Assessing the state of demersal fish to address formal ecosystem based management needs: making fisheries independent trawl survey data 'fit for purpose'

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Author contribution statement

M.M carried out all data analysis and wrote the ms. J.R. & IdBprovided technical support and guidance on analysis and provided edits for the ms. S.P.R.G was the principal researcher who lead the project, he provided major edits to the ms.

Keywords

Data quality assurance, Data quality Audit, Marine Strategy Framework Directive (EU-MSFD), Common fisheries policy (CFP), data management, Ecosystem based management (EBM)

Abstract

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In Europe, introduction of the Marine Strategy Framework Directive (MSFD) represents formal, legally-binding, adoption of ecosystem-based management (EBM) across most European waters. Member States of the European Union have invariably nominated their groundfish surveys as part of the marine monitoring programmes required under the MSFD. Groundfish surveys were originally intended to provide fisheries independent abundance indices for commercially valuable species to support fisheries stock assessments and fisheries management. However, early studies, primarily intended to make the case for the need for EBM, exposed these data to a broader range of uses and highlighted various data quality issues. Individual scientists, pursuing personal research agendas, addressed these as each thought best. This informal approach to assuring data quality is not sufficient to support formal assessments of fish species status and fish community status required under legally-mandated EBM, such as the MSFD, because quality audit, formal logging of issues identified, and remedial measures taken, is often lacking. Groundfish survey data, needed to implement legally-mandated EBM, should be subjected to a formal Quality Assurance–Quality Audit (QAQA) process to ensure that they are properly fit for purpose. This paper describes a QAQA process applied European groundfish survey data to ensure their adequacy to support MSFD needs and considers how this process might be taken forward in the future.

Ethics statements

(Authors are required to state the ethical considerations of their study in the manuscript, including for cases where the study was exempt from ethical approval procedures)

Does the study presented in the manuscript involve human or animal subjects: No

Data availability statement

Generated Statement: Publicly available datasets were analyzed in this study. This data can be found here: https://data.marine.gov.scot/dataset/.

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(213 words)

Keywords: data quality assurance, data quality audit, Marine Strategy Framework Directive, Common Fisheries Policy, data management, ecosystem-based management

Introduction

In assessing the state of marine ecosystems in European waters, data are being used to address issues for which the original survey design is potentially inadequate. In Europe, fisheries independent groundfish surveys were originally intended to sample commercial fish species populations to support formal stock assessments under the European Union's (EU) Common Fisheries Policy (CFP). More recently, groundfish survey data have been used to address questions relating to, for example, the status of populations of rarer, commercially valuable species for which data are too sparse to support full formal stock assessment (Honey et al., 2010; Needle, 2015), assessing the impact of fishing mortality on populations of non-target, non-commercial fish species (Greenstreet and Rogers, 2000; Greenstreet et al., 2012a), and for monitoring and assessing the state of the broader fish community to support implementation of ecosystem-based management (EBM) (Jennings, 2004; Shin and Shannon, 2010; Shin et al., 2010a; Shin et al., 2010b; Greenstreet et al., 2011).

Early use of these groundfish survey data, beyond simply meeting commercial stock assessment needs, focussed on developing indicators of the state of fish populations and communities (Greenstreet and Rogers, 2006; Greenstreet et al., 2011; Greenstreet et al., 2012a; Greenstreet et al., 2012b), using these to demonstrate the impact of fishing on the state of fish components of marine ecosystems (Greenstreet and Hall, 1996; Greenstreet et al., 1999, Jennings et al., 1999; Garrison and Link, 2000; Shin et al., 2005), and generally making the case for the need for EBM (Jennings 2005; Jennings and Rice, 2011). However, data quality issues soon emerged (Daan 2001; ter Hofstede and Daan, 2006; 2008). These mainly related to non-commercial species, suggesting a higher level of attention, to 'quality assurance and quality audit' (QAQA), in respect of data required for formal CFP stock assessments. Scientists involved in research to develop EBM were aware of these data QAQA issues and applied protocols to address this (e.g. Greenstreet et al., 1999; ter Hofstede et al., 2010; Fung et al., 2012). However,approaches adopted by different researchers varied, resulting in differing interpretations of multiple, different 'data products', all purporting to represent the same source data set. This raised the question as to whether these different QAQA methods produced data products that were sufficiently different as to affect research outcomes (Fung et al., 2012)?

The Marine Strategy Framework Directive (MSFD) represents formal adoption of EBM in waters under EU jurisdiction (EC, 2008; 2010; 2017); it requires monitoring and assessment of all components of marine ecosystems. Many EU Member States (MS) have designated their groundfish surveys to fulfil legally mandated EBM requirements. Despite the issues with survey design, European groundfish survey data must therefore now meet the multiple objectives of different users. Fisheries scientists will continue to use groundfish survey data for CFP stock assessment purposes, but marine ecologists will now also need access to the same data to monitor and assess the state of the broader fish community. In addition, these data will also be drawn on to support academic research and strategic planning for other marine industries. Whilst potentially adequate to meet fisheries stock assessment purposes, critically groundfish survey data currently stored in the International Council for Exploration of the Seas (ICES) "database for trawl surveys" (DATRAS) portal may not be "fit for purpose" when used for assessing the status of the broader fish community, and all species therein. It is no longer appropriate that the QAQA process be left in the hands of individual scientists; the existence of multiple data products and the possibility that choice of data product could confuse assessment and policy decisions by EU policy makers. Compounding the issue, different indicators will potentially be used to assess fish community status and the status populations of individual species making up these communities thereby confusing the interpretation of the survey results (e.g. Bundy et al., 2010; Shin et al., 2010b; Greenstreet et al., 2012a; Greenstreet et al., 2012b; Tam et al., 2017). It would be unsatisfactory if the different indicator trends were not directly comparable because data sets on which analyses were performed were not identical. Such a situation could undermine the basis for integration of individual indicator assessment outcomes to produce overall assessments of fish components of marine ecosystems (Dickey-Collas, 2014; Link and Browman, 2014; Walther and Möllmann, 2014; Borja et al., 2014; Borja et al., 2016).

Assessments that constitute a legal obligation, such as meeting MSFD requirements, should be based on definitive data products that have been subjected to a rigorous QAQA process, which incorporate fully defined protocols to establish data quality and consistency, with every step of this process fully documented. These data products would then form the basis for all subsequent assessments. Such data products would represent 'snapshots' within an ongoing dynamic process in which new data submissions, updates and revisions occur continuously. Here such a procedure is described for groundfish surveys.

Overview of the groundfish surveys

Nineteen groundfish surveys were subjected to a comprehensive QAQA protocol (Moriarty et al., 2017; Greenstreet and Moriarty, 2017a; 2017b). Source data were downloaded from the ICES DATRAS portal (ICES 2017) where available, or where not available on DATRAS, data were provided directly by the national institutes involved. The aim was to produce a suite of definitive, fully QAQA, groundfish survey 'data products' that could provide the basis for assessments of the groundfish component of marine ecosystems across the entire Northeast Atlantic region. These surveys provide a temporal coverage of between 10y and 35y and a spatial coverage spanning three of the four subregions of the Northeast Atlantic region defined in Article 4 of the MSFD in the Greater North Sea (including the Kattegat and English Channel), the Celtic Seas, and the Bay of Biscay and Iberian Coast (EC, 2008). None of the surveys considered here operated in a fourth subregion defined in the MSFD, i.e. the Macaronesian biogeographic region (EC, 2008). However, data from surveys carried out on sea mounts and plateaus beyond the continental shelf, and therefore outside the Celtic Seas and Bay of Biscay and Iberian Coast subregions, were considered, so a fourth subregion, given the OSPAR region V name, the Wider Atlantic Ocean, was included (Figure 1a).

Bottom trawl surveys carried out in the Northeast Atlantic have involved fourteen fisheries research vessels using either otter trawls or beam trawls with various rigging configurations and catch efficiencies (ICES, 2009; 2012; 2013; 2015). Survey time-series duration varied; some, e.g. The North Sea First Quarter otter trawl survey, started in the 1960s, others as late as the early 2000s (ICES 2012). Because of their large geographic size, often including several national jurisdiction areas, no single MSFD sub-region in the Northeast Atlantic has been monitored by any single groundfish survey across its entirety. Table 1 lists the 19 surveys processed to date to derive the Groundfish Survey Monitoring and Assessment (GSMA) data products, provides their respective product acronyms, and includes basic information regarding each survey. Fully QAQA data products were not published for the four Spanish surveys because only commercial species' data were available from DATRAS; data for non-commercial species were provided directly from the national data provider (NDP) and had not therefore passed through DATRAS upload data checks. Figure1b illustrates the geographical coverage provided by the remaining 15 published QAQA survey data sets.

Data quality assurance and audit

The CFP sets out key principles for data: e.g. accuracy, reliability and timeliness, avoidance of duplication through improved coordination, safe storage in data base systems, and improved availability (EC, 2013). The first step in deriving fully QAQA data products for each survey was to define their 'standard monitoring programmes' (Moriarty et al., 2017), excluding trawl samples collected with non-standard trawl gears, with non-standard tow durations, or before a defined survey protocol had been fully established. For example, first quarter (Q1) groundfish survey data held on DATRAS included data from 1966 onwards, but the modern day Q1 International Bottom Trawl

Survey (IBTS) only really became established from 1983 onwards, when all vessels involved followed a defined sampling protocol using the same GOV trawl gear towed for either 30min or 60min. Examination of the data suggested that tow durations of 15, 20, 30 and 60 min were all deemed acceptable in the various survey protocols. Consequently, samples with tow durations of 13 to 66 min were all retained as part of the survey ‘standard monitoring programmes’, but samples of shorter or longer tow duration were deemed non-standard and excluded. Data deemed part of each survey’s ‘standard monitoring programme’ were then processed following the protocol summarised in Figure 2 to derive the eventual GSMA data products (green box). The three blue oval steps constitute the main quality assurance part of the protocol; individual processes contained in these steps are summarised in Table 2. The orange and mauve ‘review’ box steps, along with the detailed documentation describing the whole QAQA protocol (Moriarty, et al. 2017; Greenstreet and Moriarty, 2017a; 2017b), constitute the quality audit part. The extent to which different surveys were affected by different data quality issues varied, with older surveys being most susceptible. A subset of the ‘standard monitoring programme’ data products was also derived, consisting only of data collected from within a ‘standard survey area’. To be part of the ‘standard survey area’, ICES statistical rectangles had to be sampled in at least 50% of years that a survey was undertaken and in at least one year in the two periods at the start and end of the time series, each constituting at least 20% of the survey duration. Thus, for rectangles to be included in the ‘standard survey area’ of a survey running 20y from 1996 to 2016, they would have to be sampled in at least 10y, and at least once in the two 4y periods 1996 to 1999 and 2013 to 2016.

The screening process involved examining parameter values for outlier and missing values. Where values were absent, the information was usually never recorded in the first place, models were developed for each parameter so that missing values could be filled by modelled estimates (Moriarty et al., 2017). Potential data errors were referred back to relevant NDPs for checking (feedback loop 1, Figure 2). Three outcomes were possible: the datum was confirmed to be correct and simply an outlier, or the datum was deemed to be either ‘erroneous’ or ‘incorrect’. ‘Erroneous data’ were a consequence of imperfect data archiving: a typo. These were corrected simply by editing the archived values and re-uploading the revised national data to DATRAS. 'Incorrect data' were more difficult to rectify; here archived values matched original values recorded at source. If mistakes had occurred, they happened at source and it was no longer possible to establish whether the value in question was in fact a data error or a correct but outlier value. In these instances it was necessary to decide whether the value in question had sufficient credibility as to be possible, or whether the recorded value was so unlikely that it must be considered wrong. Clear criteria were defined to underpin such decisions, based on expert judgement from the ICES survey working groups, the OSPAR indicator leads and the authors. Where the datum was deemed to be 'incorrect', so extreme an outlier as to not be possible, these data were deleted and a 'missing value' procedure employed to replace them with modelled estimates (Moriarty et al., 2017)..

Replacing 'incorrect' and 'missing' values in this way was preferable to the alternative of simply deleting the records concerned. Firstly, individual parameter values often affected other data. For example parameter values such as trawl sample tow distance, if deleted would have resulted in the deletion of all data for that sample with the consequent loss of a considerable amount of 'good' information. Secondly, deletion of missing or incorrect data would impart bias. For example, if species length data was absent and only count data available, deleting the data for that species would bias resulting estimates of species diversity. Replacing such missing data with modelled estimates might at worst impart noise, rather than bias. Thirdly, missing or incorrect data was more common in the early years of most surveys; deletion of these data could have compromised time series longevity. At each stage of the QAQA process the action taken to infill 'incorrect' and 'missing' values was labelled with an identifier tag, these datasets can be made available to an end user wishing to interrogate the data further. As an example of the criteria and methodology used in the QAQA protocol described in Moriarty et al. (2017), the process for assessing the reliability of recorded towed distance values, along with the criteria for correcting erroneous values, replacing incorrect values and estimating values where this information was missing is illustrated in Figure 3.

Data usage

In addition to using the data products described here to underpin assessments required to fulfil EBM needs, they can be used for any ecological research that requires estimates of numbers/abundance/biomass at length of given fish species (including many non-commercial species) at specified points in both space and time. There are now 15 fully QAQA data products available for such research (Table 1), with detailed R scripts and technical documents to allow complete reproducibility. The data products and documentation are available from https://data.marine.gov.scot and the code is accessible https://github.com/MarineScotlandScience/MSFD-QA-GFSM-A-DP/releases. It is the degree of consultation with NDPs, extent of review by experts involved in survey operations, data management, and assessment analysis (4 feedback loops, Figure 2), and the voluminous documentation describing the process (Moriarty et al., 2017; Greenstreet and Moriarty 2017a; 2017b), that separates the data products described here from those produced previously by individual scientists pursuing personal research programmes.

Looking to the Future

Here we have identified one aspect of the increasingly diverse need for data to support ecosystem approaches to assess and manage our seas. The additional demands being made of groundfish survey data associated with implementation of legally mandated EBM such as the MSFD means that QAQA issues concerning data stored on shared databases like DATRAS must now be addressed. The first steps towards this, described here, were taken specifically to meet the immediate needs of the OSPAR Interim Assessment 2017.

The data quality issues highlighted here and detailed in Moriarty et al. (2017) are part of a wider discussion relating to survey design, optimisation and managing the needs of end users. Data quality issues are inherent in historic time series, here we have identified and corrected many data issues within the European groundfish survey data. However the discussion that has been initiated on data quality within our surveys will require big picture thinking and an international response. This conversation must be placed in the context of the wider discussion of survey optimisation and modernisation in a changing environment. We must consider all the potential future changes, both mechanically (e.g. changes in fishing gears and practices) and environmentally (e.g. reducing impact of marine surveying on the environment).

The quality issues that emerged during this process related to many different aspects of the data collection process. The sampling information collected generally relates to where (e.g. location), when (e.g. date and time of day), gear configuration (e.g. type of ground-gear used), tow speed, tow duration and distance covered between the gear settling on the seabed on shooting and lifting off the seabed on hauling, and the effective width of gear to determine the area of seabed swept by the trawl. Accurate and consistent measurement and recording of all these parameters is critically important if the biological information collected is to be properly interpreted. For example, sample abundances are frequently reported as catch-per-hour, but our analyses suggest that tow speeds, and consequently the distance covered in a stipulated time (e.g. 30min), can vary by as much as a factor of two. In such circumstance the same catch-per-hour values can give very different sample abundance estimates if instead these are reported as catch-per-km^2 of seabed covered. As technology becomes more readily available to accurately measure these details it should be employed, and used consistently by all parties involved in ground fish survey operations.

The major issues found with the biological information collected on fisheries surveys were generally related to the non-commercial species. More training is required to facilitate accurate and consistent identification of clandestine species that might be encountered only infrequently. We must also consider how our surveys can help to inform on changes in our marine fish communities (e.g. shifting geographical ranges of species due to climate change). We will need to upskill our scientists to recognise fish species not previously reported. We may also need to consider adding modern, less destructive sampling techniques, such as eDNA, to our survey designs to better understand our changing fish communities. Strict guidelines relating to the sub-sampling of particularly large catches should be adhered to by all parties involved in collaborative surveys, with a single procedure for the recording of data obtained from such catches adopted by all involved. Ideally a single measurement unit would be used across all species sampled, but if this is not feasible, then the number of different measurement methods used should be kept to an absolute minimum, with clear guidelines as to the circumstances under which each particular method should be used.

Nineteen groundfish surveys were subjected to our QAQA protocol, each of these surveys follow their own survey protocols and individual survey designs (Moriarty et al., 2017). Because of their large geographic size no single MSFD sub-region in the Northeast Atlantic has been monitored by any single groundfish survey. It is important that we can appropriately integrate these surveys to assess fish community status and the status populations of individual species making up these communities. Where two surveys meet, it is imperative that paired tows are carried out on a regular basis so that we can make inference at scales that are relevant to the species. Moriarty et al. (in prep), applies a generalized additive mixed modelling framework that allows scientist to combine all nineteen surveys to make inference on fish communities at the scale of the north east Atlantic. The Iberian coast region requires more support to better integrate these surveys, currently Spain only report commercially valuable species to DATRAS, this causes problems for scientists interested in understanding species and community distribution shifts at multiregional scales. Knowledge sharing and scientist exchange is key to increasing efficiency of our shared survey areas.

The work reported here has primarily been undertaken by a single national organisation, albeit with huge cooperation from scientists, institutes, and institutions across Europe, but leaving this process in the hands of single organisations is not ideal. Firstly, resource implications, for example the manpower required, are not trivial and will need to be properly addressed moving forward. This is a huge responsibility; it is important that the job be done right, or at least, with full agreement and acceptance by all stakeholders involved. Such a task is best carried out as a formally organised co-operative collaborative enterprise. Assessments of the fish component of marine ecosystems will in the future continue to rely on the groundfish survey data collected by individual MS, and because these data are also needed to support stock assessments and implementation of the CFP, these data will continue to be uploaded and stored on DATRAS. ICES has both the expertise and the system in place, through its working groups supported by scientists from Europe and beyond, to ensure that the DATRAS can be made fully fit for purpose to meet both CFP and MSFD needs. To this end, ICES has already created a new DATRAS governance group. All that is left is to ensure that ICES has both the financial and scientific support from MS and the Regional Seas Conventions to ensure that DATRAS QAQA issues linked to MSFD implementation are fully understood and properly addressed. We propose that ICES DATRAS is the best existing solution to build on, and that the observations and lessons learned from the QAQA exercise described here should be adopted and incorporated through the means of a newly formed governance structure.

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Figure legends

Figure 1a. The Sub-regions of the North-east Atlantic Ocean Region; The Greater North Sea (including the Kattegat and English Channel), the Celtic Seas, the Bay of Biscay and Iberian Coast, and the Wider Atlantic Ocean.(Shapefile source: OSPAR website). b. Survey coverage of the 15 published datasets across the Northeast Atlantic See Table 1 for explanation of survey acronyms.

Figure 2. Overview of the groundfish survey monitoring and assessment process relevant to the ICES community. Numbers highlight the different feedback loops following consultation with national data providers (1), ICES Working Groups(2&3) and indicator leads (4).

Figure 3. Flow chart illustrating the steps involved in assessing the validity of recorded Towed distance values and to estimate missing and replace incorrect data form Moriarty et al. (2017). Source Code – GITHUB https://github.com/MarineScotlandScience/MSFD-QA-GFSM-A-DP/6_Haul_QA (Line 468 - 601)

Table legends

Table 1. List of individual surveys considered in the derivation of the OSPAR Groundfish Survey Monitoring and Assessment data products. Survey acronyms reflect sub-region/country/gear/quarter, except CS/BB in the French EVHOE survey acronym to denote a survey that extends across two sub-regions, the Celtic Seas and Bay of Biscay. Data product start and end years reflect the period when surveys were deemed sufficiently established with consistent standardised methodology (Moriarty et al., 2017). NDB refers to national database. At the time of the QAQA data product release the Spanish data could not be made available as the underlying data that was used to create the product was not open source, thus the process was not repeatable.*

Table 2. Summary of issues identified in the groundfish survey data stored on the DATRAS portal or on national databases and approaches adopted to address these.

Figure 4.TIF

Survey Acronym	DATRAS Acronym	Country	Start Year	End Year	Vessels	Quarter	Gear Type	Subregion	Data Source	DOI
GNSIntOT1	IBTS	International	1983	2017	Multiple Ships	1	Otter (GOV)	Greater North Sea	DATRAS	10.7489/1922-1
GNSIntOT3	IBTS	International	1998	2016	Multiple Ships	3	Otter (GOV)	Greater North Sea	DATRAS	10.7489/1923-1
GNSFraOT4	FR CGFS	France	1988	2016	Thalassa II, Gwen Drez	4	Otter (GOV)	Greater North Sea	DATRAS	10.7489/1959-1
CSScoOT1	SWC-IBTS	Scotland	1985	2016	Scotia II/III	1	Otter (GOV)	Celtic Sea	DATRAS	10.7489/1957-1
CSScoOT4	SWC-IBTS	Scotland	1997	2016	Scotia II/III	4	Otter (GOV)	Celtic Sea	DATRAS	10.7489/1924-1
CSIreOT4	IE-IGFS	Ireland	2003	2016	Celtic Explorer	4	Otter (GOV)	Celtic Sea	DATRAS	10.7489/1925-1
CSNIrOT1	NIGFS	Northern Ireland	1992	2016	Corystes	1	Otter (ROT)	Celtic Sea	DATRAS	10.7489/1961-1
CSNIrOT4	NIGFS	Northern Ireland	1992	2016	Corystes	4	Otter (ROT)	Celtic Sea	NDB (92-07) DATRAS (08-15)	10.7489/1962-1
CS/BBFraOT4	EVHOE	France	1997	2016	Thalassa II	4	Otter (GOV)	Celtic Sea/Bay of Biscay	NDB (92-07) DATRAS (08-15)	10.7489/1958-1
BBIC(n)SpaOT4	SP-North	Spain	1993	2014	F deP Navarro Cornide de Saavedra	4	Otter (BACA)	Bay of Biscay and Iberian Coast	NDB	Not released, no DOI
BBIC(s)SpaOT1	SP-ARSA	Spain	1990	2015	F deP Navarro Cornide de Saavedra	1	Otter (BACA)	Bay of Biscay and Iberian Coast	NDB	Not released, no DOI
BBIC(s)SpaOT4	SP-ARSA	Spain	1997	2014	F deP Navarro Cornide de Saavedra	4	Otter (BACA)	Bay of Biscay and Iberian Coast	NDB	Not released, no DOI
BBICPorOT4	PT-IBTS	Portugal	2001	2014	Capricornio, Noruega	4	Otter (NCT)	Bay of Biscay and Iberian Coast	DATRAS	10.7489/1963-1
WAScoOT3	Rockall	Scotland	1999	2016	Scotia II/III	3	Otter (GOV)	Wider Atlantic	DATRAS	10.7489/1960-1
WASpaOT3	SP-PORC	Spain	2001	2015	Vizconda de Eza	3	Otter (PBACA)	Wider Atlantic	NDB	Not released, no DOI
GNSNetBT3	BTS	The Netherlands	1999	2016	Isis, Tridens II	3	Beam (8m)	Greater North Sea	DATRAS	10.7489/1967-1
GNSEngBT3	BTS	England	1990	2016	Carhelmar, Corystes, Endevour	3	Beam (4m)	Greater North Sea	DATRAS	10.7489/1966-1
GNSGerBT3	BTS	Germany	1998	2016	Solea I/II	3	Beam (7m)	Greater North Sea	DATRAS	10.7489/1965-1
CSEngBT3	BTS VIIa	England	1993	2015	Corystes, Endevour	3	Beam (4m)	Celtic Sea	DATRAS	10.7489/1964-1

Figure 5.TIF

Issue	Solution
Haul positions missing or same as shoot position.	Haul position deleted if same as shoot position. Geo-referencing dependent on shoot position.
Shoot/Haul positions outside reported ICES statistical rectangle.	If position correct, ICES rectangle adjusted. If ICES rectangle correct, position altered to rectangle mid-point.
Reported depths checked against bathymetry map. Deviation of ± 50% checked.	Erroneous values corrected, otherwise all recorded depths considered correct.
Missing depth data (1% of samples).	Depth from bathymetry map at trawl location assigned.
Missing sweep-length data (40% of samples).	Available data suggested close adherence to survey manuals. Missing values filled with manual recommendation.
Extreme haul duration values.	Invariably correct or erroneous. If erroneous, corrected accordingly. No missing values.
Missing groundspeed data (38% of samples). Incorrect groundspeed value recorded.	Groundspeed estimated from one of two possible models using Quarter, Vessel, and Gear as factors.
Missing/incorrect towed distance data.	Estimated as: 1) Haversine distance between shoot/haul positions (15.1% samples); 2) function of tow duration x groundspeed (7.3% samples); function of tow duration and manual recommended groundspeed (0.2% samples).
Missing/incorrect wing-spread values (44% of samples).	Estimated using one of four models using door-spread, depth, and gear as factors or using value stipulated in relevant survey manual.
Missing/incorrect door-spread values (29% of samples).	Estimated using one of four models using wing-spread, depth, and gear as factors or using value stipulated in relevant survey manual.
Missing/incorrect net opening values (20% of samples).	Estimated using one of three models using depth, gear as factors or using value stipulated in relevant survey manual.
Mix of accepted and historic species names and/or synonyms.	All species assigned their unique 'accepted ' WoRMS aphia code
Species recorded outside known geographic range.	Referred to data provider for checking. Erroneous identifications corrected. Otherwise, if supported by evidence ID retained, if no supporting evidence, species ID replaced with genus/family ID code and subsequently changed to most likely Species ID code using kNN procedure (see below).
Multiple length measurement types (total length, fork length, pre-anal length, etc.) and length measurement units (cm, mm) used.	All lengths converted to 'total length' measured to 1cm below.
Recorded length outside known minimum and maximum length range for the species recorded.	Referred to data for check and erroneous species ID or length measurements altered. Otherwise extreme lengths retained if supported by taxonomic evidence or length >0.6L_{min} or <1.4L_{max}. If no supporting evidence and length <0.6L_{min} or >1.4L_{max}, species ID assumed correct and length altered to 1.1 L_{max} or 0.9 L_{min} as appropriate.
Multiple abundance measures used.	All abundances altered to actual numbers in the catch, then numbers per square kilometre of area swept in the trawl determined.
Recorded species ID code is not a species-level code, is either a genus-level or family-level code.	On a survey by survey basis, kNN procedure applied to assign most likely species-level code, or to replace all species-level codes in the genus or family to the coarser taxonomic resolution genus-level or family-level ID code.
No numbers at length data recorded, just a species count.	On a survey by survey basis, kNN procedure applied to assign most likely length frequency distribution.

Figure 6.JPEG

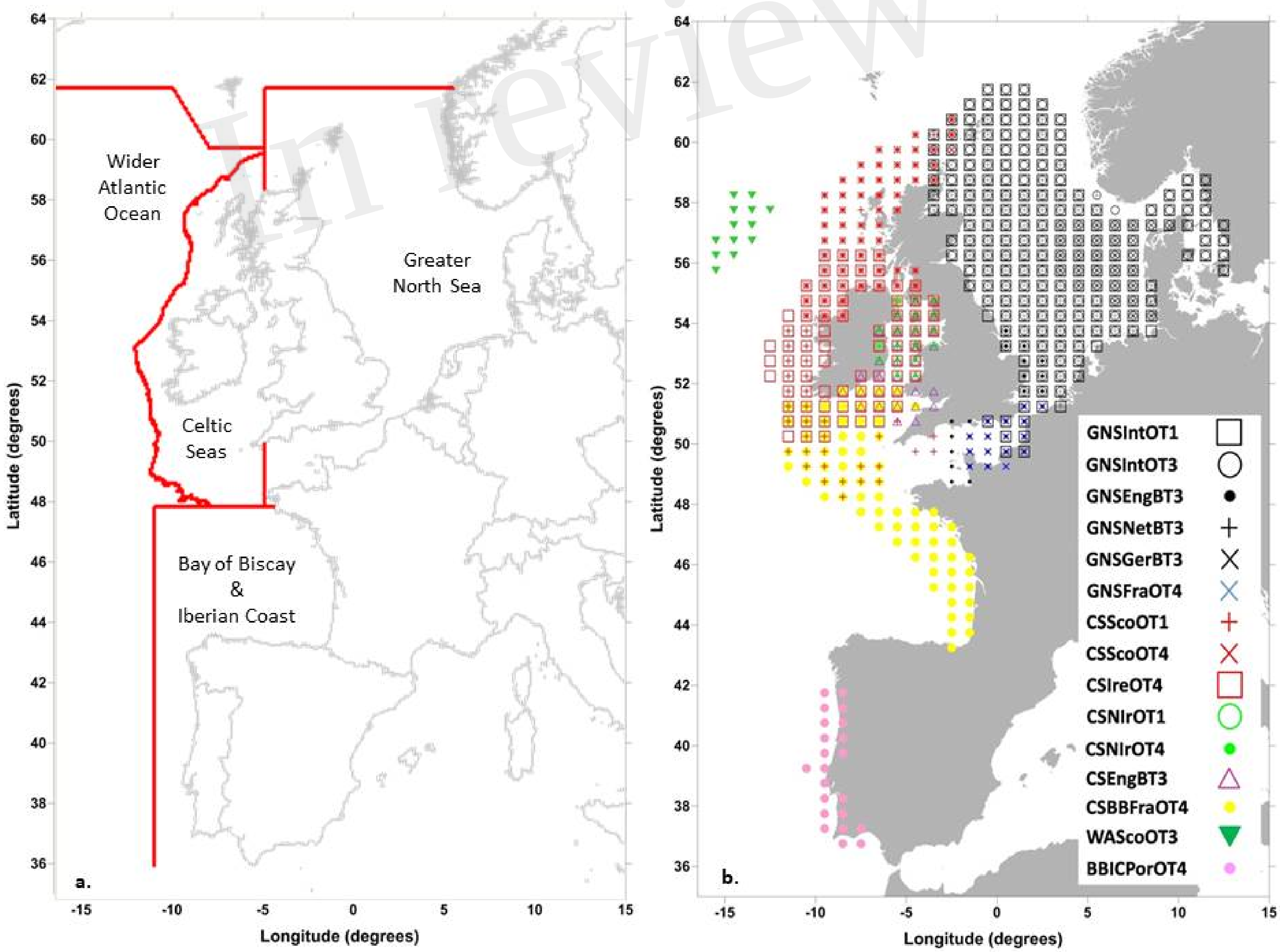

Figure 7.JPEG

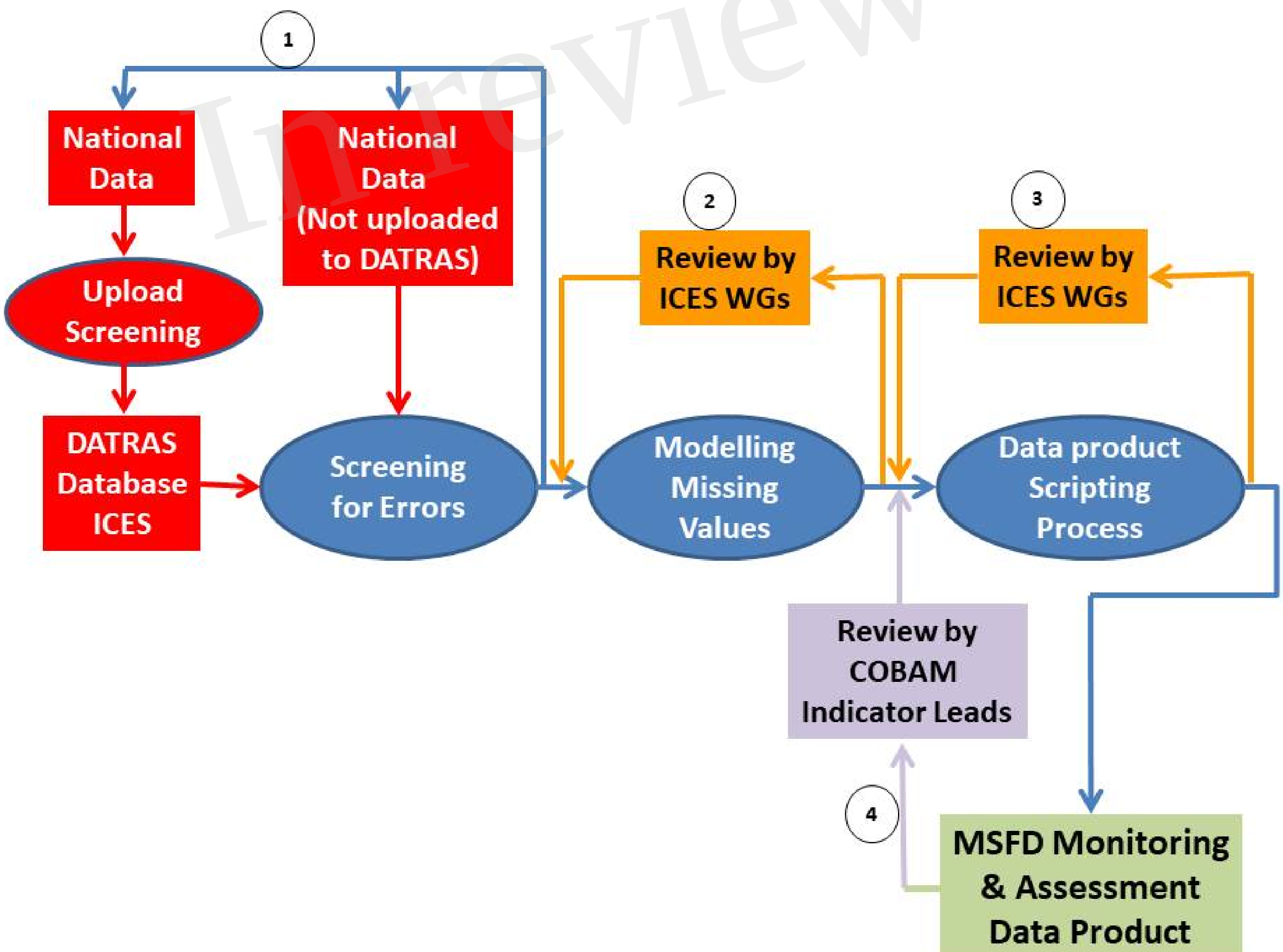

Figure 8.JPEG