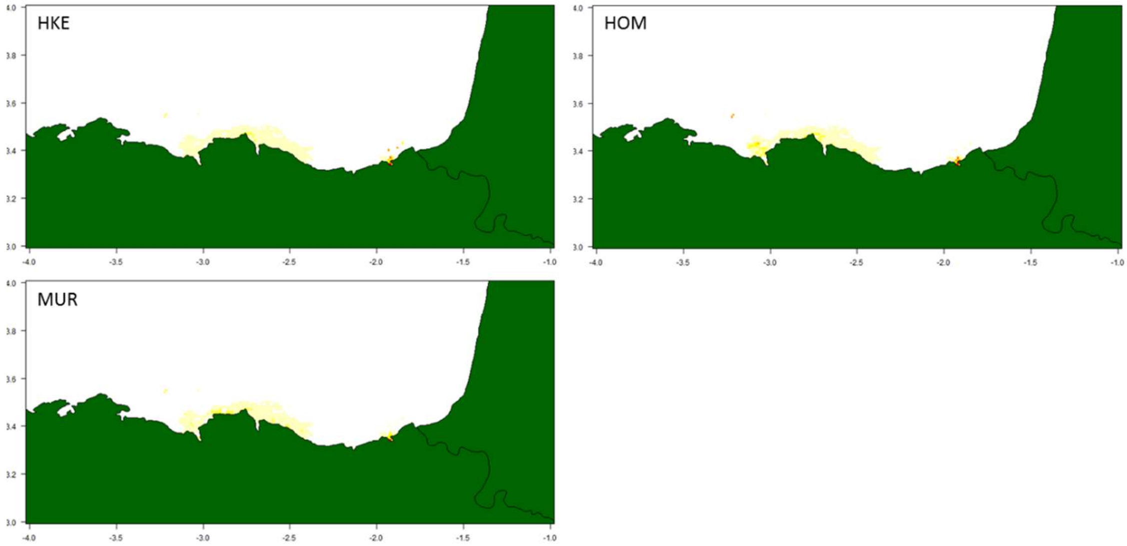


To calculate the percentage of Kg linked, only the main species targeted by each gear were taken into account (Table 11). In the first scenario, where the catch was split only among the trips which were directly linked, the percentage of catch split ranged between 34 and 49%. This percentage was significantly increased when using vessel*month*gear (scenario 2). 90% of the catch of handlines and 81% of the catch of gillnetters were split. The percentage for gillnetters was a bit lower (71%) and for tuna trolling lines presented the lowest values (56%), this can be due to catches being sold in ports outside the Basque Country.

	Sc 1: spliting by trip				Sc 2: spliting by vessel*month*gear				Sc 3: the whole catch is split			
gear	GXX	LHM	LLS	LTL	GXX	LHM	LLS	LTL	GXX	LHM	LLS	LTL
N trip EFLALO*	1,196	321	785	64	100	40	87	24	100	40	87	24
N trip TACSAT fishing*	593	206	272	50	73	35	55	12	73	35	55	12
n trip linked*	439	151	210	24	72	34	54	11	72	34	54	11
kg_tot_COE	708	-	33,883	-	708	-	33,883	-	708	-	33,883	-
kg_linked_COE	409	-	28,528	-	532	-	31,176	-	708	-	33,883	-
kg_tot_HKE	14,930	-	85,890	-	14,930	-	85,890	-	14,930	-	85,890	-
kg_linked_HKE	5,664	-	30,487	-	10,198	-	65,603	-	14,930	-	85,890	-
kg_tot_HOM	3,014	-	1,174	-	3,014	-	1,174	-	3,014	-	1,174	-
kg_linked_HOM	1,423	-	466	-	2,777	-	1,129	-	3,014	-	1,174	-
kg_tot_MAC	5,768	725,416	1,281	-	5,768	725,416	1,281	-	5,768	725,416	1,281	-
kg_linked_MAC	3,403	329,899	263	-	5,075	655,095	588	-	5,768	725,416	1,281	-
kg_tot_MUR	8,138	-	835	-	8,138	-	835	-	8,138	-	835	-
kg_linked_MUR	2,813	-	542	-	4,468	-	732	-	8,138	-	835	-
kg_tot_ALB	-	-	-	123,112	-	-	-	123,112	-	-	-	123,112
kg_linked_ALB	-	-	-	42,329	-	-	-	69,061	-	-	-	123,112
kg_tot	32,559	725,416	123,063	123,112	32,559	725,416	123,063	123,112	32,559	725,416	123,063	123,112
kg_linked	13,712	329,899	60,285	42,329	23,051	655,095	99,229	69,061	32,559	725,416	123,063	123,112
% linked	42%	45%	49%	34%	71%	90%	81%	56%	100%	100%	100%	100%

Figure 25 shows the spatial distribution of the fishing effort by fishing gear. And Figure 26, 10, 11 & 12 present the spatial distribution of the catches of the main target species for each fishing gear.

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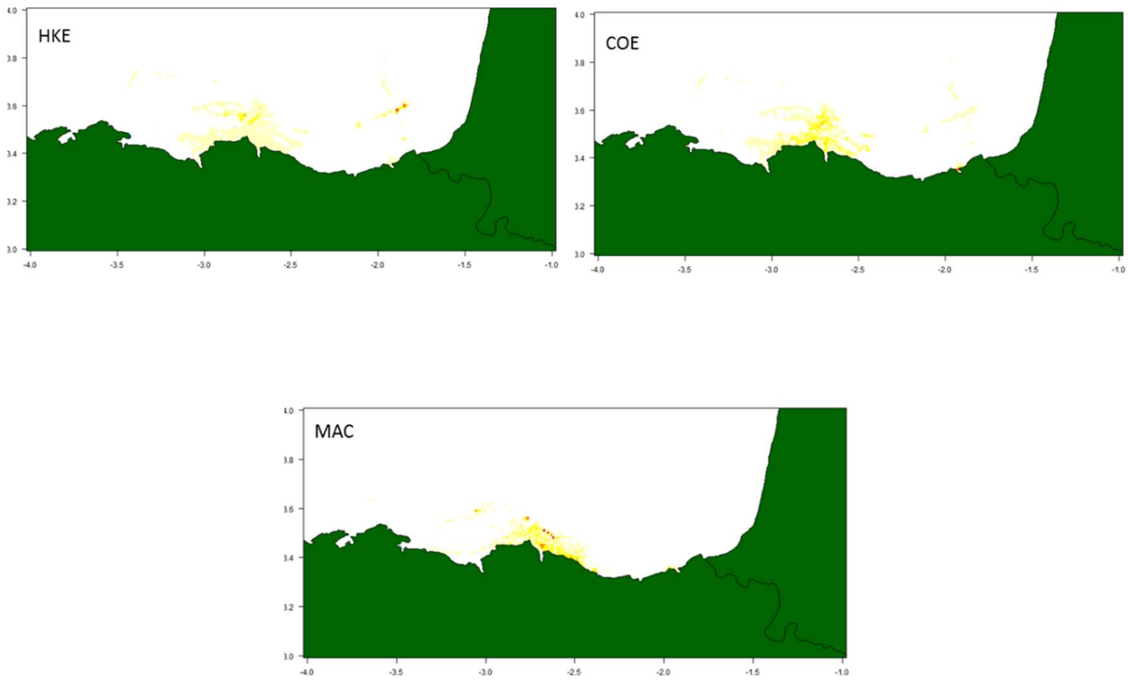
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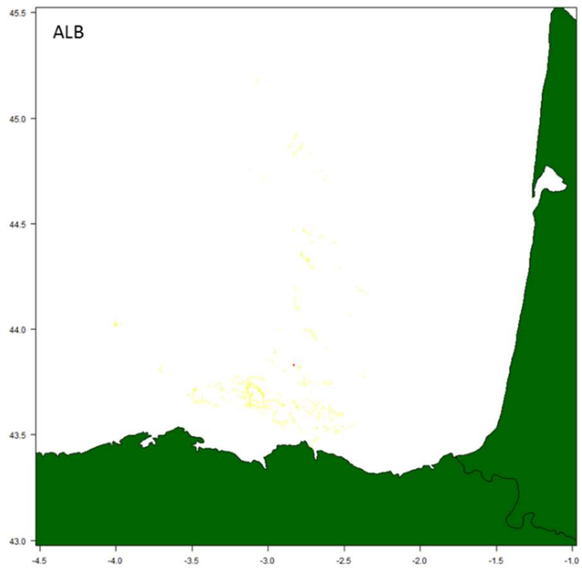
ALB
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Case Study 2: AIS data for vessels that doesn't have VMS – Danish case study

Methodology

In Denmark the VMS data have a position frequency of one hour and are available for vessels >=15 m from 2005-2011 and for vessels >=12 m from 2012 onwards. It is investigated if the AIS data can supplement the VMS data for the smaller vessels that doesn't have VMS. AIS data from the Danish Maritime Agency, that picks up AIS positions in Danish waters, have been made publicly available from 2006 onwards.

The table 1 below based on data from 2017 show that when looking at landings and value of landings, the small-scale fishery in Denmark is of low importance, but when looking at the effort (number of trips) and number of active vessels, it is an important fleet segment.

Table 1: 2017 small-scale fishery in Denmark.

Vessel length group	Landing (ton)	Value of landings (EUR)	Number of trips	Number of active vessels
<10	5,118	16,442,896	28,965	1,045
10-12	11,308	11,948,034	8,727	111
>=12	891,103	430,574,214	29,275	372

To be able to merge the AIS data with logbook/sales notes data the vessel-id is found through merging with the fleet register by call sign. In some cases where this wasn't possible, the vessel id was found directly from the AIS vessel name. To reduce the amount of data, the AIS data has been filtered to approximately one ping every 5 minutes. Based on information on the gear used, a speed filter is applied to the AIS data. For this project, the focus in the Danish case study has been on how AIS data can contribute on information on vessels that doesn't have VMS.

Figure 1 shows an example of speed filtered VMS and AIS positions from one vessel equipped with both systems in 2017. It shows that with the higher frequency data in AIS (5 minutes) than in VMS (60 minutes), the fishing tracks better represented. In the case of trawling, good algorithms have been developed to interpolate the fishing tracks between VMS positions (e.g. Hintzen, 2010), but the fishing pattern is different in the case of passive gears.

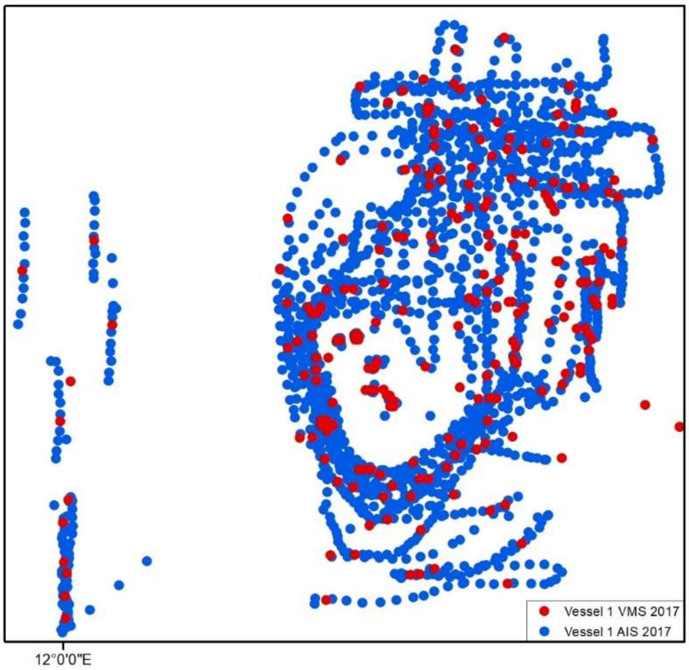

Figure 1: Example of speed filtered VMS positions (red) and AIS positions (blue) from one vessel in 2017.

In table 2 the coverage of VMS and AIS in number of trips in the main fishing areas for Danish vessels is found. It shows that the AIS data can supplement the VMS data, especially in the case of passive gears, but there is a big variation in the coverage depending on area and gear. Vessels fishing in areas with a lot of traffic are more likely to have AIS installed.

Sales notes data

In Denmark there is census data on sales notes, meaning that for the trips where there is no logbook data (vessels < 10 m oal/8 m oal in the Baltic), there is a sales note with the landing date and landing composition. For the trips with logbook information, the gear used is directly known, but for the trips with only sales notes information, an algorithm has been developed to estimate the gear and métier based on the landing composition, gear from the fleet register (quality checked by observers), information about the fishery going on within the same time period, area and with similar landing compositions.

Data coverage

Table 2: Coverage of VMS and AIS in number of trips 2017 in main fishing areas for Danish vessels. All vessels. For vessels without logbooks, the trips are based on sales notes and the gear is estimated.

Area - Gear group	Total number of trips	Number of trips with VMS	Number of trips with AIS (without VMS)	% trips with VMS	% trips with VMS and AIS
3AN					
Beam trawl DEF	13	13	0	100	100
Bottom trawl	9353	7230	1606	77	94
Gillnet	5619	857	1412	15	40
Longlines	227	0	95	0	42
Pelagic trawl	232	220	1	95	95
Demersal seine	1303	1303	0	100	100
3AS					
Bottom trawl	6524	5444	472	83	91
Gillnet	3703	85	551	2	17
Longlines	1	1	0	100	100
Pelagic trawl	71	67	0	94	94
Pots and traps	122	0	0	0	0
Demersal seine	1	1	0	100	100
3B					
Bottom trawl	170	27	16	16	25
Gillnet	2757	63	387	2	16
Longlines	20	0	0	0	0
Pelagic trawl	8	8	0	100	100
Pots and traps	285	0	0	0	0
3C22					
Bottom trawl	2469	1190	143	48	54
Gillnet	7239	385	199	5	8
Pelagic trawl	80	7	0	9	9
Pots and traps	436	0	0	0	0
Demersal seine	208	144	0	69	69
3D24					
Bottom trawl	663	528	68	80	90
Gillnet	1985	0	197	0	10
Longlines	313	1	42	0	14
Dredges	1	0	0	0	0
Pelagic trawl	254	254	0	100	100
Pots and traps	250	0	0	0	0
Demersal seine	27	26	0	96	96
3D25					
Bottom trawl	1492	859	255	58	75
Gillnet	1039	0	83	0	8
Longlines	147	2	43	1	31
Pelagic trawl	98	98	0	100	100
4A					
Beam trawl Crangon	6	6	0	100	100
Bottom trawl	636	636	0	100	100
Gillnet	18	18	0	100	100
Pelagic trawl	128	128	0	100	100
Purses seine	9	9	0	100	100
Demersal seine	161	161	0	100	100

4B					
Beam trawl DEF	58	58	0	100	100
Beam trawl Crangon	1884	1884	0	100	100
Bottom trawl	2295	1926	182	84	92
Gillnet	3673	1362	537	37	52
Longlines	3	0	0	0	0
Dredges	1	0	0	0	0
Pelagic trawl	567	560	3	99	99
Pots and traps	61	58	0	95	95
Demersal seine	119	119	0	100	100
4C					
Beam trawl Crangon	1	1	0	100	100
Bottom trawl	11	11	0	100	100
Gillnet	26	26	0	100	100
Pelagic trawl	5	5	0	100	100

Results and discussion

In the figures 2 the VMS data and AIS data are drawn together in total and by the gear groups bottom trawls, gillnets, lines and pots and traps. The VMS data in blue is overlaying the AIS data in orange to illustrate areas where the AIS data are showing fishing activity not found using the VMS data.

As a test, the AIS data merged with logbook/sales notes data were converted into the ICES VMS/logbook data call format. As the AIS positions are of higher frequency than the VMS data, the grid resolution can be on a finer scale. The VMS data are reported on a 0.05 degree grid, while the AIS data can be reported on a 0.01 degree grid. Maps in the 0.01 resolution are found in figure 3 for Mobile Bottom Contacting Gears and Gillnets. In figure 4 the difference in resolution in VMS (0.05) and AIS (0.01) data is shown in a zoomed-in example.

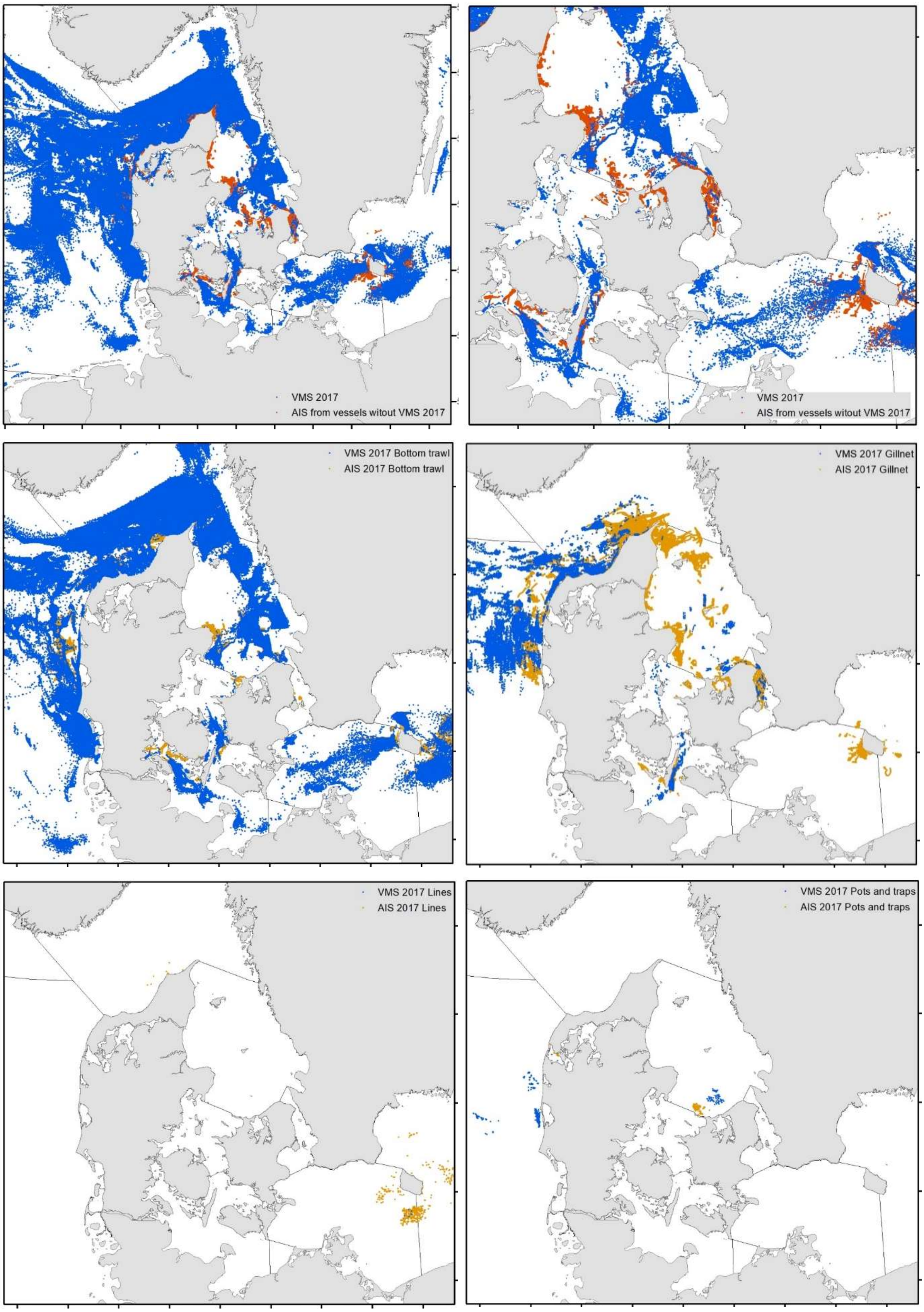

Figure 2: VMS data and AIS data from 2017 in total and by the gear groups bottom trawls, gillnets, lines and pots and traps. The VMS data in blue is overlaying the AIS data in orange.

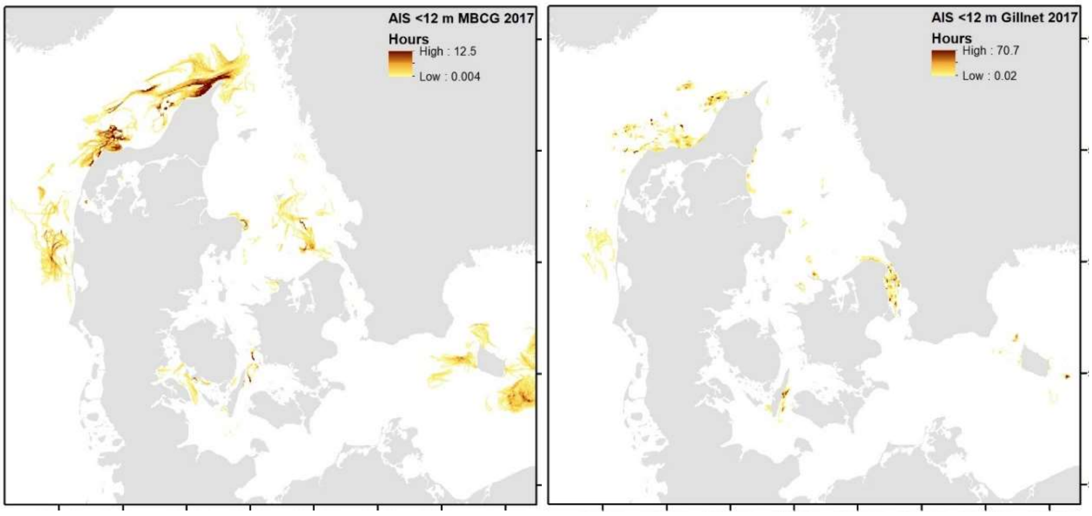

Figure 3: AIS positions for vessels less than 12 m 2017 with a grid resolution of 0.01 degreew. Mobile Bottom Contacting Gears (left) and Gillnets (right).

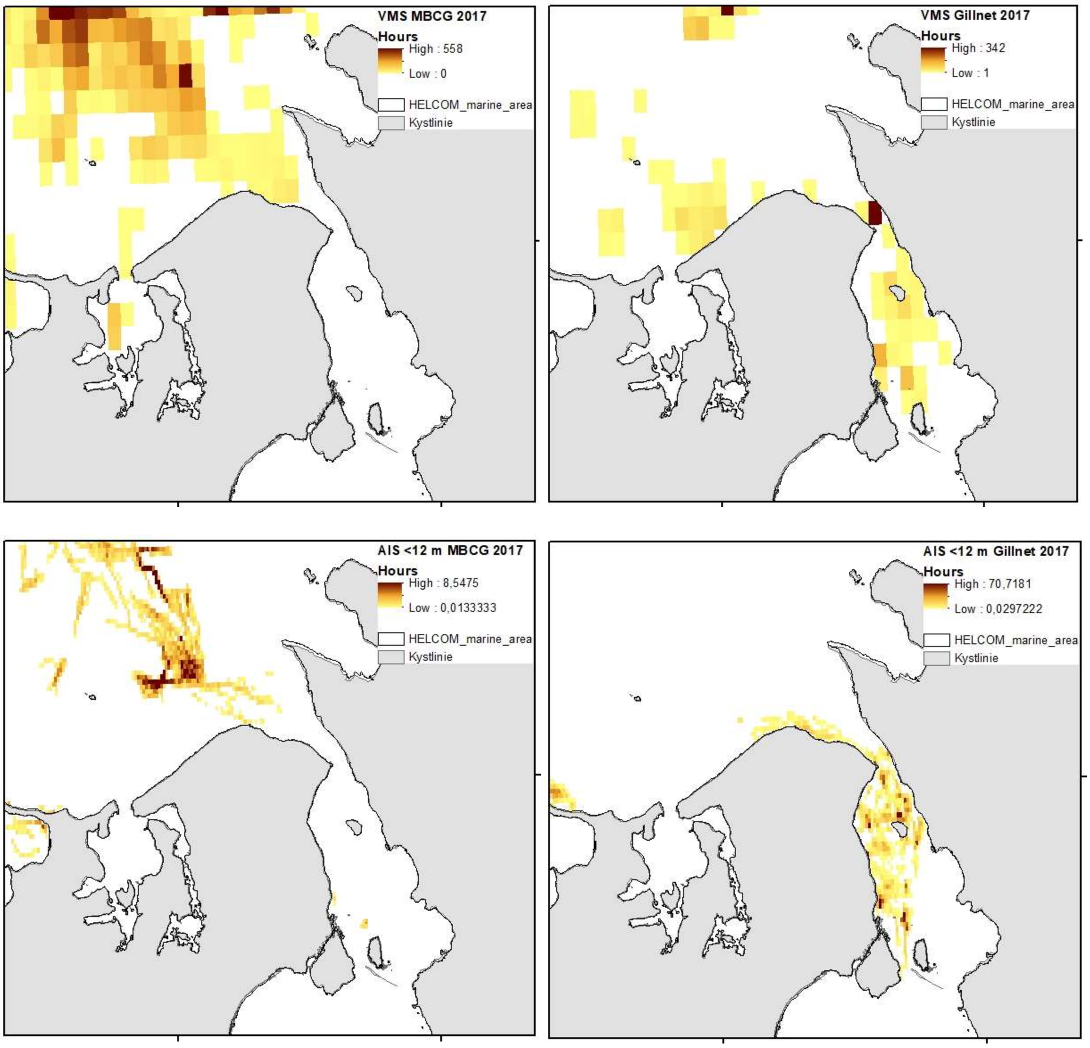

Figure 4: Figure showing zoomed-in examples of the difference in resolution with VMS (>=12 m) on 0.05 degrees resolution in the upper panels and AIS (<12 m) on 0.01 degrees resolution in the lower panels.

Common conclusions and recommendations

- This study shows that for the SSF where VMS and logbook data are usually not available, it is possible to use existing AIS and sales notes to describe the spatial distribution of the fleet and highlight relevant fishing grounds. The proposed workflow is similar to the established VMS/Logbook methods.

- AIS data are not as reliable as the VMS data and they present problems as transmission failures (and subsequent lack of pings), difficulties to link catch dates with selling dates, lack of gear information and incomplete coverage of the fleet. On the other hand, they also present advantages, such as higher spatial and temporal resolution and the ability of registering positions very near to the coastline.

- With the correct procedures in data depuration and analysis, AIS data can be used to illustrate the spatial distribution of the fisheries at high spatial and temporal resolution (the full fisheries or a part of them). This is especially relevant, as there is a general lack of information from the small-scale fishery. VMS data are at present used for many purposes, including marine spatial planning, Natura 2000 and MSFD processes. VMS data have often been used to illustrate where the fisheries are taking place and the value of landings within areas that are proposed to be closed. The lack of VMS data for SSF has been a major caveat for vessels below 12, which are often more dependent on local fishing grounds. Geospatial devices such as AIS provide information to perform high-resolution spatial analysis that can be a useful tool for the management of SSF.

- Under the MSFD there is ongoing work on fishing pressure indicators and impact indicators, e.g. in the ICES working group WGFBIT, and the resulting indicators will be underestimated when including the data from small-scale fisheries. In addition, when combining the fishing pressure data with habitats and other structures and activities in the marine environment, it is often mentioned that the spatial scale of 0.01 that is currently used is too coarse. AIS data with the much higher position frequency then the 2 hour minimum from VMS data might supplement the VMS data to make higher resolution data at 0.01 degrees.

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Annex 5.4 A simulation framework to test the influence of recreational data quality on sea bass (*Dicentrarchus labrax*) management

Executive Summary

The European sea bass is widely distributed in the Northeast Atlantic shelf waters, with the northern stock unit covering the North Sea, Channel, Celtic Sea and Irish Sea. Over that past 10 years, the northern stock has declined rapidly due to a combination of poor recruitment and increasing fishing mortality, leading to management measures for both commercial and recreational fisheries. Recreational catches of sea bass are a large proportion of total removals, representing at least 25%. However, recreational data are limited with only a single estimate from 2012 used in the assessment. Hence, there is a need to understand how uncertainty and bias in recreational fisheries catches impact the assessment, the advice and ultimately the status of the stock.

Here, the risk associated with varying levels of uncertainty in estimates of recreational catches was assessed using a management strategy evaluation (MSE) framework. A closed loop simulation framework was developed for Stock Synthesis based on the current assessment and advice approaches. Comparison of the performance of the assessment and harvest rules were made for different scenarios for the quality of recreational data, expressed as bias and precision. This performance was measured using indicators such as the risk of falling below reference points and analysing recovery trajectory trends. The outcomes were used to test and validate the potential of the tool for assessing implications of recreational data quality for management and inform regional sampling.

As the initial aim of the study was to develop the approach, the results are mainly illustrative. The highest long-term risk to the stock was if the recreational sector caught more than the catch advice, compared to catching the advised limit with some level of noise. The scenario where catch observations were systematically under-estimated was not run here. In situations where the realised recreational catches varied around the advice but remained unbiased, results did not suggest an advantage of collecting noisy data over assuming that the recreational sector caught the advised quota. However, this implied knowledge of non-bias which can only be known in the real world with existing data. Further simulations were needed to assess the impact of a broader range of uncertainty.

Several assumptions were made to build the closed-loop simulation framework, to check that it performed as expected and to generate results. Firstly, recruitment was assumed to be at a historical average, when recruitment is known to be variable. It was also assumed that the commercial catch data quality was high, the commercial fleet complied with quotas, the recreational fishers caught up to 50% of the total, and F varied between years depending on the harvest rules and without restrictions on yearly rates of increase or decrease. These assumptions can be relaxed in future scenarios, where necessary. Before the framework can be used to support advice, further model development is needed. This should include testing a more efficient computational approach to reduce run times.

Once the level of uncertainty in the regional recreational catch estimate that leads to an impact on the current assessment has been estimated, it is possible to use this to derive a regional sampling programme for an individual stock. However, designing a single optimised regional sampling programme for recreational fisheries is complex. Partitioning sampling effort between countries depends on stocks, spatial extent, exploitations rates, and assessment method, and will change over

time. As a result, further work is needed to assess how to design recreational fisheries regional sampling programmes to deal with data needs for all stocks, and should include case-studies at the regional sea level.

Introduction

Sea bass (*Dicentrarchus labrax*) is widely distributed in the Northeast Atlantic shelf waters. Although stock identities remain uncertain, ICES recognises four stock units. Analytical stock assessments have been done for the Northern (ICES divisions 4b&c, 7a, 7.d–h) and Biscay (ICES divisions 8a&b) stocks. Despite the commercial and recreational importance for several countries in Europe, particularly France and the UK, sea bass are not under quota management and assessments are only used to provide advice on effort management measures such as bag limits for the recreational sector or closed seasons (ICES 2018a;b). Estimation of recreational fisheries catches is a challenge, so several assumptions have to be made to carry out the assessment. Developing a management strategy evaluation (MSE) for sea bass can inform the impact of current management measures and data limitations on the stock and for assessing alternatives. An MSE is done using simulations to evaluate management strategies. It involves a combination of data collection schemes, specific analyses applied to these data, and harvest control rules to determine management action based on the results of these analyses (Punt et al. 2016). The MSE can be used to compare competing scenarios for data collection and management and provide an assessment of uncertainty.

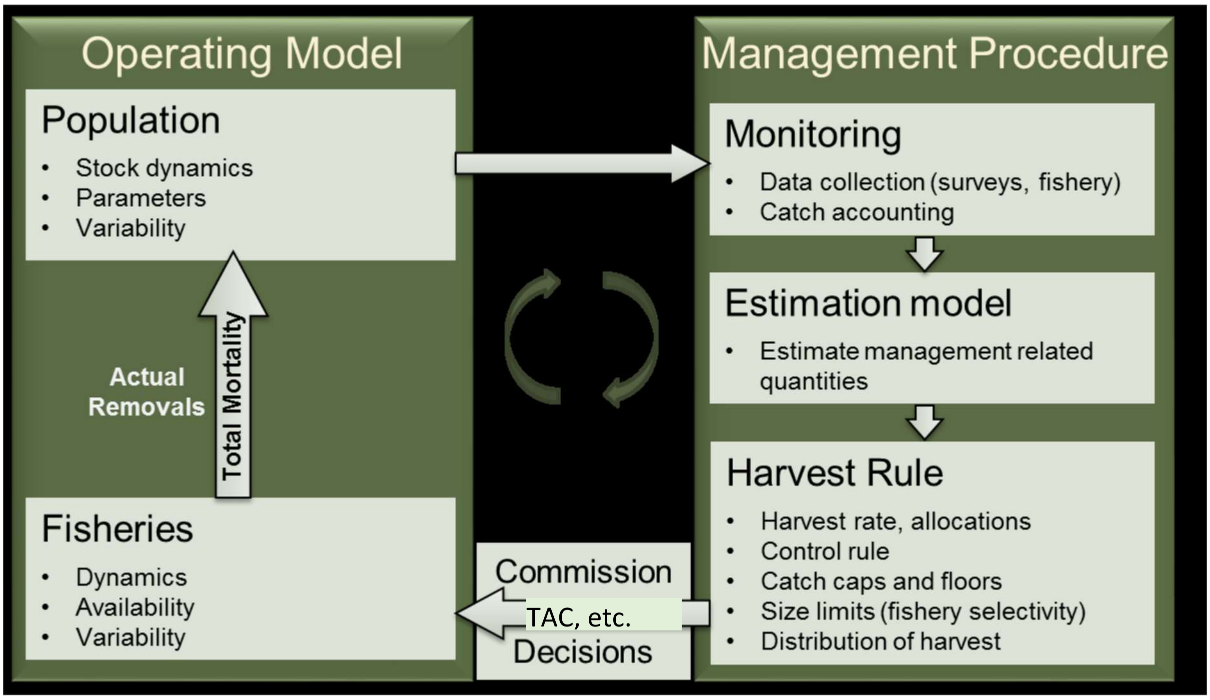
Fisheries management in the European Union relies heavily on scientific advice, and is therefore dependent on accurate, relevant, and up-to-date data. The collection, management, and use of data has been regulated since 2001 by the Data Collection Regulation (DCR; EC, 2001), the Data Collection Framework (DCF; EC, 2008a; EC, 2008b), and currently under the Regulation (EU) 2017/1004 of the European Parliament and of the Council of 17 May 2017. For recreational fisheries data, estimates of catches and releases are required for Atlantic cod, European sea bass, European eel, Atlantic bluefin tuna, Atlantic salmon, pollack, and all elasmobranchs, with variation in species requirements across regions. The statutory requirement to collect recreational fisheries data has been present in European data collection legislation since 2001, but the development of surveys has been slow due to the challenges with data collection. Since scientific assessments of marine fish stocks in Europe have focused on the impacts of commercial fisheries, these have become the main target for data collection. As a result, there is still limited data on marine recreational fishing (MRF), mainly due to the challenges of delivering robust surveys and the varied and dispersed nature of MRF. This has made inclusion of recreational fisheries in stock assessment challenging (Hyder *et al.* 2014, 2017), despite the significant social and economic impact of MRF and its impact on fish stocks (Hyder et al. 2017, 2018). Recreational removals (kept fish plus post release mortality) can be significant, representing between 2 and 43% of total catches for some stocks (Hyder et al. 2017, Radford et al. 2018). This suggests that there is a need to include information on recreational fisheries in stock assessment and management processes to ensure sustainable exploitation of fish stocks (Lewin et al., 2006).

Currently, the Northern sea bass stock assessment relies on a single estimate of recreational catches from 2012 (ICES 2018 a,b). The assessment assumes that recreational fishing mortality is constant over time, until 2015 when management measures were implemented. However, neither the robustness of the assessment to uncertainty in recreational catches, nor potential approaches for regional sampling have been explored. Here, an MSE framework is developed to test the risk associated with diverse levels of knowledge and uncertainty in recreational catch data. The results in the present study are mostly illustrative and focuses on detailing the development of the model, checking its performance and highlight the usefulness of the MSE framework in the context of testing data quality scenarios. Challenges and limitations to the approach are highlighted and key next steps identified.

Methods

Simulation framework

A closed loop simulation framework was used to test the effect of various degrees of knowledge of the recreational catch on the performance of the harvest rule. The framework of the simulations can be described in four main modules: the operating model (OM) and the management procedure (MP) split into data generation, estimation model, and harvest rule (see Figure 1). The simulations were coded in R (R Core Team (2018)) and relied mostly on the *r4ss* and *Ensemble* packages (Taylor et *al.* 2019, Hicks 2019), building on the framework developed at the International Pacific Halibut Commission (Hicks and Stewart 2018).



Operating Model (OM)

An OM is a representation of the population and the fishery, or the underlying "truth" in the simulations. It produces the total numbers-at-age, accounting for mortality and any other important processes. The ICES 2018 assessment was translated into the latest version of SS, V3.30 (Methot and Wetzel 2013), and used to condition multiple replicates of the OM. The replicates were a set of seabass populations with realistic parameters derived from the variance-covariance structure of the current assessment in order to incorporate uncertainty, using the *Ensemble* package (Hicks 2019). The original assessment model is presented in the section: “Seabass northern stock fishery and ICES assessment” and the conditioning approach and creation of OM replicates in section: ”Operating model (OM)”.

Management Procedure (MP)

Following the ICES advice procedure, the SSB on 1 January of the intermediate year (y) that follows the last year of data (y-1) was used to provide the catch advice for the following year (y+1). A set of harvest rules was adapted from those used by the ICES for the Northern sea bass stock assessment. This advice was translated into a realised catch and used to project the population one year forward in the OM. Projections were run for 35 years, period determined from test runs of the different scenarios, to allow comparison between outputs after the model had stabilised.

Different scenarios influenced the population (OM) by affecting advice and catches (realised and observed), because errors and biases were integrated into the data and advice generation processes in the MP. Two main approaches, or scenario types, were used in the MP. First, perfect knowledge of the catch was assumed to test implementation error consequences and serve as a baseline for the second type of scenarios. Second, an estimation model was included that focussed on uncertainty in the data and was used to test measurement error consequences. The estimation model was the same as the assessment model used by ICES for advice for this stock. Uncertainty was introduced using a constant level of bias or error in the advised catch, leading to scenarios where realised catches differed from the advice. In the estimation scenarios, additional uncertainty was added to the observed catch included in the assessment.

Scenarios

Perfect knowledge scenarios (A) were used to check the model, test the harvest rules, and run implementation error scenarios that served as a baseline to be compared against the estimation scenarios (B). In scenarios A, “perfect knowledge” means that the OM is known and an assessment is not needed as population size and other characteristics are known, so there is no need to collect data (Table 12). Three perfect knowledge scenarios (A) were tested: A0 where removals followed the advice (i.e. baseline or reference case); A1 where recreational fishers caught more than the advice (positive bias); and A2 where there was some variation in recreational removals compared to the advice (Table 12). Estimation scenarios (B) were used to test the influence of the data quality on the robustness of the advice. Two main alternatives were considered: recreational fishery data existed (B0-B3) or did not exist (B4-B5) (Table 12). Scenarios B0-B2 were equivalent to A0-A2 with perfect catch estimates included in the assessment (observed catch = realised catch). B3 included some noise around both the realised and observed catches (i.e. equivalent to B2 but with imperfect data). In the last two scenarios, B4 and B5, it was assumed that no observations of recreational catches were available. The assessment therefore assumed that the recreational fishery followed the catch advice (which is close to the real situation for sea bass). B4 simulated a positive bias in the realised recreational catches (such as A1 and B1) and B5 some noise compared to the advice (such as A2, B2 and B3) (Table 12). To illustrate and test the framework, a bias of +50% and noise with a CV of 50% were used.

In all scenarios, the commercial fishery was assumed to follow the advice perfectly. No error was added to the commercial catch in any of the scenarios, either in terms of realised or observed catch. The framework offers the possibility to run such scenarios into the future to assess the impact of this uncertainty on the assessment, but here the focus was on the quality of the recreational data to develop and validate the framework, with other sources of uncertainty limited.

Approach	Scenario	Realised catch	Observed catch
Perfect knowledge	A0	Advice	-------
	A1	Advice + bias	-------
	A2	Advice + noise	-------
Estimation	B0	Advice	Perfect
	B1	Advice + bias	Perfect
	B2	Advice + noise	Perfect
	B3	Advice + noise	Realised catch + noise
	B4	Advice + bias	No data – assumes advice
	B5	Advice + noise	No data – assumes advice

Seabass northern stock fishery and ICES assessment

Assessment model and data

The seabass fishery is composed of an offshore component on pre-spawning and spawning seabass in winter (November-April) mainly targeted by France and UK pelagic trawlers before they were banned in 2015. There is also a small-scale fishery catching mature fish returning to coastal areas following spawning and discarding some immature fish; they operate using a variety of gears including trawl, handline, longline, nets and rod and line.

The 2018 ICES assessment model (ICES, 2018b) was run in Stock Synthesis (SS) (Methot and Wetzel 2013). The data sets used are presented in Ta

ble 13 and model parameters in Table 14. A full description of the approach can be found in ICES (2018a,b), so only a brief summary is provided here. The assessment period is from 1985-2017 with landings split between one recreational and five commercial fishing fleets. The five commercial fleets included were: UK trawls and nets (UKOTB_nets); UK lines (Lines); UK pelagic trawlers (UKMWT); all gear combined for France (French); and all other countries and gears combined (other). A time series of discards was included for the UK trawls and nets from 2002 and the French fleets from 2009. Length and age composition of landings and discards of the UK commercial fleets have been collected since the beginning of the assessment period using observer and port sampling programmes. For France, lengths composition data exist since 2000 and age-length keys since 2008. The recreational fleet time series was reconstructed from the 2012 estimate for 1985-2017, assuming constant F over years before 2015. From 2015, multipliers for the recreational fishing mortality were calculated from 2012 catches and represented reductions due to the different management approaches including increase in minimum landing size, daily bag limits, and a closed season. Release rates of sea bass have been demonstrated to be high (Armstrong et al. 2013, Ferter et al. 2013), so it is important to include mortality of the released fish, with post release mortality assumed to be 5% (Lewin et al. 2018). Two fisheries-independent indices were used to tune the assessment: the Cefas Solent Autumn survey (AutBass) which provides a recruitment index, and the French Channel Groundfish survey (CGFS) which produced an index of adult abundance. In addition, a French landings per unit effort (LPUE; 2001 onwards) was also used to tune the model.

Data	**Northern stock (4.b–c, 7.a, and 7.d–h)**
Commercial landings	- Official statistics 1985-2017 (UK + pre-2000 rescaled for French data) - French landings 2000-2017 from separate analysis of logbook and auction data by métier - Landings by Belgium and Netherlands since 2000 - 5 fleets in the assessment: UK trawls, nets; UK lines; UK pelagic trawlers; France combined gears; Other countries and gears
Discards	- No Spanish discards - Netherlands discards for 2004-2010 (not included in assessment) - Discards for UK trawls, nets since 2002 and French gears since 2009.
Commercial length and age	- Length and age composition of UK trawls, nets and lines landings since 1985 - UK trawls, nets discards lengths since 2002 - UK pelagic trawlers landings length and age to 2012 - Length and age composition of French commercial fleet since 2000 - Age length keys for French fleet since 2008
Recreational data	- Post release mortality of 5% - Catch data reconstructed based on 2012 reference year and assuming constant F over years with changes in most recent years due to management measures - Length data for 2012
Abundance index	- 2 surveys: Cefas Solent Autumn survey – Index + Age data since 1986; France Channel Ground Fish Survey – Index since 1988 + Length data 1991-2014 - French LPUE (landings per unit effort) since 2001
Biological information (complete information in Table 2)	- Growth estimates Linf = 84.55cm K=0.097 - Maturity L50 female= 40.65cm - Natural mortality – estimated from life history data – fixed at 0.24
Stock-recruitment and Reference points	S-R segmented regression B_{lim} = 9,618 t B_{pa} = 13,465 t F_{pa} = 0.211 $F_{MSY} = F_{P.05}$= 0.203 MSY $B_{trigger} = B_{pa}$ = 13,465 t

Parameters (parms)	Name	Value	Estimated	Lower bound	Upper bound
Biology					
Natural mortality (years-1)	M	0.24	No	**0.01**	**0.5**
Minimum age (years)	a1	2	No	_	_
Maximum age (years)	Amax	28	No	_	_
Length at a1 (cm)	L1	19.67	No	_	_
Length at Amax (cm)	L∞	80.26	No	_	_
Growth rate (year -1)	K	0.097	No	_	_
CV young	CV1	3.47	Yes	2	6
CV old	CV∞	5.61	Yes	4	10
Length–weight scaling (kg cm)	alpha	1.30E-05	No	_	_
Allometric factor	beta	2.969	No	_	_
First age mature (years)	omega 2	4	No	_	_
Maturity slope (year -1)	omega 1	-0.33	No	_	_
Length at 50% maturity (cm)	L50	40.65	No	_	_
Recruitment					
Log mean virgin recruitment	ln R0	10.2	Yes	1	16
Steepness	h	0.999	No	**0.2**	**0.999**
Recruitment variability	sigmaR	0.9	No	_	_
Survey catchability					
Survey AutBass catchability (log-scale)	ln q	-7.24	No	_	_
Survey AutBass catchability SD	sd q	0.23	Yes	0	1
Survey CGFS catchability (log-scale)	ln q	4.2	No	_	_
Survey CGFS catchability SD	sd q	0.27	Yes	0	1
French LPUE catchability (log-scale)	ln q	-10.08	No	_	_
French LPUE catchability SD	sd q	0	Yes	0	1
Fleets selectivities					
UKOTB_Nets - 6 parms double-normal length	peak	40.97	Yes	20	93
	top_logit	-15	No	_	_
	ascend_se	4.56	Yes	-1	9
	descend_se	6.39	Yes	-1	9
	start_logit	-999	No	_	_
	end_logit	-999	No	_	_
UKOTB_Nets -4 parms retention curve	ascend_inflection	33.78	Yes	20	50
	ascend_slope	1.37	Yes	0.61	10.01
	max_retention	10	No	_	_

Parameters (parms)	Name	Value	Estimated	Lower bound	Upper bound
	male_offset	0	No	_	_
Lines - 2 parms logistic length selectivity	inflection	37.8	Yes	20	91
	width 95% selection	4.71	Yes	0.01	30
UKMWT - 2 parms logistic length selectivity	inflection	42.68	Yes	20	91
	width 95% selection	4.45	Yes	0.01	30
French - 6 parms double-normal length selectivity	peak	62.32	Yes	20	91
(mirrored by Other)	top_logit	-15	No	_	_
	ascend_se	6.37	Yes	-1	9
	descend_se	9	No	_	_
	start_logit	-999	No	_	_
	end_logit	9	No	_	_
French - 4 parms retention curve	P1	35.72	Yes	30	50
	P2	0.73	Yes	0.61	10.01
	P3	1	No	_	_
	P4	0	No	_	_
Recreational - 6 parms double-normal length	peak	51.98	Yes	20	93
	top_logit	-15	No	_	_
	ascend_se	5.56	Yes	-1	9
	descend_se	3.24	No	_	_
	start_logit	-999	No	_	_
	end_logit	9	No	_	_
AutBass survey - 6 parms double-normal length	peak	24.42	Yes	19	93
	top_logit	-15	No	_	_
	ascend_se	2.72	Yes	-1	9
	descend_se	1.23	Yes	-1	9

Parameters (parms)	Name	Value	Estimated	Lower bound	Upper bound
	start_logit	-999	No	_	_
	end_logit	-999	No	_	_
CGFS survey - 6 parms double-normal length	peak	31.49	Yes	20	93
	top_logit	-15	No	_	_
	ascend_se	2.88	Yes	-1	9
	descend_se	6.39	Yes	-1	9
	start_logit	-999	No	_	_
	end_logit	-999	No	_	_
AutBass survey- 2 parms age constant selectivity	min age	2	No	_	_
	max age	4	No	_	_

ICES forecasting and advice

A forecasting procedure has been developed by ICES to make recommendations based on a set of harvest rules and management options which have been applied to the Northern stock of sea bass. A full description of the method including equations can be found in Appendix A1, but a brief summary is provided below.

The year the assessment is run is the intermediate year (*y*), with data included up to the previous year (*y-1*) and advice provided for the following year (*y+1*). For example, here the 2018 assessment included data up to 2017, 2018 was the intermediate year, and advice was provided for 2019. The harvest rule used by ICES depends on the SSB on the 1 January of the advice year and leads to having an F target for the advice year (either F_{MSY} or a proportion of) or an SSB target (or lower limit) for the year after the advice. The harvest rules use the values in Ta

ble 13 and are determined as described below.

For the forecasting procedure, estimates of number-at-age in the intermediate year are extracted from the assessment (Equations A1-5, Appendix A1). SSB is then estimated for the following 2 years using the numbers-at-age and an estimate of total mortality-at-age that is dependent on the harvest rule (Equations A6-7, Appendix A1). The total mortality for each age is the sum of natural mortality (*M*) and partial fishing mortality (*F*) (Equations A8-9, Appendix A1), with *M* assumed to be constant at 0.24. The partial *F*s are derived from fleets removals grouped into commercial retained, commercial discarded and recreational, which produced proportions by fleet segment for each age. Partial *F*s are determined based on the *F*s of the three latest years of the assessment (*F*s-at-age) multiplied by the *F* multiplier. The *F* multipliers are given a value of 1 in the intermediate year for commercial fisheries, but a different value based on the current management regime for the recreational fishery (Equations A12-13 Appendix A1, Table A1.1). The value of 1 for the commercial fishery means no change in fishing mortality in the intermediate year for which catch data are not yet available. New *F* multipliers are then calculated for the advice year (*y+1*) based on the harvest rules (Equations A14-17, Appendix A1):

$$F = \begin{cases} \boldsymbol{F_{MSY}} \; where \; SSB_{y+1} \geq MSY_{B_{trigger}} \\ \boldsymbol{F_{MSY}} \times \boldsymbol{SSB_{y+1}/MSY_{B_{trigger}}} \; where \; B_{lim} \leq SSB_{y+1} < MSY_{B_{trigger}} \\ \qquad or \; where \; [\, SSB_{y+1} < B_{lim} \; and \; SSB_{y+2} \geq B_{lim}] \; if \; F_{MSY} \times SSB_{y+1}/MSY_{B_{trigger}} < F_{lim} \\ \boldsymbol{F_{lim}} \; where \; [\, SSB_{y+1} < B_{lim} \; and \; SSB_{y+2} \geq B_{lim}] \; if \; F_{MSY} \times SSB_{y+1}/MSY_{B_{trigger}} \geq F_{lim} \\ \boldsymbol{0} \; where \; [\, SSB_{y+1} < B_{lim} \; and \; SSB_{y+2} < B_{lim} \,] \end{cases} \tag{1}$$

where F_{lim} is calculated as the fishing mortality needed to reach B_{lim} in two years and the other reference values are taken from Ta

ble 13. The recreational *F* multipliers are then calculated for a range of management measure options (i.e. daily bag limits) and the commercial *F* multiplier calculated to make up the difference between the advised total F_{y+1} and the partial F_{y+1} of the recreational fleet.

Operating model (OM)

The methodology followed Hicks and Stewart (2018) where further details can be found, but a summary is presented here. OM replicates were created using sets of parameters drawn from a multivariate normal distribution using the variance-covariance matrix generated out of the assessment in which some extra parameters were freed up (i.e. estimated). This assessment with extra free parameters is later referred to as the "full model". The variance-covariance matrix is estimated by inverting the Hessian within the optimisation software, ADMB (http://www.admb-project.org/) used by SS. The process of drawing from this matrix generates uncertainty accounting for correlation between parameters, given the data and assumptions.

Prior to creating OM replicates, the method was first tested by drawing 1,000 sets of parameters from the variance-covariance matrix generated out of the ICES 2018 assessment, with no additional parameters freed up. This was to ensure that sampling using a multivariate normal distribution and the inverted Hessian produced similar results as the assessment SS models (the current best information for the historical trajectory). The uncertainty around the spawning biomass trajectory derived from the populations generated from these draws was expected to compare to the uncertainty produced by the assessment. In this process, the parameters drawn can be constrained by priors or bounds, but this did not affect the results here so only the results of constrained draws are presented below.

Freeing up and estimating extra parameters in the "full model", to create a new variance-covariance matrix to derive sets of parameters and OM replicates, would then be expected to further increase the uncertainty and thereby characterise a broader range of possibilities in terms of underlying population structure and fishing mortality. However, freeing up and estimating parameters that were originally fixed could produce stock dynamics that were not consistent with the assessment. To ensure that the OM matched the assessment and additional variability was introduced, the following steps were performed following Hicks and Stewart (2018).

1. Two additional parameters were estimated within bounds (Table 3) in the assessment model (natural mortality *M* and steepness *h*). This was called the full model.
2. A covariance matrix was constructed using the covariance of the full model, the variances from the assessment model, and the variance of the additional estimated parameters from the full

model. Point estimates from the assessment model were used alongside the covariance matrix to sample from an MVN. This kept the full model predictions near the assessment model but introduces extra variability accounting for correlation between estimated parameters.

3. The SS model was run using the sampled parameters, but without estimation to predict the historical population dynamics.
4. 1,000 models with different parameter sets were simulated and a subsample of 100 was retained, so that the median spawning biomass trajectory reflected the assessment but the uncertainty around it was increased.

Since the purpose of this study was to build a framework and check its robustness and behaviour, forward projections assumed a constant level of recruitment. In addition, the stock was treated as a quota stock for the purpose of the simulations, meaning that the removals from the population, or realised catch, were derived from the advice (see Section 2.4). This allowed validation that the model would stabilise at F_{MSY} in the long-term under minimal or no uncertainty or bias in the catch data.

Although 100 OM replicates were created, only 30 were run for each scenario tested and B2 and B4 were not run due to computational time constraints. The other scenarios that were run here covered all aspects of bias and uncertainty in the quality of the recreational data and therefore demonstrated the usefulness of the framework. Running 100 OM replicates may be appropriate to compare medians but would not be sufficient either to assess risk (related to the tails of distributions). Here, the probability of falling below the harvest rule trigger values was estimated so it was possible to use the results to rank the scenarios but should only be viewed as an illustration of the potential of the framework.

Management Procedure (MP)

Data generation and estimation model

When perfect knowledge was assumed (A), no assessment was run, making it the most efficient simulation. Uncertainty could be added to this biomass estimate to mimic an assessment effect but was not applied here. While the perfect knowledge scenarios did not require an estimation model, scenario B required indices and composition data generation, and running an assessment model at each time step. Here, data was generated from the OM by running SS as a simulator. To do so, the OM was updated each year with the new catch data and SS was run with the estimation phase off to generate expected observations for each year. Expected observations are the values created under given selectivity patterns that the assessment uses to fit to the data. Expected age and length data were thus created for each fleet and survey for which these composition data existed in the original assessment. Lengths distributions were created for: UKOTB_nets, Lines, French, the recreational fleet and CGFS, and age distributions for UKOTB_nets, Lines, French, and AutBass.

Instead of using the expected survey indices and composition distributions directly in the assessment, error was added to the expected data produced by the OM. For the survey index, a CV was estimated as the average CV of the survey times series of the original assessment and applied to the expected value. For the composition data, a given number of age and length samples was drawn from the expected distribution using a multinomial distribution, set at 8 samples per length or age bin, resulting in a sample size of 360 for length data (45 2cm length bins) and 136 for age data (17 1yr age bins).

The estimation model (EM) was analogous to the ICES stock assessment, with the same parameters fixed and estimated. Parameters were fixed at the value from the 2018 assessment, meaning the M and h were 0.24 and 0.999, respectively. This was done regardless of the OM replicate for which those parameters were drawn from the multivariate normal. One difference was that the ICES assessment iteratively reconstructs the full time series of recreational fisheries catches every time it is updated, using a single estimate for 2012 and assumptions on fishing mortality patterns, but here the time series was fixed for 1985-2017 and from then on catch data were added on every year in the projection. The sensitivity of the 2018 assessment to reconstructing the recreational time series assuming some bias and error in the 2012 estimate was tested to consider optional OMs but made little difference in the trend and scale of the assessment.

Forecast and advice

The MSE uses the ICES working group approach for the forecasting and advice modules both for scenarios A and B, but with some alterations and simplifications to fit the purpose of this study which was to develop, test and validate the framework.

In the ICES assessment the advice was based on the population biomass at the beginning of the advice year (SSB_{y+1}) and applied that year (*y+1*) (set of equations 1 section 2.2.2). Here we used the SSB of the intermediate year SSB_y which gives the advantage of not having to make assumptions on the catches, selectivity etc. of the assessment year *y*. This will have led to different recovery trajectories than if SSB_{y+1} had been used but was unlikely to influence the comparisons between scenarios. For perfect knowledge scenarios (A), SSB_y is known from the OM, for estimation scenarios (B) SSB_y is obtained from the assessment model in SS. Hence, both scenario types tested the harvest rule, the first where there was no uncertainty and each population replicate was known perfectly (A); the population replicates were perceived through the assessment, in which case, the impact of recreational data quality was also tested (B) (Table 1 section 2.1.3).

The approach used by ICES leads to a forecasted catch split between three segments, as catch-at-age and associated partial *F*s are combined into commercial landings, discards, and recreational catches in the intermediate year *y*, prior to running the forecast and applying the harvest rules. In the MSE, to avoid having to set up further allocation rules, the forecasting was conducted at the most disaggregated level (i.e. landings and discards for each of the 6 fleets projected separately). The partial *F*s used in the intermediate year *y* as part of the ICES procedure differ depending on whether *F* was consistently increasing or decreasing, or if there was no consistent change in the last 3 years (see Appendix A1.2 step 4). This was ignored in the simulations, with only the latest year *y*-1 used.

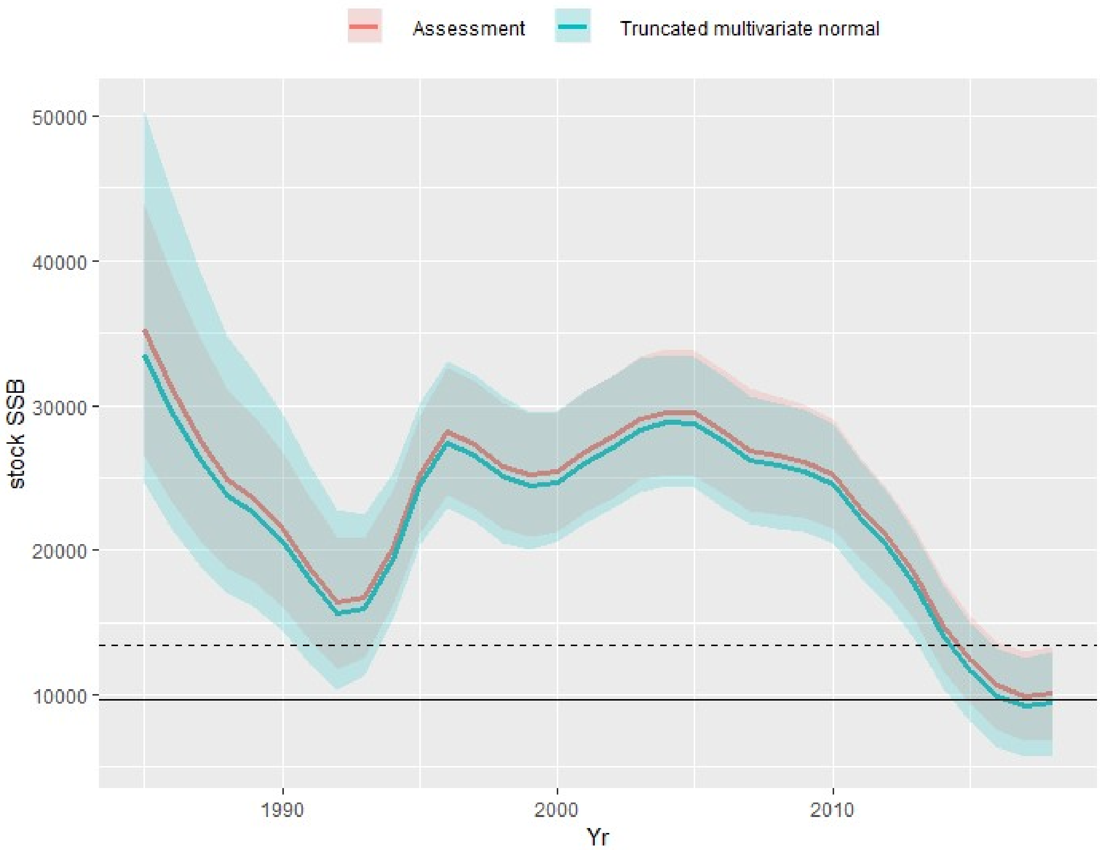
In forecasting, the ICES procedure sets a value of 1 for the *F* multipliers of the commercial fleets in the intermediate year *y.* This is because the commercial catch of the intermediate year *y* is unknown. A value of 1 means that *F* for the commercial fleets is assumed to be the same in the intermediate year *y* and in the last year of the assessment *y-1*. However, since this study was designed to test the framework under restricted uncertainty, perfect knowledge of commercial removals was assumed in the forecasting of the MSE, meaning the commercial *F* multipliers were assumed to correspond to the realised catch (set to the catch advice). Similarly, the recreational *F* multiplier for the intermediate year *y* is set by the ICES working group based on the advice provided for that year. Hence, it was set at the *F* multiplier corresponding to the realised catch to remove or reduce uncertainty in the forecasting module.

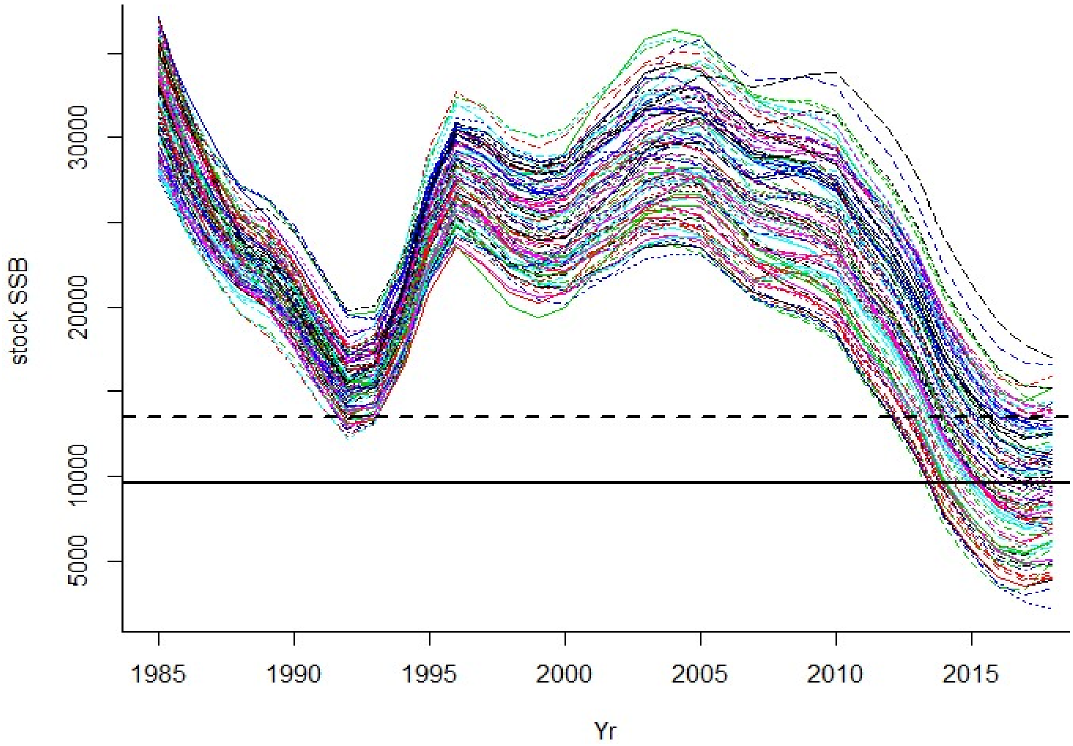
Setting the recreational *F* multiplier for the advice year *y+1* involves a decision process for which no modelling was attempted. Instead, the recreational *F* multiplier was chosen to give a recreational catch of 50% of the total advised catch. This was done as recreational catches form a significant part of the total catch and 50% ensured differences between scenarios. All *F* multipliers were allowed to vary over a wide range (0 to 15).

Results

Operating model (OM)

The SSB trajectory of the 1,000 replicates (without the added variability through the freeing up of *M* and *h*) was very similar to the current assessment (Figure 2), so the approach was deemed appropriate to create OM replicates. These were developed to cover a wider range of trajectories that better represented and increased the range of uncertainty by freeing up *M* and *h* in the "full model" to calculate a new variance/covariance matrix from which to draw new sets of parameters. The 100 trajectories selected to match the assessment (Figure 3) resulted in an increase in uncertainty in the OM compared to the assessment in the second half of the time series (Figure 4). The small bias observed in the median SSB of the OM was not an issue because the MSE focused on ranking rather than absolute values. In addition, the method was able to characterize variability and capture the dynamics of the stock (Figure 4).

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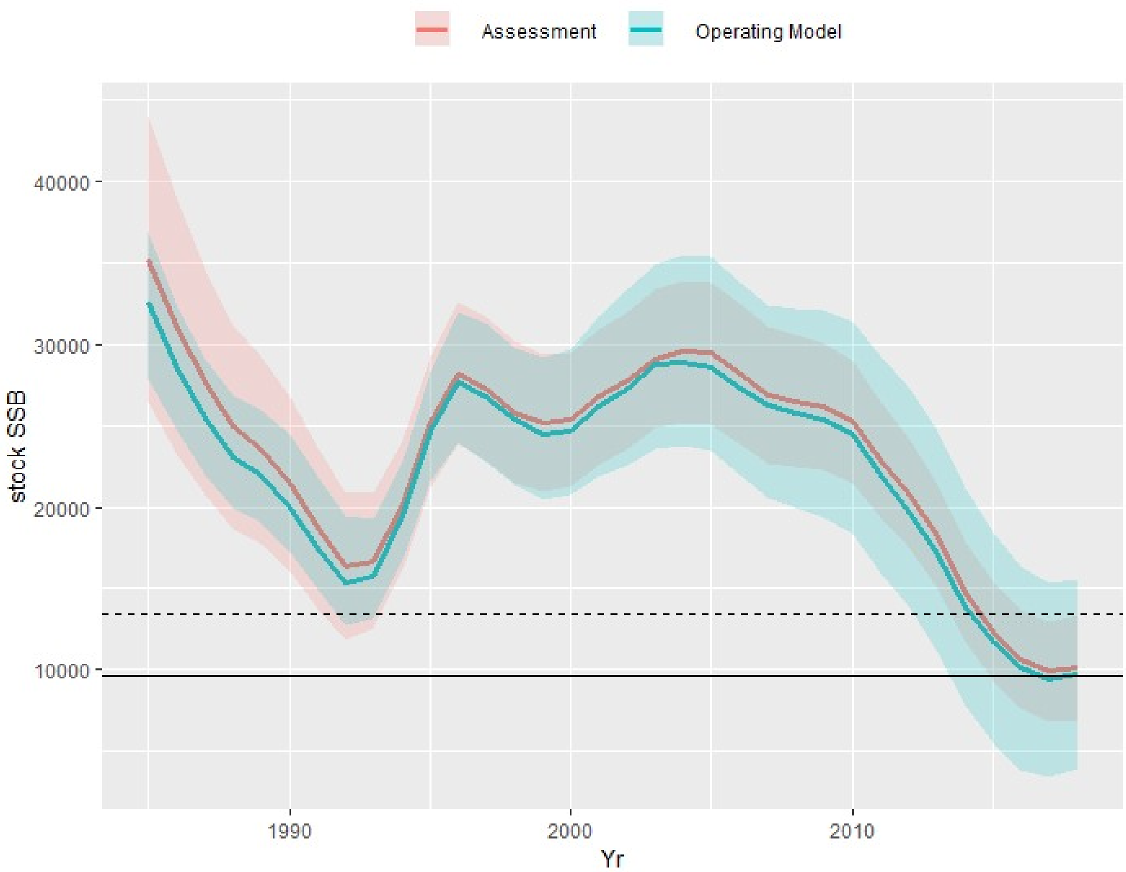
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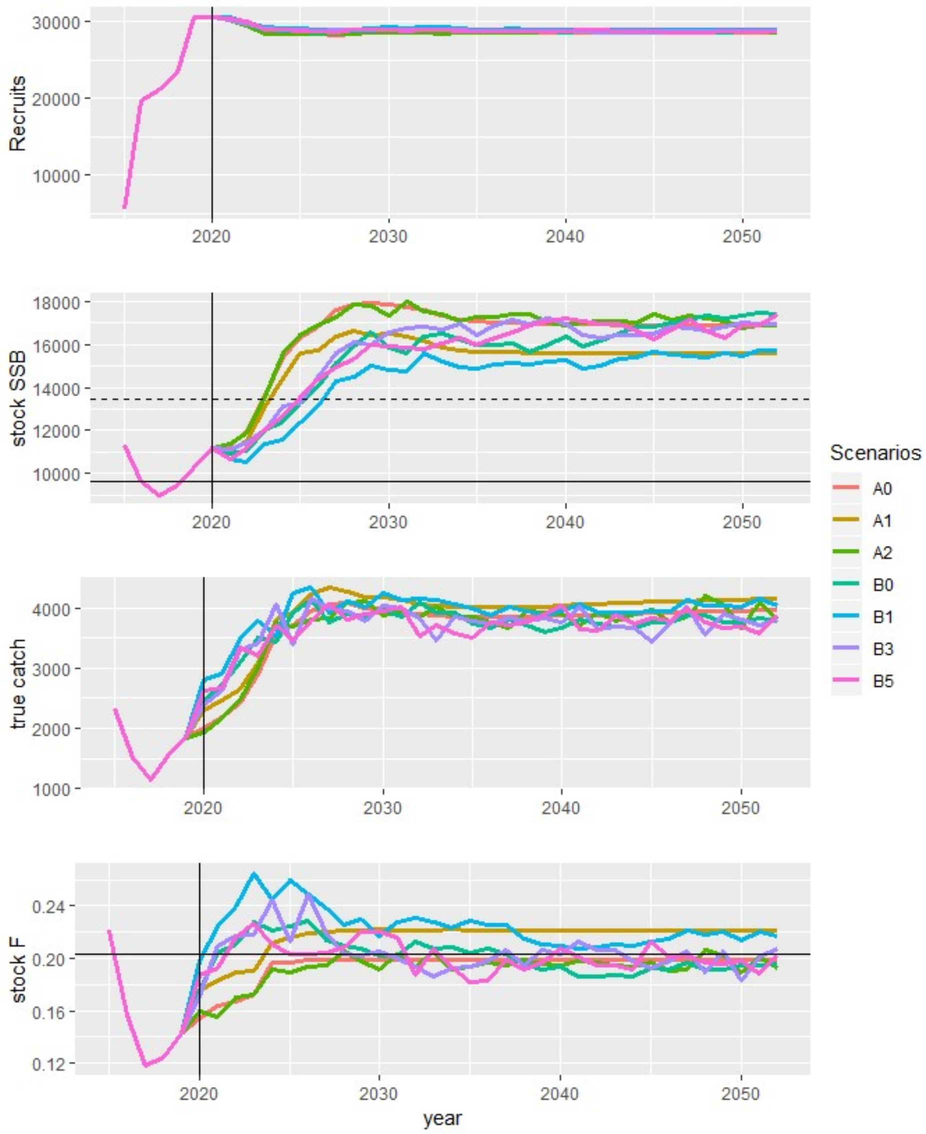
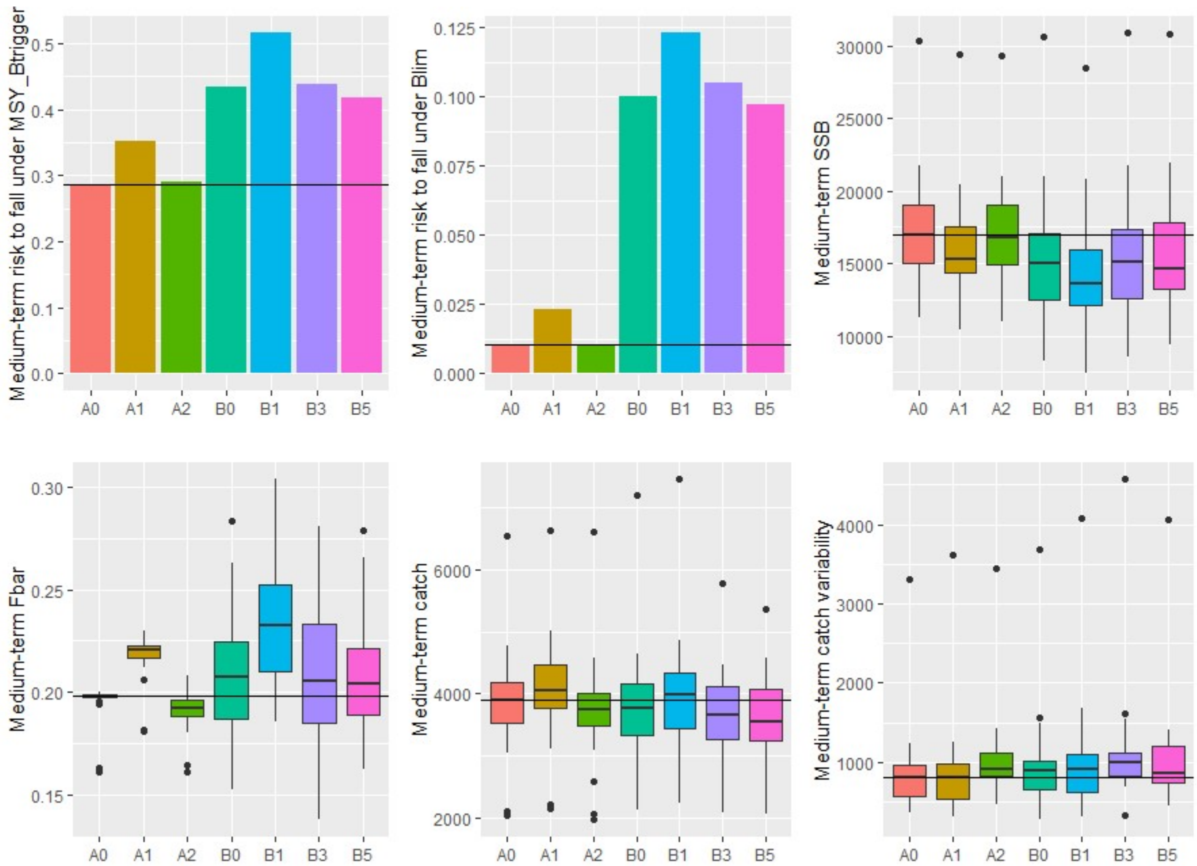
Yr

Comparing scenarios

Replicates of the OM were projected for 35 years under 7 scenarios (Table 12, excluding B2 and B4). The conclusions that can be drawn from these are purely illustrative but are useful to validate the framework. Recruitment was forced to be constant in the long-term projection and across scenarios at the historical average to restrict uncertainty and check the behaviour of the model (Figure 5). The stock SSB recovered most quickly and the trends were smoother for the perfect knowledge scenarios A, although reached the same equilibrium around the same time as scenarios B (Figure 5). Scenarios A1 and B1 simulated recreational catches that were 50% higher than the advice and led to a lower SSB (Figure 5). Similar results were seen for catches and F (Figure **Error! Reference source not found.**5). All other scenarios stabilised at higher values of SSB, corresponding to lower Fs and catches compared to bias scenarios A1 and B1 (Figure **Error! Reference source not found.**5).

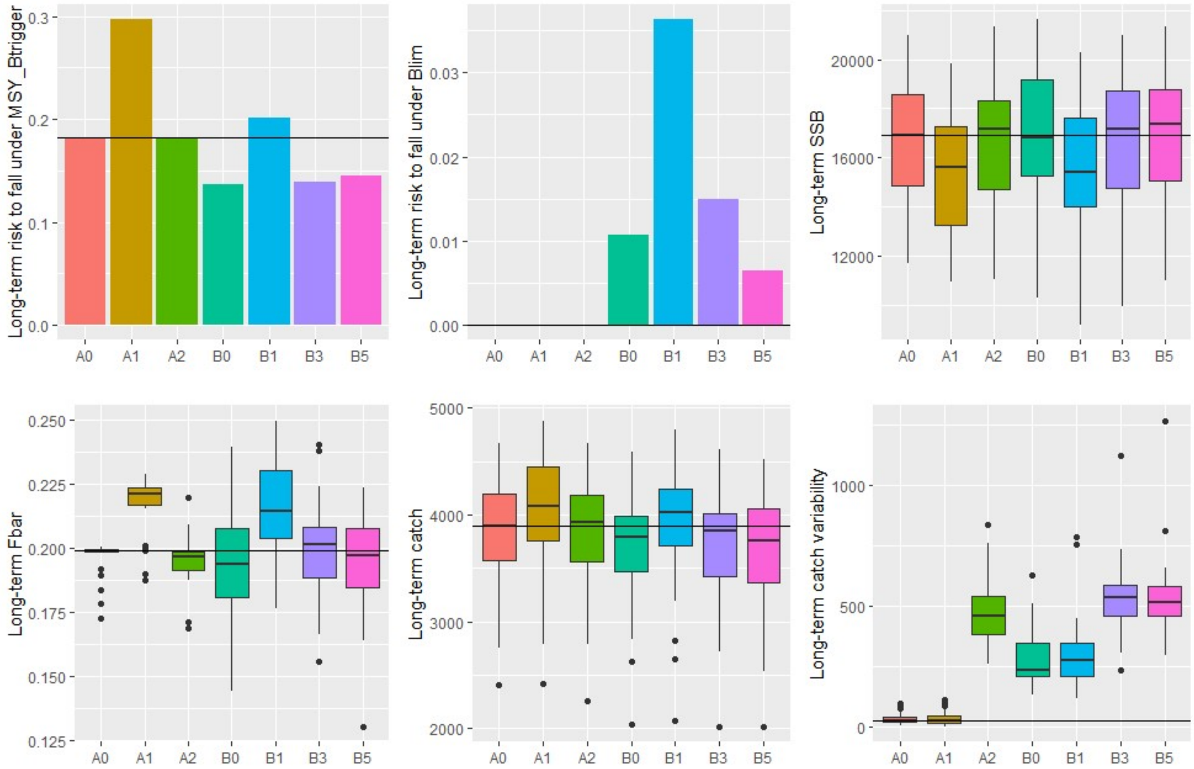


The medium-term outputs covered the period from 2020-2034 before the models were stationary (Figure **Error! Reference source not found.**6). In the medium term, there was less risk of falling below MSY $B_{trigger}$ and B_{lim} in the case of a perfect knowledge (A) than estimation (B) scenario (Figure 6). A1 and B1 represented the cases with positive bias in the realised recreational catch. These had the highest risk, lowest SSB and highest fishing pressure across cases, but yielded the highest catches (Figure 6). There was little difference between the Scenarios B3 and B5, despite some suggestion that bad data (where there was noise on the observations) (B3) may cause an increased risk compared to no data (where it is assumed in the assessment that the fishery caught as advised) (B5) (Figure 6).



Long-term outputs represented 2035-2052 where the models reached equilibrium (Figure 7). In contrast to the medium term, there was a higher risk of falling below MSY $B_{trigger}$ in the perfect knowledge scenarios A compared to the estimation scenarios B, but still a lower risk of falling below B_{lim} (Figure 7). Positive bias in the realised recreational catch (A1, B1) performed the worst in terms of risk, population SSB, and fishing pressure across all scenarios, but yielded the highest catch (Figure 7).

There was little difference between bad data (B3) and no data (B5) scenarios in the long term (Figure 7).



Discussion

The present study details the MSE approach and decisions made to develop the framework. It highlights the potential of using the MSE to test scenarios, in this case, of data quality in recreational catches. It could be expanded to test several scenarios related to catch data quality or change in harvest control rule. The results suggested that the highest long-term risk to the stock was if the recreational sector caught systematically more than the catch advice, compared to catching as advised with some level of random variation every year. It will be possible to test the effect of under-estimating the catch in the assessment and, with appropriate computational power, to assess the effect of a range of uncertainty levels on the performance of the harvest rule. The model did not suggest a significant advantage to having data compared to assuming that the recreational sector catches the advised quota in situations where the realised recreational catch was subject to random errors but was not biased. An obvious problem in this situation would be to prove that this would continue to be the case in future (i.e. advice will be followed without systematic bias), and the only way to prove this is to collect the data. Assuming that recreational catches follow management advice is a risk to the stock.

Several simplifying assumptions were made to generate these results. One of the major assumptions was that recruitment remained constant at the historical average in the projection. Sea bass has high variability in recruitment driven by environmental conditions (ICES 2018a, b). In order to generate robust conclusions on the performance of the scenarios, recruitment should reflect historical variation, including exceptionally strong and weak cohorts. The control rule here used the SSB of the intermediate year *y* rather than the advice year *y+1* as in the ICES procedure. Other assumptions included the high quality of the commercial catch data (while studies have shown that the UK under 10 m fleet landings is likely to be underestimated (ICES, 2018a)) and that the commercial fleet complied with quota advice, the recreational fishery catches 50% of the total quota and F can vary depending on the harvest rules without restriction from one year to the next. All these assumptions that were to some extent necessary to develop and test the framework can be relaxed, and complexity can be added to make the scenarios more realistic and to increase robustness of the results. An example for a simulation scenario would be to project a constant F for the commercial fleet instead of following the quota advice or add variation around it assuming an *F* multiplier of 1 in the intermediate year in the simulations, as is currently done in the ICES assessment. Generally, the uncertainty in the intermediate year forecast was purposefully removed to test the advice rule (although it was altered here by using the intermediate year as SSB reference), but more realistic scenarios can be run to mimic the ICES assessment procedures by making different assumptions on the F multipliers.

The simulations behaved as expected although two caveats were identified and will need further investigation. There was a marginal mismatch in F_{bar} (*F* stabilised at 0.199 when it was set at F_{MSY}=0.203); and the long-term risk of the perfect knowledge scenarios falling under MSY $B_{trigger}$ was higher than the risk of the estimation scenarios. The latter might be due to the low number of replicates which is not appropriate to assess risk while the former could be due to divergent methods for calculation of F-at-age within SS and outside the assessment to provide advice.

The main challenge that remains was computational time as the projection of a single replicate for 35 years in the estimation scenarios (B) took 4 to 6 hours. Generally, one thousand replicates are needed within an MSE to get good estimates of risk for a single scenario. To increase the level of uncertainty in the OM, these replicates could be created by relaxing more of the fixed parameters from the original assessment in the full model. Freeing the steepness parameter which was already at its upper bound and is not one that is usually estimated likely provided little value in creating the OM here. Generally, although the approach was satisfying in conditioning the OM, more work needs to be done around the methodology to create replicates. Developing several OMs with realistic combinations of parameters might be considered a more appropriate approach than combing variance-covariance matrices and risking that the model is not anymore informed by the data. Further, it would be worth investigating the possibility of using a more efficient framework and estimation model, a4a for example might offer this possibility.

Once the level of uncertainty in the regional recreational catch estimate that leads to an impact on the current assessment has been estimated, it is possible to use this to derive a regional sampling programme for an individual stock. The total recreational removal is the sum across all countries that exploit the stock of the tonnage retained and the dead releases. Where countries have different levels of recreational removal from a stock, it is clear from statistical theory that the error in the total estimate is driven by the precision and bias in estimates of countries that have the highest removals. There is little effect on precision of the estimate of removals from a stock for countries that have minimal recreational impact. Hence, sampling effort in a regional programme for an individual stock should focus on the countries with the highest removals, as this will have the large effect on the precision. However, it is important to retain sampling in all countries exploiting the stock to ensure that bias is not introduced through exclusion of individual countries. This approach for regional sampling is robust for an individual stock with stable exploitation and a consistent assessment method, but recreational surveys include many stocks and time series data are needed for stock assessment. The relative exploitation of recreational fisheries in individual countries is likely to change over time for an individual stock and there will be differences among stocks. In addition, the resolution of data needed for individual stocks is dependent on its spatial extent and will impact on regional sampling design. Hence, designing a single optimised regional sampling programme for recreational fisheries is complex, as it will depend on a matrix of stocks, exploitations rates, assessment method, and spatial extent that will change over time. As a result, further work is needed to assess how to design recreational fisheries regional sampling programmes to deal with data needs for all stocks, that should include case-studies at the regional sea level. Mechanisms for funding this study should be considered by the European Commission.

Acknowledgements

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Appendix A1: Forecasting and catch advice for seabass stock bss.27.4bc7ad-h

A1.1 Overview

- Extract/prepare data (steps 1,2,3)
- Define selectivity and initial F multipliers for forecasting fishing mortality (step 4,5)
- Provide catch advice based on set of rules (steps 6,7,8)

A1.2 Steps

1. Start by defining **numbers-at-age in intermediate year** (current model data up to 2017, intermediate year yr = 2018)

$$N_{yr,age} = N_{out,yr,age} \tag{A1}$$

where $N_{out,yr,age}$ is the numbers at age on the 1 January of the intermediate year (yr) out of the SS assessment model. For ages 0 - 2, the forecast does not use the direct SS outputs for N_{yr}. For age 1 and 2 this is because of the uncertainty around these estimates due to the limited information provided by the survey and discards (or unwanted catch). N_{yr} for age 0 is the geometric mean of the full time series of recruitments minus the last couple of years of data (i.e. intermediate year yr minus 3) (Equation A2):

$$N_{yr,age=0} = e^{average(\log(N_{out,1,age=0}),\ \dots\ ,\log(N_{out,yr-3,age=0}))} \tag{A2}$$

N_{yr} for age 1 (or 2) is calculated from this estimated $N_{yr,age=0}$ (Equation A2) and the ratio of numbers at age 1 (or 2) to age 0 estimated for the last (or second last) cohort of the model (Equations A3-A4):

$$N_{yr,age=1} = N_{yr,age=0} \times \frac{N_{out,yr,age=1}}{N_{out,yr-1,age=0}} \tag{A3}$$

$$N_{yr,age=2} = N_{yr,age=0} \times \frac{N_{out,yr,age=2}}{N_{out,yr-2,age=0}} \tag{A4}$$

Further, recruitment (age 0) in years *yr*+1 and *yr*+2 are set to age 0 in intermediate year

$$N_{yr+2,age=0} = N_{yr+1,age=0} = N_{yr,age=0} \tag{A5}$$

2. Express **SSB (or N) in two following years** (2019 and 2020) as a function of SSB (or N) in intermediate year (2018)

$$SSB_{yr+1,age} = w_a \times m_a \times (N_{yr,age} \times e^{-Z_{yr.age}}) \tag{A6}$$

$$SSB_{yr+2,age} = w_a \times m_a \times (N_{yr+1.age} \times e^{-Z_{yr+1.age}}) \tag{A7}$$

where w_a is weight-at-age and m_a is proportion mature-at-age in the stock for last year of assessment as provided by SS. Here we know w and N_{yr} (Equations A1-A4) but we do not know $Z_{yr,age}$, $Z_{yr+1,age}$ (or $N_{yr+1,age}$). Zs are expressed below in step 3). See Equations A8-A9 respectively for Equations A6-A7.

3. Express **Z in intermediate year and following year**, $Z_{yr,age}$ and $Z_{yr+1,age}$, (2018 and 2019), to be able to calculate SSB in 2) (i.e. SSB for 2019 and 2020)

$$Z_{yr,age} = M_{age} + (f_{mult\ ret,yr} \times F_{comm\,ret,yr*,age}) + (f_{mult\,disc,yr} \times F_{comm\,disc,yr*,age}) + (f_{mult\,rec,yr} \times F_{rec,yr-1,age}) \quad \text{(A8)}$$

$$Z_{yr+1,age} = M_{age} + (f_{mult\ ret,yr+1} \times F_{comm\,ret,yr*,age}) + (f_{mult\,disc,yr+1} \times F_{comm\,disc,yr*,age}) + (f_{mult\,rec,yr+1} \times F_{rec,yr-1,age}) \quad \text{(A9)}$$

where M is natural mortality (0.24). Here, we applied F multipliers, f_{mult}, to each of the partial Fs of commercial retained, commercial discarded, and recreational catches. These give us the partial F_{yr} and F_{yr+1}, i.e. Fs of the intermediate year and intermediate year+1 for each catch type. $yr*$ represent a single year or a combination of years as described in step 4 below. The partial $F_{yr-1,age}$ and $F_{yr*,age}$ are known from the assessment (see step 4 below). The f_{mult} can be (is) different between catch types and years as described in steps 5 and 6, and some are estimated while others are fixed. The use of f_{mult} implies that F can never be 0. One must think of applying a minimum catch value in a simulation context.

4. **Partial Fs** in the calculation of Z in intermediate and following year

In Equations A8 and A9, the partial Fs of the recreational catches are taken from $yr - 1$. It is more complex for the partial Fs of the commercial data, which are taken from $yr*$, where $yr*$ represents 2 different scenarios (a and b):

a. If F has been increasing (or decreasing) steadily over the past 3 years, the average selectivity of the past 3 years is calculated and scaled to the last F_{bar} (Equation A10)

$$if\ F_{bar\,yr-3} < F_{ba\ \ yr-2} < F_{bar\,yr-1}$$

$$or\ F_{bar\,yr-3} > F_{bar\,yr-2} > F_{bar\,yr-1}$$

$$is\ TRUE$$

$$F_{comm\,ret,yr*,age} = F_{bar,yr-1} \times \left[\tfrac{1}{3}\textstyle\sum_{y=yr-}^{yr-1} F_{comm\,ret,y,age}\right] \Big/ \left[\tfrac{1}{3}\textstyle\sum_{y=yr-}^{yr-1} F_{bar,y}\right] \quad \text{(A10)}$$

b. If there are no trends, the average F-at-age over the last 3 years is taken (Equation A11):

$$if\ F_{bar\,yr-3} < F_{bar\,yr-2} < F_{bar\,yr-1}$$

$$or\ F_{bar\,yr-3} > F_{bar\,yr-2} > F_{bar\,yr-1}$$

$$is\ NOT\ TRUE$$

$$F_{comm\,ret,yr*,age} = \tfrac{1}{3}\textstyle\sum_{y=yr-}^{yr-1} F_{comm\,ret,y,age} \quad \text{(A11)}$$

Also note that there is a time block since 2015 where the model assumes a change in selectivity, so this above can only apply back to 2015 (i.e. if intermediate year is 2017 then the averaging of selectivities can only go back 2 years instead of 3). Equations 10 and 11 also applies to $F_{comm\,disc,yr*}$.

5. Express **the F multipliers for the intermediate year yr** (i.e. f_{mult} for 2018) – these are fixed.

a. For commercial catches:

$$f_{mult\ ret,yr} = f_{mult\ disc,yr} = 1 \quad \text{(A12)}$$

i.e. $F_{comm\ disc,yr,age} = F_{comm\ disc,yr-1,age}$ and $F_{comm\ ret,yr} = F_{comm\ ret,yr-\ \ ,age}$

F-at-age for commercial catches is assumed to be the same in the intermediate year (yr) as it was in last year of data (yr-1) and so F-at-age in yr is taken as the F-at-age estimated in the last year of the assessment

Note that it would be possible for this f_{mult} to be estimated for a targeted catch in the intermediate year but the working group has decided to set it at 1.

b. For recreational catches in yr:

$$f_{mult\ rec,yr} = \frac{F_{bar\ out\ rec,yr=2012} \times f_{management\ measure}}{F_{bar\ out\ rec,yr-1}} \quad \text{(A13)}$$

where $f_{management\ measure}$ can take different values, which are predefined based on the recreational fishery management scenario assumed (see Table A1.1). The numerator therefore provides the F_{bar} (or $F_{4\text{-}15}$) which, in 2012, would have corresponded to a given management measure (one bag, zero bag etc). $F_{bar\ out\ rec,yr-1}$ and $F_{bar\ out\ rec,yr=2012}$ are extracted from the SS outputs. F-at-age for the recreational fleet in the intermediate year yr is therefore assumed to be the F-at-age estimated in the last year of the assessment yr-1 corrected to match the F_{bar} that in 2012 that would have corresponded to a given measure.

6. **Advice rules that will determine how** f_{mult} should be calculated for advice year $yr + 1$

if $\boldsymbol{SSB_{yr+1}} \geq$ MSY $B_{trigger}$ => *F advice = F target*

{ $\boldsymbol{F_{advice}} = F_{MSY}$ }

if $B_{lim} \leq \boldsymbol{SSB_{yr+1}} <$ MSY $B_{trigger}$ => *F advice = F target*

{ $\boldsymbol{F_{advice}} = F_{MSY} \times \frac{SSB_{yr+1}}{\text{MSY } B_{trigger}}$ }

if $\boldsymbol{SSB_{yr+1}} < B_{lim}$ { => *F advice = F target or F derived from B target*

i. F target

$F = F_{MSY} \times \frac{SSB_{yr+1}}{\text{MSY } B_{trigger}}$

ii. B target (see step 7 Equation A17)

if $(\widehat{SSB_{yr+2}} - B_{lim} \geq 0)$; then F_{lim} is derived from Equations A17 and A9

else if $(\widehat{SSB_{yr+}} - B_{lim} < 0)$ i.e. B_{lim} can't be reached in 2 yrs; then $F_{lim} = 0$

iii. Choice between F target or F derived from B target =

keep most precautionary (i.e. lowest F)

if $F_{lim} \leq$ F { $\boldsymbol{F_{advice}} = F_{lim}$} => *F advice = F derived from B target*

else if $F_{lim} >$ F { $\boldsymbol{F_{advice}} =$ F } => *F advice = F target*

}

7. Calculate **the F multipliers for the following year, i.e. intermediate year $\boldsymbol{yr+1}$** (i.e. f_{mult} for 2019) – These are estimated depending on objective - **F target or SSB target**

There are 2 options (Options 1 and 2 below) to calculate $f_{mult\ yr+1}$ from which the catch advice will be derived (step 8) and which depend on the advice rules (defined in step 6). Option 3 presents alternatives that are not used for advice, but only for exploration. Option 1 is when the aim is to reach an F target the year following the assessment, i.e. intermediate year + 1. Option 2 is when the aim is to reach (or rather not fall below) an SSB target 2 years after the assessment, i.e. intermediate year + 2. In both cases, the same multiplier is used for each commercial catch type in $yr + 1$ (in Equation A9)

$$f_{comm\ mult,yr+1} = f_{comm\ mult\ ret,yr+1} = f_{comm\ mult\ disc,yr+1} \quad \text{(A14)}$$

And for the recreational catches, similarly to $f_{mult\ rec,yr}$ (Equation A13):

$$f_{mult\ rec,yr+1} = \frac{F_{bar\ out\ rec,yr=2012} \times f_{management\ measure}}{F_{bar\ out\ rec,yr-1}} \quad \text{(A15)}$$

Option 1 – F target for $yr + 1$ (2019) ………………. Fix $f_{mult\ yr+1}$

$$\left(f_{comm\ mult\ ,yr+1} \times F_{bar\ comm\ ret,yr*}\right) + \left(f_{comm\ mult,yr+1} \times F_{bar\ comm\ disc,yr*}\right) + f_{mult\ rec,yr+1} \times F_{bar\ rec,yr-1} = F_{target} \quad \text{(A16)}$$

We know $f_{rec\ mult,yr+1}$, F_{target} and the $F_{bar}s$ (or $F_{4\text{-}15}$) so $f_{comm\ mult\ ,yr+1}$ can be simply calculated

Option 2 – SSB target for $yr + 2$ (2020) ………………. Estimate $f_{mult\ yr+1}$

Here, we optimise $f_{comm\ mult\ yr+1}$ so that the SSB in intermediate year +2 equals SSB target, i.e. we solve equations A7 and A9 so that SSB_{yr+2} is the closest possible to SSB_{target} with $f_{comm\ mult\ yr+1} \geq 0$

$$\min_{f_{mult\ yr+1} \in R_+} \left(\left|SSB_{yr+2} - SSB_{targe}\ \right|\right) \quad \text{(A17)}$$

Option 3 - Alternative options for exploration (not based on catch advice rules)

An alternative management option is to set F as status quo or set commercial catch target for $yr + 1$. In the latter case, using the catch equation A18, F_{yr+1}can be derived, and thereby $f_{comm\ mult\ yr+1}$.

Catch advice

For simplification, we write F_{yr+1} = $f_{mult\ yr+1} * F_{yr-1}$ without referring to the catch type but this is valid for each partial Fs (i.e. for each catch type - commercial retained and discarded and recreational catches). Catch advice for each catch type is therefore

$$C_{y+1} = N_{yr+1} * \frac{F_{yr+}}{Z_{yr+1}} * (1 - e^{-Z_{yr+1}}) \quad \text{(A18)}$$

$N_{yr+1}$is estimated from Equation A6 (which utilises Equations A8 and A10-11 to define Z_{yr}) and $Z_{yr+1}$from Equation A9. C_{y+1} , the catch numbers at age and by catch type, are turned into biomass using catch-type specific weight at age w_a obtained from SS and summed up and finally one catch quota advice is produced.

Table A1.1 Multiplier for management measures of the recreational fishery. PRM = post-release mortality, season = number of months fishing is open, BL= bag limit. BL1 means a bag limit of 1 and a value of 0.1 would be what is referred to as $f_{management\ measu}$ in A13 and A15.

		$f_{management\ measure}$					
PRM	**Season**	**BL1**	**BL2**	**BL3**	**BL4**	**BL5**	**No BL**
0.05	0	0.10	0.10	0.10	0.10	0.10	0.10
0.05	3	0.19	0.22	0.24	0.24	0.24	0.24
0.05	6	0.28	0.34	0.37	0.38	0.38	0.38
0.05	7	0.31	0.38	0.42	0.43	0.43	0.43
0.05	9	0.37	0.46	0.51	0.52	0.52	0.52
0.05	10	0.40	0.50	0.55	0.57	0.57	0.57
0.05	12	0.46	0.59	0.64	0.66	0.66	0.66
0.15	0	0.27	0.27	0.27	0.27	0.27	0.27
0.15	3	0.34	0.37	0.38	0.38	0.38	0.38
0.15	6	0.42	0.47	0.49	0.50	0.50	0.50
0.15	7	0.44	0.50	0.53	0.54	0.54	0.54
0.15	9	0.49	0.57	0.60	0.61	0.61	0.61
0.15	10	0.52	0.60	0.64	0.65	0.65	0.65
0.15	12	0.57	0.66	0.71	0.73	0.73	0.73

Annex 5.5. Inclusion of SSF and MRF data in the RDBES

Introduction

To maximize the utility and uptake of SSF and MRF data by end users, SSF and MRF data needs to be included in European databases of fisheries catches. After considering different data storage options, WGRFS and WGCATCH recommended to engage with the RDBES system being developed by ICES (ICES 2017). However, the structure of the RDBES for commercial fisheries, with aggregated catch and effort data (CL and CE tables), raw sampling data (CS) and standardized raising procedures, would be very inefficient and subject to large potential errors.

The principal focus of the RDBES at this stage database should be to ensure that data from both fisheries are properly archived and subjected to appropriate QA/QC procedures, so that they can be used by end users. The need of further developments in line with the data model developed for commercial fisheries, will need to be discussed. But now the priority should be to compile all SSF and MRF regional data in a common data base and make them available for end users.

During 2018 conversations have been held with ICES via email and also at the RCGs, to agree on the format of this data base. A key issue in the discussions has been whether the existing tables in the RDBES can be used, or a different set of tables is needed. FishPi2 in parallel with WGRFS has explored both options.

The fitting of SSF and MRF data in the RDBES designed for official catch statistics and raw sampling data will oblige to a number of modifications in the tables and will provoke the coexistence of data of different nature in the same tables: official commercial statistics with recreational estimates, and raw sampling data with raised length distributions. This is not suitable as it will increase the complexity of the tables and provoke different interpretations and misunderstandings. To avoid these problems, the option recommended by fishPi2 is the creation of new tables specifically designed to host MRF and SSF data.

These specific tables and the different scenarios considered, were proposed to the SCRDBES. Below, the proposal presented to the SCRDBES is shown:

RDBES Marine Recreational Fisheries

Introduction

To maximize the utility and uptake of MRF data by end users, MRF data needs to be included in European databases of fisheries catches. After considering different data storage options, WGRFS recommended to engage with the RDBES system being developed by ICES (ICES 2017). However, the structure of the RDBES for commercial fisheries, with aggregated catch and effort data (CL and CE tables), raw sampling data (CS) and standardized raising procedures, would be very inefficient and subject to large potential errors. The reason for that is (i) the lack of any census data on catch and effort, and (ii) the large variety of sampling designs (including on-site and off-site methods) and raising procedures, provoked by varied nature of the recreational fishery and culture differences in responses.

At this stage, the preferred solution is a data base to store raised tonnages and numbers of fish caught and released by area and year, alongside length–frequency distributions. In addition, a description of the survey and an assessment of its quality would be needed. The full process from survey design, implementation, data archiving and quality control, data analysis and reporting must be documented and transparent for each country contributing to a regionally coordinated recreational survey program. The principal focus of such a database should be to ensure that data from nation-al surveys of different types are properly archived and subjected to appropriate QA/QC procedures, so that they can be used by end users. The need of further developments in line with the data model developed for commercial fisheries, will need to be discussed. But now the priority should be to compile all MRF regional data in a common data base and make them available for end users.

During 2018 conversations have been held with ICES via email and also at the RCGs, to agree on the format of this data base. A key issue in the discussions has been whether the existing tables in the RDBES can be used, or a different set of tables is needed. FishPi2 has explored both options.

The fitting of MRF data in the RDBES designed for official catch statistics and raw sampling data will oblige to a number of modifications in the tables and will provoke the coexistence of data of different nature in the same tables: official commercial statistics with recreational estimates, and raw sampling data with raised length distributions. This is not suitable as it will increase the complexity of the tables, and provoke different interpretations and misunderstandings. To avoid these problems, **the option recommended by FishPi2 is the creation of two new tables specifically designed to host MRF data (Scenario A).** The alternative solution (fitting MRF in existing tables) have also been considered and it is presented as Scenario B.

Scenario A: New tables designed for MRF

Catch and effort estimated data

This table is designed to host estimations of catch and effort, with their corresponding error measurements, at a given temporal and spatial resolution.

Order	Name	Type	Req.	Basic checks	Comments
1	Landing Country	String	M	Code list	ISO 3166 – 1 alpha-3 codes. In the special case where a vessel lands the catch in country A, but the catch is transported directly to country B, it should be registered as if it had been landed in country B.
2	Unique survey id	String	M		The same code used in NP table 1D and table 5A can be used. This will allow to provide more information on the sampling design (type of survey, design, sampling effort, practical issues, etc)
3	Year	Integer	M	Code list	1 900-3 000
4	Season Yype	String	M	Code list	Month, Quarter, Semester, Year
5	Season	Integer	M	Code list	Indicate which month, quarter etc.
6					
7	Area Type	String	M	Code list	Reg: Regions. as defined in table 3 in the EUMAP (EC, 2017) Div: Divisions, such as 27.7, etc Subdiv: Subdivisions, such as 27.8.a, etc * Under the EUMAP it is mandatory to collect data by region, but some survey may be able to provide higher spatial resolution.
8	Fishing Area	String	M	Code list	Indicate which area type
9	Species	Integer	M	Code list	The AphiaID, which is a 6 digit code, is used for the species in the species field. The AphiaIDs are maintained by WoRMS. Only species AphiaIDs with status “Accepted” or “Alternate Representation” is allowed.
10	Catch Category	String	M	Code list	L: Landing or retained/ D: Discarded or released
11	Metier LVL 5		M	Code list	REC_ALL REC_SEA REC_LAN
12	Metier LVL 6		O		REC_ALL_FAO CODES FOR GEARS. REC_SEA_FAO CODES FOR GEARS. REC_LAN_ FAO CODES FOR GEARS. * Under the EUMAP it is not mandatory to collect data by type of recreational fisheries, but some survey may be able to provide this data.
13	Total Weight	Integer	M	0-200000000	Total weight in kg
14	Total Weight RSE	Integer	M	0-200000000	Relative Standard Error of the estimated total weight
15	NumSamplesCatch	Integer	M	0-200000000	Number of samples to get the catch estimates.
26	NumSamplesEffort	Integer	M	0-200000000	Number of samples to get the effort estimates.
27	Total Number	Integer	M	0-200000000	Number of fish caught

18	Total Number RSE	Integer	M	0-200000000	Relative Standard Error of the estimated number of fish caught
19	Catch Bias assessment	String	M	Code list	A semi-quantitative scale ranging from +++ (large overestimate) to −−− (large underestimate) can be used as in Hyder et al 2017
20	Units Effort	Integer	O	0-200000000	Boats/ fishing days… * At the moment it is not possible to standardize the effort for recreational fisheries. Additionally, this is not a mandatory information to be collected under the EUMAO, so it will be optional
21	Total Effort	Integer	O	0-200000000	Units
22	Effort RSE	Integer	O	0-200000000	Relative Standard Error of the estimated effort
23	Effort Bias assessment	String	O	Code list	A semi-quantitative scale ranging from +++ (large overestimate) to −−− (large underestimate) can be used as in Hyder et al 2017

Length distribution data

This table is designed to host raised length–frequency distributions.

Order	Name	Type	Req.	Basic checks	Comments
1	Landing Country	String	M	Code list	ISO 3166 – 1 alpha-3 codes. In the special case where a vessel lands the catch in country A, but the catch is transported directly to country B, it should be registered as if it had been landed in country B.
2	Unique survey id	String	M		The same code used in NP table 1D and table 5A can be used. This will allow to provide more information on the sampling design (type of survey, design, sampling effort, practical issues, etc)
3	Year	Integer	M	Code list	1 900-3 000
4	Season Type	String	M	Code list	Month, Quarter, Semester, Year
5	Season	Integer	M	Code list	Indicate which month, quarter etc.
6	Area Type	String	M	Code list	Reg: Regions. as defined in table 3 in the EUMAP (EC, 2017) Div: Divisions, such as 27.7, etc Subdiv: Subdivisions, such as 27.8.a, etc * Under the EUMAP it is mandatory to collect data by region, but some survey may be able to provide higher spatial resolution.
7	Fishing Area	String	M	Code list	Indicate which area type
8	Species	Integer	M	Code list	The AphiaID, which is a 6 digit code, is used for the species in the species field. The AphiaIDs are maintained by WoRMS. Only species AphiaIDs with status “Accepted” or “Alternate Representation” is allowed.
9	Catch Category	String	M	Code list	L: Landing or retained/ D: Discarded or released

10					REC_ALL REC_SEA
	Metier LVL 5	String	M	Code list	REC_LAN
11					REC_ALL_FAO CODES FOR GEARS. REC_SEA_FAO CODES FOR GEARS.
	Metier LVL 6	String	O		REC_LAN_ FAO CODES FOR GEARS.
12	NumSamplesLngt	Integer	M		Number of samples measured for length.
13	NumLngtMeas	Integer	M		Number of fish measured
14					
	Length code	String	M	Code list 1cm="cm" etc.)	(Class: 1mm= "mm", 1cm="cm" etc.)
15	Length class	Integer	M		
16	Number at length	Integer	M		Number of fishes measured at each length
17	Number at length RSE	Integer	O	0-200000000	Relative Standard Error of the estimated number at length
18	MeanWeight	Decimal	M		Mean weight for a given length class in kg

Scenario B: Fitting MRF data in existing RDBES data model

Catch and effort estimated data (CL & CE)

The proposed option is based on existing tables for aggregated catch and effort data (CL and CE).

Original CL and CE tables will need to include some new variables and code list to be adapted to the particularities of MRF. The colour key for the proposed modifications is the following:

- New variables: Blue background
- Variables which would need some changes, or new code lists: added text in red.
- Variables that are not applicable for recreational fisheries: orange background. These variables could be automatically be set to "NA" for Type of fisheries= Recreational Fisheries

a. CL table:

Order	Name	Type	Req.	Basic checks	Comments
1	Record type	String	M		Fixed value CL.
	Source	String	M	Code list (Estimate/ Census)	"Estimate": for data coming from estimates based on sampling "Census": for data coming from official census data (logbooks and sales notes)
	Type of fisheries	String	M	Code list (Commercial /Recreational)	
	Unique survey id	String	M		For estimated data: the same code used in NP table 5 can be used. This will allow to provide more information on the sampling design (type of survey, design, sampling effort, practical issues, etc) For census data, a code list can be defined for logbooks and sales notes. The code "census" is not applicable for recreational
2	Landing country	String	M	Code list	ISO 3166 – 1 alpha-3 codes. In the special case where a vessel lands the catch in country A, but the catch is transported directly to country B, it should be registered as if it had been landed in country B.
3	Vessel flag country	String	M	Code list	ISO 3166 – 1 alpha-3 codes. The flag country of the vessel. This may be different from the landing country (see description of LandingCountry).
4	Year	Integer	M	Code list	1 900-3 000.
5	Quarter	Integer	M	Code list	1-4.

					Recreational: Optional. Yearly estimates are mandatory, but MS can provide a higher resolution if needed
6	Month	Integer	O	Code list	1-4.
	Area Type	String	M	Code list	Reg: Regions. as defined in table 3 in the EUMAP (EC, 2017) Div: Divisions, such as 27.7, etc Subdiv: Subdivisions, such as 27.8.a, etc * Under the EUMAP it is mandatory to collect data by region, but some survey may be able to provide higher spatial resolution.
7	Area	String	M	Code list	See text below table. Area level 3 (level 4 for Baltic, Mediterranean, and Black Seas) in the Data Collection Regulation (EC, 2008a, 2008b). Recreationl:Area as defined in table 3 in the EUMAP (EC, 2017)
8	Statistical rectangle	String	O	Code list	Area level 5 in the Data Collection Regulation (EC, 2008a, 2008b). This is the ICES statistical rectangles (e.g. 41G9). Use '99x9' outside FAO 27 and FAO 37/Northeast Atlantic and Mediterranean.
9	Subpolygon	String	O	Code list	National level as defined by each country as child nodes (substratification) of the ICES rectangles. It is recommended that this is coordinated internationally, e.g. through the Regional Coordination Meetings (EC RCMs).
10	Species	Integer	M	Code list	The AphiaID, which is a 6 digit code, is used for the species in the species field. The AphiaIDs are maintained by WoRMS. Only species AphiaIDs with status "Accepted" or "Alternate Representation" is allowed.
11	Landing category	String	M	Code list	The intended usage at the time of landing. This should match the comparable field in the LS record (whether or not the fish was actually used for this or another purpose). Codes: "IND" = industry or "HUC" = human consumption or "BMS" = Below Minimum Size landing. The "BMS" is added added to Landing category to be able to indicate the BMS landing in the CL record.
	Catch Category	String	O	Code list	This would be relevant only for recreational fisheries LAN: retained DIS: released
12	Commercial size category scale	String	O	Code list	Commercial sorting scale code (optional for "Unsorted").
13	Commercial size category	Integer	O	Code list	Commercial sorting category in the given scale (optional for "Unsorted"). See (EC, 2006) and later amendments when scale is "EU".
14	Fishing activity category National	String	O	Code list	Fishing activity category (= métier) – National level as defined by each country as child nodes (substratification) of the level-5 codes.
15	Fishing activity category European lvl 5	String	O	Code list	Should not be filled in when Fishing activity category European level 6 is filled. Fishing activity category (= métier) – Level 5 as defined in a hierarchical structure in the Data Collection Regulation (EC 2008a, 2008b). Recreational: REC_ALL

					REC_SEA REC_LAN
16	Fishing activity category European lvl 6	String	M	Code list	Fishing activity category (= métier) – Level 6 as defined in a hierarchical structure in the Data Collection Regulation (EC, 2008a, 2008b). Level 6 is further specified by the Regional Coordination Meetings (EC RCMs, Council Regulation [EC] No. 1543/2000). REC_ALL_FAO CODES FOR GEARS. REC_SEA_FAO CODES FOR GEARS. REC_LAN_ FAO CODES FOR GEARS.
	NumSamplesCatch	Integer	M	0-200000000	Number of samples to get the catch estimates.
17	Harbour	String	O	Code list	Landing harbour. Using harbour LOCODE codes (5 alpha- numeric) from the European Master Data Register Code- Location.xls
18	Vessel length category	String	M	Code list	Grouping of vessels into fleet segments according to the vessel length categories defined in the Data Collection Regulation (EC, 2008a, 2008b).
19	Unallocated catch weight	Integer	M	-2 000 000 000-2 000 000 000	Whole weight in kg.
20	Area misreported catch weight	Integer	M	-2 000 000 000 - 2 000 000 000	Whole weight in kg.
21	Official landings weight	Integer	M	0-2 000 000 000 (i.e. 2 million t)	Whole weight in kg. Weight can be entered as fresh weight or as estimated weight based on a statement of the number of fish boxes sold to the first buyer. Here, the estimated total weight would be reported (which can be retained or released). The name of the variable could be then changed to Total weight
22	Landings multiplier	Dec(3)	O	0.500-2.000	Multiplier to correct official landings for, e.g., overweight in fish boxes. A overweigth of 5 % more would give a value of 1.05
23	Official landings value	Integer	O	1-100 000 000	In € 5. Official sales value of the landings.
	Relative Standars Error	Integer	M		For estimated data: the minimum limit of the 95% confidence interval of the Total landing weight For census data: NA
	Total Numbers				Estimated total numbers
	RSE				For estimated data: the minimum limit of the 95% confidence interval of the Total numbers For census data: NA
	Bias estimate		M		For estimated data: A semi-quantitative scale ranging from +++ (large overestimate) to ––– (large underestimate) can be used as in Hyder et al 2017 For census data: NA

b. CE table:

Order	Name	Type	Req.	Basic checks	Comments
1	Record type	String	M		Fixed value CE.
	Source	String	M	Code list (Estimate/ Census)	"Estimate": for data coming from estimates based on sampling "Census": for data coming from official census data (logbooks and sales notes)
	Type of fisheries	String	M	Code list (Commercial /Recreational)	
	Unique survey id	String	M		For estimated data: the same code used in NP table 5 can be used. This will allow to provide more information on the sampling design (type of survey, design, sampling effort, practical issues, etc) For census data, a code list can be defined for logbooks and sales notes. The code "census" is not applicable for recreational
2	Vessel flag country	String	M	Code list	ISO 31661–alpha-3 codes. The flag country of the vessel.
3	Year	Integer	M	Code list	1900-3000.
4	Quarter	Integer	M	Code list	1-4. Recreational: Optional. Yearly estimates are mandatory, but MS can provide a higher resolution if needed
5	Month	Integer	O	Code list	1-12.
6	Area	String	M	Code list	See text below table. Area level 3 (level 4 for Baltic, Mediterranean, and Black Seas) in the Data Collection Regulation (EC, 2008a, 2008b). Recreational: Recreationl:Area as defined in table 3 in the EUMAP (EC, 2017)
7	Statistical rectangle	String	O	Code list	Area level 5 in the Data Collection Regulation (EC, 2008a, 2008b). This is the ICES statistical rectangles (e.g. 41G9). Use '99x9' outside FAO 27 and FAO 37/Northeast Atlantic and Mediterranean.
8	Subpolygon	String	O	Code list	National level as defined by each country as child nodes (substratification) of the ICES rectangles. It is recommended that this is coordinated internationally, e.g. through the Regional Coordination Meetings (EC RCMs).
9	Fishing activity category National	String	O	Code list	Fishing activity category (=métier)–National level as defined by each country as child nodes (substratification) of the level-5 codes.
10	Fishing activity category European lvl 5	String	O	Code list	Should not be filled in when Fishing activity category European level 6 is filled. Fishing activity category (= métier) – Level 5 as defined in a hierarchical structure in the Data Collection Regulation (EC 2008a, 2008b).

					Recreational: REC_ALL REC_SEA REC_LAN
11	Fishing activity category European lvl 6	String	M	Code list	Fishing activity category (= métier) – Level 6 as defined in a hierarchical structure in the Data Collection Regulation (EC, 2008a, 2008b). Level 6 is further specified by the Regional Coordination Meetings (EC RCMs, Council Regulation [EC] No. 1543/2000). REC_ALL_FAO CODES FOR GEARS. REC_SEA_FAO CODES FOR GEARS. REC_LAN_ FAO CODES FOR GEARS
	NumSamplesEffort	Integer	M	0-200000000	Number of samples to get the effort estimates.
12	Harbour	String	O	Code list	Landing harbour. Landing harbour. Using harbour LOCODE codes (5 alpha-numeric) from the European Master Data Register Code- Location.xls
13	Vessel length category	String	M	Code list	Grouping of vessels into fleet segments according to the vessel length categories defined in the Data Collection Regulation (EC, 2008a, 2008b).
14	Number of trips	Integer	M	1-50 000	If a trip covers more than one rectangle/SubPolygon, the rectangle with the most fishing is used. A trip is defined as the period between when a vessel departs from a port (or factory ship) and arrives at a port (or factory ship) for discharge of the catch
15	Number of sets/hauls	Integer	O	1-250 000	
16	Fishing time/soaking time	Integer	O	1-1 200 000	In hours.
17	kW-days	Integer	O	1-2 500 000	In kW days.
18	GT-days	Integer	O	1-2 000 000	In GT (Gross Tonnage) days.
	Units Effort	Integer	O	0-200000000	Boats/ fishing days… For recreational fisheries this variable cannot be standardized at the moment
19	Days at sea	Integer	O	1-25 000	In days. A day at sea shall be measured as any continuous period of 24 hours (or part thereof) when a vessel is absent from port. Recreational: Effort estimation in the units defined in the previous variable
	RSE	Integer	M		For estimated data: the minimum limit of the 95% confidence interval of the number of trips/days at sea/both? For census data: NA
	Bias estimate		M		For estimated data: A semi-quantitative scale ranging from +++ (large overestimate) to −−− (large underestimate) can be used as in Hyder et al 2017

For census data: NA

Length distribution data

The RDBES data model defines a variety of hierarchies to host raw sampling data for length distributions and biological variables. These hierarchies are designed to reflect the sampling design, and allow the calculation of the selection probabilities in each stage. Due to the high variety of sampling designs and raising procedures, adapted to the particularities of MRF in each country, MRF are not ready to fit in this hierarchy. Length distribution need to be raised by National institutes before storage in the data base. Therefore, we would still need a separate table similar to the table defined for length distribution data in Scenario A

Small Scale Fisheries in the RDBES

Catch and effort aggregated data (CL &CE)

The RDBES data model, uses tables CL and CE to provide aggregated information on catch and effort. This information is taken from official logbooks and sales notes, which is a suitable source information for commercial fisheries, but is often incomplete for SSF.

In the forthcoming scenario of the RCBES providing estimates from raw sampling data, it is important that the total catch and effort values are as much accurate as possible. For SFF this may imply to use alternative sources of information, such as dedicated sampling using monthly sheets, interviews, alternative logbooks, etc. The estimates coming from these alternative sampling programs should be incorporated in CL and CE tables if they are considered of better quality than the official data. In addition, a description of the survey and an assessment of its quality would be needed. The full process from survey design, implementation, data archiving and quality control, data analysis and reporting must be documented and transparent for each country contributing to a regionally coordinated SSF survey program. The format to store this information should be standardized and it will be linked to the table with the Unique Survey Id.

The colour key for the proposed modifications is the following:

- New variables: Blue background
- Variables which would need some changes, or new code lists: added text in red.

c. CL table:

Order	Name	Type	Req.	Basic checks	Comments
1	Record type	String	M		Fixed value CL.
	Source	String	M	Code list (Estimate/ Census)	"Estimate": for data coming from estimates based on sampling "Census": for data coming from official census data
	Unique survey id	String	M		For non official data: the same code used in NP table 5 can be used. For official census data, a code list can be defined for logbooks and salesnotes
2	Landing country	String	M	Code list	ISO 3166 – 1 alpha-3 codes. In the special case where a vessel lands the catch in country A, but the catch is transported directly to country B, it should be registered as if it had been landed in country B.
3	Vessel flag country	String	M	Code list	ISO 3166 – 1 alpha-3 codes. The flag country of the vessel. This may be different from the landing country (see description of LandingCountry).
4	Year	Integer	M	Code list	1 900-3 000.
5	Quarter	Integer	M	Code list	1-4.
6	Month	Integer	O	Code list	1-12.

7	Area	String	M	Code list	See text below table. Area level 3 (level 4 for Baltic, Mediterranean, and Black Seas) in the Data Collection Regulation (EC, 2008a, 2008b).
8	Statistical rectangle	String	O	Code list	Area level 5 in the Data Collection Regulation (EC, 2008a, 2008b). This is the ICES statistical rectangles (e.g. 41G9). Use '99x9' outside FAO 27 and FAO 37/Northeast Atlantic and Mediterranean.
9	Subpolygon	String	O	Code list	National level as defined by each country as child nodes (substratification) of the ICES rectangles. It is recommended that this is coordinated internationally, e.g. through the Regional Coordination Meetings (EC RCMs).
10	Species	Integer	M	Code list	The AphiaID, which is a 6 digit code, is used for the species in the species field. The AphiaIDs are maintained by WoRMS. Only species AphiaIDs with status "Accepted" or "Alternate Representation" is allowed.
11	Landing category	String	M	Code list	The intended usage at the time of landing. This should match the comparable field in the LS record (whether or not the fish was actually used for this or another purpose). Codes: "IND" = industry or "HUC" = human consumption or "BMS" = Below Minimum Size landing. The "BMS" is added added to Landing category to be able to indicate the BMS landing in the CL record.
12	Commercial size category scale	String	O	Code list	Commercial sorting scale code (optional for "Unsorted").
13	Commercial size category	Integer	O	Code list	Commercial sorting category in the given scale (optional for "Unsorted"). See (EC, 2006) and later amendments when scale is "EU".
14	Fishing activity category National	String	O	Code list	Fishing activity category (= métier) – National level as defined by each country as child nodes (substratification) of the level-5 codes.
15	Fishing activity category European lvl 5	String	O	Code list	Should not be filled in when Fishing activity category European level 6 is filled. Fishing activity category (= métier) – Level 5 as defined in a hierarchical structure in the Data Collection Regulation (EC 2008a, 2008b).
16	Fishing activity category European lvl 6	String	M	Code list	Fishing activity category (= métier) – Level 6 as defined in a hierarchical structure in the Data Collection Regulation (EC, 2008a, 2008b). Level 6 is further specified by the Regional Coordination Meetings (EC RCMs, Council Regulation [EC] No. 1543/2000).
17	Harbour	String	O	Code list	Landing harbour. Using harbour LOCODE codes (5 alpha- numeric) from the European Master Data Register Code- Location.xls
18	Vessel length category	String	M	Code list	Grouping of vessels into fleet segments according to the vessel length categories defined in the Data Collection Regulation (EC, 2008a, 2008b).
19	Unallocated catch weight	Integer	M	-2 000 000 000-2 000 000 000	Whole weight in kg. This field should be revised. In the case of an estimated total weight it would probably be NA
20	Area misreported catch weight	Integer	M	-2 000 000 000 - 2 000 000 000	Whole weight in kg.
21	Official landings weight	Integer	M	0-2 000 000 000 (i.e. 2 million t)	Whole weight in kg. Weight can be entered as fresh weight or as estimated weight based on a statement of the number of fish boxes sold to the first buyer. Here, the estimated total weight would be reported. The name of the variable could be then changed to Total landing weight

22	Landings multiplier	Dec(3)	O	0.500-2.000	Multiplier to correct official landings for, e.g., overweight in fish boxes. A overweigth of 5 % more would give a value of 1.05
23	Official landings value	Integer	O	1-100 000 000	In €. Official sales value of the landings. Here, the estimated landings value can be reported. The name of the variable could be then changed to Total landing value
	Landings RSE	Integer	M	0-200000000	Relative Standard Error of the estimated landings
	Value RSE	Integer	O	0-200000000	Relative Standard Error of the estimated value
	Bias estimate		M		For estimated data: A semi-quantitative scale ranging from +++ (large overestimate) to ––– (large underestimate) can be used as in Hyder et al 2017 For census data: NA

a. CE table:

Order	Name	Type	Req.	Basic checks	Comments
1	Record type	String	M		Fixed value CE.
	Source	String	M	Code list (Estimate/ Census)	“Estimate”: for data coming from estimates based on sampling “Census”: for data coming from official census data
	Unique survey id	String	M		For non official data: the same code used in NP table 5 can be used. For official census data, a code list can be defined for logbooks and salesnotes
2	Vessel flag country	String	M	Code list	ISO 31661–alpha-3 codes. The flag country of the vessel.
3	Year	Integer	M	Code list	1900-3000.
4	Quarter	Integer	M	Code list	1-4.
5	Month	Integer	O	Code list	1-12.
6	Area	String	M	Code list	See text below table. Area level 3 (level 4 for Baltic, Mediterranean, and Black Seas) in the Data Collection Regulation (EC, 2008a, 2008b).
7	Statistical rectangle	String	O	Code list	Area level 5 in the Data Collection Regulation (EC, 2008a, 2008b). This is the ICES statistical rectangles (e.g. 41G9). Use ‘99x9’ outside FAO 27 and FAO 37/Northeast Atlantic and Mediterranean.
8	Subpolygon	String	O	Code list	National level as defined by each country as child nodes (substratification) of the ICES rectangles. It is recommended that this is coordinated internationally, e.g. through the Regional Coordination Meetings (EC RCMs).
9	Fishing activity category National	String	O	Code list	Fishing activity category (=métier)–National level as defined by each country as child nodes (substratification) of the level-5 codes.

10	Fishing activity category European lvl 5	String	O	Code list	Should not be filled in when Fishing activity category European level 6 is filled. Fishing activity category (=métier)–Level 5 as defined in a hierarchical structure in the Data Collection Regulation (EC, 2008a, 2008b).
11	Fishing activity category European lvl 6	String	M	Code list	Fishing activity category (= métier) – Level 6 as defined in a hierarchical structure in the Data Collection Regulation (EC, 2008a, 2008b). Level 6 is further specified by the Regional Coordination Meetings (EC RCMs, Council Regulation [EC] No. 1543/2000).
12	Harbour	String	O	Code list	Landing harbour. Landing harbour. Using harbour LOCODE codes (5 alpha-numeric) from the European Master Data Register Code- Location.xls
13	Vessel length category	String	M	Code list	Grouping of vessels into fleet segments according to the vessel length categories defined in the Data Collection Regulation (EC, 2008a, 2008b).
14	Number of trips	Integer	M	1-50 000	If a trip covers more than one rectangle/SubPolygon, the rectangle with the most fishing is used. A trip is defined as the period between when a vessel departs from a port (or factory ship) and arrives at a port (or factory ship) for discharge of the catch There is a need to revise how the effort is calculated for SSF (See section XX of the report)
15	Number of sets/hauls	Integer	O	1-250 000	
16	Fishing time/soaking time	Integer	O	1-1 200 000	In hours.
17	kW-days	Integer	O	1-2 500 000	In kW days.
18	GT-days	Integer	O	1-2 000 000	In GT (Gross Tonnage) days.
19	Days at sea	Integer	O	1-25 000	In days. A day at sea shall be measured as any continuous period of 24 hours (or part thereof) when a vessel is absent from port. There is a need to revise how the effort is calculated for SSF (See section XX of the report)
	Effort RSE	Integer	M	0-200000000	Relative Standard Error of the estimated effort
	Bias estimate		M		For estimated data: A semi-quantitative scale ranging from +++ (large overestimate) to −−− (large underestimate) can be used as in Hyder et al 2017 For census data: NA

Sampling data (CS)

Raw data for length distributions and biological data of SFF fit well in the RDBES data model proposed for sampling data (CS). In opinion of this group, the hierarchies proposed are enough to allocate actual sampling schemes for this fleet.

RDBES, however, is not ready to allocate raw data for catch sampling if they are not associated with length distribution data (ie recording the catch observed in a sampling trip with no length sampling, or the catch reported by the fishers in an alternative logbook). Given the large variability of sampling schemes in place, it is recommended not to include this raw data yet and focus on assuring good quality of each individual survey.

Estimates derived from these surveys would be included in CL and CS tables as explained in section 1. The inclusion of raw catch sampling data can be revised din the future (an additional lower hierarchy?).

Annex 6

Annex 6.1 - CLEFRDB elementary classes

First installation

The library is currently developed on a github (https://github.com/ices-tools-dev/FishPi2/tree/master/WP6). The installation can be done with the following instruction. The version of R must be 3.6.0.

```
devtools::install_github("ldbk/CLEFRDB")
```

An operational example

A data-call asks for the monthly total landings for all the fishing areas where vessels operate. To answer this data-call, the creation of an object `Landing` containing (1) the landings values, (2) the corresponding dates (in this case the months) and (3) areas where fishing occurs.

The object `Landing` contains three entities:

(1) the numerical values of the information requested,

(2) a `Time` object,

(3) a `Spatial` object.

The objects (2) and (3) refer only to the time and the spatial characteristics of the landing events. They are built independently, and their conformity checked during the building process. The same construction principles apply for the object (1): in this simple example, this object is a positive numerical vector. To build the final `Landing` object, the objects (1), (2) and (3) are associated together, in a way they keep their internal validations mechanisms. The `Landing` object inherits the conformity checks and the objects types from which it was built. In the R language, the definition of the objects, their validities and their inheritance are based on the class definition, here the S4 classes.

The elementary classes

The classes identified as elementary are presented in the next section. They are implemented in the present package, but their implementation is subject to change according to the user needs and the data-calls scopes. We believe that the Time and the Space classes are generic enough to be needed across every data calls.

The library is then loaded:

```
library(CLEFRDB)
#> Loading required package: sf
#> Linking to GEOS 3.6.1, GDAL 2.2.3, PROJ 4.9.3
```

The time class

Temporal references are defined by a type (TimeType) and a date (TimeDate).

```
new("Time")
```

```
#> An object of class "Time"
#> Slot "TimeType":
#> character(0)
#>
#> Slot "TimeDate":
#> POSIXct of length 0
```

The type provides the temporal resolution at which the information is recorded, and the date the central date following the POSIXct format of the temporal event. Five TimeType are available:

```
print(Timetype)
#> [1] "year"    "quarter" "month"   "day"     "date"
```

corresponding respectively to annual, quarterly, monthly, daily and date with time events.

The definition of a Time object for a regular date (a nightly haul in May 2011 for example) is:

```
hauldate<-as.POSIXct(strptime("2011-03-27 01:30:03", "%Y-%m-%d %H:%M:%S"))
new("Time",TimeType="date",TimeDate=hauldate)
#> An object of class "Time"
#> Slot "TimeType":
#> [1] "date"
#>
#> Slot "TimeDate":
#> [1] "2011-03-27 01:30:03 CET"
```

Why adding such complex definition of a temporal event when adding column for year, month, day or quarter could be more straightforward? For two reasons:

- having a POSIXct object guarantees the conformity of the date, and gives to the user the possibility to extract time informaiton using R methods without any error,
- this object carries all the redondant information sometimes requested by the data-calls.

To illustrate these properties, let see a simple example with a set of four different temporal events recorded at different time scales:

```
haultime<-c("2011-03-27 01:30:03", "2011-03-27 12:00:00", "2011-03-15 12:00:00", "2011-02-14 00:00:00")
haultime<-as.POSIXct(strptime(haultime,  "%Y-%m-%d %H:%M:%S"))
haultime<-new("Time",TimeType=c("date","day","month","quarter"), TimeDate=haultime)
print(haultime)
#> An object of class "Time"
#> Slot "TimeType":
#> [1] "date"    "day"     "month"   "quarter"
#>
#> Slot "TimeDate":
```

```
#> [1] "2011-03-27 01:30:03 CET"  "2011-03-27 12:00:00 CEST"
#> [3] "2011-03-15 12:00:00 CET"  "2011-02-14 00:00:00 CET"
```

The four haul dates are recorded respectively at the date, the day, the month and the quarter scale. The corresponding dates are the dates at the middle of the day, the month and the quarter. If a data-call request date in year, the conversion is easy to compute:

```
substr(haultime@TimeDate,1,4)
#> [1] "2011" "2011" "2011" "2011"
```

More complex time manipulations are available using the lubridate R package.

Data quality

The conformity of the Time object is checked during the object construction. A Time class object is checked:

- TimeDate has to be POSIXct,
- TimeType has to be a character vector and presents in the Timetype object,
- the lengths of the two vectors have to be equal,
- no empty values allowed.

These commands will generate an error:

```
new("Time",TimeDate=c(NA),TimeType=c("day"))
new("Time",TimeDate=.POSIXct(c(NA,NA)),TimeType=c("day","day"))
new("Time",TimeType="date",TimeDate="2011-03-27")
hauldate<-as.POSIXct(strptime("2011-03-27 01:30:03",
          "%Y-%m-%d %H:%M:%S"))
new("Time",TimeDate=hauldate,TimeType=c("a day"))
new("Time",TimeDate=hauldate)
```

This behavior is not user-friendly, but simply asks the user to be consistent for a very simple field (time !). Addressing formatting error at the very beginning of the data preparation is the best way to propagate conformity quality inside a dataset.

An example

If a data-call request a data table containing the time series of the total landings. The S4 object related to this demand can be defined using the Time class as the container for the temporal definition, adding a new slot for the landings values. In this case, the new object class named Landings will inherit the Time class properties. The conformity check and the other methods belonging to the Time class will be transmitted to the new Landings object. The function initinherit of this package copies the parameters from one object to another based on their typology. For the Landings class containing the Time class, the Time parameters will be copied inside the Landings object.

```
#a Time object related to four haul
haultime<-c("2011-03-27 01:30:03", "2011-03-27 12:00:00", "2011-03-15 12:00:00","2011-02-14 00:00:00")
```

```
haultime<-as.POSIXct(strptime(haultime, "%Y-%m-%d %H:%M:%S"))
haultime<-new("Time",TimeType=c("date","day","month","quarter"), TimeDate=haultime)
# the value of the total landings of the four hauls
w<-c(10000,3000,2000,10)
#Definition of the Landings class
setClass(Class="Landings", slots=c("landings"="numeric"), contains=c("Time"),
    prototype=prototype(Landings=numeric(), Time=new("Time")))
#a new Landings object
new("Landings")
#> An object of class "Landings"
#> Slot "landings":
#> numeric(0)
#>
#> Slot "TimeType":
#> character(0)
#>
#> Slot "TimeDate":
#> POSIXct of length 0
#a new Landings object initialized with the previous values
initinherit(new("Landings"),landings=w,Time=haultime)
#> An object of class "Landings"
#> Slot "landings":
#> [1] 10000  3000  2000    10
#>
#> Slot "TimeType":
#> [1] "date"    "day"     "month"   "quarter"
#>
#> Slot "TimeDate":
#> [1] "2011-03-27 01:30:03 CET"  "2011-03-27 12:00:00 CEST"
#> [3] "2011-03-15 12:00:00 CET"  "2011-02-14 00:00:00 CET"
```

Space

The Space class follows the same class structure of the Time class. Spatial references are defined by a type (SpaceType) and a place (SpatialPlace).

```
new("Space")
#> An object of class "Space"
#> Slot "SpaceType":
#> character(0)
#>
#> Slot "SpacePlace":
#> character(0)
```

The type provides the spatial type at which the information is recorded, and the place the name of the spatial area corresponding to the type Both parameters are character vector Four SpaceType are available:

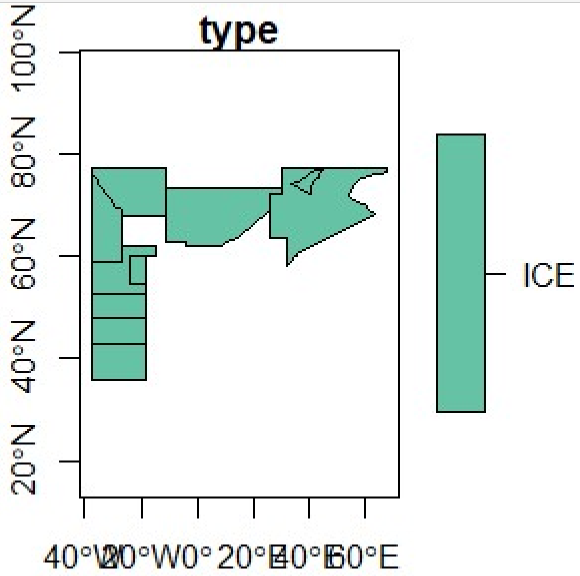
```
print(Spacetype)
#> [1] "ICESdiv"  "ICESrect" "harbour"  "GSA"
```

corresponding respectively to the ICES division (e.g. 27.7.g), the ICES rectangle (e.g. 50H6), the harbour in UNLOCODE (e.g. DEBRB) and the GSA area (e.g. GSA07). The object defspace of class sf gives the spatial geometry of these different spatial entities using simple features ISO standard definition.

```
head(defspace)
head(defspace)
#> Simple feature collection with 6 features and 4 fields
#> geometry type:  POLYGON
#> dimension:      XY
#> bbox:           xmin: -37.61719 ymin: 36 xmax: 67.85156 ymax: 77.23507
#> epsg (SRID):    4326
#> proj4string:    +proj=longlat +datum=WGS84 +no_defs
#>      type      id label country                  geometry
#> 1 ICESdiv  27.1.b    Ib    <NA> POLYGON ((67.85156 76.60384...
#> 2 ICESdiv  27.1.a    Ia    <NA> POLYGON ((40.66 73.17, 40.5...
#> 3 ICESdiv 27.10.a    Xa    <NA> POLYGON ((-18 43, -18 41.6,...
#> 4 ICESdiv 27.10.b    Xb    <NA> POLYGON ((-18 48, -18 47, -...
#> 5 ICESdiv 27.12.c  XIIc    <NA> POLYGON ((-18 52.5, -18 51....
#> 6 ICESdiv 27.12.b  XIIb    <NA> POLYGON ((-18 54.5, -18 54....
```

A plot of this object shows a map of all the geometry available.

```
library(sf)
plot(defspace[1:10,"type"], axes=T)
```

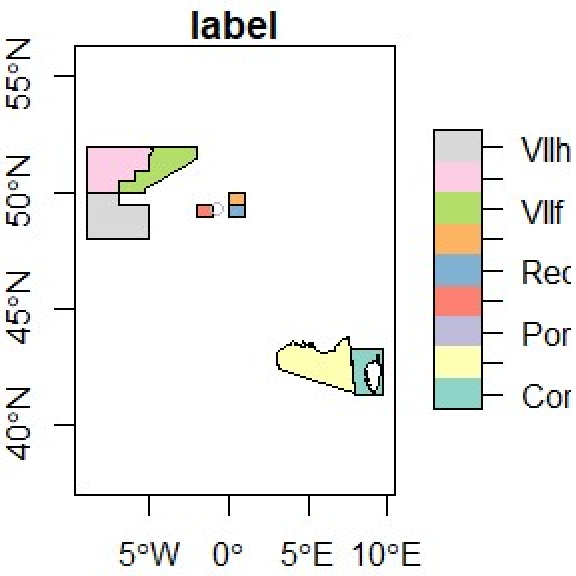


The construction of a simple Space object containing nine spatial objects (three ICES divisions, three ICES rectangles, two GSA areas and a harbour) is:

```
tripgeo<-new("Space",SpacePlace=c("27.7.f","27.7.g","27.7.h",
             "27E8","27F0","28F0", "GSA07","GSA08",  "FRRTB"),
 SpaceType=c("ICESdiv","ICESdiv","ICESdiv", "ICESrect", "ICESrect", "ICESrect", "GSA", "GSA",  "harbour"))
print(tripgeo)
#> An object of class "Space"
#> Slot "SpaceType":
#> [1] "ICESdiv"  "ICESdiv"  "ICESdiv"  "ICESrect" "ICESrect" "ICESrect"
#> [7] "GSA"      "GSA"      "harbour"
#>
#> Slot "SpacePlace":
#> [1] "27.7.f" "27.7.g" "27.7.h" "27E8"   "27F0"   "28F0"   "GSA07"  "GSA08"
#> [9] "FRRTB"
```

The plot method attached to the Space class map the geometry of the resulting object:

```
plot(tripgeo, axes=T)
```



Validation mechanisms are operating on the SpacePlace and SpaceType slots. The following commands will return an error.

```
new("Space",SpacePlace=c("27.7.h","GSA078"),          SpaceType=c("ICEdiv","GSA"))
new("Space",SpacePlace=c("27.7.h","GSA07","FRRTB","DEBRB"),
```

```
        SpaceType=c("ICESdiv","GSA","harbour"))
```

An example

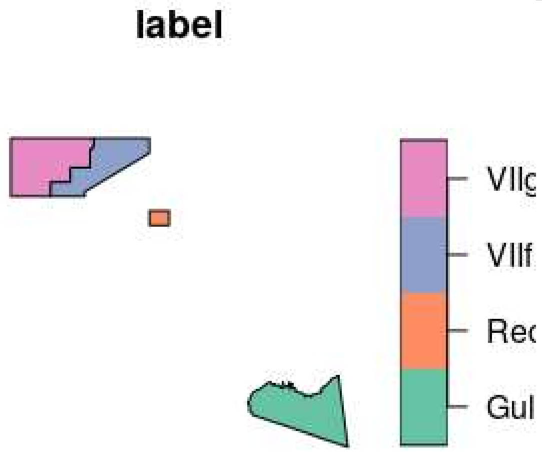
To illustrate the Space class use in an operational example, the previous example is extended. The data-call demands now the landings located in time and space. To define the new object, as previously, a Time object is build related to the date at which the four hauls were made, and a Space object referencing the areas where the hauls occur is added. Then the new object is defined as a new S4 class containing the landings values (the landings slot), the date of the hauls (the Time slot) and their positions (the Space slot). The values of the haultime and haulspace are copied in the new Landings object using the initinherit function. There is no need to check the conformity of the haultime and haulspace objects; this property was checked during the construction.

```
#a Time object related to four hauls
haultime<-c("2011-03-27 01:30:03",   "2011-03-27 12:00:00",
        "2011-03-15 12:00:00",   "2011-02-14 00:00:00")
haultime<-as.POSIXct(strptime(haultime,  "%Y-%m-%d %H:%M:%S"))
haultime<-new("Time",TimeType=c("date","day","month","quarter"),
                TimeDate=haultime)
# the value of the total landings of the four hauls
w<-c(10000,3000,2000,10)
#the area where the hauls were located
haulspace<-new("Space",SpacePlace=c("27.7.f","27.7.g",
            "27E8","GSA07"),
SpaceType=c("ICESdiv","ICESdiv","ICESrect","GSA"))

#Definition of the Landings class
setClass(Class="Landings",
      slots=c("landings"="numeric"),
      contains=c("Time","Space"),
      prototype=prototype(landings=numeric(),
                  Time=new("Time"),
                  Space=new("Space"))
      )
#a new Landings object
new("Landings")
#> An object of class "Landings"
#> Slot "landings":
#> numeric(0)
#>
#> Slot "TimeType":
#> character(0)
#>
#> Slot "TimeDate":
#> POSIXct of length 0
#>
#> Slot "SpaceType":
#> character(0)
```

```
#>
#> Slot "SpacePlace":
#> character(0)

#a new Landings object initialized with the previous values
haullanding<-initinherit(new("Landings",landings=w),Time=haultime,Space=haulspace)
print(haullanding)
#> An object of class "Landings"
#> Slot "landings":
#> [1] 10000  3000  2000    10
#>
#> Slot "TimeType":
#> [1] "date"    "day"     "month"   "quarter"
#>
#> Slot "TimeDate":
#> [1] "2011-03-27 01:30:03 CET"  "2011-03-27 12:00:00 CEST"
#> [3] "2011-03-15 12:00:00 CET"  "2011-02-14 00:00:00 CET"
#>
#> Slot "SpaceType":
#> [1] "ICESdiv"  "ICESdiv"  "ICESrect" "GSA"
#>
#> Slot "SpacePlace":
#> [1] "27.7.f" "27.7.g" "27E8"   "GSA07"
map(haullanding)
```




```
#dimclass(haullanding)
```

Regarding the conformity checks of the Landings object, one issue remains. The initinherit function checks if the numbers of objects in each class are the same, and the conformity of the Time and Space objects was checked during their constructions, but the condition of having only positive values in the landing slot is not test. To implement this new conformity check, a validity function can be define and associated to the

Landings cass. This function checks for an equal number of objects in each class, and test if the landings are positive values. For a more advanced discussion on how to define this validation mechanism, see the R's help about the setValidity method.

```
#validity of the landings object
validLandings<-function(object){
  if(any(object@landings<0)){print("negative landings !!");FALSE}else{TRUE}
}
#associate the validation function to the landings object
setValidity("Landings",validLandings)
#> Class "Landings" [in ".GlobalEnv"]
#>
#> Slots:
#>
#> Name:    landings   TimeType   TimeDate  SpaceType SpacePlace
#> Class:    numeric  character    POSIXct  character  character
#>
#> Extends: "Time", "Space"
#the original object is still valid
initinherit(new("Landings"),landings=w,Time=haultime,Space=haulspace)
#> An object of class "Landings"
#> Slot "landings":
#> [1] 10000  3000  2000    10
#>
#> Slot "TimeType":
#> [1] "date"    "day"     "month"   "quarter"
#>
#> Slot "TimeDate":
#> [1] "2011-03-27 01:30:03 CET"  "2011-03-27 12:00:00 CEST"
#> [3] "2011-03-15 12:00:00 CET"  "2011-02-14 00:00:00 CET"
#>
#> Slot "SpaceType":
#> [1] "ICESdiv"  "ICESdiv"  "ICESrect" "GSA"
#>
#> Slot "SpacePlace":
#> [1] "27.7.f" "27.7.g" "27E8"   "GSA07"
#a negative value in the landings slot will throw an error
## w<-c(10000,3000,-2000,10)
## initinherit(new("Landings",landings=w),Time=haultime,Space=haulspace)
```

Application

In this section, two examples are provided. The first example show how to generate object from the one available in this package, and some new objects to generate the table TR in the Fishframe format (ICES, 2018b). The second example will use these objects to generate the Fishing Trip table of the new RDBES format (ICES, 2019).

*The table **Trip** in Fishframe*

This table contains information regarding the fishing trip (identifier of the trip, number of hauls, days at sea, harbour of landing), the vessel (identifier, flag, length, power, size, type), and the sampling (type, year, method, sampling country, project name). To complete the information needed in this table, the class Space and Time will be used to provide the harbour and the year, while the Vessel and Sampling classes are built from scratch to provide the requested information.

*A **Vessel** class*

The Vessel class contains all the information related to the vessel. In the six slots of this class, the vessel identifier, its flag, type, length, power and size are recorded. To lighten this example, the conformity of the object will be not adressed here. Only the type of the slot (character, integer, numeric…) are checked. To validate the conformity of the object, the previous example shows how to define a validation function and to associate it to the object. The information of a fictional vessel populate this new object.

```
#Vessel class
setClass(Class="Vessel",
	slots=c(VesselId="character",
		VesselFlag="character",
		VesselType="character",
		VesselLength="integer",
		VesselPower="integer",
		VesselSize="integer"
		),
	prototype=prototype(VesselId=character(),
			VesselFlag=character(),
			VesselType=character(),
			VesselLength=integer(),
			VesselPower=integer(),
			VesselSize=integer()),
	)
#a fictional vessel
myVessel<-new("Vessel",
	VesselId="AAAA123",
	VesselFlag="FRA",
	   VesselType=c("Trawler"),
	VesselLength=as.integer(20),
	VesselPower=as.integer(5000),
	   VesselSize=as.integer(1000))
```

A new class Sampling is defined following the same approach.

```
#Sampling class"
setClass(Class="Sampling",
    slots=c(SamplingId="character",
       SamplingType="character",
       SamplingMethod="character",
       SamplingProject="character",
```

```
      SamplingCountry="character"),
    prototype=prototype(SamplingId=character(),
            SamplingType=character(),
            SamplingMethod=character(),
            SamplingProject=character(),
            SamplingCountry=character())
    )

#a fictionnal sample
mySampling<-new("Sampling",
      SamplingId="SAMP2199",
      SamplingType="S",
      SamplingMethod="Observer",
      SamplingProject="SamplingProjectFRA",
      SamplingCountry="FRA")
```

To complete the trip information, two Time and wto Spatial objects are defined for this trip. They refer to the location and the date of the beginning and the end of fishing trip:

```
mySpaceDep<-new("Space",SpacePlace=c("FRCOC"),SpaceType=c("harbour"))
mySpaceArr<-new("Space",SpacePlace=c("FRCOC"),SpaceType=c("harbour"))
myTimeDep<-new("Time",
      TimeDate=as.POSIXct(strptime("2011-03-15 12:16:00","%Y-%m-%d %H:%M:%S")),
      TimeType="date")
myTimeArr<-new("Time",
      TimeDate=as.POSIXct(strptime("2011-03-19 04:00:32","%Y-%m-%d %H:%M:%S")),
      TimeType="date")
```

Then, a new class corresponding to the Trip table is defined:

```
# a new Trip class
setClass(Class="Trip",
      slots=c(nbhaul="integer",
            daysatsea="integer",
      TripId="character",
      TimeDep="Time",
      TimeArr="Time",
      SpaceDep="Space",
      SpaceArr="Space"
            ),
      contains=c("Vessel",
            "Sampling"
            ),
       prototype=prototype(TripId=character(),
            nbhaul=integer(),
```

```
                    daysatsea=integer(),
                    Vessel=new("Vessel"),
                    Sampling=new("Sampling"),
                    TimeDep=new("Time"),
                    TimeArr=new("Time"),
                    SpaceDep=new("Space"),
                    SpaceArr=new("Space")
                    )
)

myTrip<-initinherit(new("Trip",
        TripId="FR872",
        nbhaul=as.integer(12),
        daysatsea=as.integer(5)),
        Sampling=mySampling,
        Vessel=myVessel,
        TimeDep=myTimeDep,
        TimeArr=myTimeArr,
        SpaceDep=mySpaceDep,
        SpaceArr=mySpaceArr)
```

Then, the export this object into the Trip format requested by Fishframe is only a matter of formatting (we suppose that all the field were checked for conformity, with the right validation function associated to each object). Here an example of such formatting:

```
FishframeTrip<-data.frame(`Record type`="TR",
         `Sampling type`=myTrip@SamplingType,
         `Landing country`=myTrip@SamplingCountry,
         `Vessel flag country`=myTrip@VesselFlag,
         `Year`=substr(myTrip@TimeArr@TimeDate,1,4),
         `Project`=myTrip@SamplingProject,
         `Trip code`=myTrip@TripId,
         `Vessel length`=myTrip@VesselLength,
         `Vessel power`=myTrip@VesselPower,
         `Vessel size`=myTrip@VesselSize,
         `Vessel type`=myTrip@VesselType,
         `Harbour`=myTrip@SpaceArr@SpacePlace,
         `Number of hauls`=myTrip@nbhaul,
         `Days at sea`=myTrip@daysatsea,
         `Vessel identifier`=myTrip@VesselId,
         `Sampling country`=myTrip@SamplingCountry,
         `Sampling method`=myTrip@SamplingMethod)
```

*The table **Fishing Trip** in the RDBES*

According to the Trip object, the formatting for the Fishing Trip table of the RDBES is done using the same information. Some parameters are not available in the original Trip object, but they can be added by the user according to its needs. For example the probability of sampling can be added to the Sampling object in order to complete the information requested by the RDBES. The export with the original Trip object to the RDBES format is:

```
RDBESTrip<-data.frame(`FishingTripID`=myTrip@SamplingId,
	`OnShoreEventID`="",
	`VesselSelectionID `="",
	`VesselDetailsID `=myTrip@VesselId,
	`SampleDetailsId`=myTrip@SamplingId,
	`Record type`="FT",
	`National Fishing trip Code`=myTrip@TripId,
	`Stratification`="",
	`Trip Stratum`="",
	`FishingTripsClustering`="",
	`FishingTripsClusterName`="",
	`Sampler`="",
	`NumberOfHauls`=myTrip@nbhaul,
	`Departure location`=myTrip@SpaceDep@SpacePlace,
	`Depature date`=substr(myTrip@TimeDep@TimeDate,1,10),
	`Depature time`=substr(myTrip@TimeDep@TimeDate,12,19),
	`Arrival location`=myTrip@SpaceArr@SpacePlace,
	`Arrival date`=substr(myTrip@TimeArr@TimeDate,1,10),
	`Arrival time`=substr(myTrip@TimeArr@TimeDate,12,19),
	`FishingTrips Total`="",
	`FishingTrips Sampled`=1,
	`FishingTripSampelProbability`="",
	`Selection method`="",
	`Selection Method Cluster`="",
	`FishingTripsTotClusters`="",
	`FishingTripsSampClusters`="",
	`FishingTripsClustersProb`="
```

Annex 6.2 – Participant list to the WP face to face meeting (Port-en-Bessin, France, October 2018)

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Annex 7

Annex 7.1 List of invited attendees and attendees at the fishPi2 Knowledge Exchange Workshop – 20-2-19

Date: Wednesday 20th February 2019 (09.30-15.00)

Location: Scotland House, Rond-point Robert Schuman 6, 1040 Bruxelles, Belgium

Purpose: The fishPi^2 project is designed to strengthening regional cooperation in the area of fisheries data collection for the Eastern Arctic, North Sea and North Atlantic regions with the strategic objectives of:

1. Building on the work achieved in the fishPi project, further strengthening regional cooperation
2. Providing clear guidance on the implementation phase of regional sampling
3. Looking to build both within region expertise and pan regional cooperation

The fishPi^2 knowledge exchange workshop was designed to share the results of the fishPi^2 project including draft recommendations for regional sampling designs and plans. The discussions were targeted at those with high-level responsibility for organising and delivering national fisheries data for statutory purposes.

Mark James chaired the event, which covered:

- Governance (WP Leader – Katja Ringdahl, SLU)
- Suitability for Regional Sampling (WP Leader - Liz Clarke, MSS)
- Regional Sampling Plan Designs (WP Leader - Liz Clarke, MSS)
- Impact on Marine Ecosystems (WP Leader - Anna Rindorf, DTU-Aqua)
- Small Scale and Recreational Fisheries (WP Leader – Estanis Mugerza, AZTI)
- Data Quality (WP Leader – Joel Vigneau, IFREMER)

The feedback from participants in the knowledge exchange event was collated by Emma Defew as part of fishPi2 Work Package 8, which will reflect upon the consultation through the Regional Co-ordination Groups.

Programme:

The programme consisted of a combination of 20-minute presentations, followed by 10 minutes for questions on each presentation. Time was also allowed for general discussion and feedback.

The main notes and actions from each of the work package sessions are recorded below.

WP1 session - Governance (WP Leader – Katja Ringdahl, SLU)

- The room agreed that the subgroup reports should have contributing authors named on them, and agreed that it was necessary to make the RCG work more attractive and career promoting for the individuals involved.
- The fishPi[2] project has resulted in a momentum for change within the RCGs.
- A regional sampling plan (RSP) is part of a regional work plan (RWP), but with a significant number of other components such as methodologies etc. Some of the easier tasks should start to be worked on now.
- There is an exponential growth of meetings, and care was needed in this regard.
- People are not aware of the regional work in the DCF, and increasing awareness was key. A user-friendly website to make the wider community aware of the DCF work was required.
- The room agreed that a Secretariat would be a very good idea, but it would need commitment from the Members States (MS) to support this work. Costings should be provided by the fishPi[2] project to allow MS to react to these at the next RCG meeting.
- It was important to consolidate expertise as current expertise was stretched too thinly.
- For now, pan regional coordination is only for the northern RCGs, but there was no need for this to be exclusive since there were many issues of general interest.

Action: Final report to include costings for a website and Secretariat/project manager, together with examples of a Secretariat model.
Action: RCGs to identify what roles/tasks the Secretariat could assist with.

WP2 session - Suitability for Regional Sampling (WP Leader - Liz Clarke, MSS)

- Deliverables from WP2 will aid discussions about what fisheries to select for regional sampling, and a set of tools will be provided on a website to aid these discussions.
- All functions will be accompanied by documentation and details of a relevant contact person. The tools themselves are relatively simple to use, therefore a high level of expertise is not required to use them.
- It was noted that redundancy in sampling could be one result of using these tools, which may be considered good for regional work.
- Data can be more difficult to collate when stocks are shared, and a discussion was needed about how best to facilitate future data calls (e.g. could calls for data be coordinated by the RCGs?). It was noted that it was important to establish trust and a precedent around data-sharing.
- Getting logbook data was not always easy and could be a barrier to using the tools.
- There was significant data available within the regional databases, and ICES could be asked to coordinate data calls for specific species through the RCGs.

Action: Provide some “How to” Youtube style videos, targeted at user groups.

WP3 session - Regional Sampling Plan Designs (WP Leader - Liz Clarke, MSS)

- The project team should bear in mind that EMFF is only running until 2020, and this could have an impact on costs and funds available.
- Stocks should be taken into account, and some small stocks would still need to be sampled.
- Value had not been looked at as part of the study. Numbers correlate with landed weight and therefore had some realism. Value could contribute to importance.
- Log book and sales data have been included, but this was dependent on institutions, and therefore differed between countries.
- At-sea sampling had not been investigated within the timeframe available for fishPi^2, sonshore sampling had been the main focus.
- Redeployment of resources between onshore and at sea sampling may need to be considered in certain countries.

WP4 session - Impact on Marine Ecosystems (WP Leader - Anna Rindorf, DTU-Aqua)

- It was noted that cost at sea was the biggest cost.
- The Baltic was currently being surveyed every year, but not all the data was being worked up.
- It would be better to send samples to a central centre of expertise, rather than every MS training someone up to undertake stomach contents identification work at substantial cost.
- Three predators surveys each year may be too much for some countries.
- There is significant variation in salaries between countries for working up stomach data. Some countries have already started, and therefore it may be better to have a joint initiative.
- IBTSWG could be approached, but they need a clear need/purpose in order to assist.
- Scientists will always agree that more data is beneficial, but the more data is collected, the more it costs.
- Many stock assessments are based on data from 1981 and 1991, but the composition of diets has very likely changed since then.

WP5 session - Small Scale and Recreational Fisheries (WP Leader – Estanis Mugerza, AZTI)

- There is currently a misunderstanding about Marine Recreational Fisheries (MRF) data being able to be used for stock assessments. Guidelines will be provided from fishPi^2 for future work and surveys in this area.
- The current RDB format is different to what is required for Small Scale Fisheries (SSF) and MRF.
- EMS and human observer system data is already being collated – could this be uploaded to the RDB? It should be possible to transform the EMS data into the correct format, but a workshop at the end of February 2019 was scheduled to discuss this matter.
- For MRF, time series data should be used, but unfortunately good time series data is not always available, and therefore significant extrapolation has to take place.

Action: Ensure that the recommendations for revision of EUMAP are officially communicated to the subgroups, who can then look at the financial implications of the recommendations.

WP6 session - Data Quality (WP Leader – Joel Vigneau, IFREMER)

- There was no significant discussion or questions about this WP presentation.
- The WP will devise an annual calendar for the implementation of the minimum set of data quality checks on national data and the quality checks on regional data that is consistent with the annual timeline of the data submission process to ICES expert groups and data calls to the RBD.

Final discussion session

- It was suggested that the strong recommendations from fishPi^2 required a mechanisms for incorporation into EUMAP. Mark James noted that the fishPi^2 project would deliver it recommendations to DGMARE.
- Grants were available to strengthen and help the RCGs develop intersessional work. There could be some specific information provided from the RCGs to the EUMAP meeting taking place in June 2019. DGMARE was very favourable to this cooperation.
- A short discussion took place on whether the EMFF provided the best possible mechanism for financing the RCGs. For example, in its current state it would not allow for a Secretariat to be financed from these funds. Most MS are willing to make commitments but need a 'process'.
- There was a requirement to resource the activities that would allow for change. The room agreed that decisions were needed at high-level around the issues of resources and funding.
- The room agreed that no further consultation was required and the fishPi^2 project team should concentrate on production of the draft final report.

Action: The fishPi^2 project would provide a short document that contained bullet points of the key recommendations from each WP. This document would be sent to the RCG Chairs and subgroups.
Action: Circulate slides from KE workshop.

[**Post meeting note:** *It has been agreed that the draft Summary Report containing recommendations would be shared with the RCG Chairs prior to formal sign off of the report by DG MARE, in order to allow the contents of the report to be considered in forthcoming RCG meetings*]

List of attendees (those in red registered to attend, but did not join the workshop on the day):

Name	**Job Title**	**Company**
Adrian Antonescu	Programme manager	DG MARE
Cannelle Beauchesne	Policy Assistant	European Commission
Eleni Bintoudi	Blue Book Stagiaire	European Commission - DG MARE
Anna Cheilari	Policy officer	European Commission
Blanca Garcia Alvarez	MARE-C3 Data Collection	European Commission

Stanislovas Jonusas	Policy officer	European Commission
Venetia Kostopoulou	Policy officer	DG MARE
Vedran Nikolic	Policy officer - Nature protection	European Commission
Joana Patricio	Fisheries Inspector	European Commission, DG MARE
Kenneth Patterson	Senior Expert	European Commission
Oana Surdu	Policy officer	European Commission - DG MARE
Javier Villar Burke	Economic Analyst	European Commission - DG MARE
Belgium		
Els Torreele	Scientist	ILVO
Denmark		
Marie Storr-Paulson	Head of Monitoring section	DTU Aqua
Estonia		
Elo Rasmann	Senior officer	Ministry of Environment
Finland		
Heikki Lehtinen	Ministerial Adviser	Ministry of Agriculture and Forestry
France		
Camille Dross	National Correspondent	France / Directorate for marine fisheries and aquaculture
Germany		
Matthias Bernreuther	Fisheries Biologist	Thuenen Institute of Sea Fisheries
Christoph Stransky	DCF National Correspondent	Thuenen Institute of Sea Fisheries
Ireland		
Andrew Campbell	Team Leader	Marine Institute
Leonie O'Dowd	Section Manager	Marine Institute
Italy		
Alessandro Ligas	Researcher	CIBM
Latvia		
Didzis Ustups	National Correspondent	Institute of Food Safety, Animal Health and Environment ”BIOR”
Lithuania		
Remigijus Sakas	Researcher	Klaipeda University

Antanas Kontautas	Researcher	Klaipeda University
Juranda Savukyniene	DCF LTU National Correspondent	Ministry of Agriculture Lithuania
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Emilia Batista	National Correspondent	DGRM-Directorate General for Natural Resources, Safety and Maritime Services
Suzana Faria Cano	Data Analyst	DGRM-Directorate General for Natural Resources, Safety and Maritime Services
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María Moset	Technical Advicer	Ministerio de Agricultura, Pesca y Alimentación
Jon Ruiz	Researcher	AZTI-Tecnalia
<u>Sweden</u>		
Maria Hansson	Environmental analyst	SLU aqua
<u>UK</u>		
Matthew Elliott	DCF National Correspondent	Marine management Organisation
Matthew Gubbins	Fisheries Data Programme Manager	Marine Scotland

The fishPi² Project

Regional co-operation in fisheries data collection

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