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Scottish Marine and Freshwater Science Vol 8 No 16

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marine scotland

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Published by Marine Scotland Science
ISSN:2043-7722
DOI: 10.7489/1984-1

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This report presents the results of marine and freshwater scientific work carried out by Marine Scotland Science.

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Derivation of Groundfish Survey Monitoring and Assessment Data Products for the Northeast Atlantic Area

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Executive Summary

Under the Marine Strategy Framework Directive (MSFD), Member States (MSs) of the European Union (EU) are required to achieve 'Good Environmental Status' (GES) in respect of biodiversity and food web structure and function. In marine ecosystems, fish constitute a major fraction of marine biota in the size range 4 g to 200 kg, and they fulfil a pivotal role in food web structure and functioning. Fish communities are, therefore, key components of marine biodiversity and marine food webs. Monitoring and assessment of fish communities is, therefore, essential to demonstrating the achievement of GES across the waters of the Northeast Atlantic covered by the MSFD. Coastal MSs bordering the Northeast Atlantic have invariably nominated their groundfish surveys as part of their monitoring programmes to supply the data necessary to derive the indicators that will be used to assess the state of fish communities, both within their national waters and across the whole Northeast Atlantic region.

Data obtained by these groundfish surveys are, for the most part, freely available for download from the DATRAS database portal on the ICES website. Data are initially checked by national data centres prior to submission to ICES and a further screening process is applied at ICES before the data are accepted and incorporated into the DATRAS database. However, this screening process was implemented in 2009 only for data from 2004 onwards. Some survey time-series extend back to the 1960s and more historic data may not have been subject to the same level of quality control as these more recent data. Furthermore, data were initially collected to address fisheries management needs, which primarily focused attention on commercial species. Gradual adoption of an ecosystem approach to management has raised the importance of non-target species, in order to facilitate the development and application of ecological indicators for the broader fish community. Thus the type of information collected, the level of detail and resolution in the data, has gradually evolved over time. These historic changes in groundfish survey practices have left a quality assurance legacy in the data that needs to be addressed to ensure that the

groundfish survey monitoring programmes are fully fit to meet modern day needs of the MSFD.

Historically the surveys operated by different countries have followed their own particular sets of protocols and practices. The procedure for uploading data to DATRAS has tended to preserve these national differences in data format, and this has necessitated the inclusion in DATRAS of numerous additional fields, each informing as to how other fields in the database should be interpreted. Here 19 surveys involving a dozen different countries are examined. In order to derive a single format, quality assured monitoring programme data product covering the entire Northeast Atlantic region, these national, inter-survey, inconsistencies all need resolution. In many instances, particularly in the more historic data, key information is either absent or incorrect, and these missing or erroneous values need replacement by modelled estimates. This document describes the process by which these issues were all resolved to derive 19 separate consistent and fully quality assured survey data products. These data products constitute a unified monitoring programme covering the continental shelf waters of the Northeast Atlantic, from northern Norway to Gibraltar, which can facilitate assessment of the state of fish communities across this whole region.

Each survey is first described and a brief history provided. Then approaches to deriving first, the “standard monitoring programme”, and second, the “standard survey area”, for each survey are presented. The former involved excluding trawl samples of either extreme short or extreme long duration, or were collected in years prior to the establishment of standardised survey protocols. The latter involved excluding trawl samples that were collected from ICES statistical rectangles that were only sampled in less than 50% of years that each survey was in operation.

Catch-per-unit-effort (CPUE) has long been the traditional abundance metric (nos h^{-1}) derived from groundfish surveys. However, concern over high variability in trawl speed, which can vary by a factor of two, suggests that such CPUE data might be extremely noisy, and that this noise could contribute to the apparent low power of many fish community indicators to detect actual change. Here an alternative abundance metric is used, a density measure determined as numbers of fish per square kilometre of seabed swept by the trawl gear (nos km^{-2}). Deriving this metric requires data on the distance towed in each trawling operation, which explicitly takes account of variation in trawling speed, and data on the width of the gear. For beam trawl surveys, gear width is constant and always known, being simply the width of the beam. But for otter trawl surveys, the width of the gear varies and, ideally, should be monitored throughout the course of each fishing operation. Often gear width data were missing and had to be modelled and estimated, and the need for such modelled data was more pronounced among older survey records. Full details are provided in this document regarding the modelling approaches used to estimate missing gear geometry data for each survey.

As time has progressed the resolution of the data collected has improved. Especially in the more historic data records, identification of non-target fish may not always have been to species-level. Clearly, many community indicators, such as indicators of species diversity (evenness and richness), Abundance of Sensitive Species indicator and the Mean-Maximum-Length indicator, rely on the availability of species-level identification data. Similarly catches of some species may not always have been length resolved, such that only species count data were recorded. Again, many community indicators, such as the Large Fish Indicator or the Typical Length Indicator (geometric mean length) require abundance-at-length data. Where coarser resolution identification data, or just species count data, were all that was available, a k-Nearest-Neighbour (kNN) algorithm was used to model the missing information and resolve genus- or family-level identifications to species-level, and species count data to abundances-at-length. In some cases the kNN model could not adequately resolve genus- or family-level data to species level. Where this was the case, all the species identification information was merged so that all individuals of a genus or family were recorded at the genus or the family level, whichever was the finest level resolution possible.

A strict error checking protocol was developed and applied to data in all key fields used in deriving the survey data products. Details of each of these are provided in this document. Fundamental to these error check procedures was the distinction between what has been termed “erroneous” data and “incorrect” data. On every occasion that a datum was trapped by an error check filter, the record was referred back to the appropriate data provider to ensure that the datum in question matched the value held in their national archive. Frequently, this was found not to be the case; some sort of transcription error had occurred somewhere between the original recording of the piece of information and the uploading of the data onto DATRAS. These were deemed to be instances of “erroneous” data, which were easily corrected simply by re-uploading the correct data to the DATRAS database. The process of deriving the data product was then repeated, with the hope that the new corrected data should pass unhindered through the error trap routine. However, where a datum trapped by the error check filter matched the original value in the national archive, then the value must either be “correct” or “incorrect”, and if the latter, then the error had to have occurred at source and there was now no way of correcting the mistake. Under these circumstances, criteria were applied to assess whether or not the value in question was at all feasible, and if so it was accepted and retained in the data product, or whether it was simply too big an outlier as to be possible. In these circumstances the value was deleted from the data product and replaced by a value estimated using the appropriate missing values routine.

Finally, detailed descriptions are provided of the two types of file that make up each individual survey data product: “Sampling Information” and “Biological Information”.

1. Introduction

1.1. Background

Under the Marine Strategy Framework Directive (MSFD), Member States (MSs) of the European Union (EU) are required to achieve ‘Good Environmental Status’ (GES) against 11 Descriptors of GES by 2020. Descriptor One (D1) and Descriptor Four (D4) focus respectively on “*Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climate conditions*” and “*All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity*” (EC, 2010). Fish communities perform a pivotal role in marine food web structure and functioning (Greenstreet et al., 1997; Heath 2005a; 2005b). Fish also constitute a major fraction of marine biota in the size range 4 g to 200 kg, and as such are important components of marine biodiversity. Furthermore, fish communities have long been directly impacted by human activity: it is well established that fishing has caused changes in fish community species composition, richness and evenness (Greenstreet and Hall 1996; Greenstreet et al., 1999; Greenstreet and Rogers, 2006), size composition (Greenstreet et al., 2011; 2012a; Shephard et al., 2011; Modica et al., 2014), and life-history trait composition (Jennings et al., 1998; Jennings et al. 1999; Greenstreet and Rogers 2000; Greenstreet et al., 2012b). Monitoring and assessment of fish communities will, therefore, be essential to demonstrating the achievement of GES across the waters of the Northeast Atlantic covered by the MSFD.

Article 9 of the MSFD defines GES and Article 5 requires EU MSs to have established what GES looks like in their waters. By July 2012, MSs should have defined a series of environmental targets representing GES for a set of associated indicators that should then be used to monitor the change in status of key aspects of marine ecosystems contributing to GES. By July 2014, MSs were required to have introduced appropriate monitoring programmes to supply the data necessary to derive these indicators (EC 2008). Invariably, Northeast Atlantic coastal EU MSs have proposed potential metrics to fulfil the role of fish community indicators to support both D1 and D4, and these same MSs have also invariably nominated their groundfish surveys, presently undertaken to meet fisheries management requirements under the Common Fisheries Policy (CFP) and Data Collection Framework (DCF), as monitoring programmes to provide the data necessary to derive these indicators. The data obtained by these groundfish surveys are, for the most part, freely available for download from the DATRAS database portal on the ICES website. Data on the DATRAS database has been provided by most[1] European coastal nations bordering the Northeast Atlantic including: England, Denmark, France, Germany, Ireland, Northern Ireland, Norway, Portugal, Scotland, Spain, Sweden and The Netherlands.

Data are initially checked by the national data centres concerned prior to submission to ICES in a highly specified format. A further screening process is applied at ICES before the data are accepted and incorporated into the DATRAS database. However, this full screening process was implemented in 2009 only for data from 2004 onwards. Some survey time-series extend back to as early as the 1960s. Where this is the case, therefore, the more historic data may not have been subject to the same level of quality control as more recent data. Furthermore, over time the resolution level of the data collected has improved, reflecting the fact that the data have been increasingly used to address purposes for which the surveys were not originally intended. For example, addressing the needs of just fisheries management focused attention on the need to provide detailed catch-at-length information for only the commercial species. Information collected for non-target species was ancillary to this primary objective and the level of detail in the data recorded for such species could become compromised if circumstances merited it. Thus, instead of identifying unusual specimens to species, they might just be identified only to genus or perhaps even family if the time available to process particular trawl samples was short, or instead of measuring individuals to derive catch-at-length data, a simple non-size resolved catch total only might be recorded if the catch of the species concerned was large. However, with development of an ecosystem approach to management, these groundfish survey data have increasingly been used to derive fish community ecological indicators. To meet this need, such practices have steadily reduced to the point now where few specimens sampled are not identified to species level and full catch-at-length data are invariably recorded for all species caught. Nevertheless, these practices of the past, and the legacy they have left in the data, still need to be addressed if the ecological indicators which will being used to assess of fish community status for MSFD purposes are to be derived for full survey time-series (Greenstreet and Hall, 1996;

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[1] In 2016, Belgium began the process of uploading their national Beam Trawl survey onto DATRAS, at the time of this project the survey dataset wasn't fully available on DATRAS, and through conversations with the Belgium data providers it was established that the data wouldn't be fit for this purpose at this time, but in future iterations of this process the data should be available. [1]

Greenstreet et al., 1999; Daan 2001). All data downloaded from DATRAS need, therefore, to be checked rigorously before use to ensure that the data being analysed are fully fit for the purpose intended.

Until recently, catch-per-unit-effort (Nos hr^{-1}) data derived from the groundfish surveys have generally been used to support the stock assessment process. However, high variability in the area swept by the trawls for any given trawl duration time, primarily linked to variation in tow speed, but also related to depth and its effect on the door- and wing-spread separation, preclude the use of such data for most ecological indicators used to assess the state of fish communities. Such indicators tend instead to use estimates of fish density (Nos km^{-2}) (Greenstreet et al., 2012b); density-based indicators have been used to support the OSPAR Ecological Quality Objective project (Greenstreet et al., 2011; Shephard et al, 2011) and proposed for use in support of the MSFD (Greenstreet et al., 2012c). Initially, at the start of several surveys, the technology necessary to measure the distance between the trawl wings, or between the otter doors, simply was not available, and in the earlier years when such equipment did come on stream, it was not always reliable and its take-up by the MSs operating the different surveys was staggered. Consequently, the information required to estimate the area swept by the trawl is frequently missing, particularly in the early years of the longer survey time-series. Even more recently such information could be missing as a consequence of equipment malfunction. Where this is the case, statistical modelling is necessary so that the relevant parameter values can be estimated, where absent, to permit the full range of ecological indicators to be derived across as much of the full time-series of data available in each survey as possible.

The area covered by groundfish surveys operated by EU MSs bordering the Northeast Atlantic falls across all four of the Subregions of the North-east Atlantic Ocean Region defined in Article 4 of the MSFD; The Greater North Sea (including the Kattegat and English Channel), the Celtic Seas, the Bay of Biscay and Iberian Coast, and the Atlantic Ocean (EC 2008). These surveys use different vessels; the trawl gears used also vary between surveys, and might even change over time within any given survey. Even where the same trawl gear is used, different vessels involved in a survey might differ in the way that the gear is rigged. Time-series duration varies markedly between surveys; some starting in the 1980s, others as late as the early 2000s. The extent to which the different surveys suffer the various data quality issues described above also varies. No MSFD Subregion in the Northeast Atlantic is monitored across its entire extent by a single groundfish survey and this has the potential to cause difficulty in assessing status at any spatial scale larger than the areas covered by the individual surveys.

Article 5 of the MSFD stipulates that "*Member States sharing a marine region or subregion shall cooperate to ensure that, within each marine region or subregion, the measures required to achieve the objectives of this Directive, in particular the different elements of the marine strategies referred to in points (a) and (b), are coherent and coordinated across the marine region or subregion concerned,*" where point a covers the "*determination, … of good environmental status for the waters concerned*", "*establishment, …, of a series of environmental targets and associated indicators*", and "*establishment and implementation, …, of a monitoring programme for ongoing assessment and regular updating of targets*". Article 9 addresses GES stating "*Member States shall, in respect of each marine region or subregion concerned, determine, for the marine waters, a set of characteristics for good environmental status, on the basis of the qualitative descriptors*". Article 10 deals with environmental targets, requiring "*Member States shall, in respect of each marine region or subregion, establish a comprehensive set of environmental targets and associated indicators for their marine waters so as to guide progress towards achieving good environmental status in the marine environment*". Article 11 addresses the monitoring programmes "*Member States shall establish and implement coordinated monitoring programmes for the ongoing assessment of the environmental status of their marine waters*", later reiterating "*Monitoring programmes shall be compatible within marine regions or subregions*" and "*monitoring methods are consistent across the marine region or subregion so as to facilitate comparability of monitoring results*".

The MSFD, therefore, requires that monitoring, assessment and reporting of the status of the marine environment in waters under its jurisdiction be undertaken at the spatial scale of the defined Subregions or Regions. To achieve the level of regional co-operation implied by this, Article 6 requires that "*Member States shall, where practical and appropriate, use existing regional institutional cooperation structures, including those under Regional Sea Conventions, covering that marine region or subregion*". T his confers an important role on OSPAR to ensure that the activities of all EU MSs whose coastlines border one of the four defined Subregions of the Northeast Atlantic, the majority of which are also Contracting Parties (CPs) to OSPAR, are co-ordinated. In order to arrive at assessments of the status of fish communities at the spatial scale of the four Subregions of the Northeast Atlantic, the issues associated with the groundfish survey data described above all have to be addressed. Variation between the different methodologies of surveys operating within single Subregions somehow has to be reconciled, so that the disparate surveys can be treated as a coordinated monitoring process, serving a single unified assessment procedure. The procedures used to estimate missing parameter values should be consistent, or follow a single consistent underlying logical approach. The processes, and underlying methodology, used to address data quality issues should be the same across all surveys. If this can be achieved, then it should be possible to derive equivalent ecological indicators in all four Subregions, ultimately delivering consistent and equitable assessment outcomes across the entire OSPAR area of the Northeast Atlantic.

1.2. Overview of the Monitoring and Assessment Process.

Figure 1.2.1. illustrates the monitoring and assessment process based on groundfish survey data needed to support implementation of the MSFD. This document describes that part of this process that will deliver the monitoring programme data product on which the assessment can be carried out; that part of the process to the pale green box labelled MSFD Monitoring and Assessment Data Product in the figure. In many instances national groundfish survey data are uploaded to the ICES DATRAS data portal, which involves the data passing through a data upload screening procedure. Despite this, it is well known and widely acknowledged that there is a considerable number and variety of quality issues regarding the data resident on the DATRAS portal and held in national databases (Daan, 2001; ICES, 2004; ICES, 2005; ICES, 2006; ter Hofstede & Daan, 2006; 2008; ICES, 2007a; ICES, 2007b; ICES, 2008; ICES, 2009a; ICES, 2010a; ICES, 2011; ICES, 2012a and ICES, 2013a). Before these data can be used for scientific research or assessment purposes, therefore, rigorous error screening and data quality assurance and auditing are necessary. (Greenstreet and Hall 1996; Greentreet et al., 1999; Greenstreet et al., 2009a; Greenstreet et al., 2009b; Greenstreet et al., 2012b).

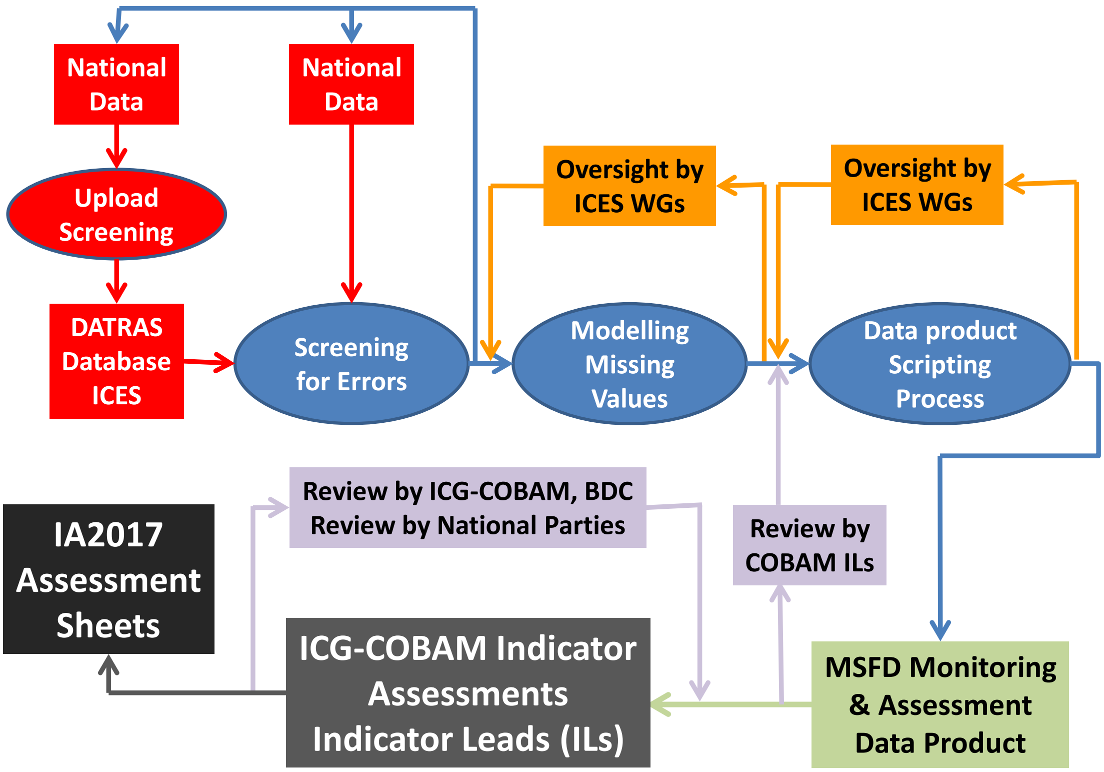

Figure 1.2.1: Overview of the full groundfish survey monitoring and assessment process.

The initial quality screening process primarily involves examining the full range of parameter values contained within the database for outlier values, or values that simply seem unlikely, such as tow distances exceeding 6 km for 30 minutes duration tows at a nominal speed of 7.4 km h^{-1}, or recorded fish lengths that exceed 1.1 times the maximum ever recorded length for the species in question. Where potential data errors are detected, the next step involves requesting the data providers to check each potential error for reliability (the blue feedback loop in the top-left of Figure 1.2.1). This part of the process identifies two types of data error: 'erroneous data' and 'incorrect data'. Erroneous data are a consequence of a breakdown in the data archiving procedure. At some point a mistake occurs during the archiving process such that the datum value in the database no longer matches the original value recorded at source. Such errors are easily corrected simply by editing the archived data values in the database. Incorrect data are more difficult to rectify; in these instances the archived values do match the original values recorded at source. If a mistake has occurred, it happened at source and it is, therefore, now not possible to establish absolutely that the outlier value in question is in fact a data error, and if so what the correct value should be. In these instances a judgement must be made as to whether the data value under scrutiny has sufficient credibility as to be possible, or whether the recorded value is so unlikely that it must be deemed to be wrong. In making these judgements, guidelines or criteria, need to be established. Where 'incorrect data', are deemed to be such extreme outliers as to not be possible, and so wrong, these data values are essentially deleted and a missing value procedure employed to replace them with more likely data.

Fixing obvious problems in this way was seen as the better option to the alternative of simply deleting seemingly incorrect data. Deleting records would certainly impart a bias to the data for the sample in question. The safest alternative approach, therefore, would be to delete the entire sample where dubious records were found, but this would have resulted in the loss of considerably more good data simply to eliminate a small quantity of poor data. Furthermore, given the number of actual data problems encountered, adopting this approach would have resulted in the loss of an unacceptable number of samples, compromising the entire monitoring programme.

Ideally, having identified all erroneous data and made the necessary corrections to national data sets, the data providers would re-upload their edited national data onto the DATRAS data portal for second round error screening (i.e. feeding back into to the "Screening for Errors" procedure vie the left red coloured pathway in Figure 1.2.1). In reality though, many data providers fed corrected data back into the "Screening for Errors" procedure direct from their national data base, rather than re-uploading the corrected data to DATRAS (i.e. feeding back into to the "Screening for Errors" procedure via the right red coloured pathway in Figure 1.2.1). Initially this will have caused divergence between the original data held on DATRAS and the data contained in the MSFD Monitoring and Assessment data product, but it is to be assumed that all such edited data will eventually be re-uploaded onto DATRAS. However, these data will not have passed through the second "Screening for Errors" procedure.

Missing data present as serious an obstacle to the production of a systematic monitoring and assessment data product for the whole northeast Atlantic area as 'incorrect data'. Like 'incorrect data', the solution to the problem is rarely to be found with the data providers; if parameter values are absent in the DATRAS database, then in most cases, for one reason or another, the information was never recorded in the first place. In many cases the missing information is vital. Since the data required to estimate the ecological indicators on which the assessment of the status of fish communities across the northeast Atlantic will be based are point estimates of density, the number of fish of a given length and given species per square kilometre, a key example of this concerns the information necessary to determine the area of seabed swept by the trawl at each sample location. To do this we need information on the towed distance and the mean width of the fishing gear (for an otter trawl the mean distance between the net wings or otter doors). The technology to measure wing-distance or door-distance has only become available and routinely used in the surveys during the 1990s. If the data needed to calculate the area swept by the trawl are missing, then the biological data collected on such hauls becomes much less useful for MSFD assessment purposes. Without a means of deriving estimates for such missing data, few of the surveys contribution to the monitoring and assessment data product would extend back in time much before the mid-1990s at the earliest. Species diversity indicators are dependent on fish being identified to species level, where identification is to a lower taxonomic level, a maximum-likelihood approach must be adopted to estimate the most likely species. Similarly, size-based indicators require numbers-at-length data, so if species count data only are provided, then a maximum-likelihood approach must be used to estimate the most probable length frequency distribution. In both instances possible errors in species identification and/or length class assignment need to be trapped and rectified.

Since, as discussed above, most 'incorrect data' are likely to be treated as 'missing data', then modelling of missing values becomes perhaps the most critical step in the generation of the monitoring and assessment data product. For this reason the procedures used to facilitate this were subjected to review by the key ICES working groups responsible for the otter trawl and beam trawl surveys, and on the basis of feedback from these WGs, these missing value procedures were revised where needed (Figure 1.2.1). Under the MSFD, assessment of the status of the fish community will be necessary every six years. Consequently another key aspect of the process to derive the MSFD groundfish survey monitoring and assessment data product centred around the computer scripting necessary to ensure that the whole process could be made as routine as possible, so that the same set of procedures could be employed each time that assessment was required. This step of the process was also reviewed by the survey WGs to ensure that as far as possible these script routines were compatible with the known past history of each survey, and took account of possible changes in survey methodology that were being considered for the future (Figure 1.2.1).

Another key aspect of the data scripting procedure was the selection of individual trawl samples that, together, would constitute the 'standard monitoring programme' for each survey. Sampling variability can have profound effects on ecological indicator values (Greenstreet and Piet, 2008). To ensure that, as far as is possible, indicator variation reflected actual change in the structure and composition of the fish community rather than change in sampling effort or spatial pattern, it has become a routine practice to select a ‘standard survey’ data subset from the full survey data set available; excluding trawl samples of exceptionally short or long duration, or which were collected on occasion from areas rarely sampled throughout the greater part of the survey time series (Shephard et al., 2011; Greenstreet et al., 2012c). Figure 1.2.2 illustrates the steps in this procedure. Once again, the ICES survey WGs were considered the most appropriate people to review this aspect of the data scripting procedure.

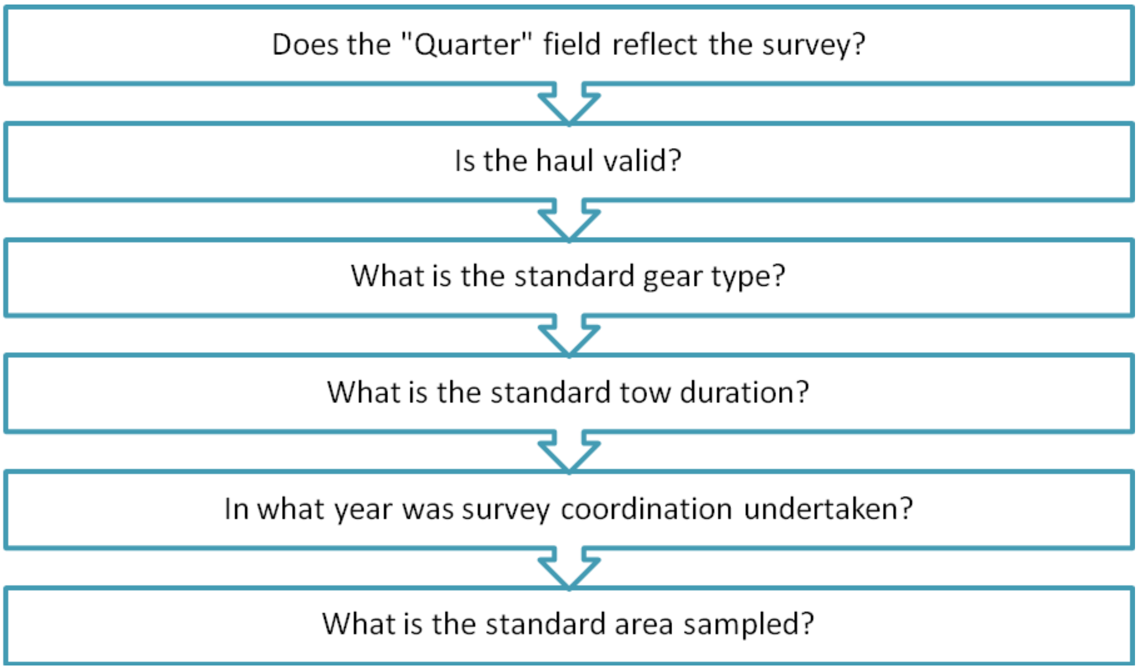

Figure 1.2.2.: Steps in the selection of trawl samples to constitute standard surveys.

In DATRAS, the field quater currently reflects the season when any given trawl sample was actually collected, and so duplicates the information contained in the field month. Both ICES survey WGs have previously recommended that the field quater would be more appropriately used to reflect the survey time series, or survey name. Thus even if trawl samples were collected, for example, in early April, but at the time the vessels was involved in the first quarter international bottom trawl survey, then the field quarter should be used to reflect the survey times series (i.e. Quarter 1) and not the actual season the samples were collected (i.e. Quarter 2). This recommendation has been implemented here.

There are several reasons why a haul might be considered invalid; for example if net geometry wasn't correct during the haul, if haul duration was too short, or if the net was damaged during trawling. Trawl samples labelled as invalid were considered unfit for monitoring purposes and excluded from the MSFD data product.

In several instances, the first quarter international bottom trawl survey being a prime example, surveys evolved over a number of years resulting in highly variable survey designs and practices, especially early on in survey times series. The data were considered sufficiently reliable as to be included as part of a 'standard monitoring programme' only when surveys became fully coordinated. Related to this, only when a standard fishing gear was routinely used across the survey could the data be considered sufficiently reliable as to be included as part of a 'standard monitoring programme'.

Larger sized fish have a greater capacity to avoid falling back into the net for longer; shorter duration hauls are, therefore, likely to generate samples that are disproportionately biased towards the shorter end of the length-frequency distribution. Since short duration hauls cover a smaller area, they are less likely to encounter rare species. Species richness estimates will, therefore, be biased downwards; a simple function of the species-area relationship (Greenstreet and Piet, 2008). Variation in trawl duration, therefore, has the capacity to profoundly affect many ecological indicators. Most surveys cover a 'core area' but frequently locations outside these 'core areas' are sampled when weather is unexpectedly favourable, or additional resources are on occasion available. But peripheral areas often include different habitats and so hold different species assemblages. The periphery effect on ecological indicators is a well-established ecological phenomenon (Donovan et al., 1997; Bieringer and Zulka, 2003; Hart, 2007), and establishing standard survey areas, and so excluding rarely sampled locations from contributing to the data set, is a well-established means of avoiding this source of variability.

1.3. Purpose of the Document

This document describes the process applied to produce a quality assured dataset for use in MSFD assessment. The various groundfish survey datasets for surveys that currently operate across Northeast Atlantic shelf seas waters are described. The procedures used to check existing data, correct erroneous data, replace incorrect data and estimate missing data in the haul chronology and biological information are presented and explained. The aim being to derive a single, internally consistent, "OSPAR/MSFD Groundfish Survey Monitoring and Assessment" data product to support assessment of the state of fish communities across the whole OSPAR area. Finally, a decription of the resulting data product is provided.

2. The Groundfish Surveys

In this section the various groundfish trawl surveys that have operated within the EC waters of the Northeast Atlantic, and which could potentially contribute MSFD groundfish monitoring and assessment data products, are described. Two broad classes of survey have operated: those using an otter trawl and surveys using a beam trawl; these are considered separately. For each survey considered, a brief history is provided; the process by which trawl samples were selected for inclusion in the ‘standard’ monitoring and assessment data product is then documented.

The degree to which different countries’ survey activity is integrated varies. The first quarter (Q1) and third quarter (Q3) International Bottom Trawl Surveys both involve several participating countries. This combined survey activity is closely co-ordinated by ICES through the International Bottom Trawl Survey Working Group (IBTSWG). In these two surveys, each individual nation’s survey activity is fully integrated with that of all other participating nations. All countries involved follow the same specified sampling protocol, using the same trawl gear towed at a specified speed for a stipulated length of time. The stations sampled by each individual country are assigned prior to the start of survey work and each countries’ nominated stations are widely dispersed across the whole survey area so that each nation’s stations are interspersed spatially with stations sampled by other participating countries.

In other instances a degree of pseudo-integration exists, whereby a process to coordinate survey activity is in place, usually under the auspices of ICES working groups such as IBTSWG (see above) or the Working Group on Beam Trawl Surveys (WGBEAM), but the actual survey activity is not fully integrated. For example, three countries undertake otter trawl surveys in the Celtic Seas region to the west of the UK and Ireland. To some extent the timing of the survey, the trawl gear used, and the area to be covered by each country is agreed beforehand, but the particular groundgear used by each country may differ (for good operational reasons) and each country surveys its own particular ‘patch’’. There may be some overlap in spatial coverage, but the areas covered by each of the countries involved are quite distinct; there is little interspersion of survey activity. Furthermore, the basis for spatial stratification of the area covered by each country to determine spatial sampling units also differs. Three countries undertake beam trawl survey in the North Sea. While this survey activity is coordinated to some extent by WGBEAM and the data stored in a common database on DATRAS, each country essentially undertakes its own separate survey, covering their own particular areas of interest and, in this case, even using different trawl gears (ICES 2009a). The three countries carrying out surveys in the Bay of Biscay and the Iberian Coast subregion all use different trawl gears and the degree of survey integration and coordination, if any, is low.

The IBTSWG considers surveys to be coordinated, and under their umbrella, if they meet the following criteria:

1) They are carried out in the ICES areas IIIa, or IV-IX;
2) A brief outline of the management need/context for the survey has been provided by an ICES assessment working group;
3) It is an otter trawl survey, but noting that there may be other working groups better placed to coordinate some bottom trawl surveys;
4) The survey either has appropriate sampling methods and protocols (including gear descriptions) that conform to the standards encouraged by the IBTSWG, or that can be improved after joining IBTSWG;
5) The survey enhances existing IBTS surveys by improving data collection for important stocks. For example, proposed surveys should either overlap and extend existing survey areas, using a comparable gear, or operate on more specific grounds or at particular times of year with a gear more appropriate to the target species;
6) Data should be uploaded and freely available on the DATRAS database portal following standard DATRAS data quality checking;
7) The nations involved in such surveys should send participants to attend and present data at the annual meetings of IBTSWG;
8) Assessment working groups should confirm (e.g. after a five year period) that any surveys targeting specific stocks and not using gears used in the standard IBTS surveys are still providing data of sufficient quality that can be used for stock assessment and the provision of management advice.

As will be seen, important operational differences between surveys operating within any given single MSFD subregion mean that, even though meeting these criteria, these surveys still cannot be considered fully co-ordinated, and merged to form single data series. In developing the various survey data products, only fully coordinated and integrated surveys were considered as single entities; essentially assuming that all samples included in such data sets had equivalent sampling power. In all other cases, each country’s contribution to what we have termed pseudo-integrated surveys was deemed to be a separate individual survey until comparative catch analysis provided the evidence to suggest that particular surveys might be combined and treated as single entities. This rapidly increased the number of individual data sets, which made continued use of the commonly adopted survey acronyms confusing and difficult to sustain. Consequently a fixed acronym protocol was adopted and applied to all surveys. This acronym protocol combines the OSPAR Region GNS, CS, BBIC, and WA (for Greater North Sea, Celtic Seas, Bay of Biscay and Iberian Coast, and Wider Atlantic respectively), the first three letters of the Country name (Bel, Net, Eng, Ger, Int, Sco, Ire, Fra, NIr, Spa and Por (for Belgium, the Netherlands, England, Germany, International, Scotland, Ireland, France, Northern Ireland, Spain and Portugal respectively), the main gear type OT or BM (for Otter trawl or Beam trawl respectively), and the season of the year 1, 2, 3, or 4 (for first, second, third, or fourth quarter of the year respectively). One survey spanned two OSPAR regions, the Celtic Sea and the Bay of Biscay, and was therefore assigned a region acronym component CSBB.

The acronyms assigned to each survey are introduced in the table below to give clarity on the source of the original data. Each acronym follows a similar pattern, Region/Area, Country, Gear Type, and Quarter. Table 2.1 lists the 19 surveys so far considered to derive the OSPAR Groundfish Survey Monitoring and Assessment data products to date, provides their respective acronyms, and includes some basic information regarding each survey.

Survey Acronym	Previous name(s)	Country	Years of Data	Vessels	Quarter	Gear Type	Subregion	Data Source
GNSIntOT1	Q1 IBTS	International	1983-2016	Multiple ships	1	Otter (GOV)	Greater North Sea	DATRAS
GNSIntOT3	Q3 IBTS	International	1998-2016	Multiple ships	3	Otter (GOV)	Greater North Sea	DATRAS
GNSFraOT4	FR CGFS	France	1988-2015	Thalassa II, Gwen Drez	4	Otter (GOV)	Greater North Sea	DATRAS
CSScoOT1	SWC Q1 IBTS	Scotland	1985-2015	Scotia II, Scotia III	1	Otter (GOV)	Celtic Seas	DATRAS
CSScoOT4	SWC Q3 IBTS	Scotland	1985-2015	Scotia II, Scotia III	4	Otter (GOV)	Celtic Seas	DATRAS
CSIreOT4	IE IGFS	Ireland	2003-2015	Celtic Explorer	4	Otter (GOV)	Celtic Seas	DATRAS
CSNIrOT1	Q1 NIGFS	Northern Ireland	1992-2015	Corystes	1	Otter (ROT)	Celtic Seas	NDB 92-07, DATRAS 08-15
CSNIrOT4	Q4 NIGFS	Northern Ireland	1992-2015	Corystes	4	Otter (ROT)	Celtic Seas	NDB 92-07, DATRAS 08-15
CS/BBFraOT4	EVHOE	France	1997-2014	Thalassa II	4	Otter (GOV)	Celtic Seas, Bay of Biscay	DATRAS (Cors. NDB)
BBIC(s)SpaOT1	SP-ARSA	Spain	1993-2014	Cornide de Saavedra, F de P Navarro	1	Otter (BACA)	Bay of Biscay and Iberian Coast	NDB
BBIC(n)SpaOT4	SP-North	Spain	1990-2014	Cornide de Saavedra, F de P Navarro	4	Otter (BACA)	Bay of Biscay and Iberian Coast	NDB
BBIC(s)SpaOT4	SP-ARSA	Spain	1997-2014	Cornide de Saavedra, F de P Navarro	4	Otter (BACA)	Bay of Biscay and Iberian Coast	NDB
BBICPorOT4	PT-IBTS	Portugal	2001-2011	Capricornio, Noruega	4	Otter (NCT)	Bay of Biscay and Iberian Coast	DATRAS
WAScoOT3	Rockall	Scotland	1999-2015	Scotia II, Scotia III	3	Otter (GOV)	Wider Atlantic	DATRAS
WASpaOT3	PS-PORC	Spain	2001-2014	Vizconda de Eza	3	Otter (PBACA)	Wider Atlantic	DATRAS
GNSNetBT3	BTS	The Netherlands	1987/1996-2015	Isis, Tridens II	3	Beam (8m)	Greater North Sea	DATRAS
GNSEngBT3	BTS	England	1990-2015	Carhelmar, Corystes, Endevour	3	Beam (4m)	Greater North Sea	DATRAS
GNSGerBT3	BTS	Germany	2002-2015	Solea I, Solea II	3	Beam (7m)	Greater North Sea	DATRAS
CSEngBT3	BTS/VIIa	England	1993-2014	Corystes, Endevour	3	Beam (4m)	Celtic Seas	DATRAS

Table 2.1: List of individual surveys considered in the derivation of the OSPAR Groundfish Survey Monitoring and Assessment data products. Basic information is provided for each survey and their new acronyms are indicated. See text for details regarding the acronym protocol, except note here the use of CS/BB in the French EVHOE survey acronym to denote a survey that extends across two subregions, the Celtic Seas and Bay of Biscay. In the data source column, NDB refers to national database.

All the otter trawl surveys operating in the Greater North Sea and the majority of surveys operating in the Celtic Seas use the Grande Ouverture Vertical (GOV). The French EVHOE survey covers a substantial fraction of the southern Celtic Seas subregion, but also extends over the entire coastal shelf waters of the Bay of Biscay in the French Exclusive Economic Zone (EEZ). The Scottish Rockall survey also uses a GOV trawl, extending survey coverage using this sampling gear well to the west into the Wider Atlantic subregion. This makes the GOV trawl the single most widely used groundfish sampling gear in European waters: certainly in European Northeast Atlantic area (Figure 2.1). However, rigging of the GOV differs from country to country, and this could introduce between survey variation in the catchability of some fish species. Differences include; use of different ground gears to accommodate hard ground or soft ground, or differences in sweep lengths applied at different depths.

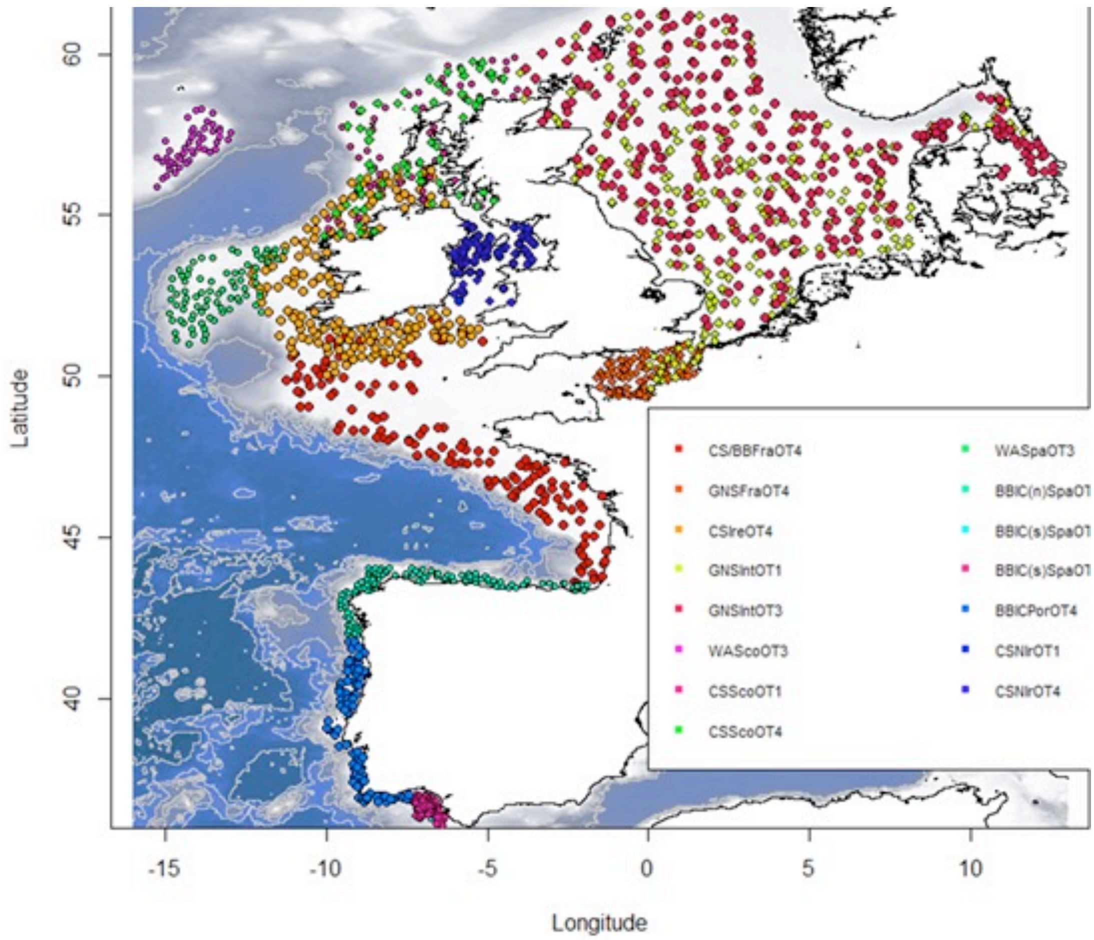

Figure 2.1: Survey coverage across the Northeast Atlantic by surveys using the five types of otter trawls; GOV, ROT, BAKA, Porcupine BAKA and NCT otter trawl. See Table 2.1 for explanation of survey acronyms.

GOV surveys are primarily undertaken to determine the distribution and relative abundance of pre-recruits of the main commercial species to derive recruitment indices, and to monitor change in commercial species stock abundance from fisheries independent data. Further goals include monitoring the distribution and relative abundance of all fish species and selected invertebrates; collecting data for the determination of biological parameters for selected species; and collecting hydrographical and environmental information. The data collected using GOV trawl surveys dates back as far as 1965 for the NS-IBTS, while the newest of the surveys is from the Irish survey (IE-IGFS) which began in 2003.

In 1994, it was suggested to extend the remit of the IBTS Working Group to co-ordinate the surveys in the western and southern areas (i.e. English Channel, Celtic Sea, Bay of Biscay, eastern Atlantic waters from the Shetlands to the strait of Gibraltar). International coordination of surveys in this region began in 1997. While the GOV is the most popularly used gear type in the IBTS surveys within the North-eastern Atlantic region (Greater North Sea and most of the Celtic Seas), other types of otter trawls are employed in the Bay of Biscay and Iberian Coast region. While some attempts have been made in order to achieve a consensus on the choice of a standard gear, this was not achieved due to the variation in bottom types, and each country uses a different gear (GOV for France, BAKA for Spain and Norwegian Campell Trawl (NCT) for Portugal). The French, Portuguese and Spanish surveys are conducted in adjacent areas with no overlapping survey areas.

The Southern and Northern Spanish groundfish surveys use a Baka trawl 44/60 with a 43.6 m footrope and a 60.1 m headline. The traditional trawl doors used are rectangular, weighting 650 kg and 3.6 m^2 of surface (2.67*1.34 m). The diameter of warp used is 22 mm (1.9kg m^{-1}). The mean vertical opening is 1.8 m and the horizontal opening is 21 m. Up to 1985, a codend cover of 20 mm mesh was used, and since then, a 20 mm mesh codend liner has been adopted. The Porcupine bank survey is carried on the R/V "*Vizconde de Eza*". This vessel is a stern trawler of 53 m length and 13.5 m wide with gross tonnage of 1400t. Fishing gear used is a Porcupine baca 40/52 with 39.46 m footrope and a 51.96 m headline. Doors are oval with 800 kg and 4.5 m^2 surface. Diameter of warp used is 20 mm, of sweeps is 55 mm and the groundrope 98 mm with a double synthetic coat. Mean vertical opening is around 3.5 m and door spread 120 m. Codend mesh size is 20 mm.

The surveys are carried with the Portuguese RV "*Noruega*", which is a stern trawler of 47.5 m length, 1500 horse power and 495 GRT. In the autumn surveys the fishing gear used is a bottom trawl (type Norwegian Campell Trawl 1800/96 NCT) with a 20 mm codend mesh size. The main characteristic of this gear is the groundrope with bobbins. The mean vertical opening is 4.6 m and the mean horizontal opening between wings and doors is 15.1 m and 45.7 m, respectively. The polyvalent trawl doors used are rectangular (2.7 m x 1.58 m) with an area of 3.75 m^2 and weighting 650kg. In the Winter surveys the fishing gear used is a bottom trawl net (CAR) type FGAV019, without rollers in the groundrope. The mean horizontal opening between the wings is 25 m, the mean vertical opening is 2.5 m and the codend mesh size is 20 mm. The trawl doors used are the same as those used in the NCT gear. In autumns 1996, 1999, 2003 and 2004, the Portuguese RV "*Noruega*" was unavailable and RV "*Capricórnio*" was used. R/V "*Capricórnio*", is a stern trawler of 46.5 m length, 1200 horse power (880 KW) and 494 GRT. The fishing gear is a bottom trawl (CAR, FGAV019), the same used in winter surveys.

A rock-hopper otter trawl (ROT) in used in the Irish Sea by Northern Ireland, where there is overlap with the Irish and Scottish GOV data in some years. The surveys are carried out on the RV "*Lough Foyle*", a 43.5 m stern trawler of 880 kw and GRT 547 tonnes. The fishing gear is a rock-hopper otter trawl with a 17 m footrope fitted with 250 mm non-rotating rubber discs. The gear has a mean vertical opening of 3 m. The door spread varies from around 25 m at 20 m depth to 40 m at 80 m depth. A 20 mm (inside mesh) codend is fitted.

The beam trawl surveys operating in the Greater North Sea use three different beam widths, the German Survey uses a 7.2 m beam trawl, while the Netherlands survey uses an 8 m beam trawl. The English surveys operating in the Channel and the Irish Sea use a 4 m beam trawl (Figure 2.2). These differences are due to the type of ground covered by the different surveys. And this may introduce variation in the catchability of some fish species.

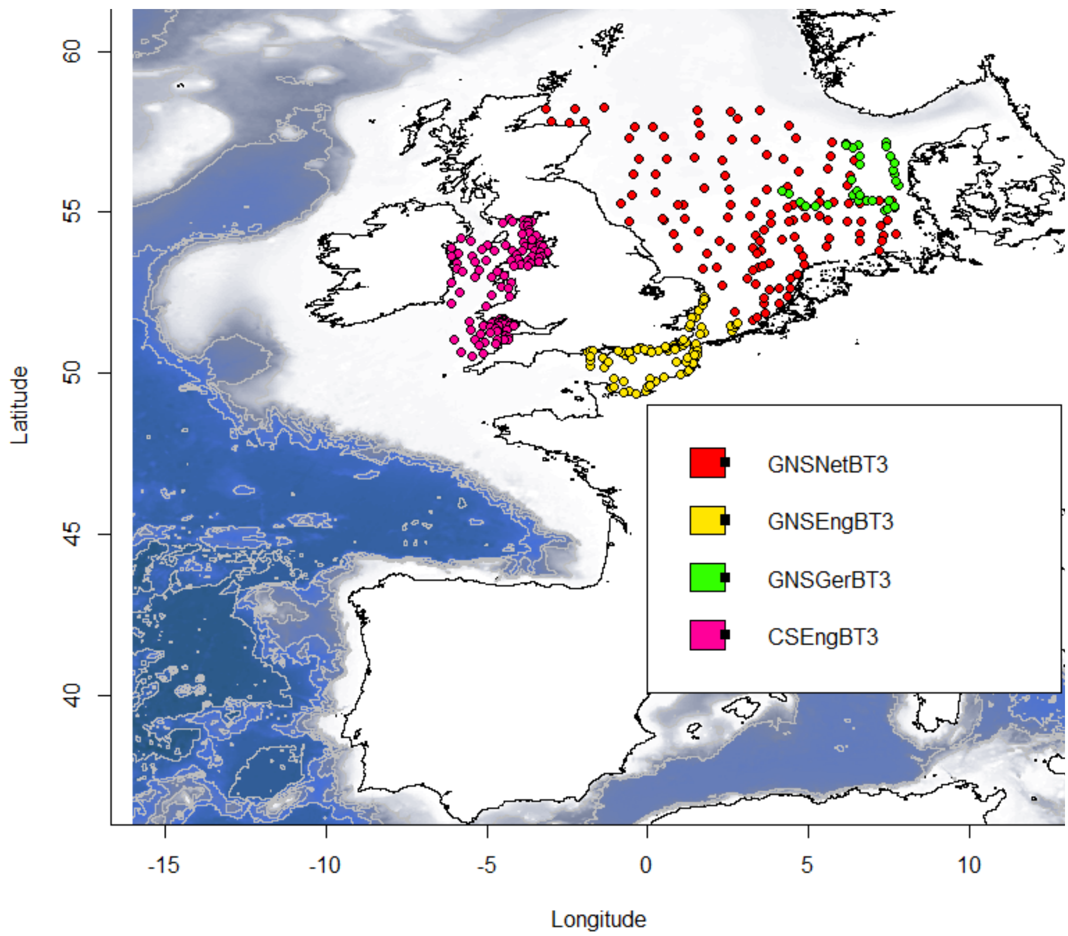

Figure 2.2: Survey coverage across the Northeast Atlantic by surveys using beam trawls, and currently available in DATRAS for use in this process. See Table 2.1 for explanation of survey acronyms.

Beam trawl surveys are primarily undertaken to determine the distribution and relative abundance of pre-recruits of the main commercial flatfish species to derive recruitment indices. Further goals include: monitoring the distribution and abundance of all fish species and some invertebrates; data collection for the determination of selected biological parameters for selected species; and the collection of basic hydrographical and environmental information. The Dutch offshore survey is the longest running survey, having started in 1985 as a coastal survey within the Dutch EEZ. In 1996 the Dutch began a full scale third quarter North Sea beam trawl survey using RV *Tridens II*, which limited resources for the third quarter otter trawl survey. The purpose of the German beam trawl is to provide additional information within the German EEZ, to supplement the flatfish information within their waters. England carries out beam trawl surveys in the French Channel and Irish Sea. Other beam trawl surveys are carried out by Scotland, Belgium, France and most recently Ireland, but at the time of the preparation of this document, these were not readily available for the groundfish survey monitoring and assessment data product. In future iterations of this product it is envisioned that these surveys will be assessed for their suitability for inclusion.

2.1. The Otter Trawl Surveys

In this section the various otter trawl based surveys are described, along with the process used to determine the subset of data that constitutes ‘the standardised monitoring programme’ for each survey. The surveys are considered subregion by subregion.

2.1.1. The Greater North Sea

Here otter trawl surveys carried out in the Greater North Sea subregion are considered. The Greater North Sea subregion includes the main North Sea, the Kattegat and Skagerrak, and the English Channel.

2.1.1.1. The First Quarter International Bottom Trawl Survey (GNSIntOT1)

2.1.1.1.1. Survey History

The most recent edition of the IBTS manual provides a history of the survey, describing the changing survey objectives and sampling gears used (ICES, 2012a). With ICES backing, in 1960 and 1961 four large international research vessel trawl surveys were organised to map the distribution of juvenile herring *Clupea harengus* and to investigate links between herring nursery grounds and the adult populations in the North Sea (ICES, 1963). From 1966 onwards the surveys were conducted annually with the objective of obtaining annual recruitment indices for the combined North Sea herring stocks. With the gradual participation of more countries, the International Young Herring Survey (IYHS) was established. Up to 1969 sampling was restricted primarily to the southern and central North Sea, but then from1969 the Skagerrak and Kattegat area was also included. From the start of these surveys the main focus was on herring, but data collected for whiting *Merlangius merlangus* were also analysed. During the 1970s it became apparent that the IYHS could provide recruitment indices not only for herring, but also for roundfish species such as cod *Gadus morhua*, haddock *Melanogrammus aeglefinus* and whiting. This resulted in a northwards extension of the survey area to cover the entire distribution of juvenile haddock in the North Sea, and also that of Norway pout *Trisopterus esmarki*. The whole North Sea, including the Skagerrak and Kattegat, has been surveyed since 1974. In 1981, the survey was renamed the International Young Fish Survey (IYFS), and the first manual was produced (ICES, 1981), and in 1984 the ICES Working Group on Young Herring Surveys and the Gadoid 1-Group Working Group were combined to form the International Young Fish Survey Working Group (ICES, 2012a).

Before the IBTS became fully coordinated many different survey gears were used. In 1960 the Netherlands used a Dutch Herring Trawl, in 1966 Germany commenced survey work in the North Sea using a different type of Herring Trawl. In 1967, England and Scotland joined in and used the Dutch herring Trawl, but with slightly different riggings. By 1969, three differently rigged Dutch Herring trawls and the German version of a Herring Trawl were being used in the North Sea to carry out the herring surveys. As the surveys moved away from concentrating on just herring, there was a move towards using more multipurpose gears. By 1976 six different survey gears were being used by eight different nations. Then, in 1978, one multipurpose gear started to be used by more and more nations, and by 1983 all nations participating in the Quarter 1 IYFS were using the GOV 36/47, albeit with slightly different rigging configurations of the sweep lengths. Since then, the GOV has been the recommended standard gear of the IBTS. By 1992, the GOV was used in all quarters of the IBTS (see next section).

In 2006, the French started to carry out additional tows in the Eastern English Channel as part of their standard IBTS survey. This proved successful and in 2007 RV *Thalassa* carried out eight GOV trawls and 20 MIK stations. Consequently, the

2009 IBTSWG created Roundfish Area 10 to accommodate these new stations (ICES, 2009b).

Since 2000, a number of countries have noted that the gear parameter tables contained in the historical North Sea IBTS manuals have been difficult to adhere to when trawling. Between 2007 and 2010, analysis has been carried out to assess whether new tables or a new definition of the standard parameters for towing were needed. The 2010 working group decided that the standard tow would be re-defined with achievable gear parameters (ICES, 2010a). In the next revision of the manual the old warp out to headline height and door-spread plots were removed and replaced with plots of headline height and door spread corresponding to depth and these were intended to be used as a guide for ensuring optimum gear geometry (Figures 2.10 and 2.11 in the IBTS Manual: (ICES, 2012b). This paragraph is also pertinent to the third quarter IBTS (see next section).

Because the histories of both the first and the third (see Section 2.1.1.2.1 below) quarter IBTS surveys are so closely entwined, Table 2.1.1.2.1.1 summarising the chronological development of both surveys is presented in Section 2.1.1.2.1.

2.1.1.1.2. Defining the Standard Monitoring Programme

The HH file for the North Sea International Bottom Trawl Survey (IBTS), downloaded from the ICES DATRAS portal on 27 August 2015 at 10:40 hours, contained a total of 29,641 records. These were examined to define the specific first and third quarter monitoring programme data time-series.

Initially, the field Quarter exactly reflected the month of the year, so that if Quarter=1, then Month=1, 2, or 3, or if Quarter=2, then Month=4, 5, or 6, and so on. Quarter used in this way is effectively redundant, since it simply mirrors the information contained in the Month field. Instead, the field Quarter should be used as part of the survey name, not simply to define the three-month period in which each trawl sample was collected. For example, consider a survey mainly undertaken in March, but where the last few samples were collected in April. This whole survey should be classed as a Quarter 1 survey, contributing to the Quarter 1 monitoring programme time-series, and Q1 would, therefore, feature in the survey name. Month and day information for each sample are still retained for filtering if required.

Each date was converted to a JulianDay number (e.g. 12th January JulianDay = 12; 1st February, JulianDay = 32, 1st March JulianDay = 60, etc). The HH data were then sorted by Ship, then by Year, then by Julian Day, then by Haul Number, so that for each vessel, all the hauls were ordered in chronological sequence. A logical filter was then used to establish temporal breaks in each vessel's sampling programme and individual unique TripID codes were assigned. The filter used was {If in sequential records, Country=Country AND Ship=Ship AND Year=Year AND JulianDay differed by <20, then a TRUE result ensued}. If any of the conditions were not met then the filter produced a FALSE result. The TripID was set to one for the first record, and increased by one each time the logical filter gave a FALSE result. TripID consists of the values for Country/Ship/Year/TripID where TripID is a number from one to 596 (e.g. FRA/THA/1995/448). Eight trips were found to bridge two Quarters (Table 2.1.1.1.2.1). These trips were examined to determine the number of days and count of hauls occurring in each Month and the field Quarter edited to reflect the dominant quarter of the year in which the survey was undertaken.

Country	Ship	Year	TripID	Quarter	Month	No. Hauls	No. Days	Assigned Quarter
ENG	CLI	1971	ENG/CLI/1971/132	1	3	12	5	1
ENG	CLI	1971	ENG/CLI/1971/132	2	4	4	2	
NED	WIL	1965	NED/WIL/1965/591	1	3	8	2	2
NED	WIL	1965	NED/WIL/1965/591	2	4	23	7	
NOR	HAV	2003	NOR/HAV/2003/270	3	9	43	11	3
NOR	HAV	2003	NOR/HAV/2003/270	4	10	18	5	
NOR	HAV	2004	NOR/HAV/2004/272	3	9	60	17	**3**
NOR	HAV	2004	NOR/HAV/2004/272	4	10	10	2	
NOR	JHJ	2006	NOR/JHJ/2006/314	2	6	6	2	3
NOR	JHJ	2006	NOR/JHJ/2006/314	3	7	52	23	
NOR	JHJ	2007	NOR/JHJ/2007/315	2	6	9	5	3
NOR	JHJ	2007	NOR/JHJ/2007/315	3	7	45	15	
NOR	JHJ	2011	NOR/JHJ/2011/318	2	6	1	1	3
NOR	JHJ	2011	NOR/JHJ/2011/318	3	7	45	17	
NOR	JHJ	2012	NOR/JHJ/2012/319	2	6	10	5	3
NOR	JHJ	2012	NOR/JHJ/2012/319	3	7	37	15	

Table 2.1.1.1.2.1: Eight trips identified in the full North Sea IBTS adjudged to have spanned the temporal boundary between quarters of the year. For each trip the number of days of survey, and the number of trawl samples collected, in each quarter is shown. Each trip was assigned to the most dominant quarter.

- From this point on, therefore, the field Quarter is no longer strictly temporal, and instead reflects the quarter of the year in which each trip principally occurred. The Field Quarter now defines the four separate survey time-series stored within the North Sea IBTS survey data set lodged on DATRAS.

Within the whole IBTS data set, thirteen different Gear codes are recorded, with different Countries often using different Gears. For the Quarter 1 Survey, eleven

Gear codes were used. From 1986 onwards, only the GOV was used, but even by 1983, the GOV was the primary Gear (Figure 2.1.1.1.2.1). Trawl Duration in the Quarter 1 survey was variable, but distinct modes were apparent at 30 minutes and 60 minutes (Figure 2.1.1.1.2.2). Figure 2.1.1.1.2.3a shows trends in the number of hauls in each year taken by all gears and taken by the GOV. These two trend lines are also broken down to illustrate trends in the numbers of hauls in each category (all Gears and GOV only) that were of 30 ± 4 minutes duration. The proportions of these nominal 30 minutes duration hauls within each category are also shown in the two sub-panels (Figure 2.1.1.1.2.3b and 2.1.1.1.2.3c). By 1983, 30 minute duration tows were dominating the Quarter 1 survey.

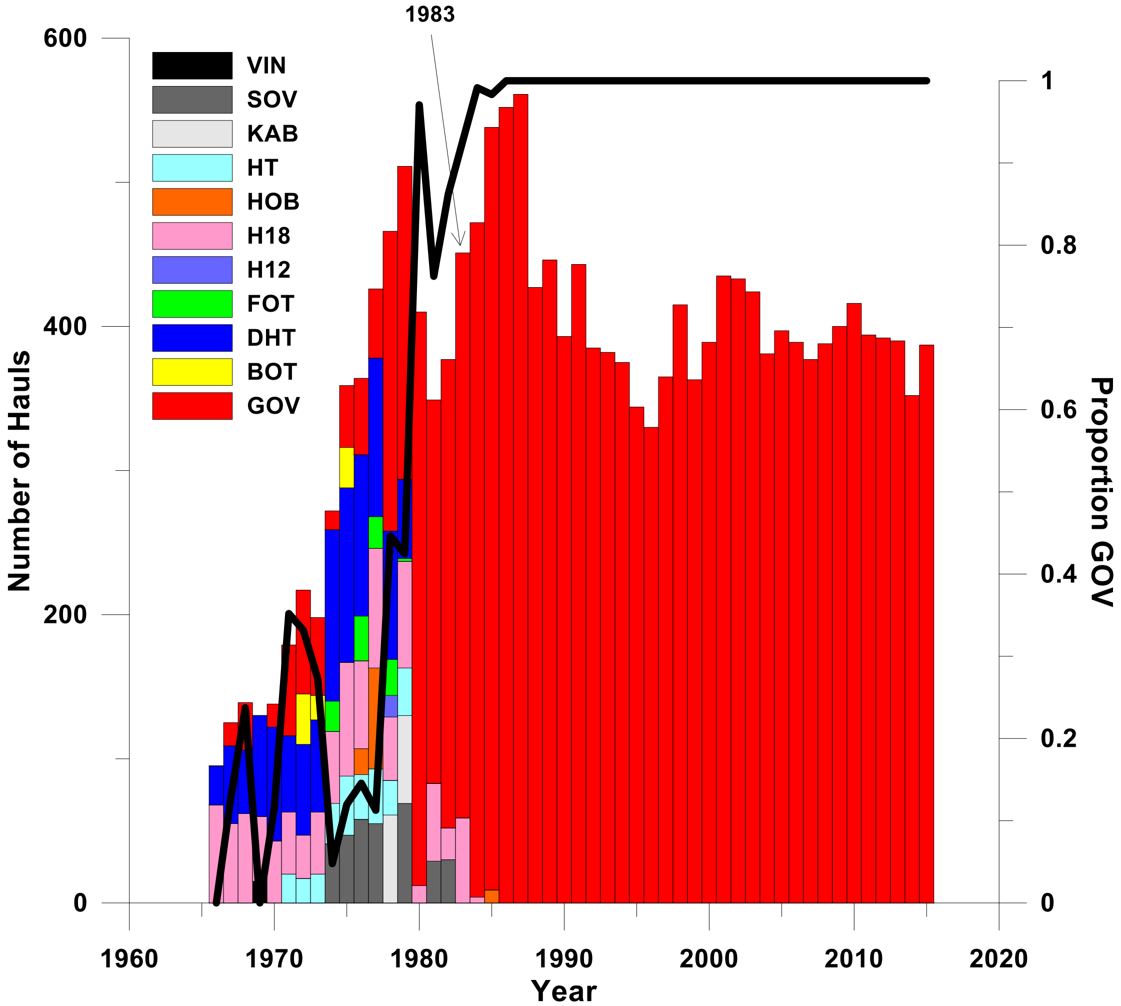

Figure 2.1.1.1.2.1: Trends in the use of different gears in the Quarter 1 IBTS.

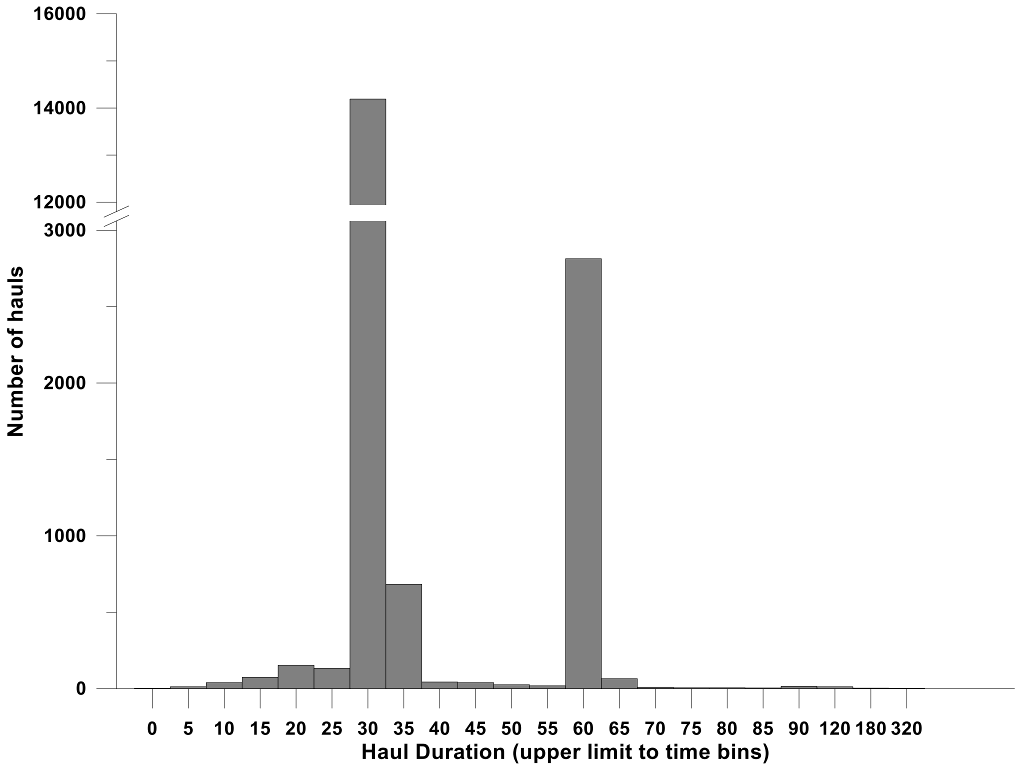

Figure 2.1.1.1.2.2: Frequency distribution of haul durations.

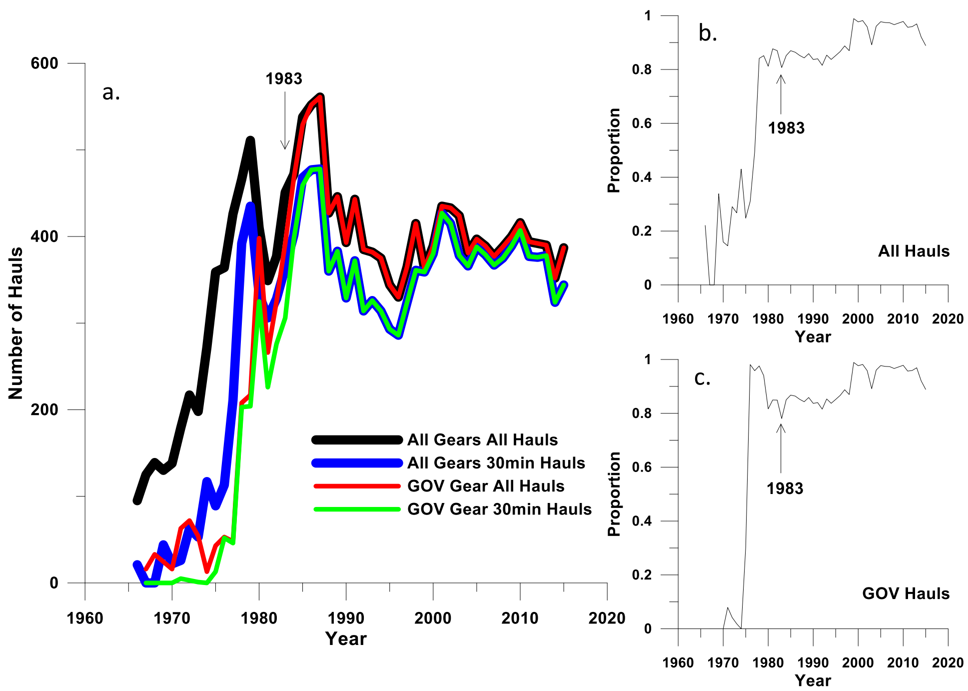

Figure 2.1.1.1.2.3: Trends in the numbers of hauls in each year taken by all gears and by GOV only, and in the numbers of each category of haul comprising nominal 30(±4) minute duration tows (a). The proportion of nominal 30 minute tows in each category are shown for all gears (b) and for the GOV (c).

The number of ICES rectangles sampled by the Quarter 1 survey in each year increased markedly during the late 1960s and early 1970s, but it was not until the late 1970s that the number of rectangles sampled by the GOV trawl increased. By the 1983, most ICES rectangles were sampled by the GOV trawl, and principally with tows of 30 minutes Duration (Figure 2.1.1.1.2.4). By 1983, the countries involved in carrying out the Quarter 1 survey had also stabilised (Figure 2.1.1.1.2.5).

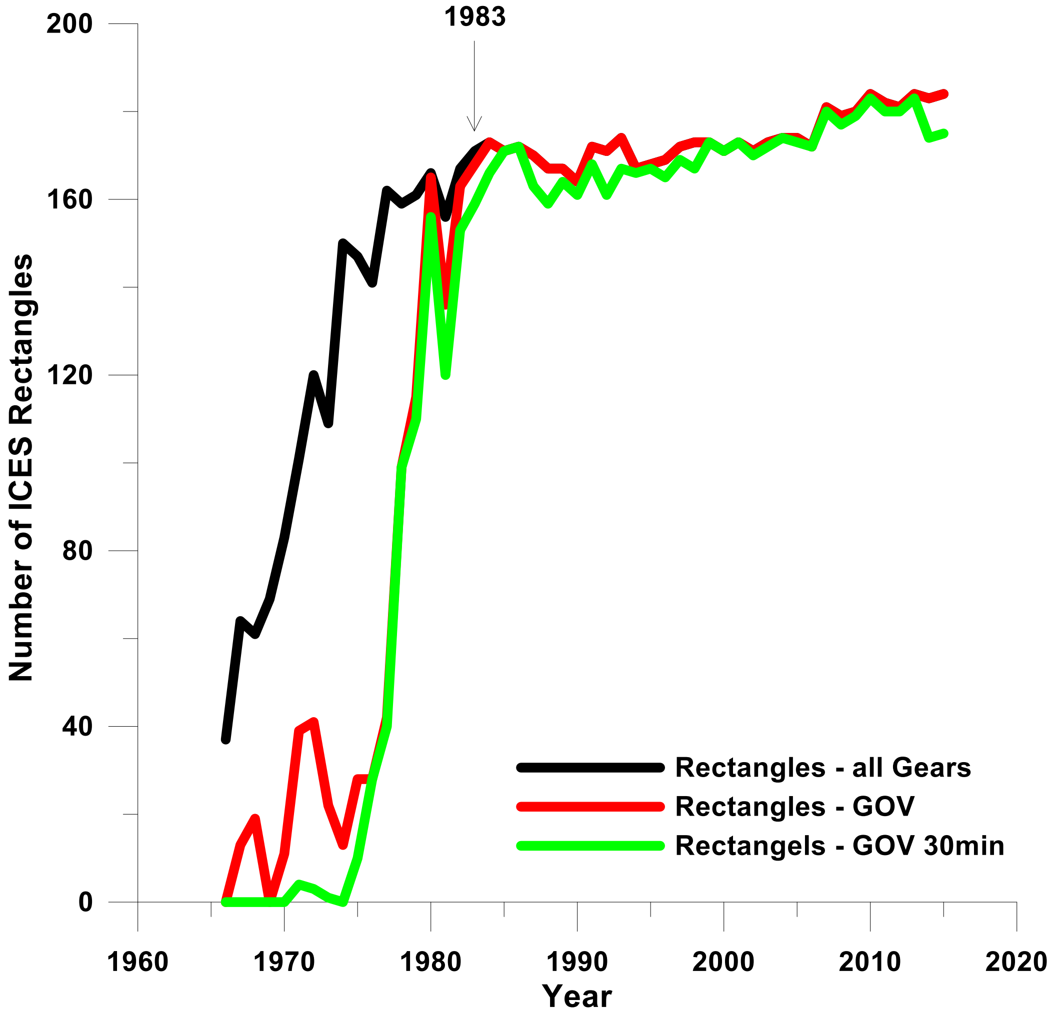

Figure 2.1.1.1.2.4: Trends in the numbers of ICES rectangles sampled each year in the Quarter 1 survey by all gears, by GOV, and by GOV hauls of nominal 30 minutes duration.

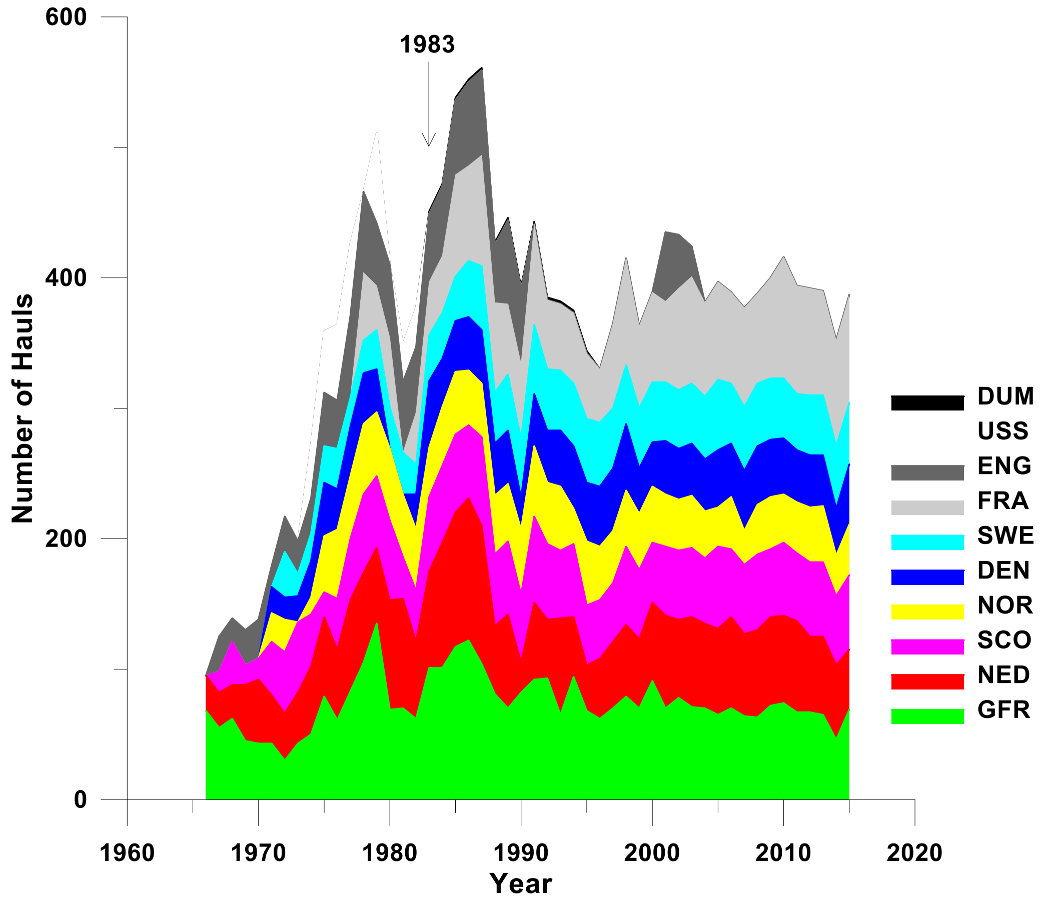

Figure 2.1.1.1.2.5: Trends in the number of trawl samples collected each year by each country participating in the Quarter 1 survey.

- On the basis of all the above information, 1983 is deemed the natural start year of the Quarter 1 Monitoring Programme; a conclusion also reached in the IBTS manual (ICES, 2012b). Data collected before 1983 were, therefore, excluded. The total number of Quarter 1 records in the entire IBTS data set was 18,341. Restricting the Greater North Sea Quarter 1 IBTS Monitoring programme to the 33 year period 1983 to 2015 reduced the number of available trawl samples to 13,586.

Although the GOV trawl is considered the standard survey gear for the Quarter 1 IBTS Monitoring Programme, other Gears were used in 1983, 1984, and 1985.

1) In 1983 GFR fished 59 ICES statistical rectangles once each using an H18 Gear. In the same Year, GFR also fished 36 ICES statistical rectangles with between one and three trawls using the GOV. There was no spatial overlap; each ICES rectangle sampled by GFR was either fished by the GOV or the H18; none were fished by both. However, of the 59 ICES statistical

rectangles sampled by GFR using the H18 Gear, 56 were sampled by other participating countries using the GOV gear; 19 with one haul and 37 with two hauls, leaving just three ICES rectangles that were only sampled by GFR using the H18 gear.

2) In 1984 GFR fished only one ICES statistical rectangle using the H18 Gear and collected four trawls samples from it. However, GFR also collected four GOV hauls from the same rectangle. This rectangle was also sampled by two other countries in the same year giving a total of six GOV hauls.

3) In 1985 the Norwegian ship ELD sampled nine ICES rectangles using the HOB gear. One of these rectangles was also sampled by NOR using the GOV. However, all nine rectangles were also fished by one or more of six different countries so that each rectangle had between one and four hauls collected (one rectangle with four hauls, two rectangles with three hauls, two rectangles with two hauls, four rectangles with one haul).

- The GOV was, therefore, deemed to be the standard Gear for the Quarter 1 Monitoring Programme and data for all other Gears was excluded. Excluding all Gears other than the GOV from the first quarter Greater North Sea IBTS Monitoring programme further reduced the number of available trawl samples to 13,514.

From 1983 onwards, the predominant haul duration (HaulDur) has been '30 minutes', but Figure 2.1.1.1.2.3 suggests a systematic event occurring between 1997 and 1999 during which time the proportion of 30 minute hauls increased from around 86% to >95%. In 1998 the Ship SCO3 replaced SCO2. In this year SCO3 collected twelve hauls of nominal 30 minute duration and forty-five hauls of nominal 60 minute duration. Similarly in the two years prior to the vessel change, SCO2 collected thirty-four 60 minute duration and nine 30 minute duration in 1996 and thirty-five 60 minute duration and ten 30 minute duration hauls in 1997. Prior to 1996, the great majority of SCO samples were 60 minutes duration, while from 1999 onwards, following the vessel change, SCO3 primarily collected 30 minute duration hauls. In all three years, 1996-1998, there was no spatial overlap in the location of the nominal 30 minute and nominal 60 minute duration hauls; no ICES rectangle was sampled by either of the Scottish vessels using both a 30 minute and a 60 minute duration haul.

Of the thirty-four ICES rectangles sampled by SCO2 using nominal 60 minute duration hauls in 1996, only one was not otherwise sampled, only two were sampled by a single alternative nominal 30 minute duration tow, and a further single rectangle was sampled by two alternative nominal 30 minute duration tows. The remaining thirty rectangles had between three and seven alternative nominal 30 minute duration hauls collected by other vessels participating in the survey. Of the thirty-four ICES rectangles sampled by SCO2 using nominal 60 minute duration hauls in 1997, two were not otherwise sampled, six were sampled by a single alternative nominal 30 minute duration tow, and a further fifteen rectangles were sampled by two alternative nominal 30 minute duration tows. The remaining eleven rectangles were sampled with either three (n=8) or four (n=3) alternative nominal 30 minute duration hauls. Of the forty ICES rectangles sampled by SCO3 using nominal 60 minute duration hauls in 1998, three were not otherwise sampled, thirteen were sampled by a single alternative nominal 30 minute duration tow, and a further twenty-one rectangles were sampled by two alternative nominal 30 minute duration tows. The remaining three rectangles were sampled with three alternative nominal 30 minute duration hauls. During the earlier part of the Quarter 1 IBTS time series, from 1983 to 1998, when Scotland primarily used nominal 60 minute duration hauls, the ICES rectangles sampled thus were, in most years, sampled at least once more by another participating country with a haul of nominal 30 minute duration (Figure 2.1.1.1.2.6). However, the fraction of these rectangles sampled by at least two other nominal 30 minute duration hauls was highly variable (Figure 2.1.1.1.2.6).

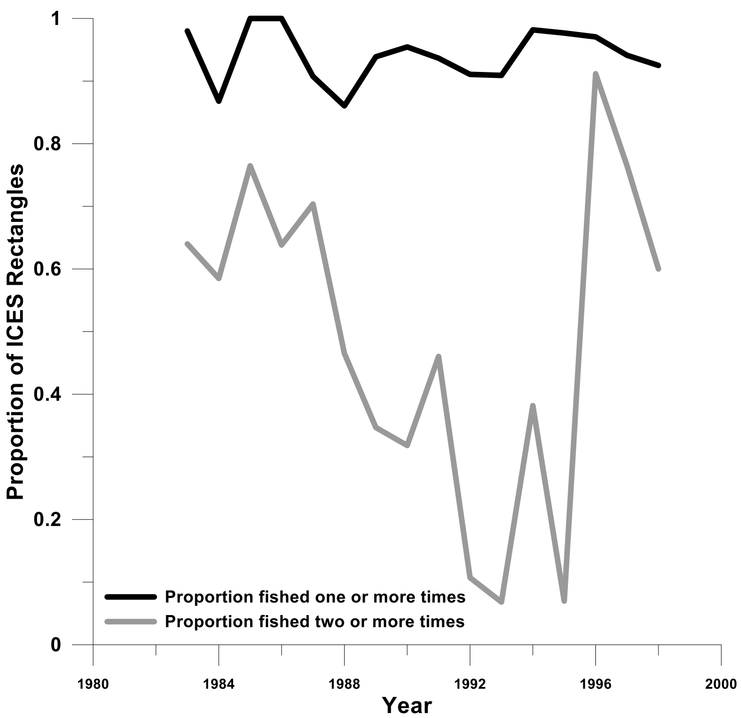

Figure 2.1.1.1.2.6: Trends in the proportion of ICES rectangles fished by Scotland using nominal 60 minute duration hauls also sampled by other countries with nominal 30 minute duration hauls.

The Quarter 1 data were then checked to assess whether the fraction of nominal 30 minute duration hauls collected by other countries participating in the survey was consistent from year to year. Seven instances were identified where the fraction of nominal 30 minute duration hauls fell below 80% of the total: Denmark in 1983; Norway in 2003, 2004, 2015; and Sweden in 1983, 1985 and 1987 (Figure 2.1.1.1.2.7). In 1983, Denmark primarily used 30 minute duration tows, but a substantial number were of longer duration: up to 60 minutes duration. Norway in 2003 appeared primarily to collect 20 minute hauls. In 2004, the majority of Norwegian hauls were 30 minutes duration, but a substantial fraction were of 20 minutes duration, while in 2015, although the majority of Norwegian hauls were again of 30 minutes duration, a substantial fraction were of 15 minutes duration. In all three anomalous years, Sweden primarily collected 30 minutes duration hauls, but hauls of shorter duration (15 minutes or 20 minutes) and of longer duration (up to 60 minutes) were also collected. In 1983 and 1985, four Swedish hauls were of 90 to 120 minutes duration (Figure 2.1.1.1.2.8).

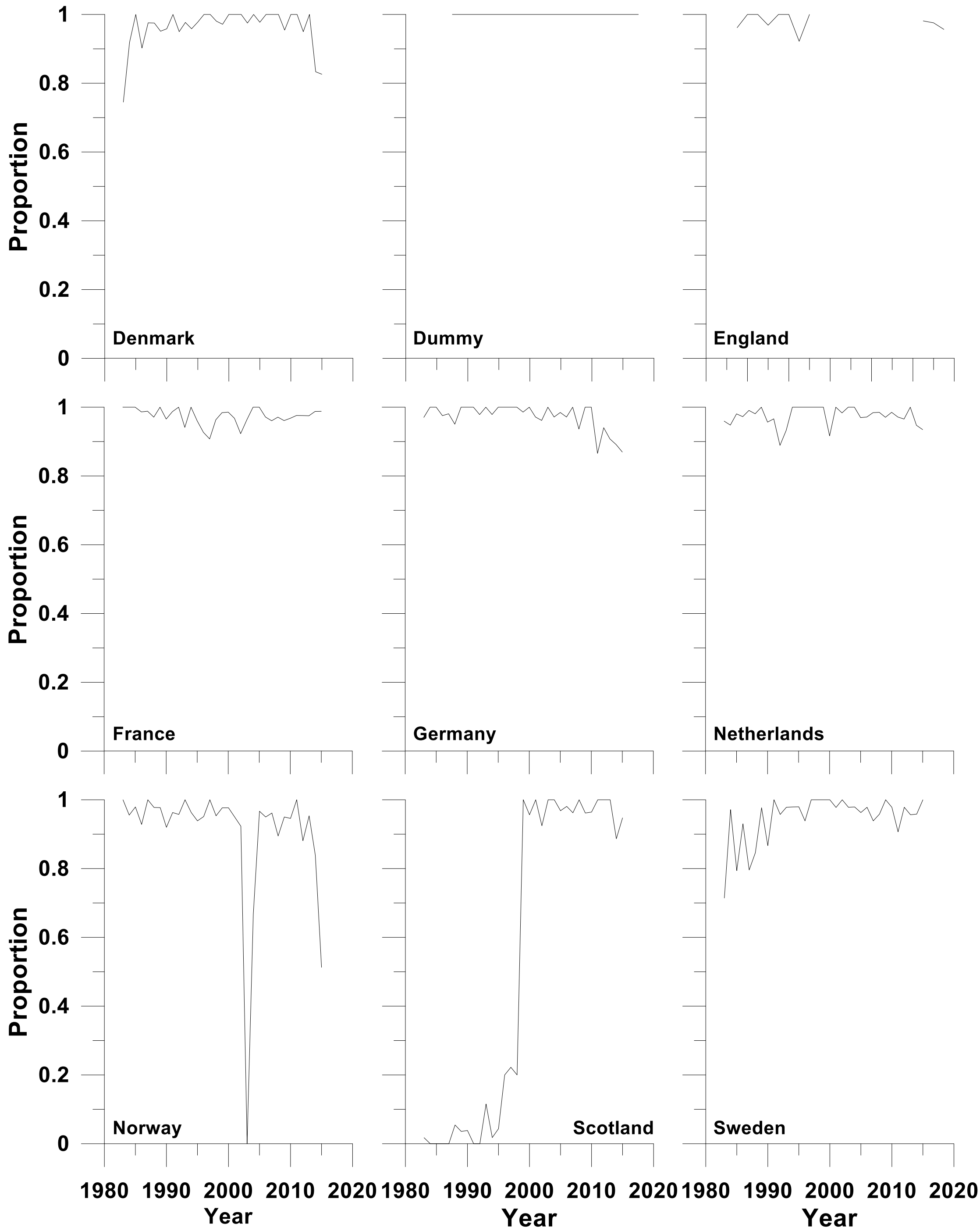

Figure 2.1.1.1.2.7: Proportion of hauls collected by each participating country within nominal 30 minute duration limits of ±4 minutes in each year.

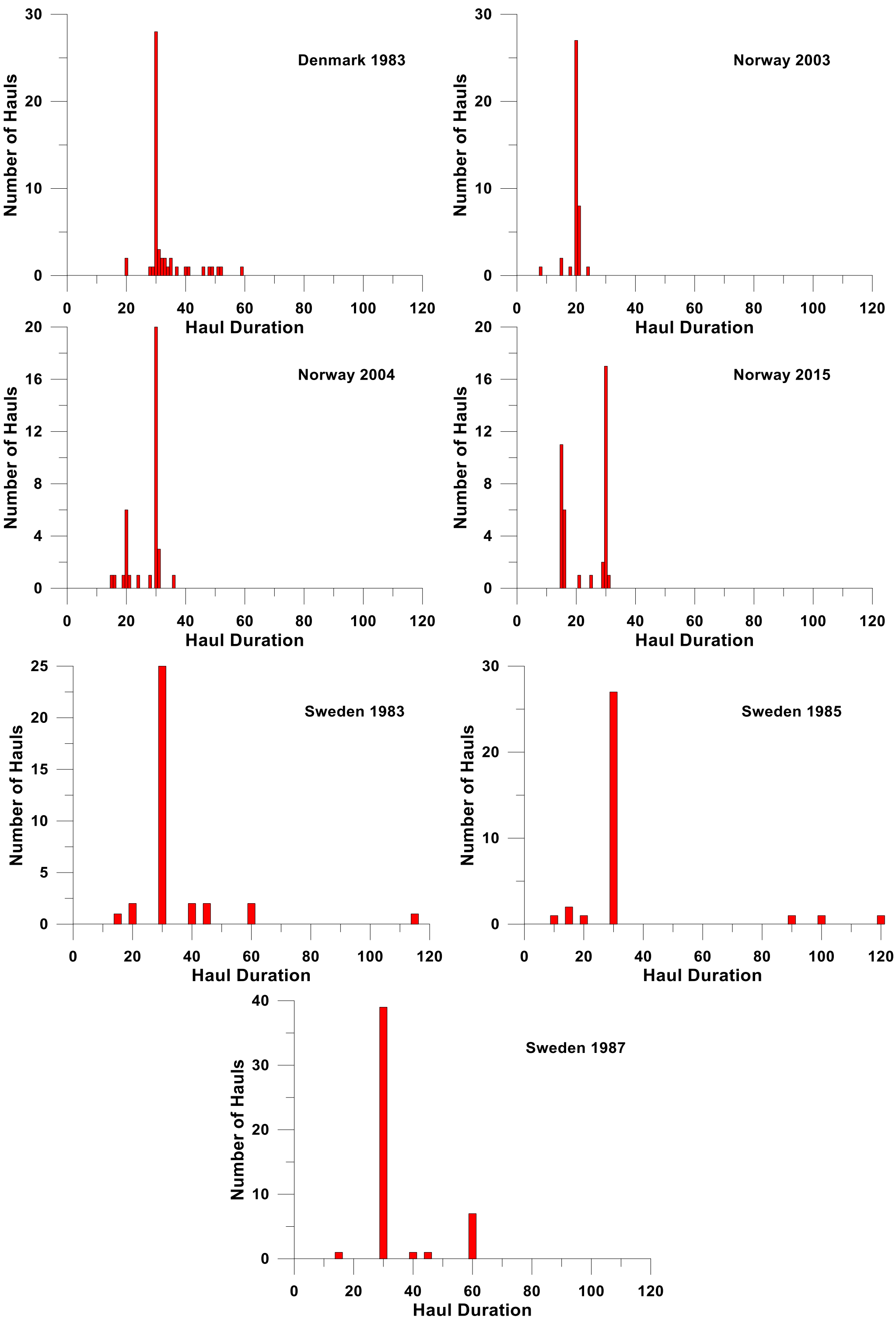

Figure 2.1.1.1.2.8: Haul duration frequency distribution for countries and years when the fraction of nominal 30 minute duration hauls dropped below 80%.

- Although the standard haul duration for the Quarter 1 survey is supposed to be 30minute, there is sufficient deviation from this norm that restricting the monitoring programme data set to just 30 minute duration hauls would impart significant year to year variability in survey spatial coverage and sampling effort. A range of haul durations must, therefore, be accepted, such that hauls of between 13 minutes and 66 minutes duration were deemed permissible and included in the data product. Thus extreme short- and long-duration hauls would still be excluded. The rule applied is essentially that hauls of nominal 15 minutes to 60 minutes duration, allowing a range of ±10% of these values to take account of operational variability, were deemed acceptable. Excluding all extreme long- and extreme short-duration hauls from the Greater North Sea Quarter 1 IBTS Monitoring Programme data product further reduces the number of available trawl samples to 13,454.

Examination of trends in the number of Hauls collected and ICES rectangles sampled each year in the Greater North Sea Quarter 1 IBTS Monitoring Programme defined thus far suggests an initial pulse of sampling effort between 1983 and 1987, but from 1988 onwards variation in sampling effort has been relatively low. However, a steady increase in the number of ICES rectangles sampled in each year was apparent (Figure 2.1.1.1.2.9a), and this is of some concern with regard to the calculation of biodiversity indicators.

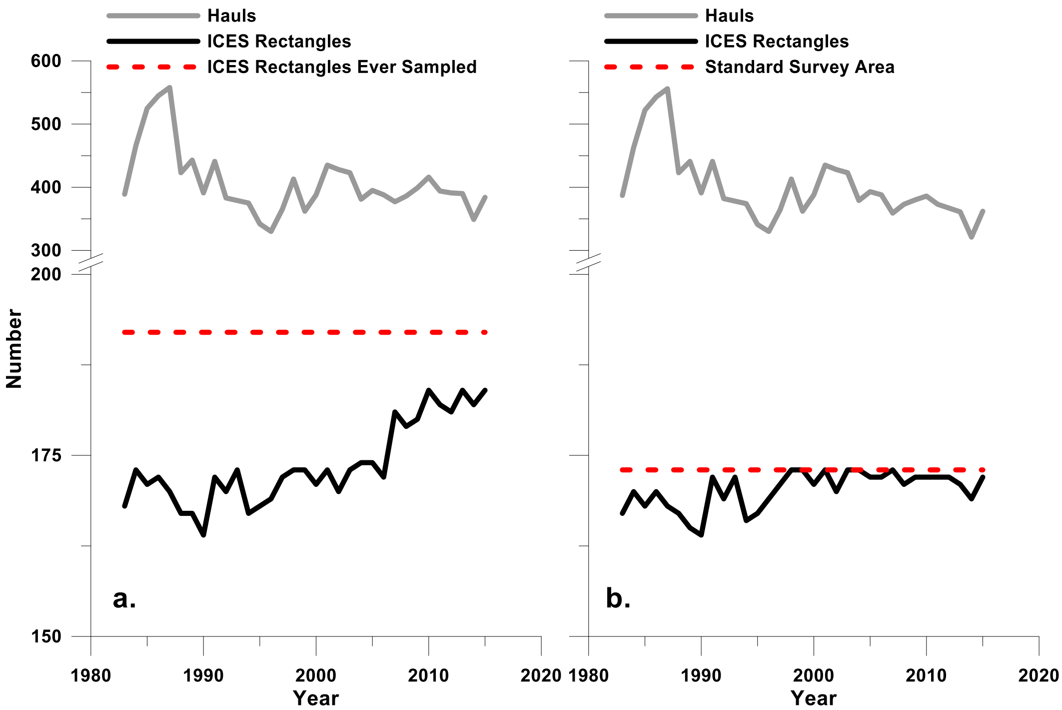

Figure 2.1.1.1.2.9: Trends in the numbers of hauls collected and ICES statistical rectangles sampled in each year of the Quarter 1 IBTS (a) in all rectangles sampled and (b) in a standard survey area consisting only of rectangles sampled in ≥50% of years of the survey time span.

The maximum number of ICES rectangles sampled in any one year was 184 (in 2010, 2013 and 2015), but across all years, 1983 to 2015, the total number of ICES rectangles ever sampled was 192. To reduce the effect of this variation in survey spatial coverage on biodiversity indicator metric values, a standard Quarter 1 survey area was defined, such that only samples collected from ICES rectangles sampled in at least 50% of years making up the Greater North Sea Quarter 1 IBTS Monitoring Programme (i.e. ≥17 years of the current 33 years time span) would be accepted. Applying this rule had minimal effect on total annual sampling effort, but it greatly reduced the trend in the number of ICES rectangles sampled in each year (Figure 2.1.1.1.2.9b). Furthermore, the fraction of the standard survey area sampled each year (Figure 2.1.1.1.2.9b) was considerably greater than the fraction of the total number of ICES rectangles ever sampled (Figure 2.1.1.1.2.9a). Spatial variation in survey coverage was all but eliminated. The standard survey area consisted of 173 ICES rectangles and the number of these rectangles sampled each year varied between 164 (in 1990) and 173 (in 1998, 1999, 2001, 2003, 2004 and 2007). Figure 2.1.1.1.2.10 shows how frequently (number of years) a given number of ICES rectangles within the standard survey area was actually sampled, the cumulative proportion is also shown. This indicates that in at least 50% of the 33 years making up the Greater North Sea Quarter 1 IBTS Monitoring Programme, 171 or more ICES rectangles, or 98.8% of the full standard survey area, were sampled. Figure 2.1.1.1.2.11 shows the standard survey area.

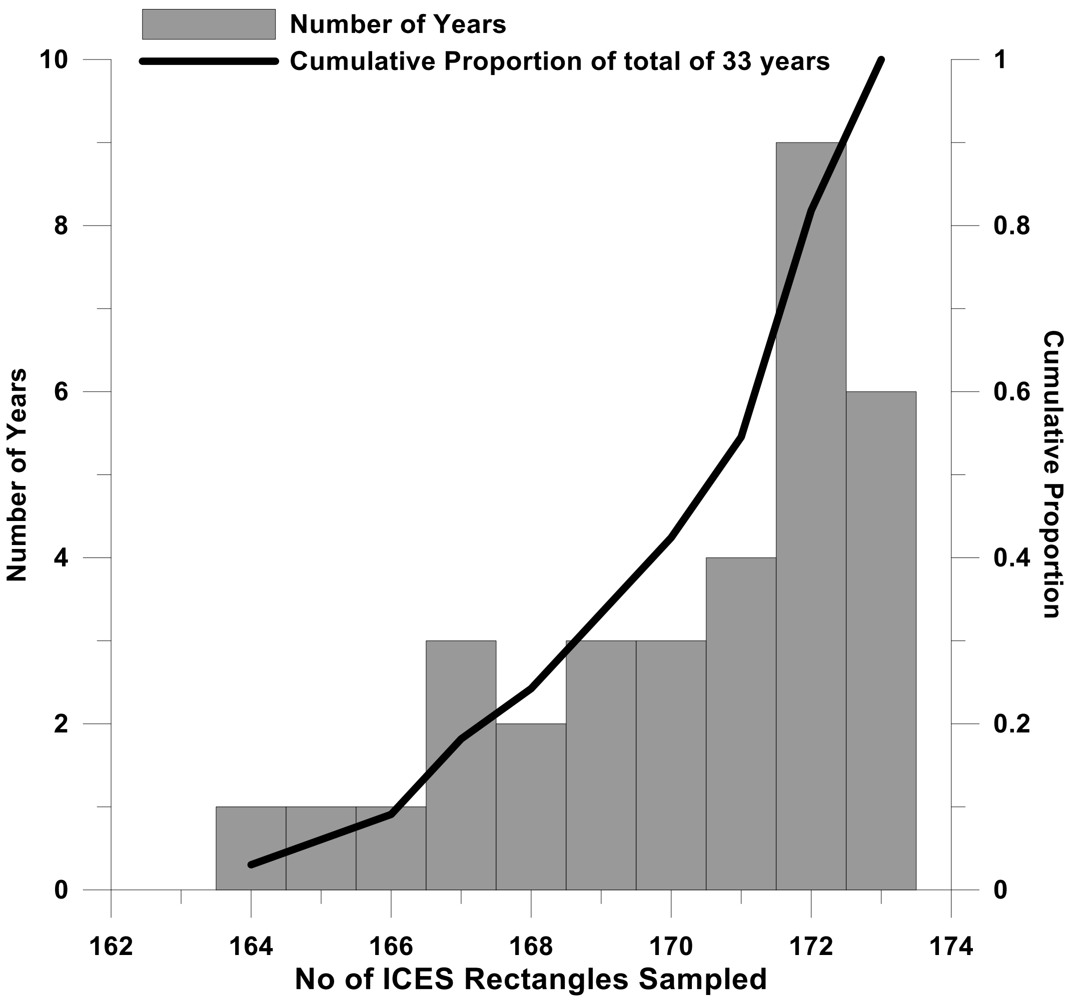

Figure 2.1.1.1.2.10: Frequency distribution of the number of ICES statistical rectangles within the standard survey area of 173 rectangles sampled a given number of years. The cumulative proportion of the total of 33 years is also shown.

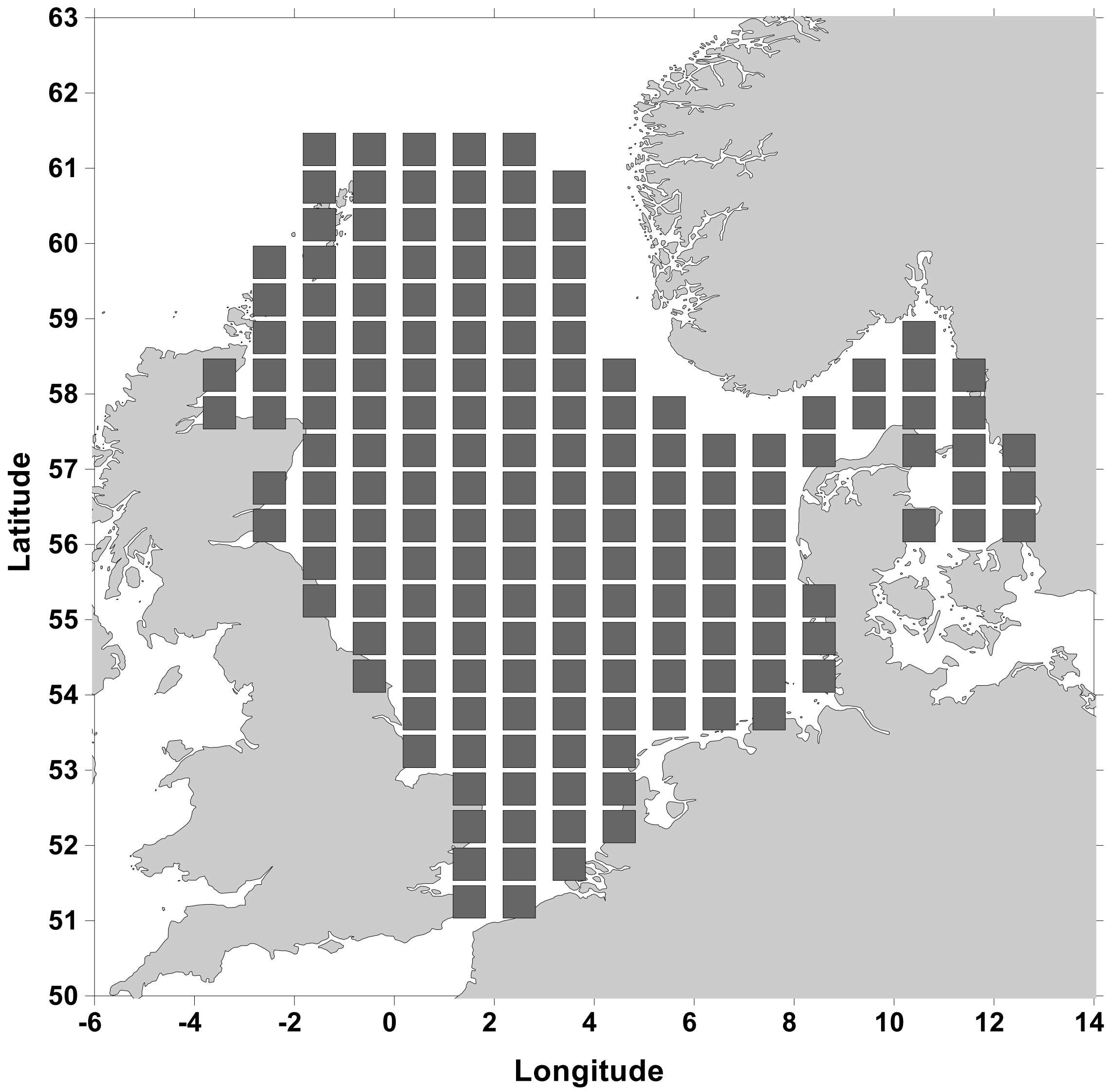

Figure 2.1.1.1.2.11: Chart showing the 173 ICES statistical rectangles that make up the standard sampling area for the Greater North Sea Quarter 1 IBTS monitoring programme.

- Only data collected from this standard survey area of 173 ICES rectangles should be included in the Greater North Sea Quarter 1 IBTS Monitoring Programme. Restricting the monitoring programme time-series to data collected from just these 173 ICES rectangles further reduces the number of samples available to 13,227.

2.1.1.2. The Third Quarter International Bottom Trawl Survey (GNSIntOT3)

2.1.1.2.1. Survey History

In 1990, the IYFS Working Group evaluated the usefulness of a number of bottom trawl surveys in the North Sea, Skagerrak and Kattegat (ICES, 1990). Apart from the international IYFS, these surveys were composed of at least seven different national surveys. The IYFS WG proposed that this combined survey effort be amalgamated to form four coordinated surveys, one survey to be undertaken in each quarter of the year, covering the whole North Sea, Skagerrak and Kattegat; these surveys would be known as the International Bottom Trawl Surveys (IBTS). Initially it was recommended that these quarterly surveys should run for a period of five years, to facilitate seasonal sampling of fish stomachs in 1991 for diet and consumption rate estimation, and to provide information on the seasonal distribution of the principal stocks considered necessary for development of multispecies assessments and spatially disaggregated assessment models. Six years of quarterly surveys covering most of the North Sea, Skagerrak and Kattegat followed (ICES, 1996). However, this level of survey effort proved difficult to maintain; by 1997 survey effort in Quaters 2 and 4 was much reduced with just a few countries contributing. Since 1998, the resources available have been directed towards maintaining full coordinated survey coverage of the area in just the first and third quarters.

Since the histories of both the first (see section above) and the third quarter IBTS are so closely entwined, Table 2.1.1.2.1.1 lists developments in both surveys. The fundamental objectives of both surveys are summarised as:

1. To determine the distribution and relative abundance of pre-recruits of the main commercial species with a view of deriving recruitment indices;
2. To monitor changes in the stocks of commercial fish species independently of commercial fisheries data;
3. To monitor the distribution and relative abundance of all fish species and selected invertebrates;
4. To collect data for the determination of biological parameters for selected species;
5. To collect hydrographical and environmental information;
6. To determine the abundance and distribution of late herring larvae (first quarter survey only).

Year	Chronology of the International Bottom Trawl Survey
1960 to 1961	Spring and autumn trawl surveys to map distribution of herring (ICES 1963)
1965 to 1968	International Young Herring Survey (IYHS) annually - Southern/Central North Sea - tow duration 60min, - see: ICES (1963)
1966	Annual surveys in the southern and central North Sea established to obtain recruitment indices for the combined North Sea herring stocks - the International Young Herring Survey (IYHS).
1969	Skagerrak and Kattegat included in survey area
1970s	Many different survey trawls being used by various institutes carrying out different surveys in the North Sea, Skagerrak and Kattegat, among them the Dutch Herring Trawl, GOV and Herring Trawl
1974	Northern North Sea included in survey area to collect data for gadoids Entire North Sea, Skagerrak and Kattegat surveyed
1975	Recommendation for participants in IYHS to use Isaacs Kidd midwater trawl to fish for herring larvae at night, MIK gear as standard for larvae.
1976	Some participants start to fish ½ hour tows in order to reduce gear damage and increase numbers of hauls per day
1977	IYHS Working Group and Gadoid I-Group Working Group recommend that all participants change to ½ hour tow duration. Working Groups also recommend that from 1978 the GOV trawl be the standard gear for future surveys. At least 4 countries were to use this gear in 1978, with other participants changing over to the GOV at the earliest possible occasion (ICES, 1977)
1978	4 vessels using GOV, 30 mins was standard in all areas but one still at 60 mins
1981	Survey was renamed the International Young Fish Survey (IYFS)
1983	All Quarter 1 participants use standard GOV, 30 mins was standard in all areas but one still at 60 mins.
1984	ICES Working Group on Young Herring Surveys and the Gadoid 1-Group Working Group were combined to form the International Young Fish Survey (IYFS) Working Group.
1990	IYFS WG proposed to combine the IYFS and other national surveys into Quarterly Coordinated Surveys in the North Sea, Skagerrak and Kattegat, which were to be known as the International Bottom Trawl Surveys (IBTS). (ICES 1990, ICES 1996)
1991 to 1996	Quarterly surveys undertaken
1991	England had no Quarter 1 survey, to allow preparation for Q2-4 surveys.(ICES, 1992)
1991	Sweden conducted own surveys in each quarter in Skagerrak and Kattegat but not part of co-ordinated survey. But willing to look at possibility of joining along with Norway and Danish surveys.
1992	All participating countries now using GOV as standard survey gear for all quarters.
1997	National financial constraints reduce coordinated surveys to Quarter 1 and Quater 3 with target coverage of 2 hauls per ICES rectangle per survey.
1997 to 1998	Twice annually - 30 mins was standard in all areas but one still at 60 mins (Heessen et al 1997)
1999 to current	Twice annually - all countries tow for 30 min.
2001	Western Areas IBTS surveys first coordinated manual produced.
2005	New revision to North Sea Survey Manual Revision VII
2008	France extend Q1 survey area into the Eastern English Channel
2009	Norway unable to participate in Q3 IBTS. Eastern English Channel area cover by France recognized as new Roundfish Area (RFA) 10.
2010	New revision of North Sea Survey Manual Revision VIII
2011	Start of regular collection of marine litter data from GOV trawl

Table 2.1.1.2.1.1: Chronology of the International Bottom Trawl Survey from Annex 1a of SISP-IBTS VIII (ICES 2012b).

2.1.1.2.2. Defining the Standard Monitoring Programme

Figure 2.1.1.2.2.1 shows the number of hauls collected, and the number of ICES rectangles sampled, in each year in the Quarter 2, Quarter 3, and Quarter 4 surveys.

The Quarter 2 and 4 surveys only took place between 1991 and 1997, but even by 1997, the number of samples collected and the number of rectangles sampled had both declined markedly. The only gear used during the short Quarter 2 and Quarter 4 survey time-series was the GOV. However, during the period that these two surveys were in operation, other gears were also used in the Quarter 3 survey, and it was not until 1998, when the Quarter 2 and Quarter 4 surveys had ceased, that the GOV became the sole gear used in the Quarter 3 survey (Figure 2.1.1.2.2.2). Tow duration also varied markedly, both between surveys and during the course of each survey. The majority of hauls collected in the Quarter 4 survey were of nominal 30 minutes duration, while the proportion of nominal 30 minute duration hauls in the Quarter 2 survey decreased markedly over the survey span. While the Quarter 2 and 4 surveys were in operation, the proportion of nominal 30 minute tows in the Quarter 3 survey increased, but it was only in 1998, after these two surveys had ceased, that the proportion of nominal 30 minute tows in the Quarter 3 survey approached 100% (Figure 2.1.1.2.2.2).

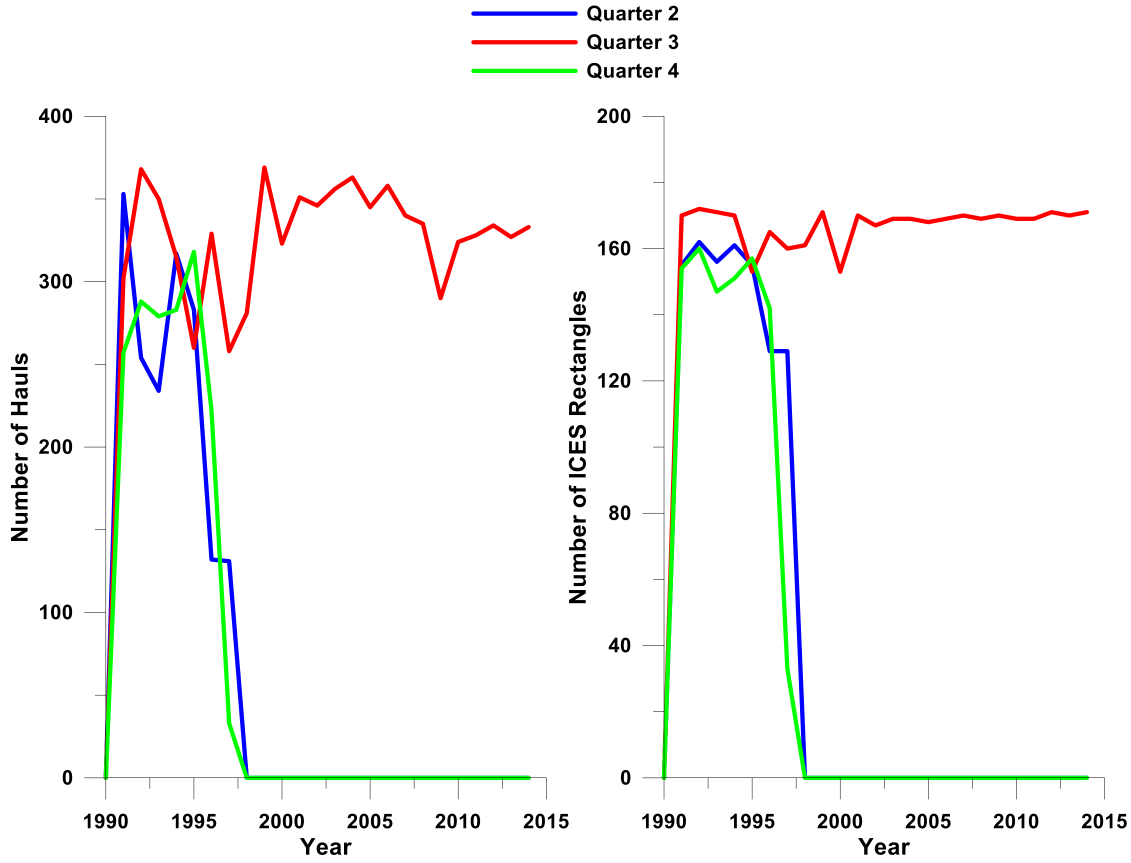

Figure 2.1.1.2.2.1: Trends in the number of samples collected, and the number of ICES statistical rectangles sampled, by the Quarter 2, Quarter 3 and Quarter 4 surveys.

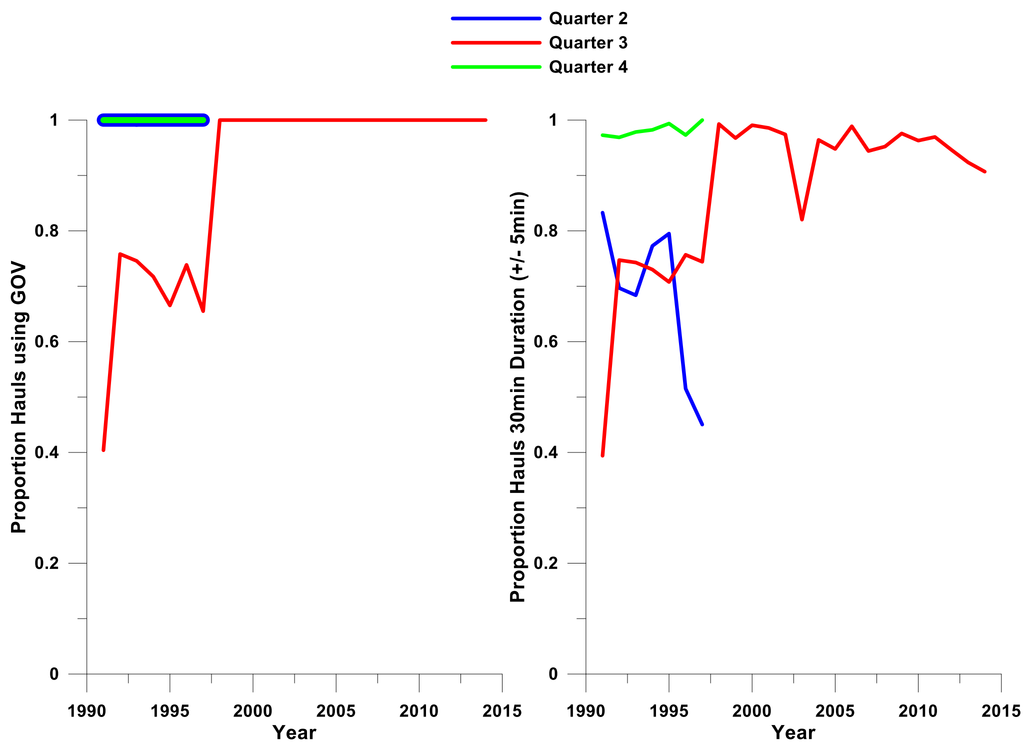

Figure 2.1.1.2.2.2: The proportion of hauls using the GOV gear and the proportion of hauls of nominal 30 minutes duration in the Quarter 2, Quarter 3 and Quarter 4 surveys.

- The Quarter 2 and Quarter four time-series are too short to constitute useful monitoring programmes. They are no longer running so cannot contribute to any assessment of current status and their time-spans are too recent to provide useful target-setting insight. Analysis of seasonal variation is not currently needed for MSFD purposes. The Quarter 2 and Quarter 4 data were, therefore, ignored.
- The IBTS database includes records for 7,885 trawl samples collected during Quarter 3 survey trips. The Quarter 3 IBTS only really became properly established as a monitoring programme in its own right from 1998 onwards, by which point the GOV was the principal sampling gear and the majority of hauls collected in the survey had settled around a duration of 30 minutes (Figure 2.1.1.2.2.2). Restricting the Greater North Sea Quarter 3 IBTS Monitoring Programme to just GOV Hauls collected from 1998 onwards reduced the number of available samples to 5,703.

Although the vast majority (5,391 of the total of 5,703; 94.5%) of Quarter 3 hauls collected since 1998 were of nominal 30±4 minutes duration, distinct modes in the duration frequency distribution were also apparent around durations of 15 minutes and 20 minutes, and the occasional haul of up to 60 minutes duration was noted

(Figure 2.1.1.2.2.3). The Quarter 3 data were, therefore, checked to assess whether the fraction of nominal 30 minutes duration hauls collected by countries participating in the survey was consistent from year to year. Seven instances were identified where the fraction of nominal 30 minutes duration hauls fell below 85%: involving Norway in 2003, 2005, 2007, 2008 and 2014 and Scotland in 2013, and 2014 (Figure 2.1.1.2.2.4). Norway predominantly collected hauls of 20 minutes duration in 2003, 15 minutes duration in 2008, while in 2007 and 2014 a range of shorter duration tows were collected, and in 2005 a range of both longer and shorter duration tows were collected (Figure 2.1.1.2.2.5). In 2013 and 2014, Scotland had an increasing tendency to collect hauls of 20 minutes duration (Figure 2.1.1.2.2.5).

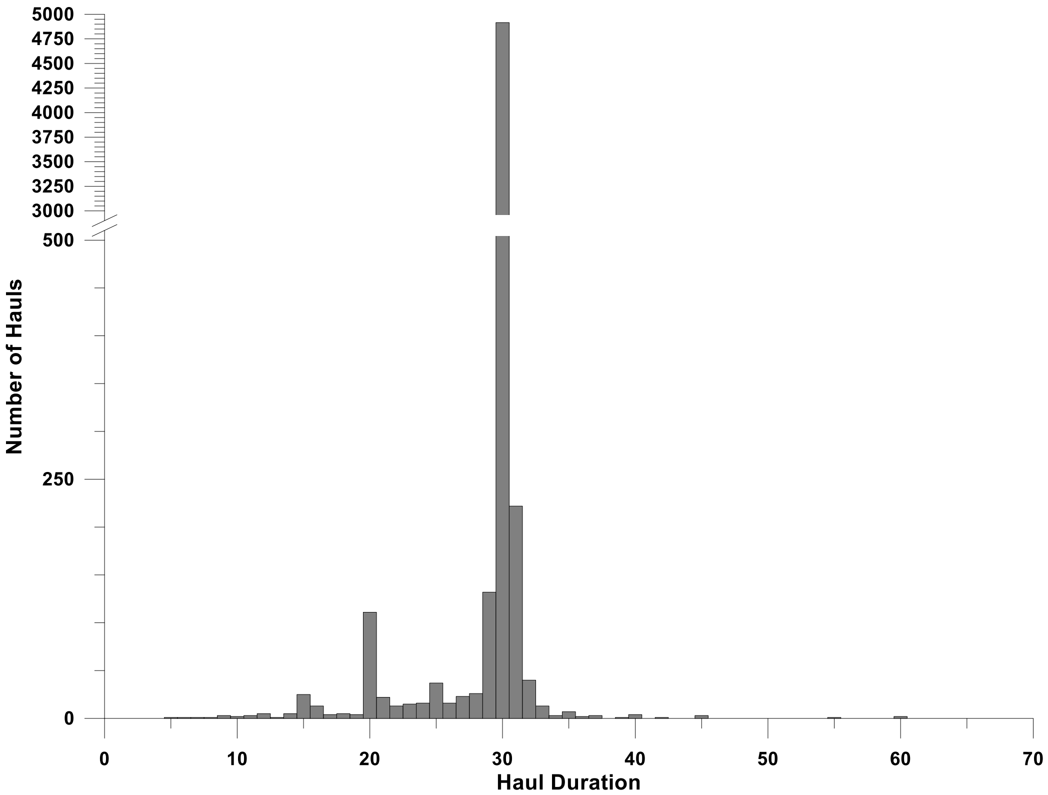

Figure 2.1.1.2.2.3: Frequency distribution of haul durations in the Quarter 3 IBTS.

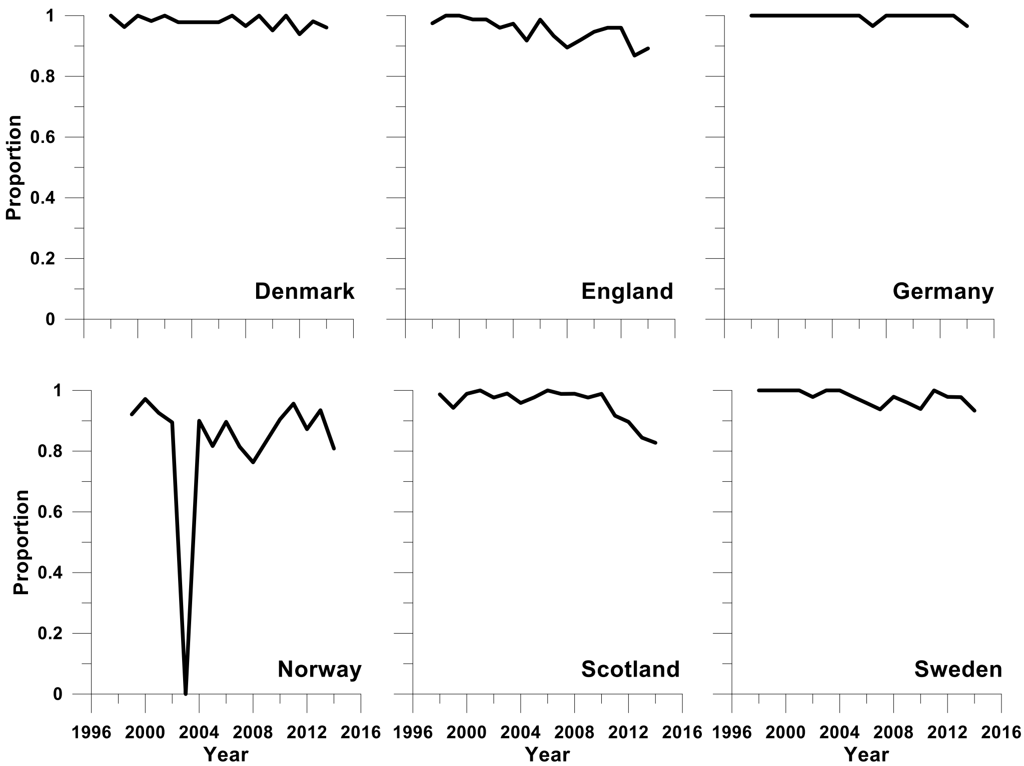

Figure 2.1.1.2.2.4: Proportion of hauls collected by each country participating in the Quarter 3 IBTS within nominal 30 minutes duration limits of ± 4 minutes in each year.

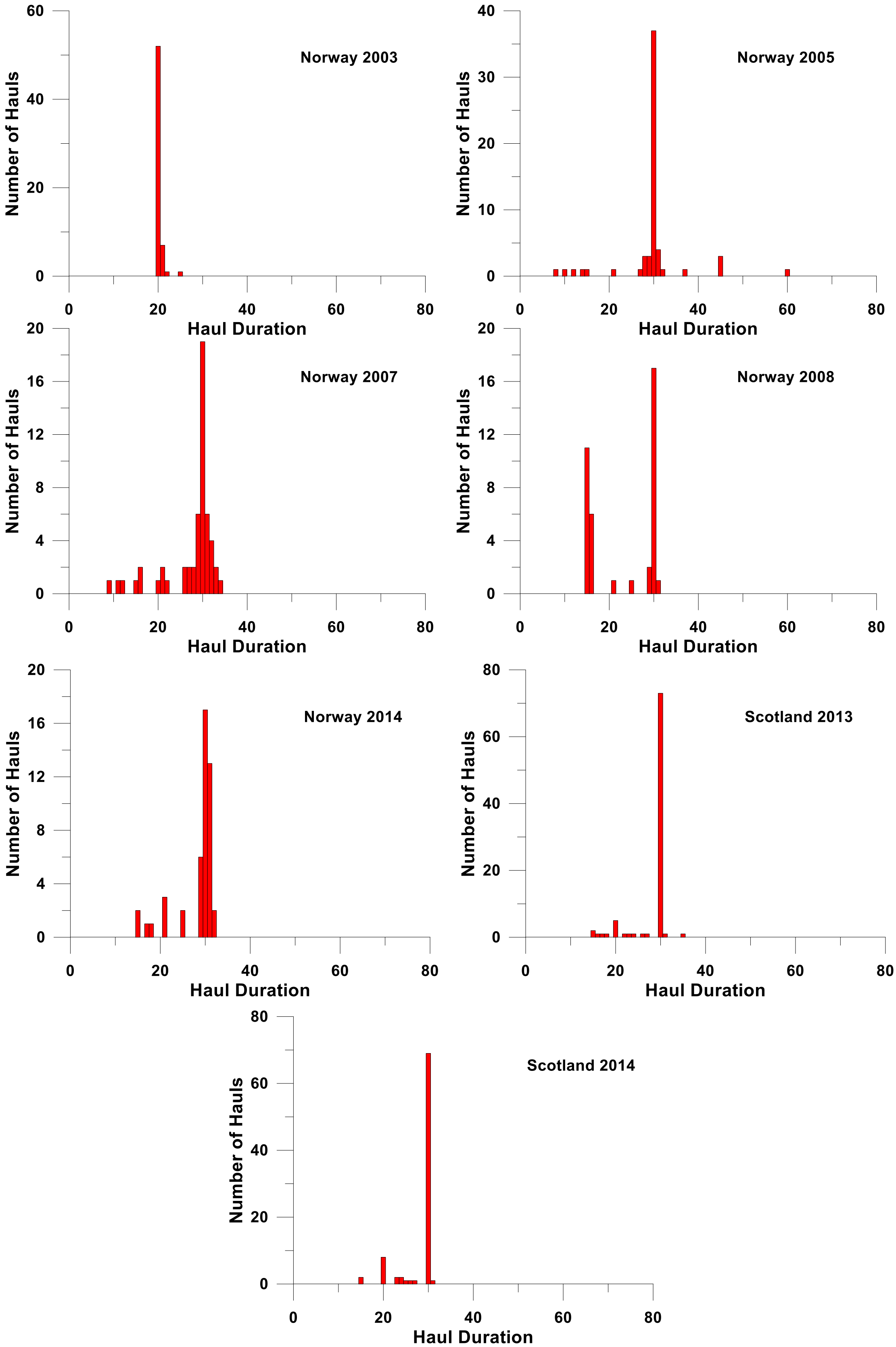

Figure 2.1.1.2.2.5: Haul duration frequency distribution for countries and years when the fraction of nominal 30 minutes duration hauls dropped below 85%.

- Although the standard haul duration for the Quarter 3 survey is supposed to be 30 minutes, there was sufficient deviation from this norm that restricting the monitoring programme data set to just 30 minutes duration hauls would have imparted significant year to year variability in survey spatial coverage and sampling effort. A range of haul durations was, therefore, necessary, and hauls of between 13 minutes and 66 minutes duration were accepted. Extreme short- and long-duration hauls were still excluded. The rule applied was essentially that hauls of nominal 15 minutes to 60 minutes duration, allowing a range of ±10% of these values to take account of operational variability, were deemed acceptable. Excluding all extreme long- and extreme short-duration hauls from the Greater North Sea Quarter 3 IBTS Monitoring Programme further reduced the number of available trawl samples to 5,686.

Examination of trends in the number of Hauls collected and ICES rectangles sampled each year in the Greater North Sea Quarter 3 IBTS Monitoring Programme defined thus far suggests an initial increase in sampling effort from 1998 to 1999, then a marked decline in 2000. From 2001 onwards sampling effort is relatively steady at around the 1999 level, apart from a sharp dip that occurred in 2009 (Figure 2.1.1.2.2.6a). The decline in sampling effort in 2000 is associated with the lack of Swedish data in this year. Variation in the number of ICES rectangles sampled in each year matched the trend in sampling effort: an increase between 1998 and 1999, followed by a marked reduction in 2000, then a recovery in 2001 to previous levels, and remaining steady, or perhaps exhibiting a gentle positive trend, through the remainder of the time series (Figure 2.1.1.2.2.6a). The dip in total sampling effort in 2009 was not matched by any reduction in spatial coverage by the survey.

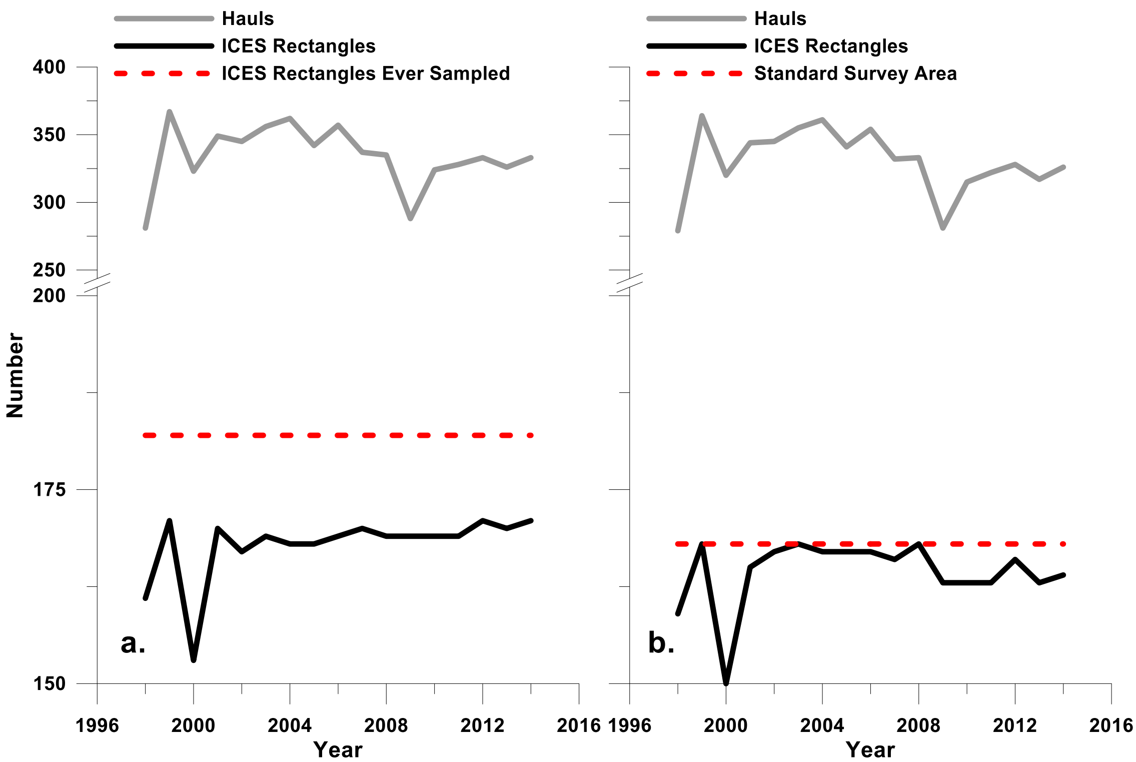

Figure 2.1.1.2.2.6: Trends in the number of hauls collected and rectangles sampled in each year of the Quarter 3 IBTS (a) in all rectangles sampled and (b) in a standard survey area consisting only of rectangles sampled in ≥ 50% of years of the survey time span.

As with the Quarter 1 time series, the maximum number of ICES rectangles sampled in any one year was 171 (in 1999, 2012 and 2014), but across all years, the total number of ICES rectangles ever sampled between 1998 and 2014 was 182; indicative of year to year variation in survey spatial coverage. To reduce the effect of this variation in survey spatial coverage on biodiversity indicator metric values, a standard Quarter 3 survey area was defined, such that only samples collected from ICES rectangles sampled in at least 50% of years making up the Greater North Sea Quarter 3 IBTS Monitoring Programme (i.e. ≥9 years of the current 17 year time span) would be accepted. Applying this rule had minimal effect on total annual sampling effort, but it removed any trend in the number of ICES rectangles sampled in each year (Figure 2.1.1.2.2.6b). Furthermore, the fraction of the standard survey area sampled each year (Figure 2.1.1.2.2.6b) was considerably greater than the fraction of the total number of ICES rectangles ever sampled (Figure 2.1.1.2.2.6a). Spatial variation in survey coverage was all but eliminated. The standard survey area consisted of 168 ICES rectangles and the number of these rectangles sampled each year varied between 150 (in 2000) and 168 (in 1999, 2003 and 2008). Standardising the survey area did little or nothing to reduce the impact of the lack of Swedish survey data in 2000. Not only did this reduce the level of sampling effort, but a significantly sized part of the standard survey area was also not covered as a result. Figure 2.1.1.2.2.7 shows how frequently (number of years) a given number of ICES rectangles within the standard survey area was actually sampled, the cumulative proportion is also shown. This indicates that in at least 50% of the 17 years making up the Greater North Sea Quarter 3 IBTS Monitoring Programme, 166 or more ICES rectangles, or 98.8% of the full standard survey area, were sampled. Figure 2.1.1.2.2.8 shows the standard survey area.

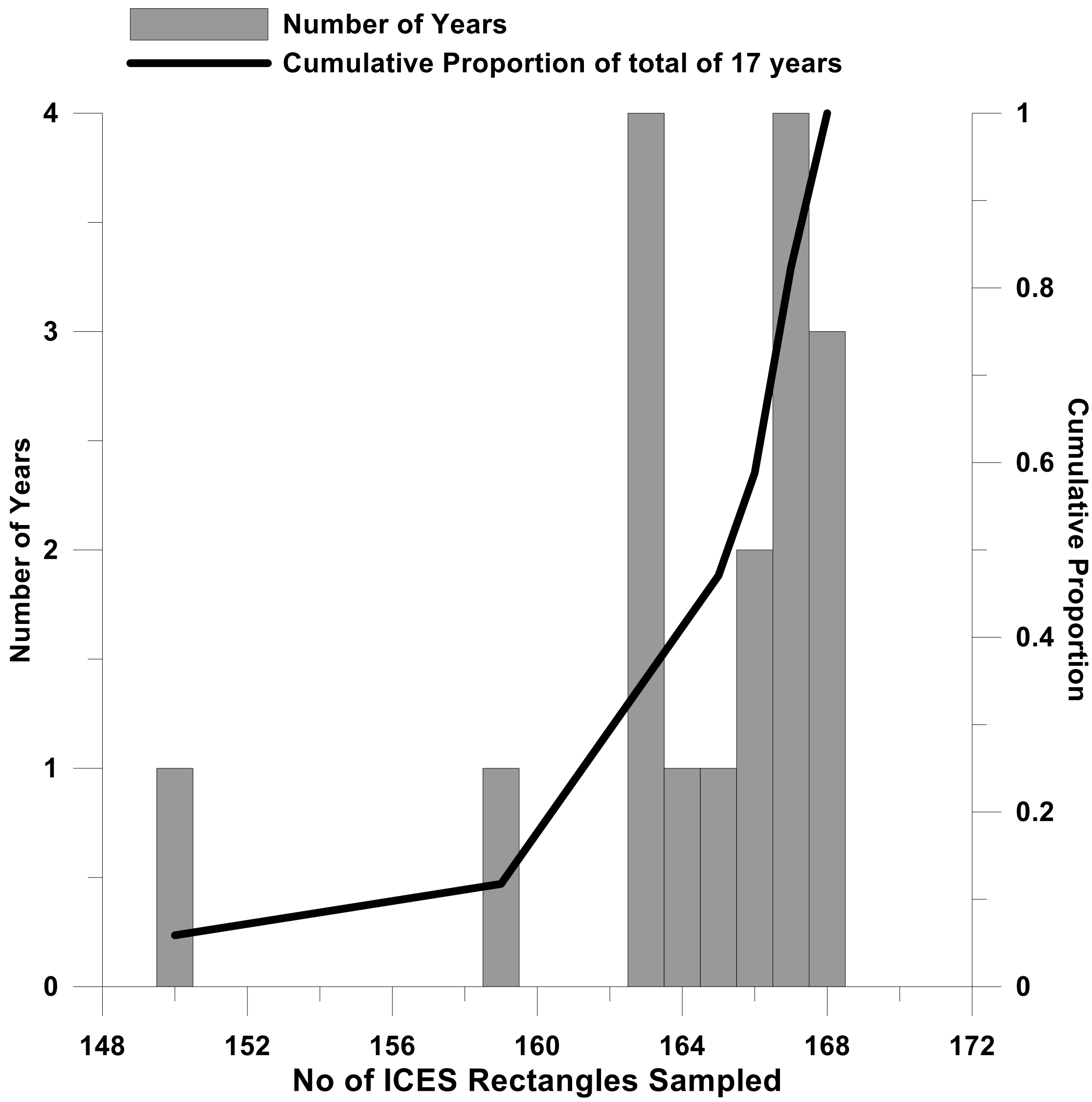

Figure 2.1.1.2.2.7: Frequency distribution of the number of ICES statistical rectangles within the standard survey area of 168 rectangles sampled a given number of years. The cumulative proportion of the total of 17 years is also shown.

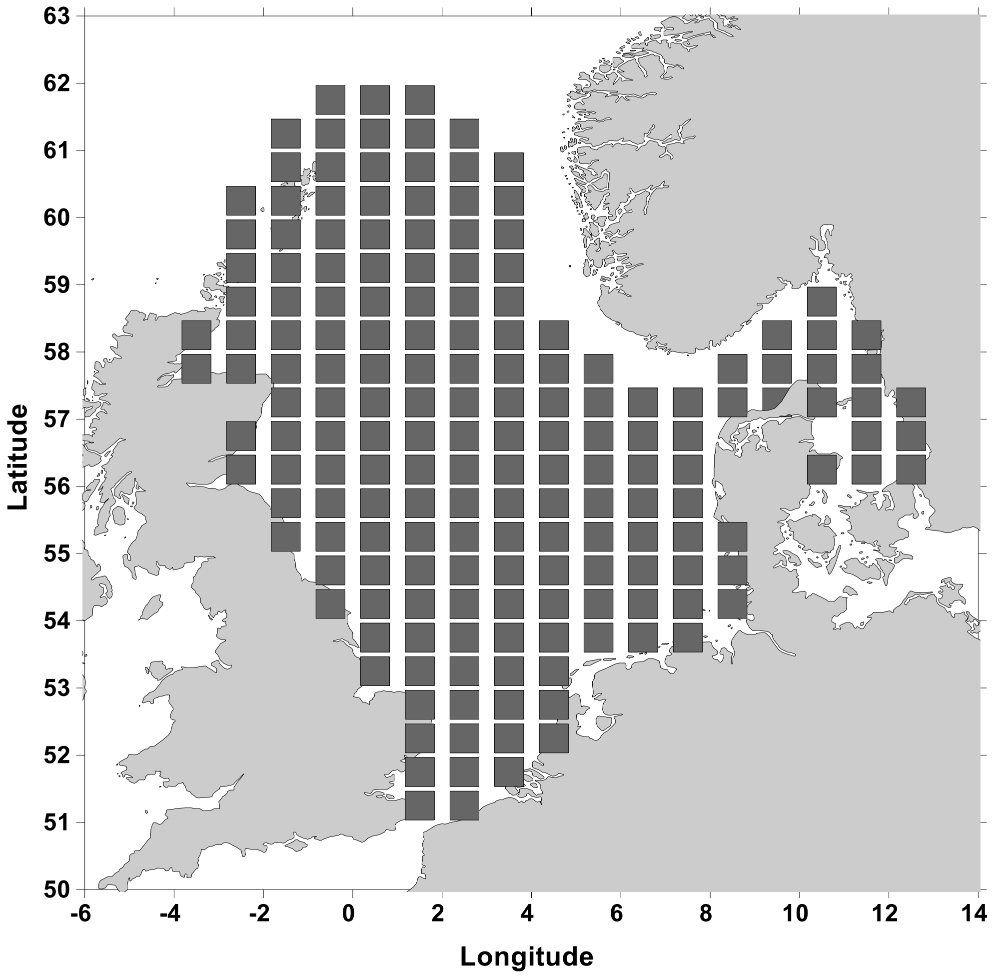

Figure 2.1.1.2.2.8: Chart showing the 168 ICES statistical rectangles that make up the standard sampling area for the Greater North Sea Quarter 3 IBTS Monitoring Programme.

- Only data collected from this standard survey area of 168 ICES rectangles were included in the Greater North Sea Quarter 3 IBTS Monitoring Programme. Restricting the monitoring programme time-series to just data collected from these 168 ICES rectangles further reduced the number of samples available to 5,617.

2.1.1.3. The Fourth Quarter French Channel Groundfish Survey (GNSFraOT4)

2.1.1.3.1. Survey History

The French Channel Ground Fish Survey (CGFS) covers the Channel area extending from the south of the North Sea in ICES Division IVc and the Eastern Channel in Division VIId. The survey, which commenced in 1988, is undertaken annually in October each year. From 1988 until 2014 the survey was undertaken using the RV "*Gwen Drez*", in 2015 the *Thalassa II* took over the survey from the "*Gwen Drez*". The survey follows a systematic even sampling design, similar to that used for the Q1 and Q3 IBTS, but instead of being based on the 0.5° latitude by 1.0° longitude ICES statistical rectangles, it uses the "CGFS grid" of rectangles of 15' latitude and 15' longitude. One or two 30 minutes trawl samples using a GOV trawl gear rigged in the same way as the GOV used in the French EVHOE survey (see Section 2.1.2.6) are collected from within each rectangle of the CGFS grid (two in the coastal zone and one offshore) (ICES, 2012b). The fishing method is standardized using the same sampling station locations in each year. However, in recent years the IBTSWG has voiced some concern regarding internal consistency of cohort abundance index estimates (ICES, 2009a; ICES 2010a). Different methods are being explored and this sampling design may be revised in the future.

2.1.1.3.2. Defining the Standard Monitoring Programme

The HH file for the French GOV survey in the English Channel was downloaded from The DATRAS portal on 18 November 2015 at 10:58. The database held data for 2406 trawl samples, collected over a 27 year period from 1988 to 2014. It is a fourth quarter survey undertaken during the months of October and November by a single vessel ('GWD') using a GOV trawl. At the time that this analysis was done, the 2015 Thalassa II data were not yet available on DATRAS.

The majority of trawl samples were of 30 minutes duration, but other duration modes were also apparent at 15 minutes, 20 minutes and 25 minutess (Figure 2.1.1.3.2.1). Following precedent established for surveys examined previously, a range of haul durations from 15 minutes to 60 minutes with a 10% margin to account for operational vagaries meant that hauls with durations 13 minutes to 66 minutes were again considered to be acceptable. Six hauls were shorter than 13 minutes duration, none were longer than 66 minutes, and excluding these samples reduced the database to 2399 records.

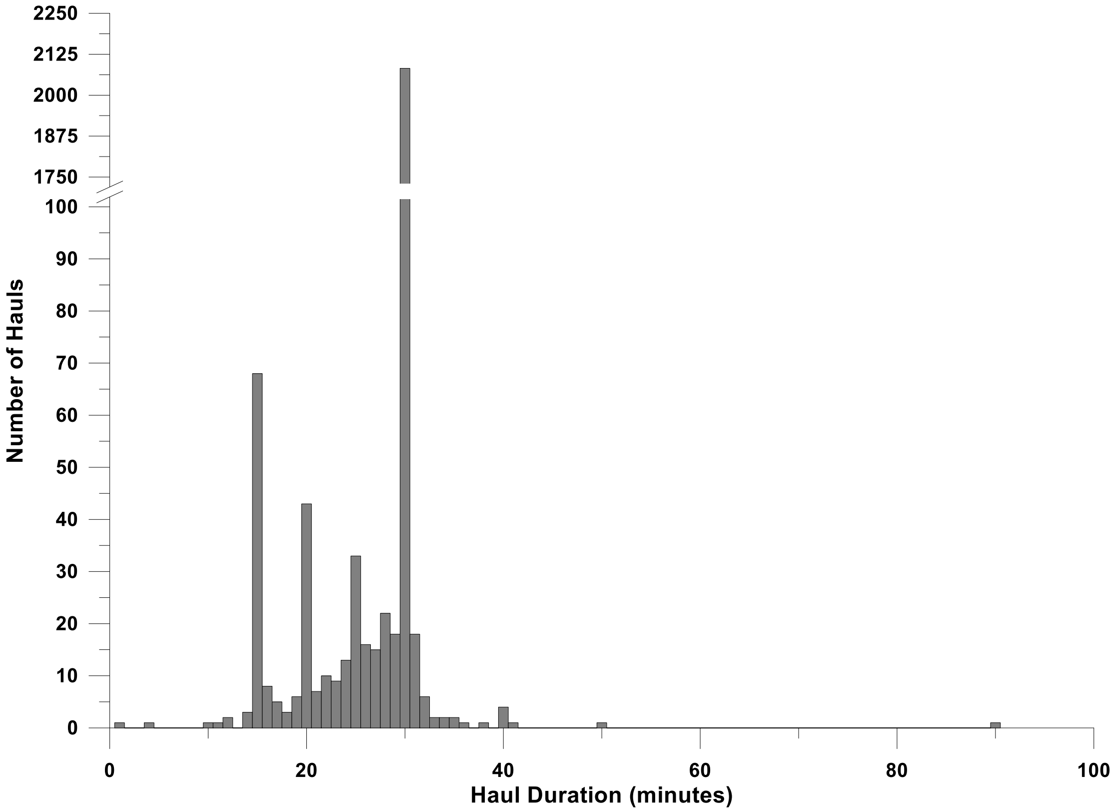

Figure 2.1.1.3.2.1: Frequency distribution for hauls durations for GOV otter trawl samples collected by the French research vessel.

During the late 1990s there was an appreciable increase in sampling effort. In the first two years of the survey time series, not only was the number of trawl samples especially low, but the proportion of these hauls that was of nominal 30 ± 4 minutes was particularly low; much lower than in any other year of the survey (Figure 2.1.1.3.2.2). This raises the question as to whether the first two years of the survey time series should be excluded from a monitoring programme intended to support assessment of the state of the fish community using biodiversity indicators?

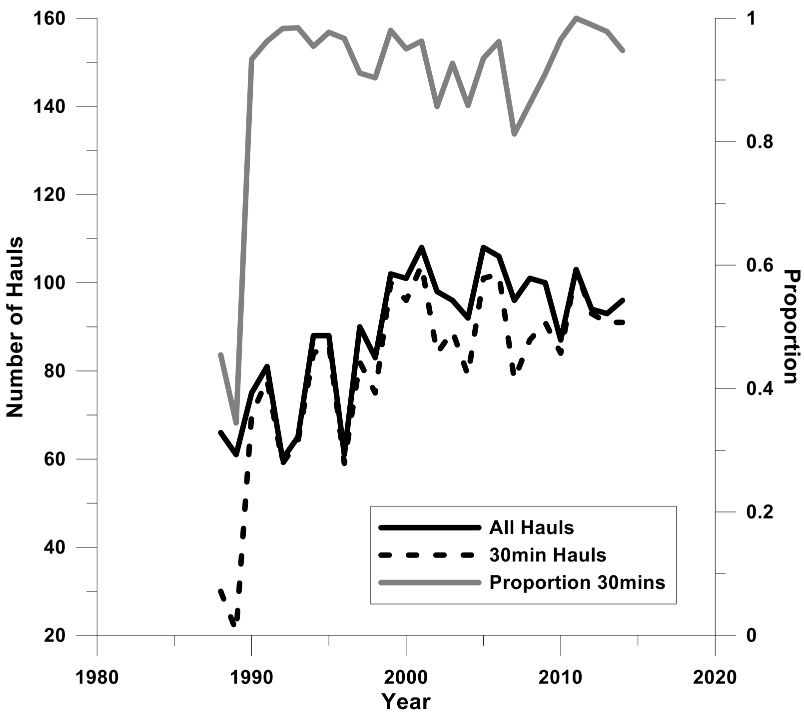

Figure 2.1.1.3.2.2: Trends in the number of all GOV trawl samples collected by the French research vessel in each year, and the number of these hauls that were a nominal 30 ± 4 minutes duration. The proportion of all hauls in each year that was of nominal 30 minutes duration is also shown.

Over the full course of the survey time series, 16 ICES statistical rectangles were sampled. The number of rectangles sampled in any one year ranged from 12 to 16; indeed all sixteen rectangles ever sampled were sampled in nine out of the 27 years that the survey operated. All 16 ICES statistical rectangles were sampled in at least 50% (≥14 years) of the survey time series so that the standard survey area for the survey consisted of the full suite of ICES statistical rectangles ever sampled (Figure 2.1.1.3.2.3). Figure 2.1.1.3.2.4 charts the locations of the 16 rectangles making up the standard survey area for the French Quarter 4 GOV groundfish survey. Two of these rectangles are actually located in the extreme southwest of ICES Area IV, the North Sea. Excluding the first two years of the time series had no effect on the extent of the standard survey area, perhaps providing some argument for retaining these two years in the monitoring programme. In 1988 and 1989 the proportion of trawl samples that were 30 minutes duration was low because of a decision to fish for only 15 minutes on many occasions. In all other surveys, and including this one, hauls of 15 minutes duration have been considered adequate to be included as part of the survey standard monitoring programme. In respect of the GNSFraOT4 survey, the lower fraction of 30 minutes duration hauls in 1988 and 1989, because so many 15 minutes duration samples were collected, does not, therefore, constitute sufficient reason to exclude these years from the standard survey programme.

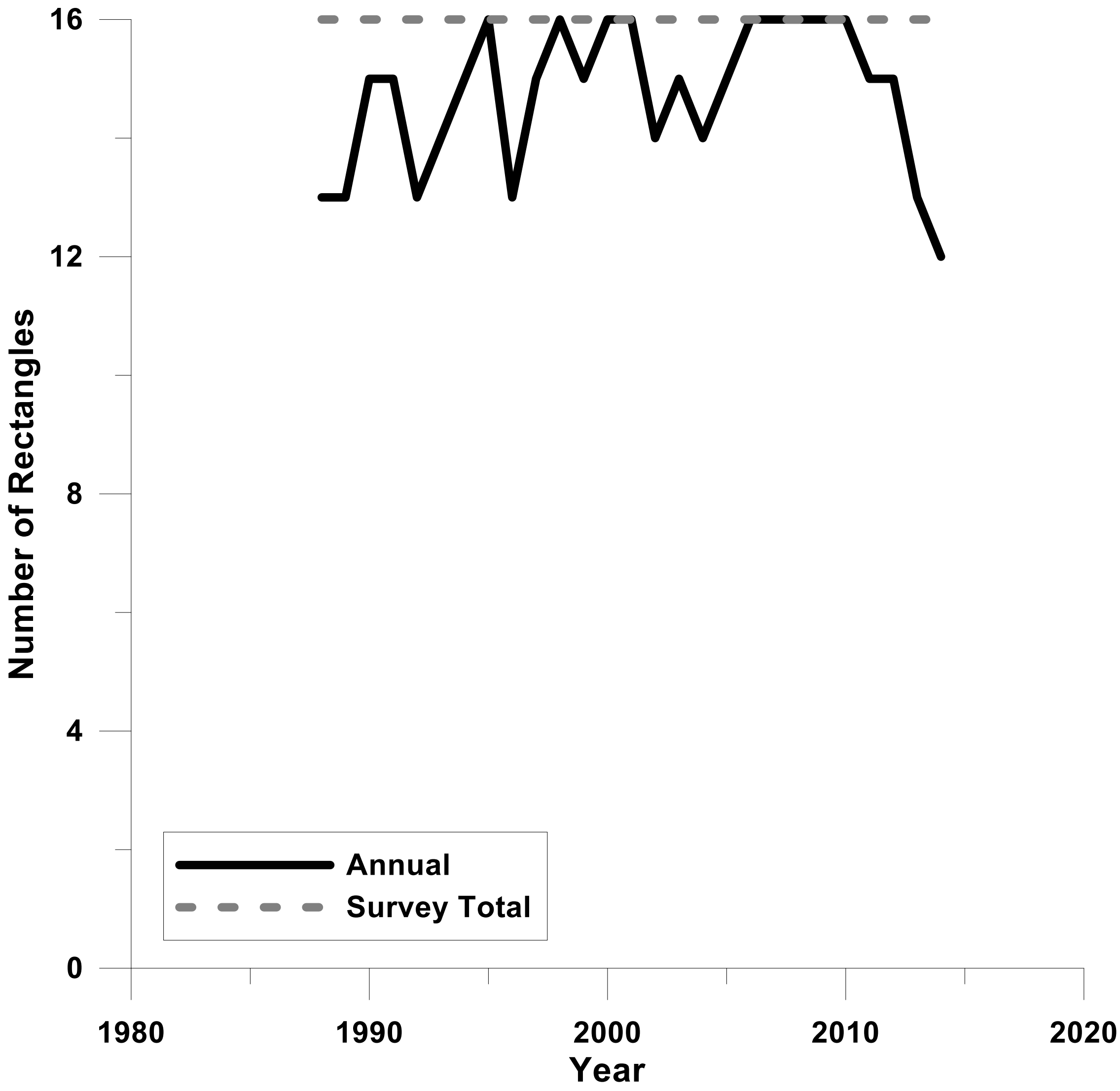

Figure 2.1.1.3.2.3: Trends in the number of ICES statistical rectangles sampled by France in each year. The number of rectangles ever sampled is also shown.

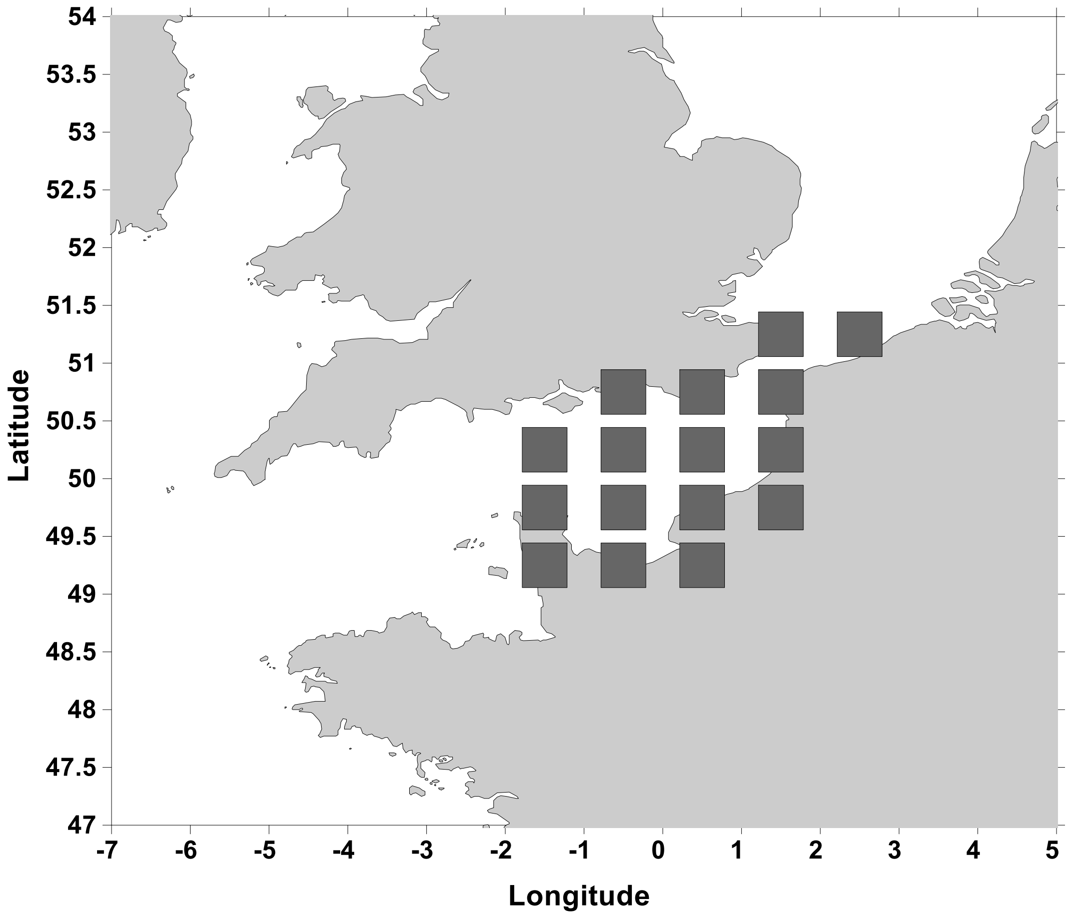

Figure 2.1.1.3.2.4: The standard survey area covered by the French GOV Trawl Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

2.1.2. The Celtic Seas

Here otter trawl surveys carried out in the Celtic Seas subregion are considered. The Celtic Seas subregion includes the continental shelf waters to the northwest, west and southwest of the UK and Ireland including the Irish Sea and St George's Channel.

2.1.2.1. The First Quarter Scottish West Coast IBTS (CSScoOT1)

2.1.2.1.1. Survey History

The first quarter Scottish West Coast Survey started in 1985 to provide similar information for western Scottish waters as the information gained from the Q1 IBTS carried out in waters to the east of Scotland: the North Sea. The only gear used throughout the duration of this survey has been the GOV trawl, but from the start of the time series, the standard sample was 60 minutes duration. To begin with the survey was carried out using the RV *Scotia II*, but this was replaced in 1998, so from 1999 onwards, the survey used the RV *Scotia III*. At the same time the decision was taken to reduce the standard trawl duration from 60 minutes to 30 minutes. For most of the time series, the survey used an ICES rectangle-based, even sampling design, similar to that used in the North Sea Q1 IBTS, attempting to obtain at least one trawl sample from each ICES statistical rectangle covered in each survey. Trawl stations were selected using a library of clear tow locations and frequently the same position was sampled in many years. The potential for introducing a degree of stratification was considered in 1999. This led to rectangles which displayed substantial internal depth variation being sampled twice at different depths. In 2011, the survey design was altered to a stratified random design. Parameters for the new stratification included depth, and abundance of key commercial species (e.g. cod, haddock).

2.1.2.1.2. Defining the Standard Monitoring Programme

The Scottish west coast GOV trawl survey data base held data for 3442 trawl samples, but this included data for two separate survey time series undertaken in the first and the fourth quarters of the year. The actual database includes data where the Quarter field holds a value of two. Figure 2.1.2.1.2.1 shows the frequency distribution of hauls by date and this confirms that some samples were collected in April. This occurred in 1995 when the survey commenced on 22 March and finished on 6 April. Even on this survey, the majority of the samples collected were still taken in the first quarter of the year, so following the precedent set for the North Sea IBTS, these Quarter 2 records were changed to Quarter 1 so that the field Quarter now relates to the name of the survey rather than the strict time of year when the data were actually collected. This precise date information is still retained in the Year, Month, and Day fields if required. Figure 2.1.2.1.2.1 also reveals that some Quarter 1 survey occurred earlier in the year in January. This occurred in 1985 when the Scottish first quarter West Coast Survey was carried out between 5 January and 21 January.

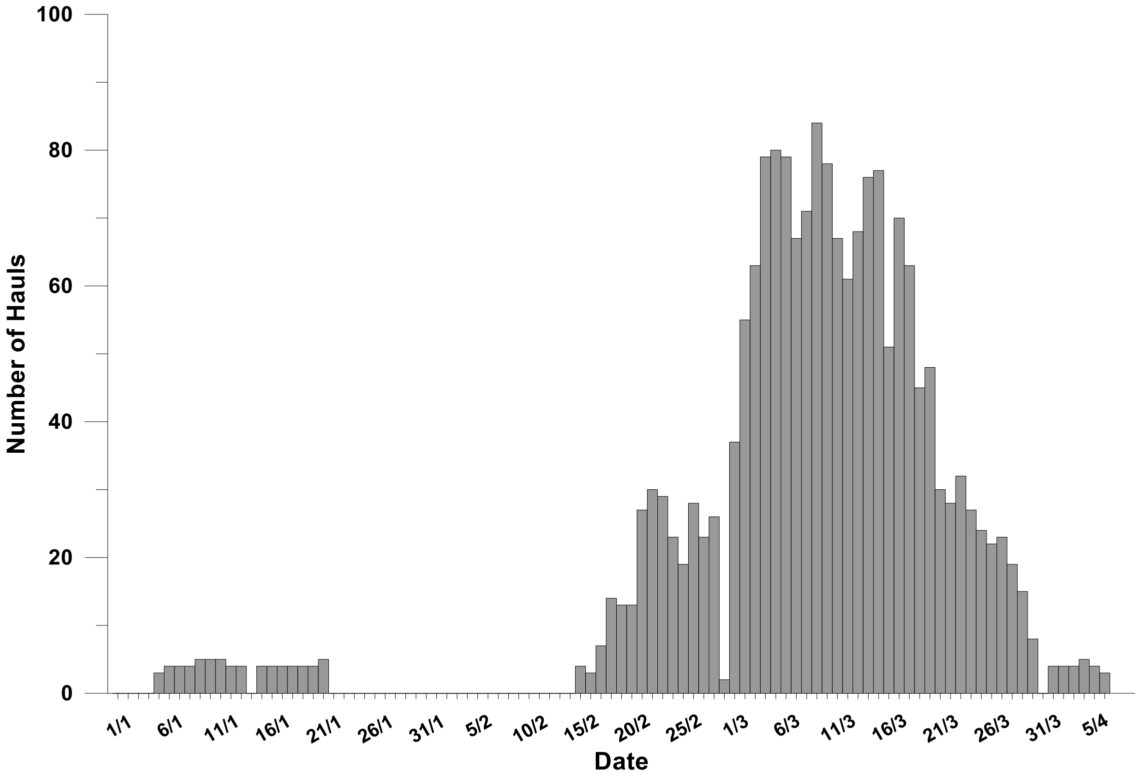

Figure 2.1.2.1.2.1: Frequency distribution of hauls over all years of the Scottish first quarter West Coast Survey by date (day/month).

- The Scottish first quarter West Coast Survey accounted for 1899 records. Of these 148 had invalid haul code entries I in the "HaulVal" field. Excluding these records reduced the data base to 1751 valid records.

The Scottish first quarter West Coast Survey runs from 1985 to 2015, spanning a total of 31 years. Between 1985 and 1998, the research vessel used was the RV "*Scotia II*", which was replaced by the RV "*Scotia III*" from 1999 onwards. The sampling gear deployed has always been the GOV, but four different sweep lengths have been used (47, 60, 97, and 110). Prior to and including 2010, a short sweep was always used, but then from 2011 onwards, to standardise the two Scottish West Coast Surveys with the equivalent Irish surveys, two different sweeps were used; a short sweep for depths shallower than 80 m and a long sweep for depths greater than 80 m. The short sweep consisted of the sweep of 47 m and a back-strop of 13 m, giving a total length of 60 m, while the long sweep consisted of a 97 m sweep and the 13 m back-strop, summing to a length of 110 m. From 2011 to 2013, the sweep lengths recorded in database were the summed length for both the sweep and the back-strop, thus 60 m and 110 m, but from 2014 onwards only the sweep lengths, 47 m and 97 m, were recorded. Thus sweep lengths of 60 m and 47 m, and of 110 m and 97 m, mean exactly the same configuration, so arguably, for consistency sake, all 60 m entries should be changed to 47 m and all 110 m entries changed to 97 m. Up to 2010, a null value of -9 was only ever recorded for the ground gear field GearExp. Over this period the only ground gear ever used was gear C. From 2011 onwards, again to match the Irish survey, the Scottish first quarter West Coast Survey switched to using a modified D ground gear, but because the code D was already used in the DATRAS system for a slightly different gear, this was assigned a code of I2. In many instances a null value of -9 was recorded in the SweepLngt and GearExp fields. In almost all cases, these null value entries coincided with invalid hauls codes I in the HaulVal field. In one instance, howeve,r (Haul No 34 on 3/8/1991) a valid haul code was assigned in a record where null values of -9 were recorded for both GearExp and SweepLngt.

A range of haul durations was evident in the Scottish first quarter West Coast Survey database with clear modes apparent at 30 minutes and 60 minutes, but also at 15 minutes, 20 minutes, and with some evidence also of modes at 10 minutes, 25 minutes and at every 5 minutes from 30 minutes to 60 minutes (Figure 2.1.2.1.2.2). Again, therefore, it was not considered reasonable to define a specific standard haul duration and, following previous precedent, all hauls between 13 minutes and 66 minutes duration were deemed valid.

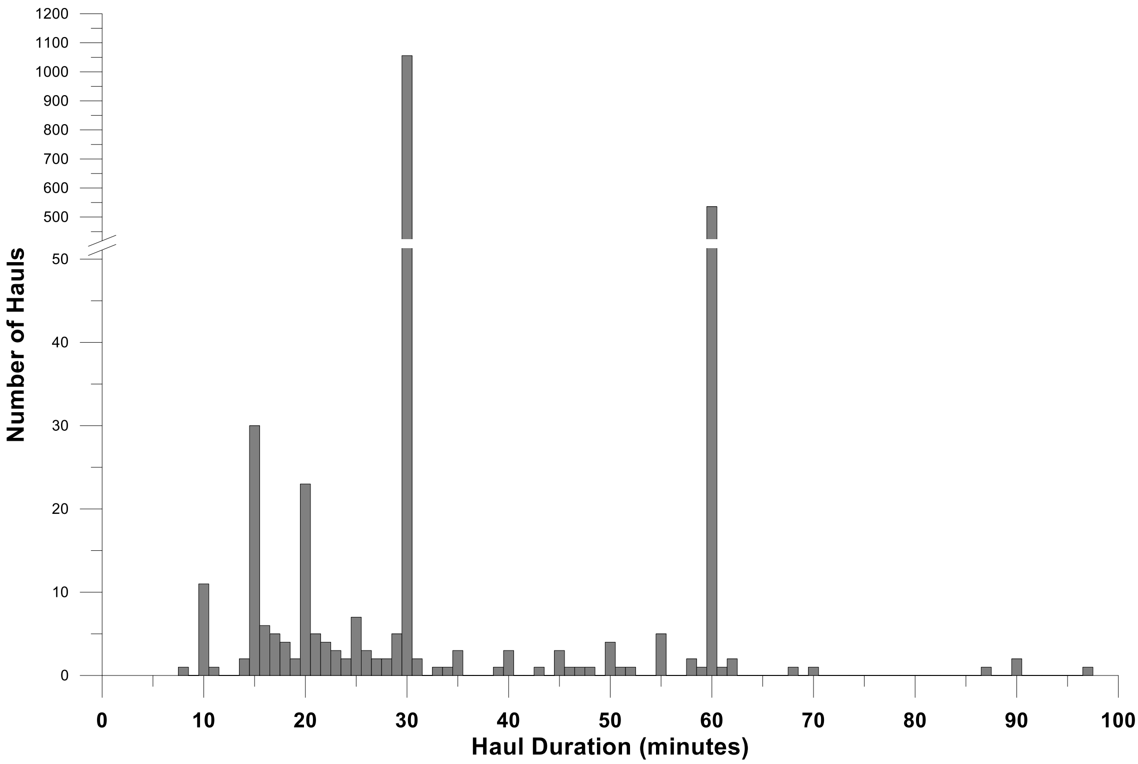

Figure 2.1.2.1.2.2: Frequency distribution for hauls durations for GOV otter trawl samples collected by the Scottish first quarter West Coast Survey.

Figure Figure 2.1.2.1.2.3 shows the trends in sampling effort in the Scottish first quarter West Coast Survey; several points are evident. Firstly, towards the late 1990s there was an increase in the overall number of trawl samples collected, Secondly there was a switch in the primary duration of the trawl samples. At the start of the time series the majority of hauls were 60 minutes duration and few, if any 30 minutes duration hauls were taken, but then through the late 1990s this situation reversed. By 1999 no 60 minutes duration hauls were being made, and the proportion of trawl samples being collected that were 30 minutes duration had increased to near 100%. This change coincided with the switch from RV *Scotia II* to RV *Scotia III* and the decision at this time to align to the Scottish sampling methodology more closely with that of other surveys operating in the region. Figure 2.1.2.1.2.4 shows the trend in the number of active survey days in each year of the Scottish first quarter West Coast Survey, and this infers that the apparent increase in sampling effort in the late 1990s, suggested in Figure 2.1.2.1.2.3, could not really be explained by an increase in the length of the survey and more likely reflected the fact that the new research vessel could operate in more difficult weather and sea conditions.

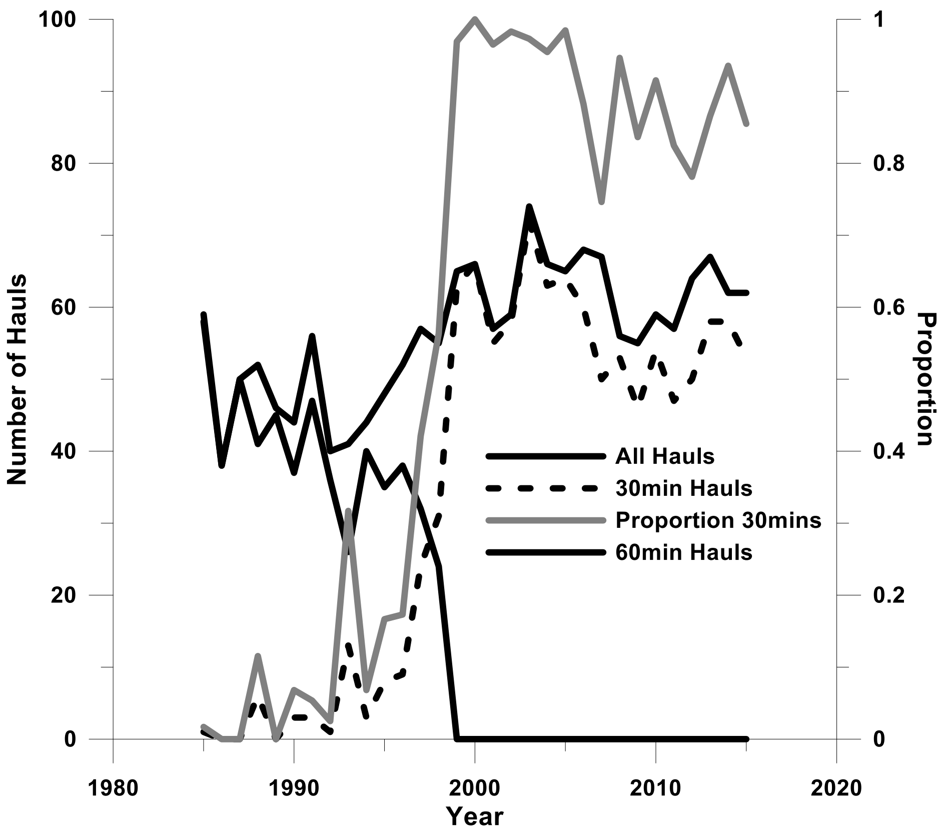

Figure 2.1.2.1.2.3: Trends in the number of all GOV trawl samples collected during the Scottish first quarter West Coast Survey in each year, and the number of these hauls that were a nominal 30 ± 4 minutes duration or a nominal 60 ± 5 minutes duration. The proportion of all hauls in each year that was of nominal 30 minutes duration is also shown.

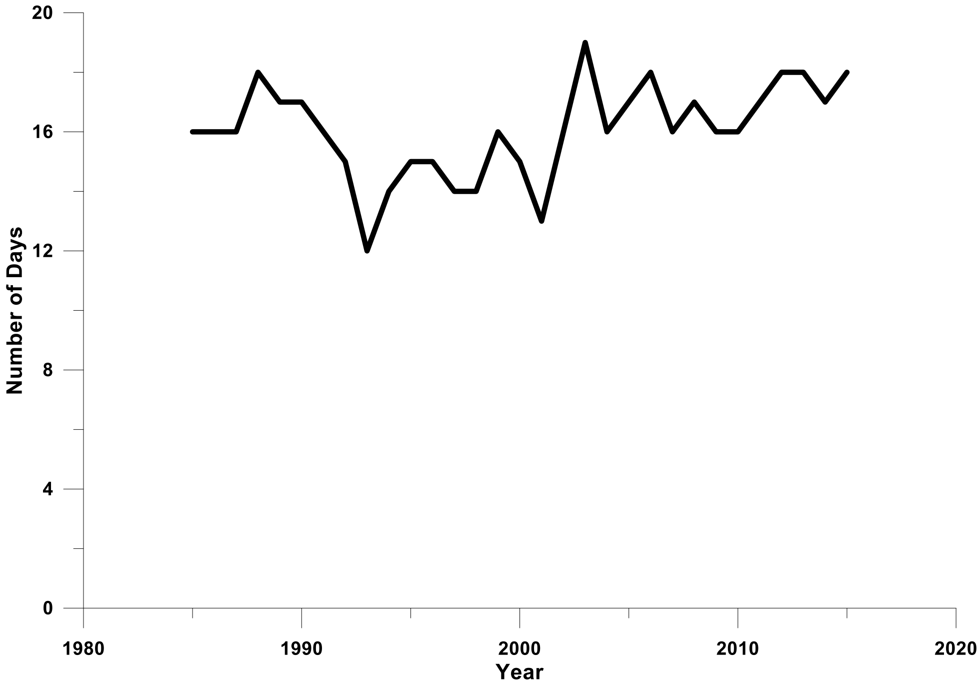

Figure 2.1.2.1.2.4: Variation in the number of days trawl sampling in each year over the course of the Scottish first quarter West Coast Survey.

The number of ICES statistical rectangles sampled each year also increased sharply in the late 1990s before dropping back again from around 2008 onwards (Figure 2.1.2.1.2.5a). Over the course of the whole survey, a total of 69 rectangles were sampled, but the standard survey area, those rectangles sampled in 50% of the years the survey was undertaken (≥ 16 years in the 31 years time series), was limited to just 39 ICES statistical rectangles (Figure 2.1.2.1.2.6). Even within this standard survey area, clear temporal trends were evident with the fraction of the area sampled increasing in a series of steps separating the periods 1985 to 1992, 1993 to 2001, 2002 to 2010, and 2011 onwards (Figure 2.1.2.1.2.5b). Closer examination of the Scottish first quarter West Coast Survey data suggested distinct changes in the area sampled (Figure 2.1.2.1.2.7). Between 1985 and 1995 sampling was restricted to Scottish waters north of Ireland. Between 1996 and 2007, sampling extended south into the northern half of the Irish Sea and to the northwest of Ireland. Between 2008 and 2010, sampling became more restricted once more and limited primarily to the region north of Ireland again. Then from 2011, sampling again extended into the area to the northwest of Ireland, but the sampling design was changed to a stratified random design, rather than using the ICES statistical rectangles as the sampling unit. This meant that over this period, although the sampling appeared more widespread, the random nature of the design meant that in any one year, some rectangles within the standard survey area might well have been sampled several times, while others might not have been sampled at all.

The CSScoOT1 survey has varied markedly throughout, and there is no sound basis for deciding a specific standard monitoring programme. Consequently the whole time series, from 1998 onwards, was included and only samples collected from ICES statistical rectangles deemed to lie outside the standard survey area, defined on this basis, were excluded from the groundfish survey monitoring and assessment data product.

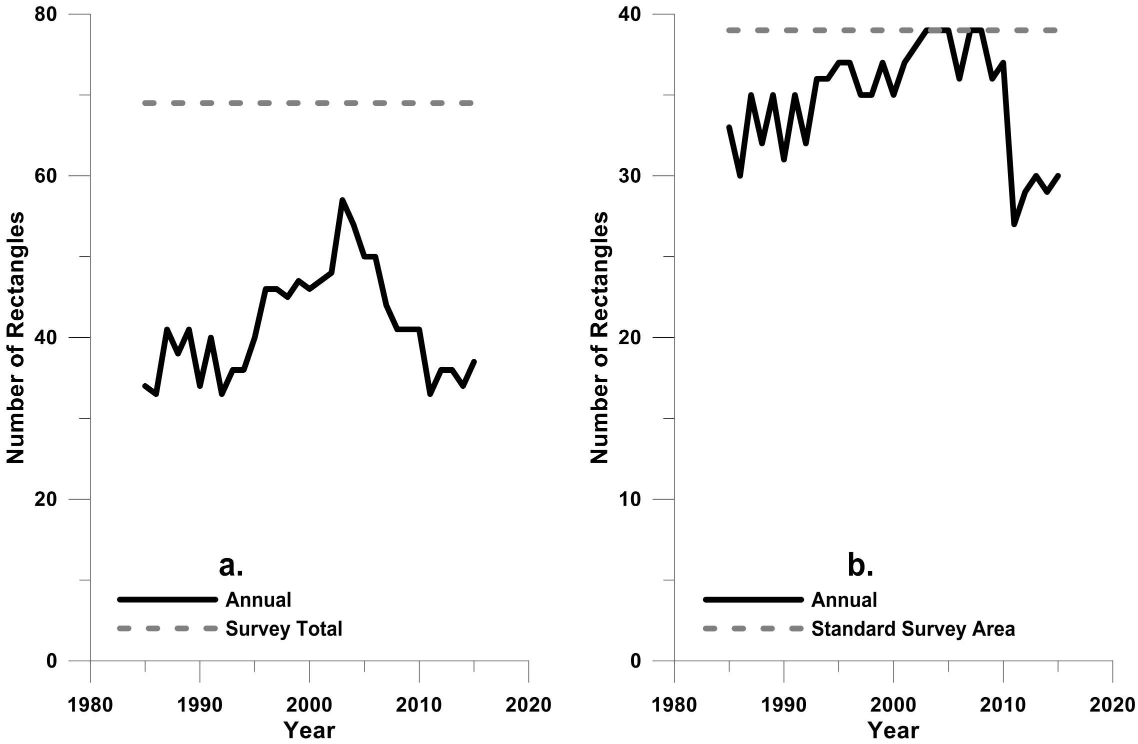

Figure 2.1.2.1.2.5: Trends in the number of ICES statistical rectangles sampled in each year of the Scottish first quarter West Coast Survey (a) in all rectangles sampled and (b) in a standard survey area consisting only of the 39 rectangles sampled in ≥50% of years of the survey time span.

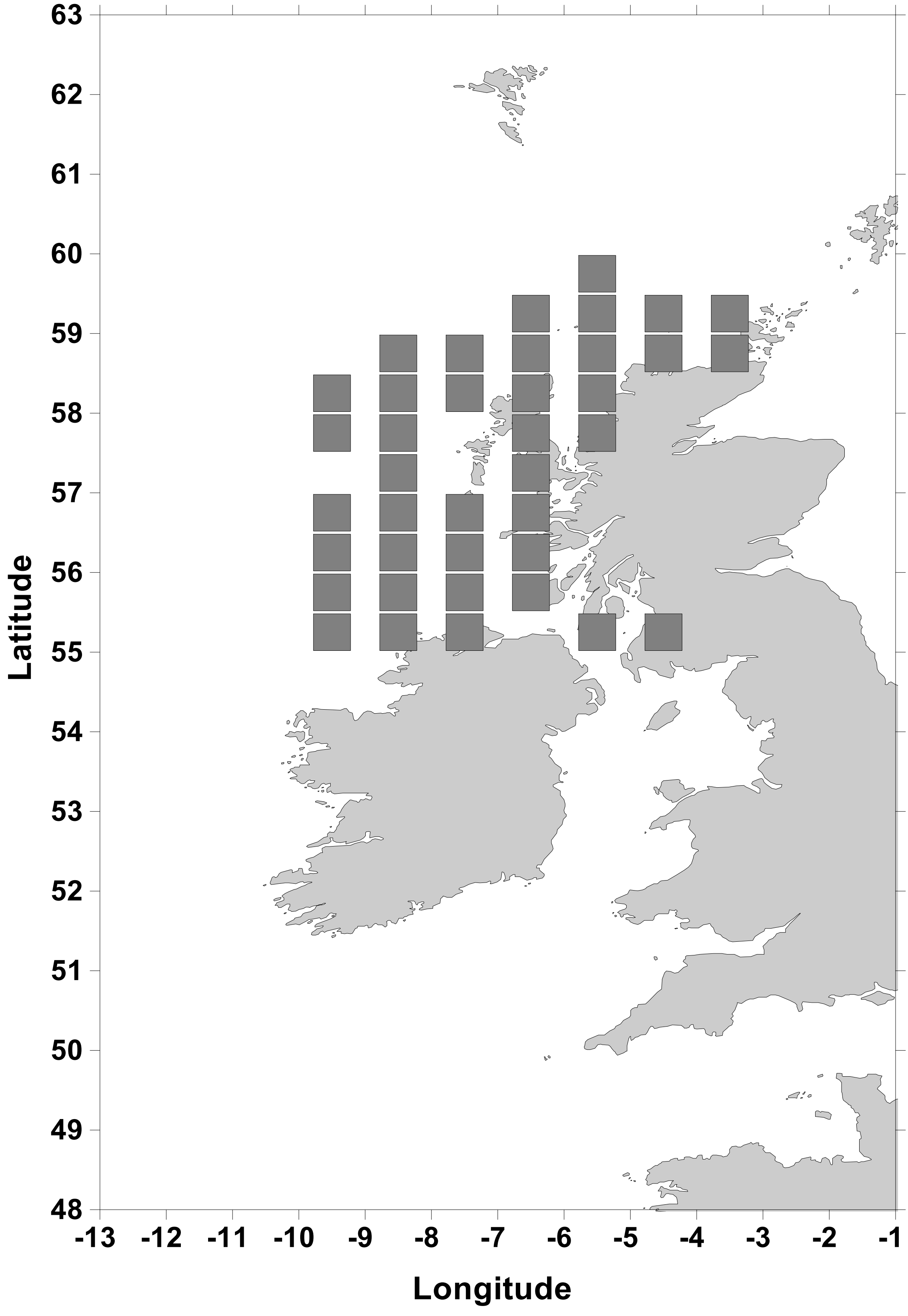

Figure 2.1.2.1.2.6: Chart showing the standard survey area covered by the Scottish first quarter West Coast Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

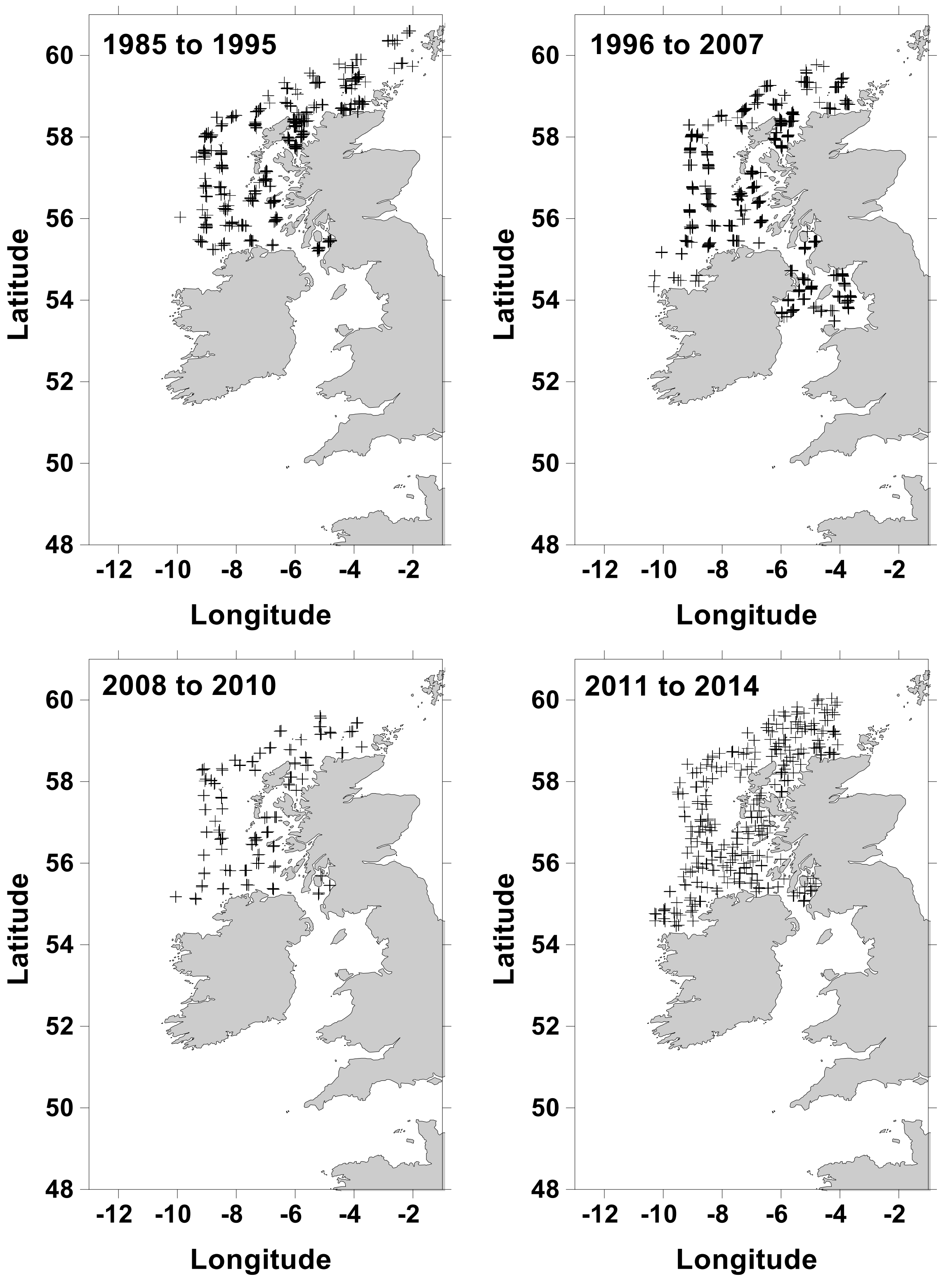

Figure 2.1.2.1.2.7: Charts showing variation in the spatial distributions of trawl samples collected during four periods of the Scottish first quarter West Coast Survey.

2.1.2.2. The Fourth Quarter Scottish West Coast IBTS (CSScoOT4)

2.1.2.2.1. Survey History

The fourth quarter Scottish West Coast Survey started in 1985 as a mackerel recruit survey to provide key recruit abundance information to support the mackerel stock assessments; mackerel being one of the most important stocks economically to the Scottish fishing industry. To begin with the survey was carried out using the RV *Scotia II*, but this was replaced in 1998, so from 1998 onwards, the survey used the RV *Scotia III*. At the same time the decision was taken to reduce the standard trawl duration from 60 minutes to 30 minutes. However, the GOV has been the only fishing gear used throughout the duration of the survey. For most of the time series, the survey used an ICES rectangle-based, even sampling design, similar to that used in the North Sea Q1 IBTS, attempting to obtain at least one trawl sample from each ICES statistical rectangle covered in each survey. Trawl stations were selected using a library of clear tow locations and frequently the same position was sampled in many years. The potential for introducing a degree of stratification was considered in 1999. This led to rectangles which displayed substantial internal depth variation being sampled twice at different depths. In 2011, the survey design was altered to a stratified random design. Parameters for the new stratification included depth, and abundance of key commercial species (e.g. cod, haddock).

2.1.2.2.2. Defining the Standard Monitoring Programme

- The Scottish fourth quarter West Coast Survey accounted for 1543 records. Of these, 73 had invalid haul code entries I in the “HaulVal” field. Excluding these records reduced the data base to 1470 valid records.

The Scottish fourth quarter West Coast Survey runs from 1990 to 2014, but no data are recorded for 2010. Thus from a time span of 25 years, only 24 years of data are available. Many of the characteristics of the Scottish first quarter West Coast Survey are also common to the fourth quarter West Coast Survey. Between 1990 and 1997, the research vessel used was the RV “*Scotia II*”, which was replaced by the RV “*Scotia III*” from 1998 onwards. The sampling gear deployed has always been the GOV, but again four different sweep lengths have been used (47, 60, 97, and 110). Up to 2009, a short sweep was always used, but then in 2011 a long sweep was used. From 2012 onwards, again to standardise the Scottish West Coast Surveys with the equivalent Irish surveys, two different sweeps were used; a short sweep for depths shallower than 80 m and a long sweep for depths greater than 80 m. Once more the short sweep consisted of the sweep of 47 m and a back-strop of 13 m, giving a total length of 60 m, while the long sweep consisted of a 97 m sweep and the 13 m back-strop, summing to a length of 110 m. In 2012 the sweep lengths recorded in database were the summed length for both the sweep and the back-strop, thus 60 m and 110 m, but from 2013 onwards only the sweep lengths, 47 m and 97 m, were recorded. So again, the sweep lengths of 60 m and 47 m, and of 110 m and 97 m, mean exactly the same configuration, so arguably, for consistency sake, all 60 m entries should be changed to 47 m and all 110 m entries changed to 97 m. In 1997 (HaulNo 67) and 1999 (HaulNos 1 and 60) some null values (-9) were recorded in the SweepLngt field. The two 1999 records also held null values in many of the other fields and it is questionable whether these hauls were indeed really valid. Invalid hauls generally held null values in the SweepLngt field, but in 2005 one invalid haul held a 60 SweepLngt values and in 2013 and 2014, invalid hauls held 97 SweepLngt values.

Up to 2009, a null value of -9 was usually recorded for the ground gear field GearExp, but in 2004, six records (Haul numbers 43 to 47 and 49) had a code of S entered (Haul number 49 had a null value of -9 entered). Over this period the normal ground gear used was gear C. From 2011 onwards, again to match the Irish survey, the Scottish fourth quarter West Coast Survey switched to using a modified D ground gear, but as stated for the Scottish first quarter West Coast Survey, because the code D was already used in the DATRAS system for a slightly different gear, this was assigned a code of I2.

The survey primarily operated through November to early December (Figure 2.1.2.2.2.1). A range of haul durations was again evident in the Scottish fourth quarter West Coast Survey database with clear modes apparent at 30 minutes and 60 minutes, but also at 15 minutes and 20 minutes (Figure 2.1.2.2.2.2). Once more it was not considered reasonable to define a specific standard haul duration and, following previous precedent, all hauls between 13 minutes and 66 minutes duration were deemed valid.

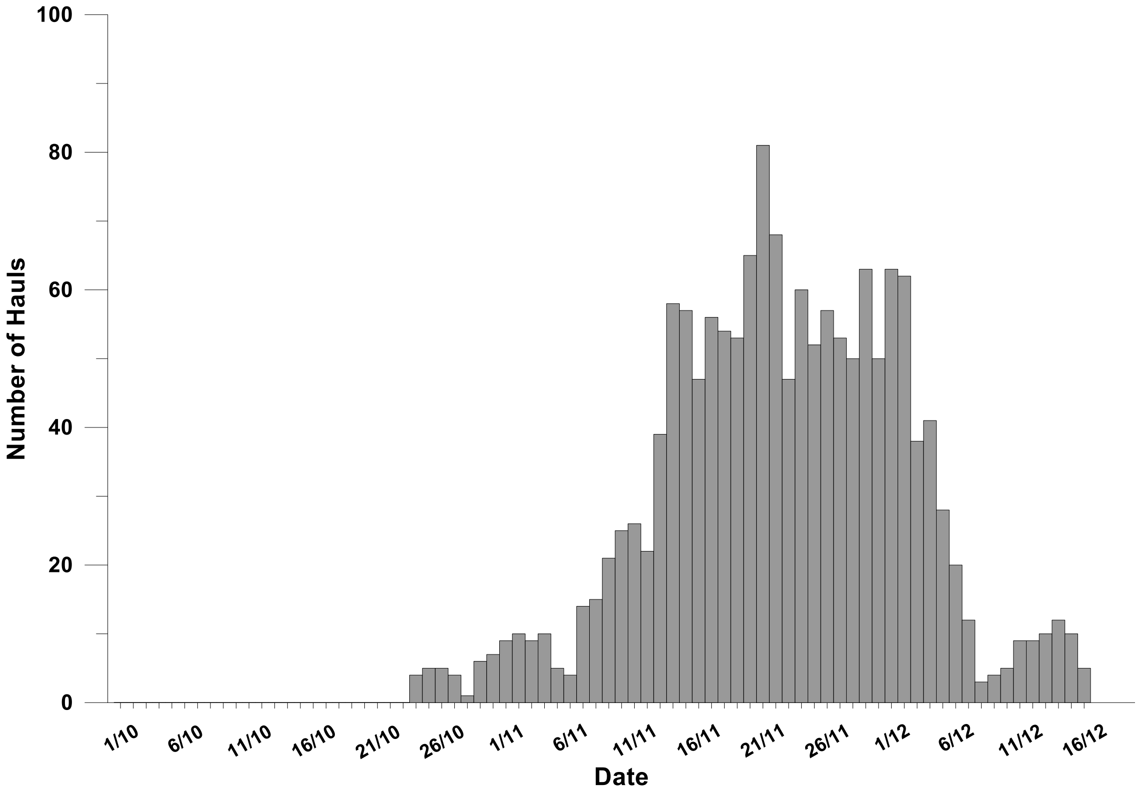

Figure 2.1.2.2.2.1: Frequency distribution of hauls over all years of the Scottish fourth quarter West Coast Survey by date (day/month).

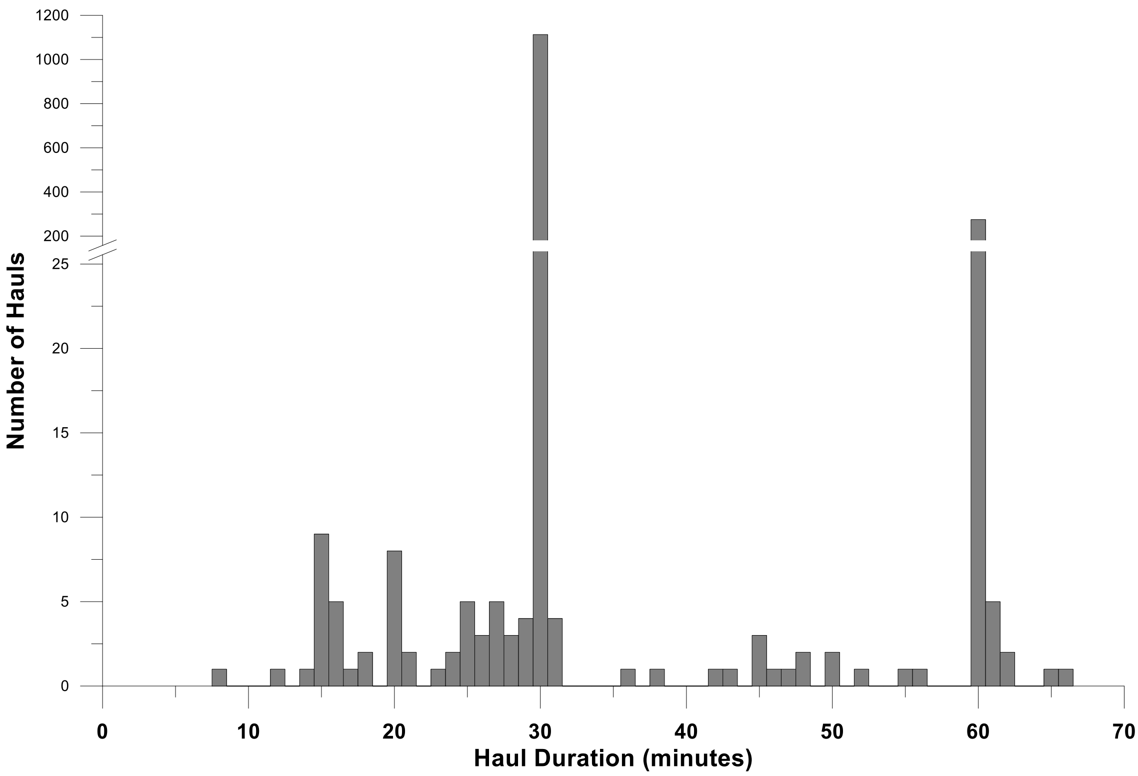

Figure 2.1.2.2.2.2: Frequency distribution for hauls durations for GOV otter trawl samples collected by the Scottish fourth quarter West Coast Survey.

Figure 2.1.2.2.2.3 shows the trends in sampling effort in the Scottish fourth quarter West Coast Survey and several points similar to those described previously for the Scottish first quarter West Coast Survey are again evident. There was again an increase in the overall number of trawl samples collected each year from the start of the time series through to shortly after 2000, and again there was a switch in the primary duration of the trawl samples, from primarily 60 minutes duration early in the time series to mainly 30 minutes duration hauls by 1999 onwards. Again, these changes coincided with the switch from RV *Scotia II* to RV *Scotia III* and the decision at this time to align to the Scottish sampling methodology more closely with that of other surveys operating in the region. Figure 2.1.2.2.2.4 shows the trend in the number of active survey days in each year of the Scottish first quarter West Coast Survey, and this again infers that the apparent increase in annual sampling effort at the start of the time series could not entirely be explained by an increase in the length of the survey and more likely reflected the fact that the new research vessel could operate in more difficult weather and sea conditions. Finally, the marked reduction in 2013 in both the number of trawl samples collected, and the number of days of trawl sampling activity was associated with mechanical problems experienced on RV "Scotia III" in this year.

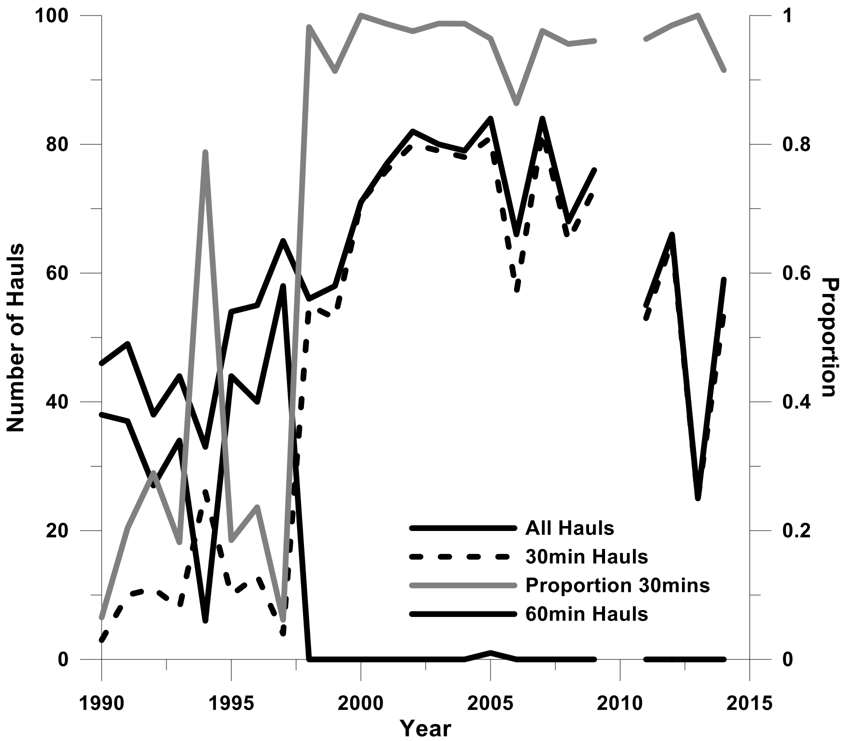

Figure 2.1.2.2.2.3: Trends in the number of all GOV trawl samples collected during the Scottish fourth quarter West Coast Survey in each year, and the number of these hauls that were a nominal 30 ± 4 minutes duration or a nominal 60 ± 5min duration. The proportion of all hauls in each year that was of nominal 30 minutes duration is also shown.

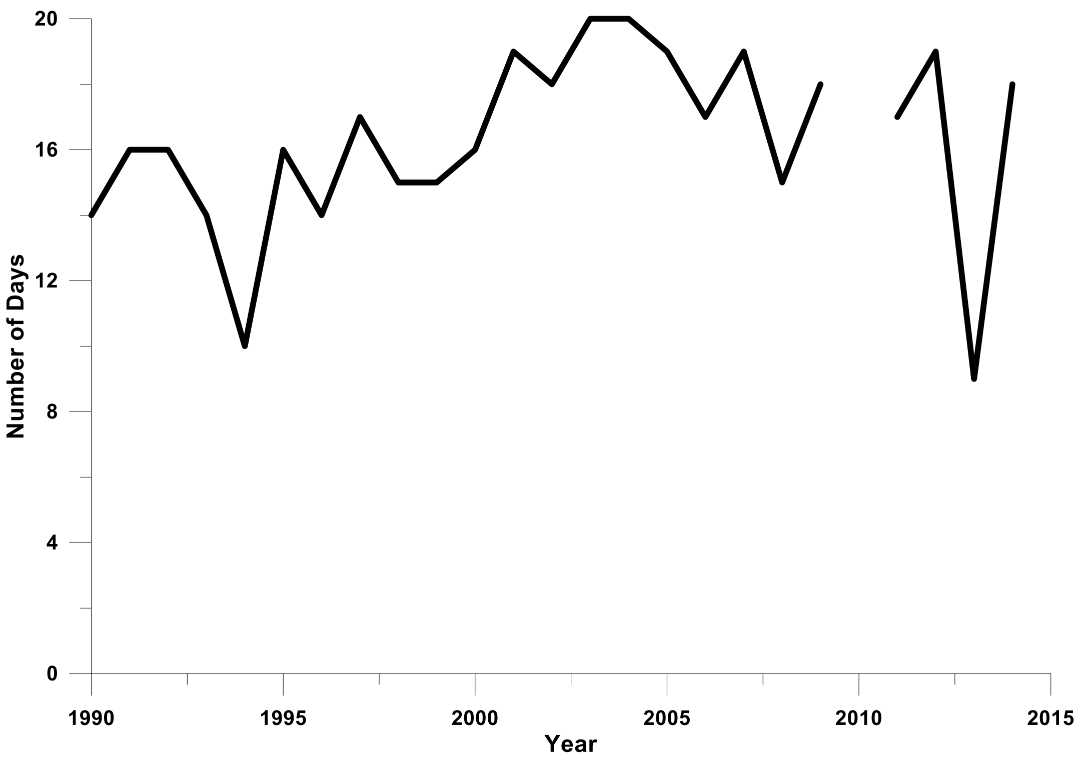

Figure 2.1.2.2.2.4: Variation in the number of days trawl sampling in each year over the course of the Scottish fourth quarter West Coast Survey.

The number of ICES statistical rectangles sampled each year increased considerably around the mid-1990s and a declining trend was evident from around 2005 onwards. Over the course of the whole survey, a total of 112 rectangles were sampled, considerably more than were ever sampled during the Scottish first quarter West Coast Survey (Figure 2.1.2.2.2.5a). However, the standard survey area, those rectangles sampled in 50% of the years the survey was undertaken (≥ 12y in the 24 years of data available), was limited to just 49 ICES statistical rectangles (Figure 2.1.2.2.2.6). Within this standard survey area, clear temporal trends were again evident, with a marked increase occurring between 1995 and 1997 in the fraction of the standard survey area sampled each year. Over the period 1990 to 1995, the number of rectangles within the standard survey area that was sampled each year averaged approximately 23, but between 1997 and 2009, this average increased to over 47 (Figure 2.1.2.2.2.5b). Following consultation with the data provider, and given the results of subsequent analysis (Greenstreet and Moriarty 2017), considering 1995 to be the start year for the CSScoOT4 survey provided the optimal compromise between long-term temporal coverage and standardised spatial coverage.

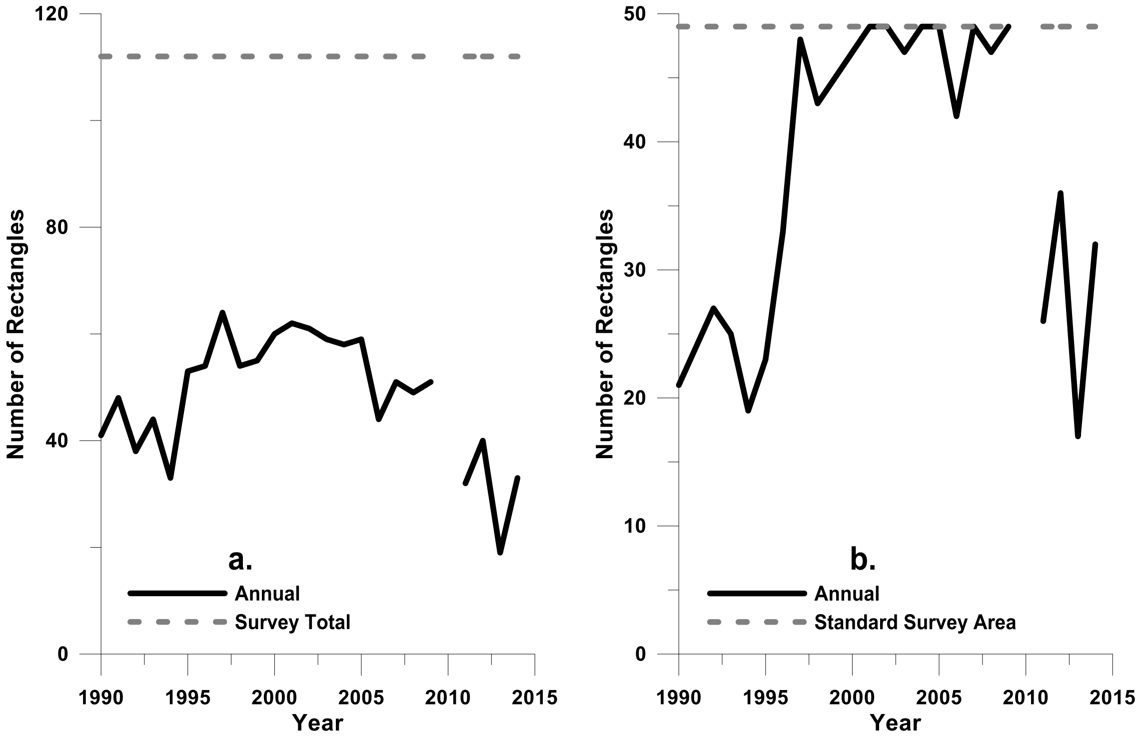

Figure 2.1.2.2.2.5: Trends in the number of ICES statistical rectangles sampled in each year of the Scottish fourth quarter West Coast Survey (a) in all rectangles sampled and (b) in a standard survey area consisting only of the 49 rectangles sampled in ≥50% of years of the survey time span.

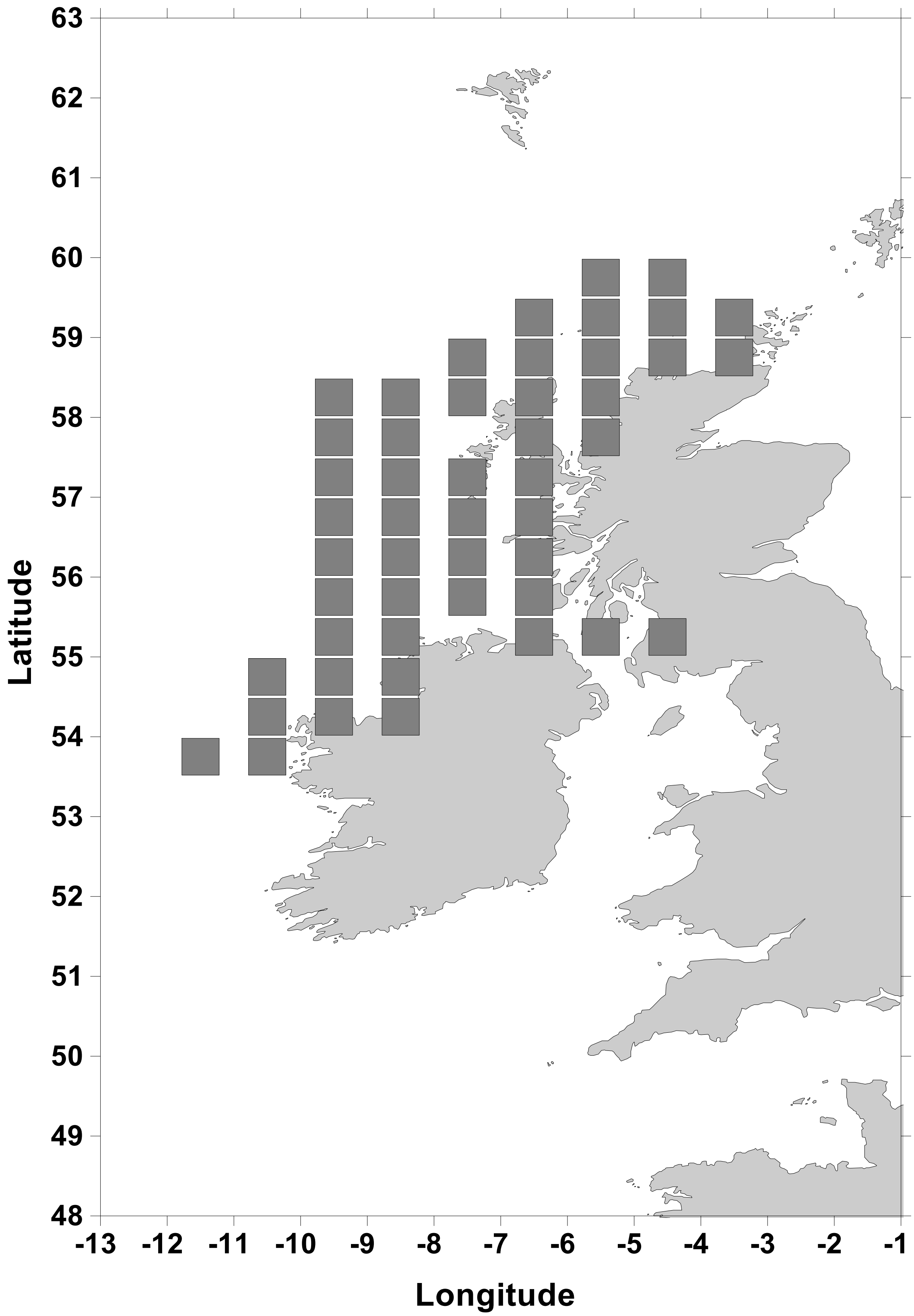

Figure 2.1.2.2.2.6: Chart showing the standard survey area covered by the Scottish fourth quarter West Coast Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

Closer examination of the Scottish fourth quarter West Coast Survey data confirmed that distinct changes in the actual area sampled by this survey had indeed taken place (Figure 2.1.2.2.2.7). Between 1990 and 1995, no sampling took place in the Minch, around the Inner Hebrides and into the Irish Sea. Instead the survey extended down the entire west coast of Ireland and well south into the Celtic Sea and even into areas around southwest England. In 1996, the transition year, survey in the seas close to mainland Scotland was still absent, but it no longer extended further south than southwest Ireland. From 1997 to 2009, the area covered did include the Northern Irish Sea, Inner Hebrides and the Minch, but it now only covered the northern half of the shelf seas west of Ireland. During this time the area covered by the survey much more closely resembles the standard survey area shown in Figure 2.1.2.2.2.6. Between 2011 and 2014, the number of rectangles sampled each year declined considerably and the fraction of the standard survey area covered each year also decreased (Figure 2.1.2.2.2.5). Locations of haul samples collected in this period suggest that the survey had ceased to extend into the northern Irish Sea, but otherwise the area covered by the survey had not changed much. However, the survey design was changed to a stratified random design, rather than using the ICES statistical rectangles as the sampling unit. Over this period, although the sampling appeared nearly as widespread, the random nature of the design meant that in any one year, some rectangles within the standard survey area could have been sampled several times, while others might not have been sampled at all.

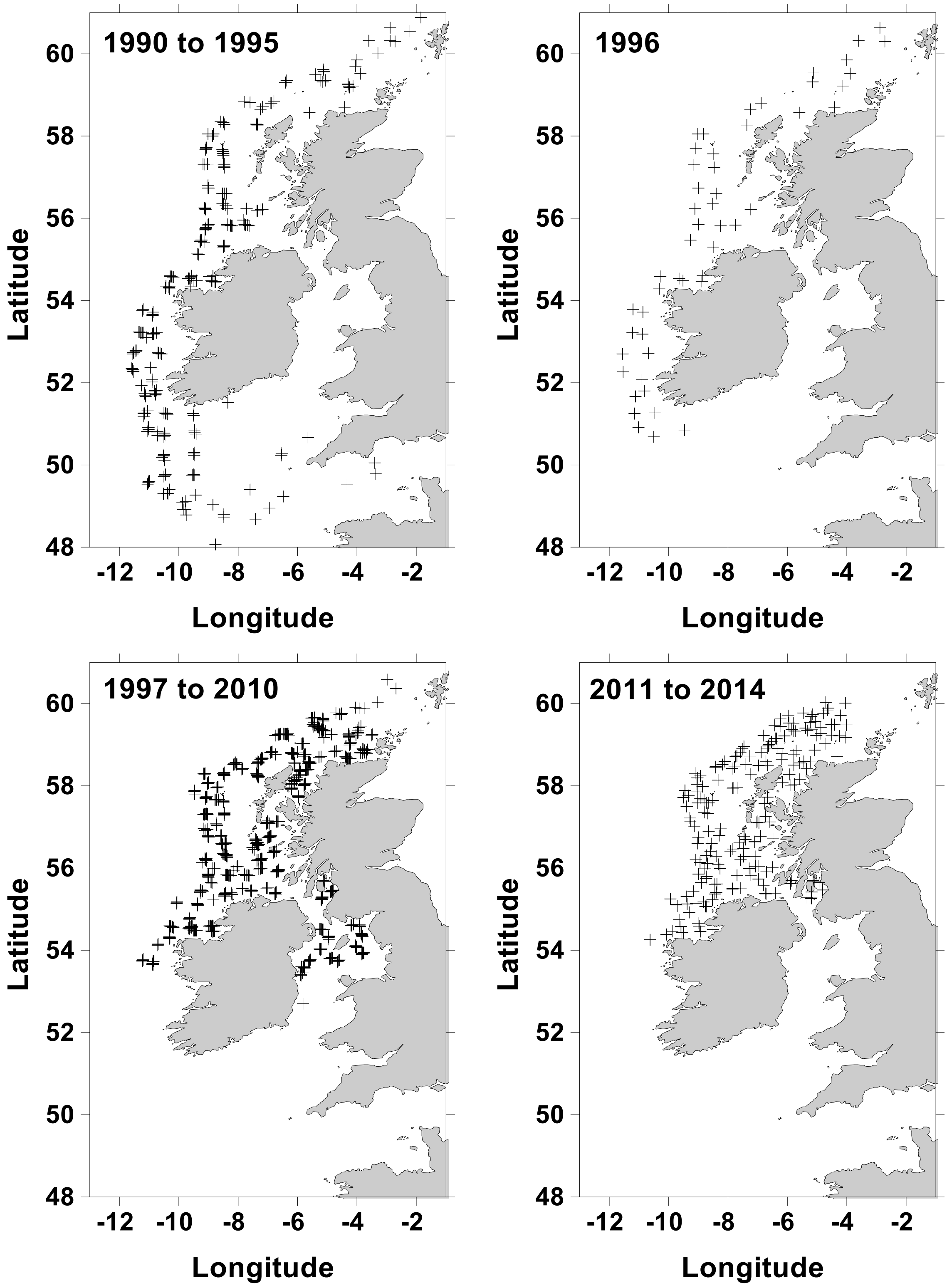

Figure 2.1.2.2.2.7: Charts showing variation in the spatial distributions of trawl samples collected during four periods of the Scottish fourth quarter West Coast Survey.

The marked changes in sampling effort and spatial coverage that occurred during the early years of the Scottish fourth quarter present a compelling argument for excluding the first six years of the time series from the monitoring and assessment data product and considering 1997 as the effective start date.

2.1.2.3. The Fourth Quarter Irish Groundfish Survey (CSIreOT4)

2.1.2.3.1. Survey History

Historically, Irish groundfish survey data were collected by the Marine Institute (MI) using two chartered commercial fishing vessels, which covered ICES areas VIa, VIIb & VIIj, and one research vessel, the RV *Celtic Voyager*, which covered ICES areas VIIa & VIIg. Given the limited facilities for scientific data collection aboard different commercial fishing vessels, and with the arrival of the new RV *Celtic Explorer* (65 m in length with a power of 4320 KW), it was decided that a new time-series would commence from 2003 onwards and this became known as the Irish Groundfish Survey (IGFS). The IGFS covers divisions VIa South, VIIb VIIc VIIg VIIj, and has some overlap with the Spanish Porcupine Survey in eastern VIIc. The survey is carried out in fourth quarter of the year and uses a semi-random depth-stratified sampling design. Depth boundaries are 0–80 m, 81–120 m, 121–200 m, 201–600 m; corresponding to Coastal, Medium, Deep and Slope respectively. In total, 170 stations are allocated annually with 75% of these being selected at random from the historical survey tow positions. A further 25% are selected at random from a 5 nm grid and clear ground is sought within 10 nm of the allocated point from historical data (ICES, 2010a).

IGFS uses the GOV 36/47 trawl gear, similar to the gear used in the North Sea and in western Scotish waters (see above), different groundgears have been used in different parts of the area covered by the survey since 2004. Groundgear “A” (200 mm disks in centre) was the gear used across most of the area, but low catches of target species, such as cod, prompted adjustment of the GOV toggle chains to a single link. However, given the lack of technical information to confirm that this modification would adequately address the perceived problem, and since the ‘new’ time series was only one year old, the Marine Institute and the Marine laboratory in Aberdeen developed a new groundgear, groundgear D (16” disks in centre) and this has been used in area VIa exclusively since 2004. As with groundgear A, operated outside VIa, the footrope is attached to the fishing-line by a single link. In all other aspects the trawls are rigged and operated as per the guidelines set out in the IBTS manual. In line with the IBTS recommendations, sweeps are lengthened to maintain trawl geometry in deeper water, from 55 m up to depths of 80 m to 110 m in deeper water (ICES, 2010a). Analysis in the Celtic Sea area by Ifremer using other ground type variables resulted in some modification of the French EVHOE survey design (Poulard and Mahé, 2004). It was agreed that similar minor modifications would be standardized also across the Irish Survey area and the 75 m contour was adjusted to 80 m and for simplicity this is now the depth at which sweeps are changed (ICES, 2010a).

With the commencement of Northern Irish survey in the Irish Sea in 2005, the WGIBTS agreed that some Irish survey effort should be reallocated from ICES area VIIa to the wider Atlantic area and northern Celtic Sea (ICES, 2004). A number of stocks of interest to assessment working groups such as monkfish (*Lophius piscatorius*), megrim (*Lepidorhombus whiffiagonis*) and hake (*Merluccius merluccius*) were known to be distributed beyond the then existing 200 m range of the survey. In order to more adequately survey these stocks and avoid interrupting the ongoing time-series, the effort transferred from VIIa was entirely allocated to a new strata beyond the shelf edge, extending the survey down the slope from 200 m to the 600 m contour (ICES, 2010a).

2.1.2.3.2. Defining the Standard Monitoring Programme

The Irish Quarter 4 Western Shelf survey database holds records for 2060 trawl samples. Of these only 1971 have a valid haul code V in the HaulVal field. Further analysis was restricted to only these valid hauls. The survey has been carried out by a single vessel, RV *Celtic Explorer*, using only the GOV trawl gear over the full 12 year period from 2003 to 2014. The fields Rigging, Tickler, WarpDen, and KiteDim held only null values -9. DoorType was always recorded as P, WarpDia as 26, DoorSurface as 5.2, DoorWgt as 1400 and Buoyancy as 247. Two different sweep lengths of 55 m and 110 m have been deployed over the course of the time series. In line with the two Scottish surveys, the shorter sweep was used in shallower water while the longer sweep was used in deeper water. The cross-over depth appears to have been approximately 83 m (Figure 2.1.2.3.2.1). Codes of 95 and 2000 were recorded in the WgtGroundRope field and the GearExp field also contained two different codes, indicating the use of ground-gears I2 and S. These two fields varied in line with each other; when the I2 ground-gear was used, the weight of the ground rope was 2000 and when the S ground-gear was used the ground rope weight was 95. Both ground-gears and ground rope weights were used throughout the time span of the survey, and their use appears most related to geography; use of the I2 ground-gear and heavier ground rope being restricted to the waters to the north of Ireland (Figure 2.1.2.3.2.2).

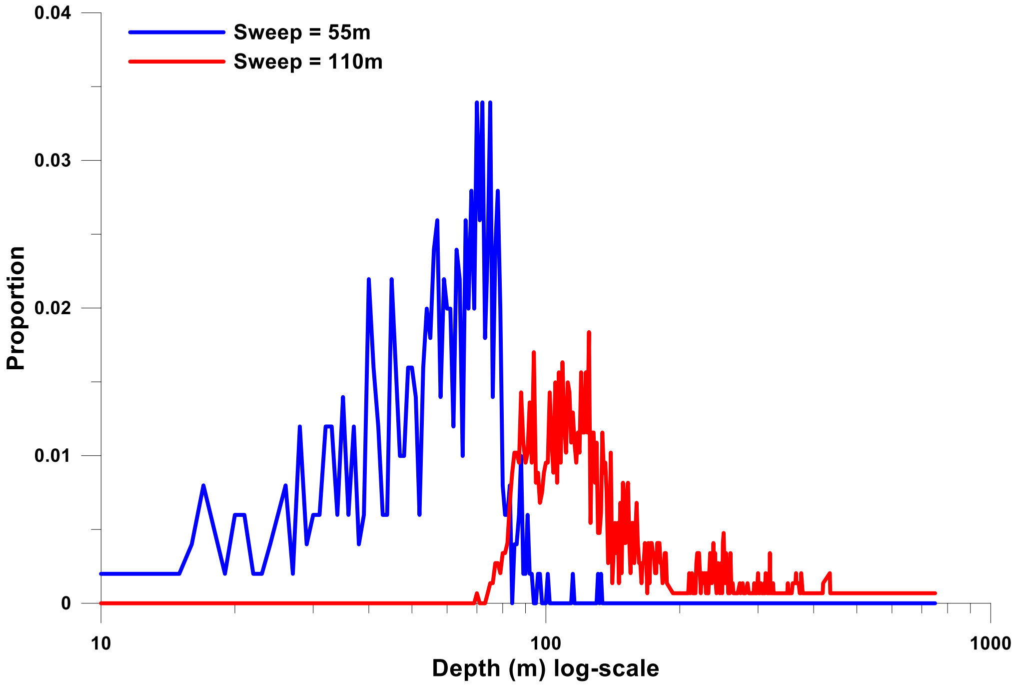

Figure 2.1.2.3.2.1: Depth distributions of samples collected using sweep lengths of 55 m and 110 m in the Irish Quarter 4 Celtic Sea Survey. Switch-over depth occurred at approximately 83 m.

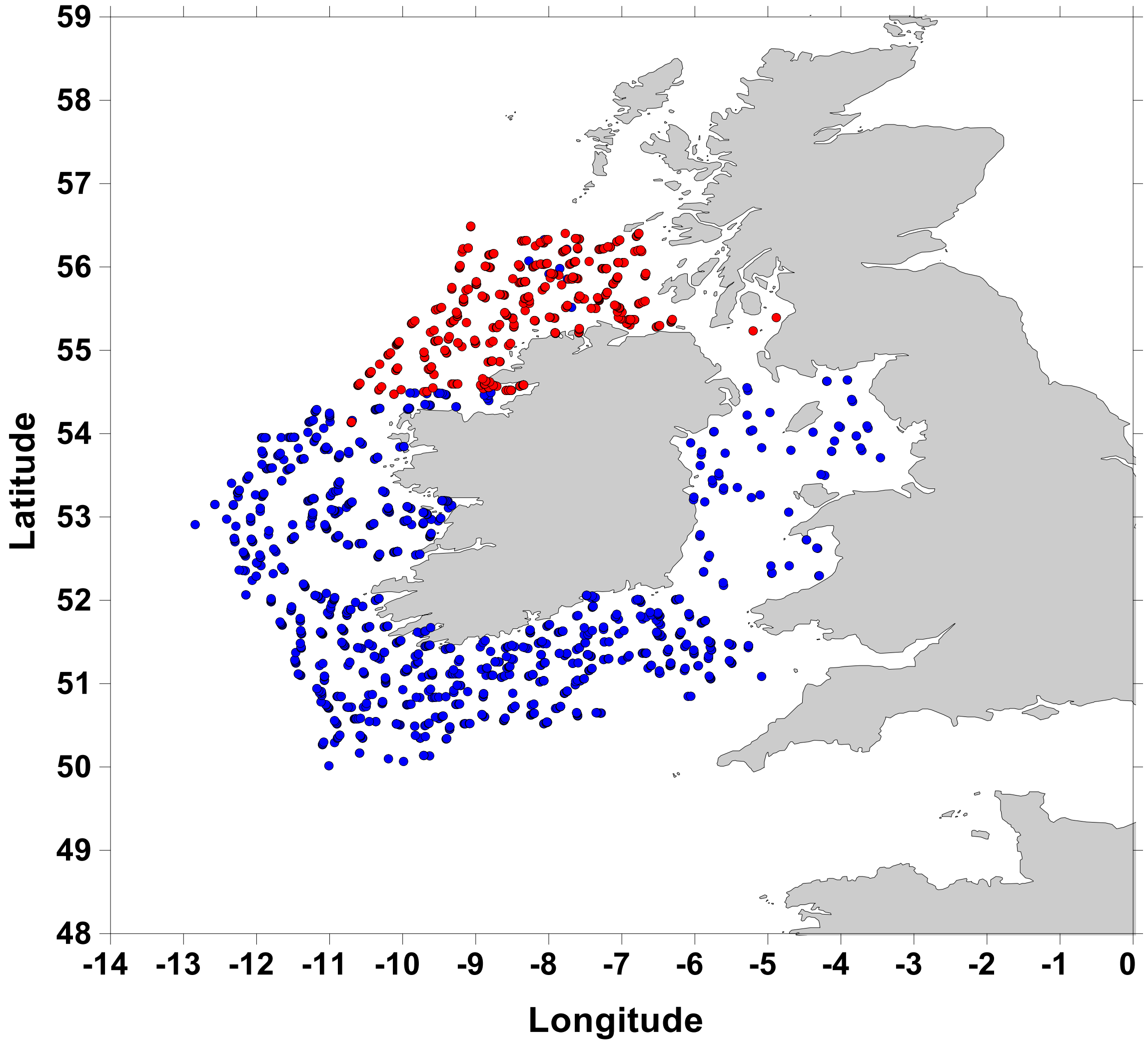

Figure 2.1.2.3.2.2: Locations of trawl samples collected using the 'S' type ground-gear (blue circles) and the 'I2' type ground-gear (red circles) in the Irish Quarter 4 Celtic Sea Survey.

Over the course of the time series, sampling has been undertaken throughout most of the fourth quarter (Figure 2.1.2.3.2.3). In fact some samples were collected in September, and even though strictly this month lies in the third quarter of the year, these records were still tagged with a four code in the Quarter field. So here the Quarter has been used more as part of the survey name, rather than in a strict temporal sense, and as such this already follows the approach adopted for all other data sets examined. There was no indication of any systematic shift in the timing of the survey as the time series progressed. September survey occurred in all years 2005 to 2014, and October and November survey occurred in all years. The survey lingered on into December in 2003, 2006, 2010 to 2012 and in 2014. The majority of trawl samples collected were of nominal 30 ± 4 minutes duration. However, a range of durations, from 12 minutes to 40 minutes, was evident and a small mode at 20 minutes was apparent (Figure 2.1.2.3.2.4). Imposition of the criterion that only hauls ranging from 13 minutes to 66 minutes should be included in the standard monitoring programme resulted in the exclusion of the single 12 minutes duration haul.

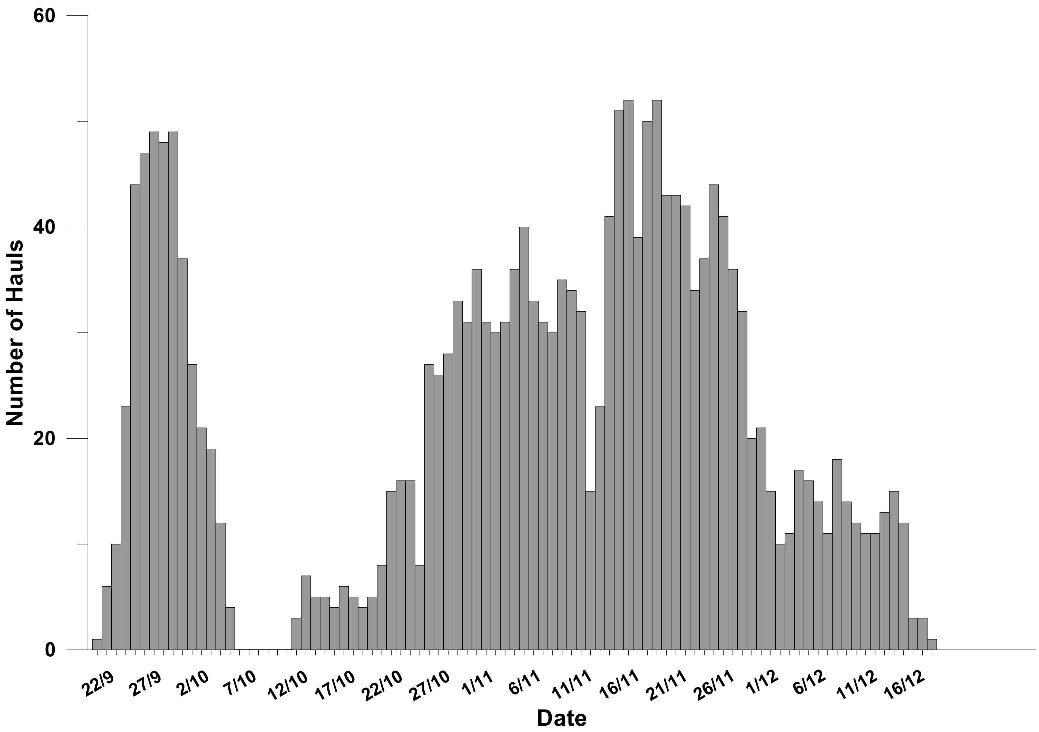

Figure 2.1.2.3.2.3: Frequency distribution of hauls over all years of the Irish fourth quarter Celtic Sea Survey by date (day/month).

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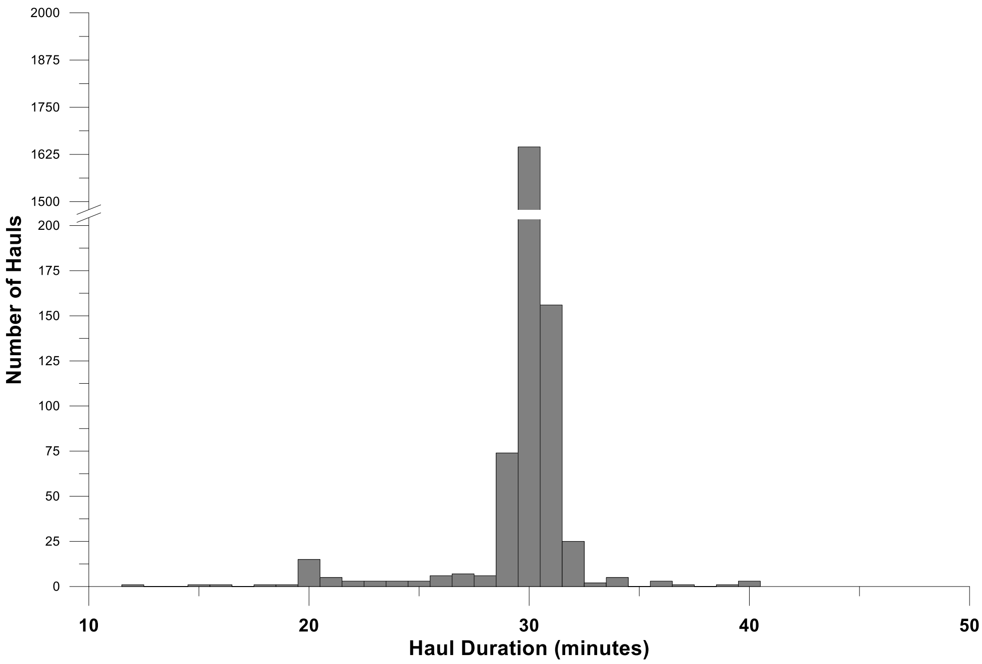

Figure 2.1.2.3.2.4: Frequency distribution for hauls durations for GOV otter trawl samples collected by the Irish fourth quarter Celtic Sea Survey.

There was some evidence of an increase in the number of trawl samples collected each year over the first four years of the time series, and some evidence of a slight decline in the fraction of trawl samples collected that were of nominal 30 minutes duration as the time series progressed (Figure 2.1.2.3.2.5). There is some suggestion that the apparent increase in sampling effort could have been linked to a marginal increase in the length of time allocated to the survey (Figure 2.1.2.3.2.6). Over the course of the whole time series, a total of 78 ICES statistical rectangles were sampled, but the number sampled in any one year varied between 45 and 64, indicative of year-to-year variation in spatial coverage (Figure 2.1.2.3.2.7a). The standard survey area, those rectangles sampled in 50% (≥6 years) of more years of the survey time span, extended to 54 ICES statistical rectangles (Figure 2.1.2.3.2.8). While the actual number of rectangles surveyed annually may have declined sharply in the first few years of the survey, the fraction of the standard survey area covered actually increased, indicative of a survey becoming established and more consistent (Figure 2.1.2.3.2.7).

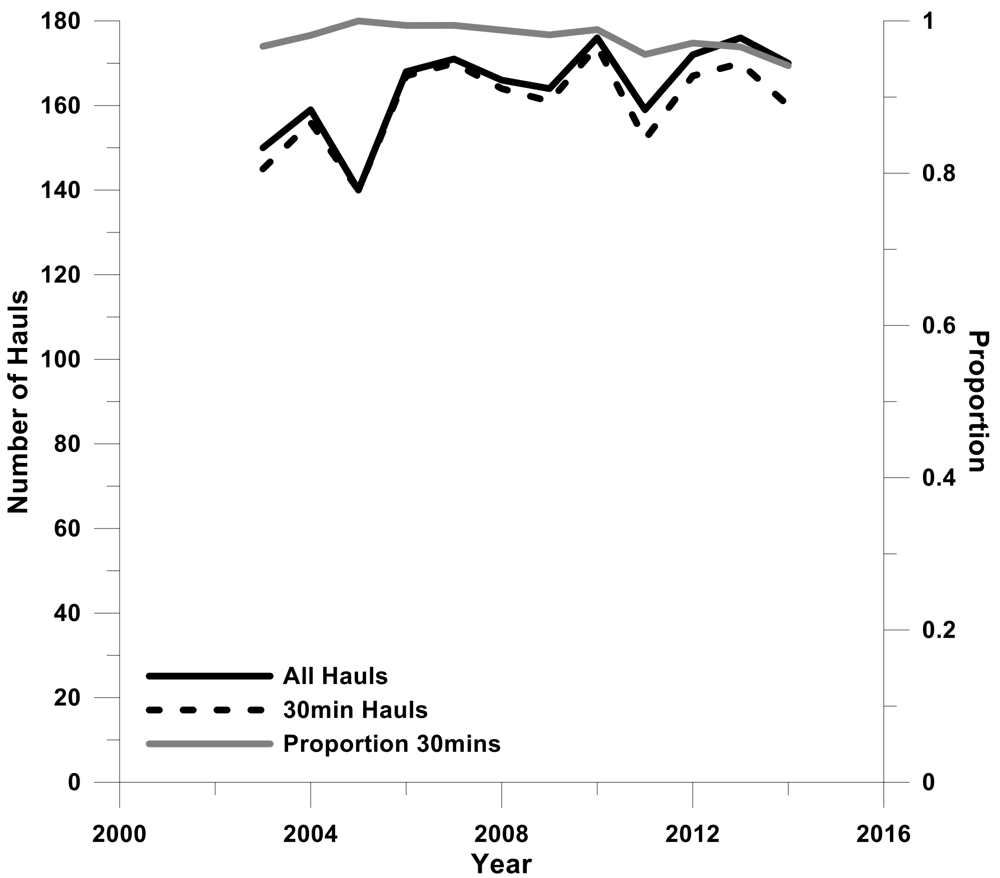

Figure 2.1.2.3.2.5: Trends in the number of all GOV trawl samples collected during the Irish fourth quarter Celtic Sea Survey in each year, and the number of these hauls that were a nominal 30 ±4 minutes duration. The proportion of all hauls in each year that was of nominal 30 minutes duration is also shown.

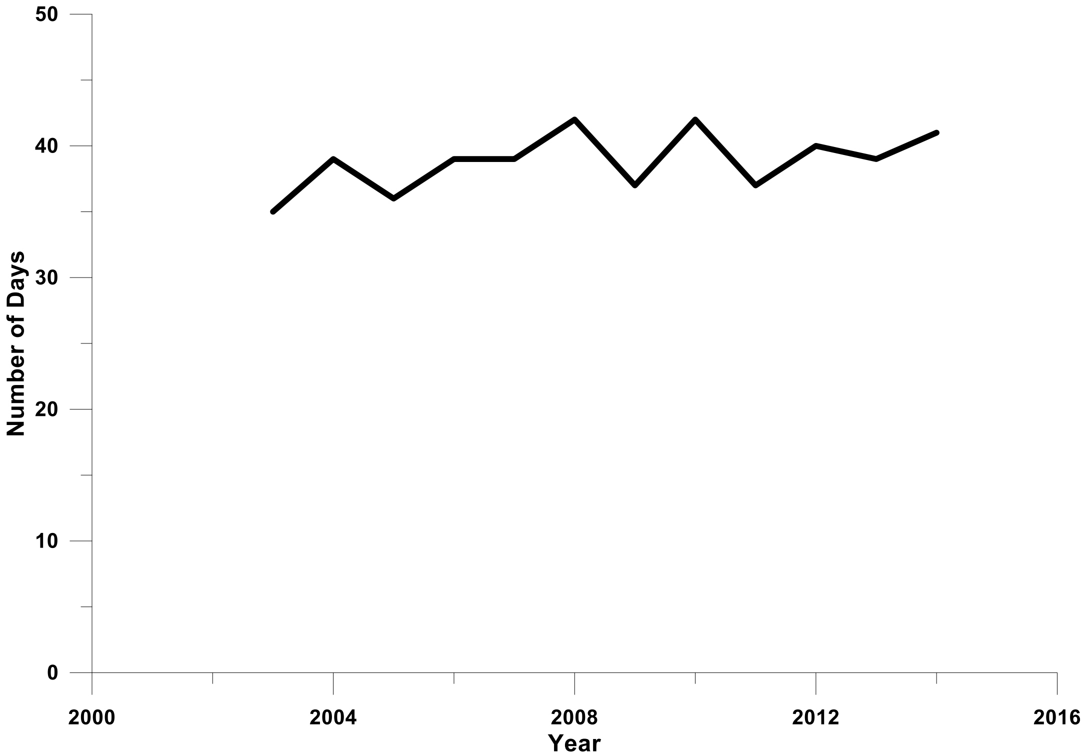

Figure 2.1.2.3.2.6: Variation in the number of days trawl sampling in each year over the course of the Irish fourth quarter Celtic Sea Survey.

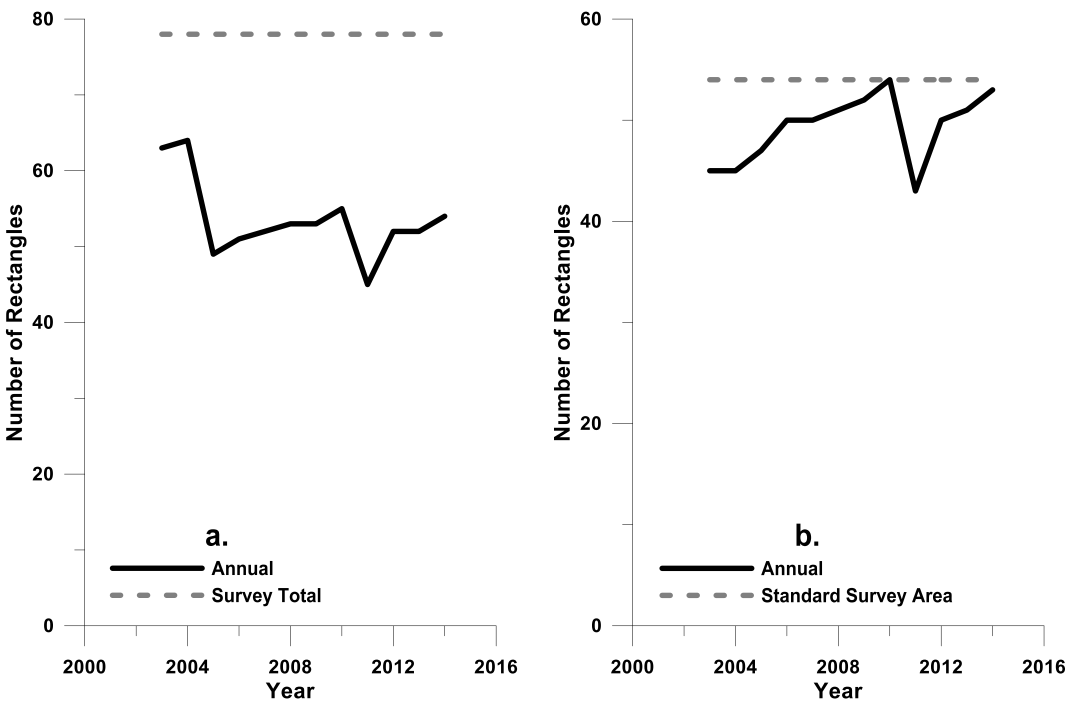

Figure 2.1.2.3.2.7: Trends in the number of ICES statistical rectangles sampled in each year of the Irish fourth quarter Celtic Sea Survey (a) in all rectangles sampled and (b) in a standard survey area consisting only of the 54 rectangles sampled in ≥50% of years of the survey time span.

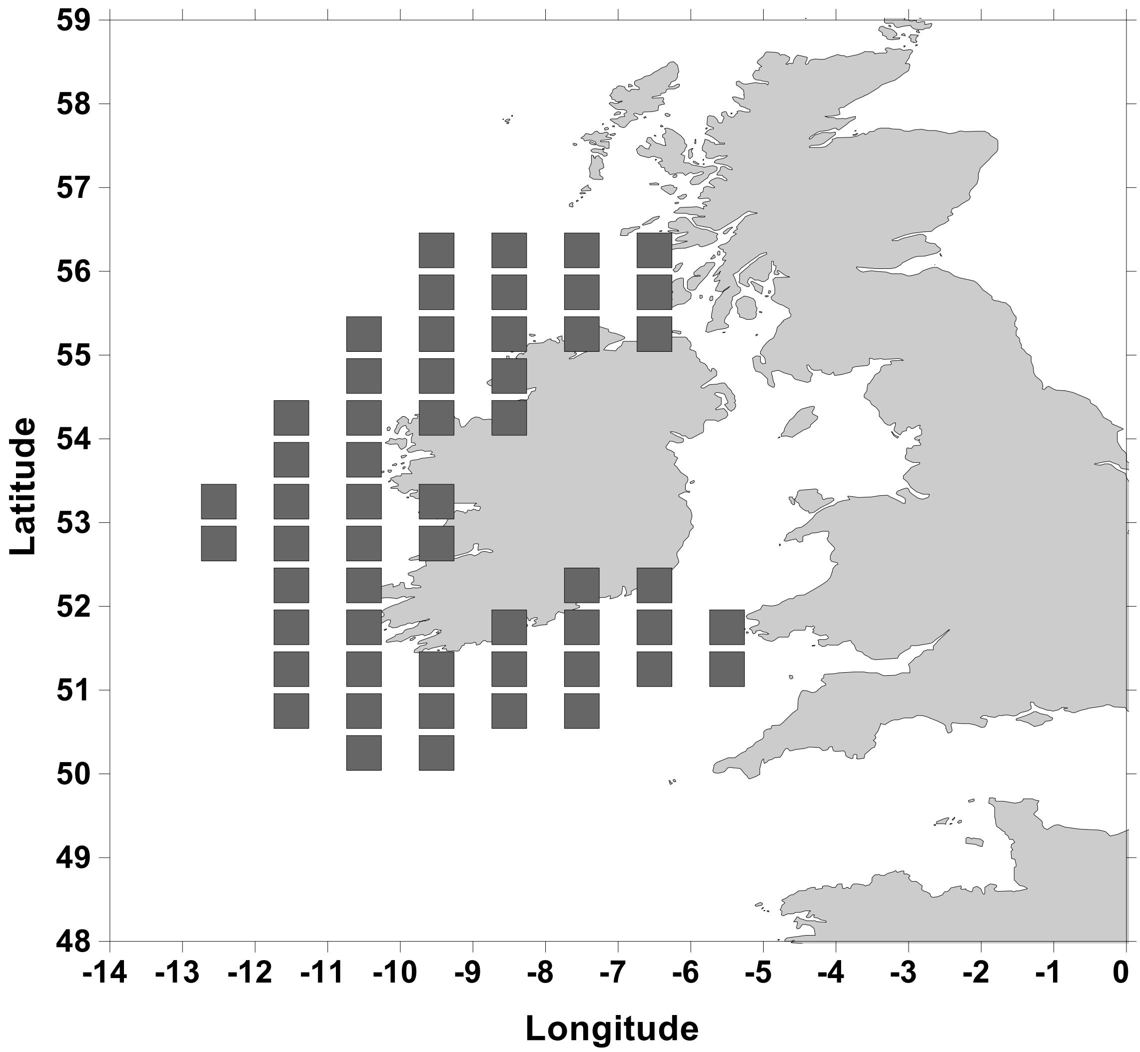

Figure 2.1.2.3.2.8: Chart showing the standard survey area covered by the Irish fourth quarter Celtic Sea Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

2.1.2.4. The First Quarter Northern Irish Groundfish Survey (CSNIrOT1)

2.1.2.4.1. *Survey History*

Both the first and fourth quarter Northern Irish groundfish surveys use a Rockhopper otter trawl. The survey is carried out in the Irish Sea and St Georges Channel area, the waters separating the UK from the Republic of Ireland in the Celtic Seas subregion, which constitutes ICES Division VIIa (Figure 2.1.2.4.1.1). All depths in the area are sampled following a fixed station stratified design based on depth strata. The surveys began in 1992. The surveys are carried out twice every year in the first and fourth quarters However, continuity of the first quarter survey was under threat when, in 2007, it wasn't considered for co-funding under the DCF (ICES, 2010).

Only data from 2008 onwards are contained in the DATRAS data portal and the analysis presented here was carried only on these data. At the time of this analysis, data for the years 1992-2007 were undergoing a process of local quality assurance by the data providers. These data were subsequently made available to this project and then been subjected to the full quality assurance procedure described in this document before being added to the standard groundfish survey monitoring and assessment data product. Summary analysis and description of the full CSNIrOT1 survey data product are presented in Greenstreet and Moriarty (2017).

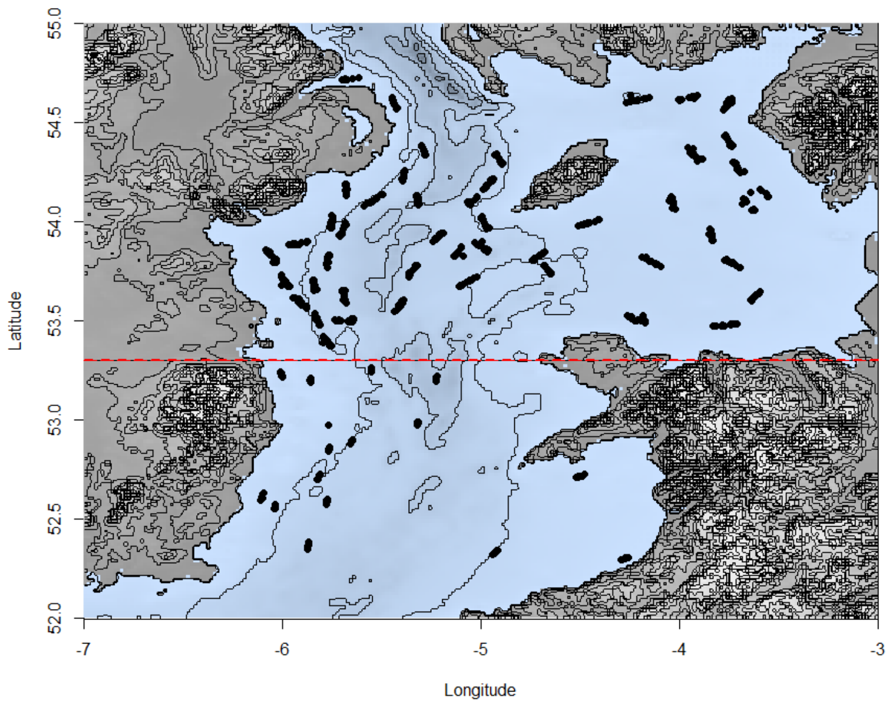

Figure 2.1.2.4.1.1: Bathymetry map covering the area from longitude 7 to 3 degrees west and latitude 52 to 55 degrees north showing spatial coverage (trawl locations: black dots) of the Northern Ireland groundfish surveys carried out by in the Irish Sea (above red dashed line) and St. George's Channel (below red dashed line).

In both the Quarter 1 and Quarter 4 surveys the northern Irish Sea portion of the survey aims to achieve a three nautical mile tow between settlement of the net on the seabed and lifting of the gear off the seabed, in a time as close to 60 minutes as possible in order to maintain a consistent balance between speed of the net over the ground and flow-rate of water through the net. Whereas stations in the St George's Channel are one nautical mile at three knots and as close to 20 minutes, Figure 2.1.2.4.1.1 shows the distinction between the two areas with a dashed red line. There are 46 stations in northern Irish Sea and 15 in St George's Channel, all sampled in daylight hours. The surveys are carried out using the RV "*Corystes*", a 52.5 m double hulled research vessel with Diesel-Electric engine. The fishing gear is a rock-hopper otter trawl with a 17 m footrope fitted with 250 mm non-rotating rubber discs. The gear has a mean vertical opening of 3 m. The door spread varies from around 25 m at 20 m depth to 40 m at 80 m depth. A 20 mm codend is fitted. SCANMAR sensors are fitted to the gear and trawl parameters are recorded. A warp length appropriate to the depth of water is used: usually 3 to 3.5 times the depth (ICES, 2010a).

2.1.2.4.2. Defining the Standard Monitoring Programme

A single vessel, the RV *Corystes*, and a single gear, the ROT was used throughout the Northern Irish survey work in the Irish Sea. The complete database contained a total of 774 records of which 762 held a valid V code in the HaulVal field. No gear information was provided; the fields SweepLngt, GearExp, DoorType, WarpLngt, WarpDia, WarpDen, DoorSurface, DoorWgt, Buoyancy, KiteDim and WgtGroundRope all held -9 null values. Of the 762 valid hauls 406 were first quarter survey and 356 were fourth quarter. Analyses presented in this section relate to the 406 valid first quarter records.

The Northern Irish first quarter Irish Sea survey was primarily undertaken in March, although in 2014 the survey was carried out in the first half of April (Figure 2.1.2.4.2.1). Despite this technically falling into the second quarter, this survey was part of the first quarter series, and was, therefore, tagged with a 1 code in the Quarter field. The Quarter field is, therefore, used to define the survey series, rather than to depict a strict time of year, and this follows the use of this field applied to all other surveys. The majority of trawl samples collected in the first quarter survey were of 60 minutes duration, although another mode at 20 minutes was also evident (Figure 2.1.2.4.2.2). One haul not shown in Figure 2.1.2.4.2.2 (no 44 shot at 1544 on 18 March 2010) had a duration of 891 minutes recorded. No distance towed information was provided to confirm the extreme length of this single trawling operation. This tow duration was subsequently corrected by the data provider, as a 60 minutes tow. Trawl durations of 13 minutes to 66 minutes were considered valid.

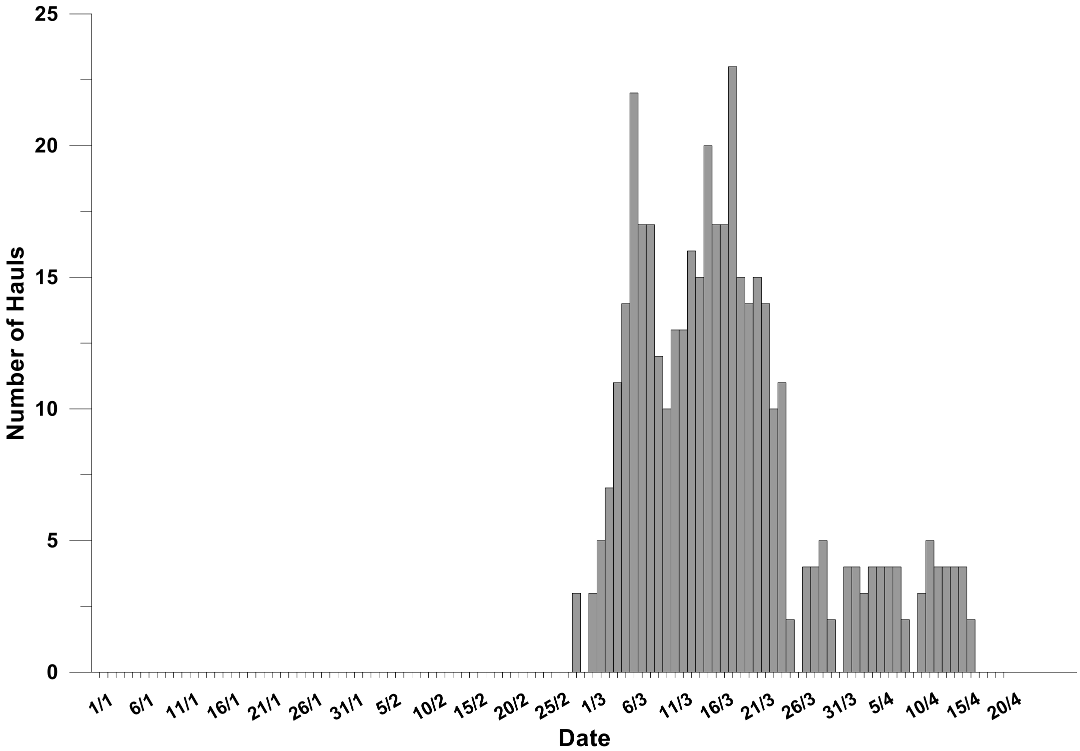

Figure 2.1.2.4.2.1: Frequency distribution of hauls over all years of the Northern Irish first quarter Irish Sea Survey by date (day/month).

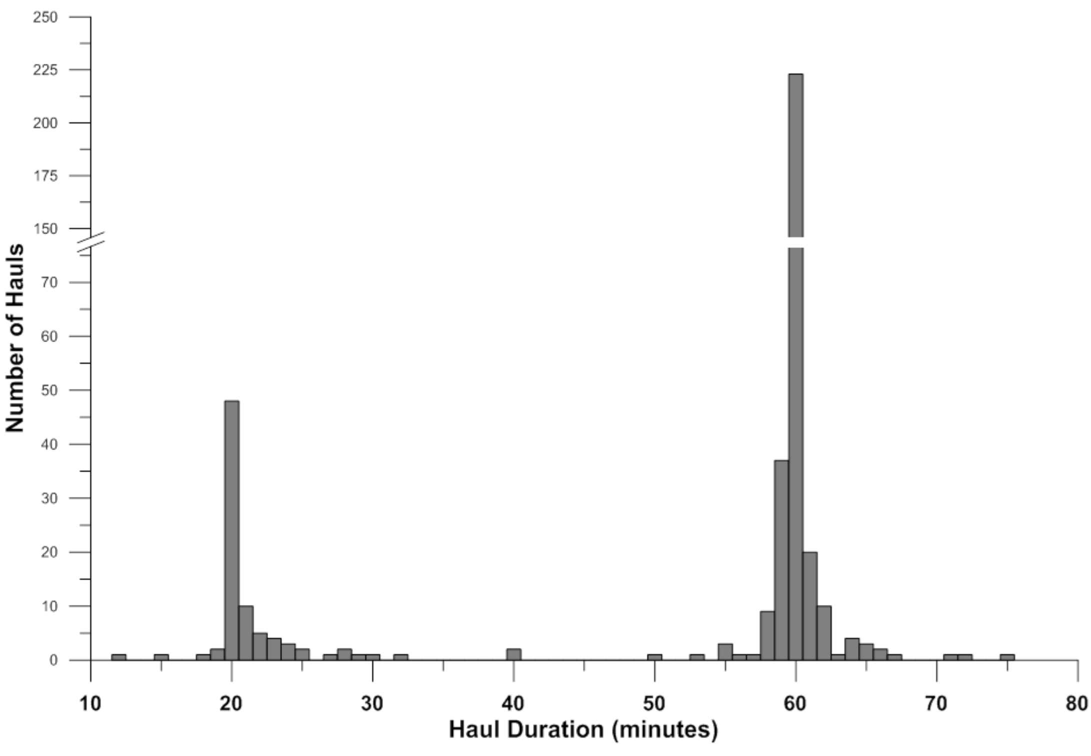

Figure 2.1.2.4.2.2: Frequency distribution for hauls durations for ROT otter trawl samples collected by the Northern Irish first quarter Irish Sea Survey.

Figure 2.1.2.4.2.3 shows trends in annual sampling effort in the Northern Ireland first quarter Irish Sea survey. The database contains records for single trawl samples collected in each year 2005 to 2007. On their own, these single samples could not be considered to be part of an effective monitoring programme so they were excluded leaving survey with an effective start date of 2008. Variation in sampling effort was minimal over the period 2008 to 2014 and no systematic trend was apparent. Cruise duration over this survey period was also relatively constant at around 15-17 days (Figure 2.1.2.4.2.4).

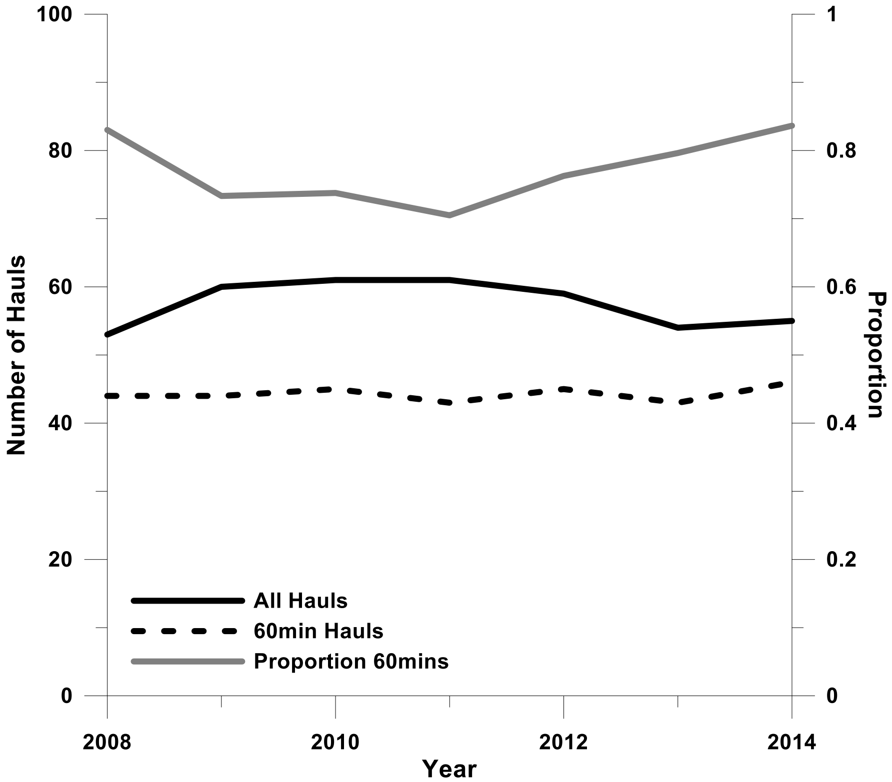

Figure 2.1.2.4.2.3: Trends in the number of all ROT trawl samples collected during the Northern Irish first quarter Irish Sea Survey in each year, and the number of these hauls that were a nominal 60 ± 6 minutes duration. The proportion of all hauls in each year that was of nominal 60 minutes duration is also shown.

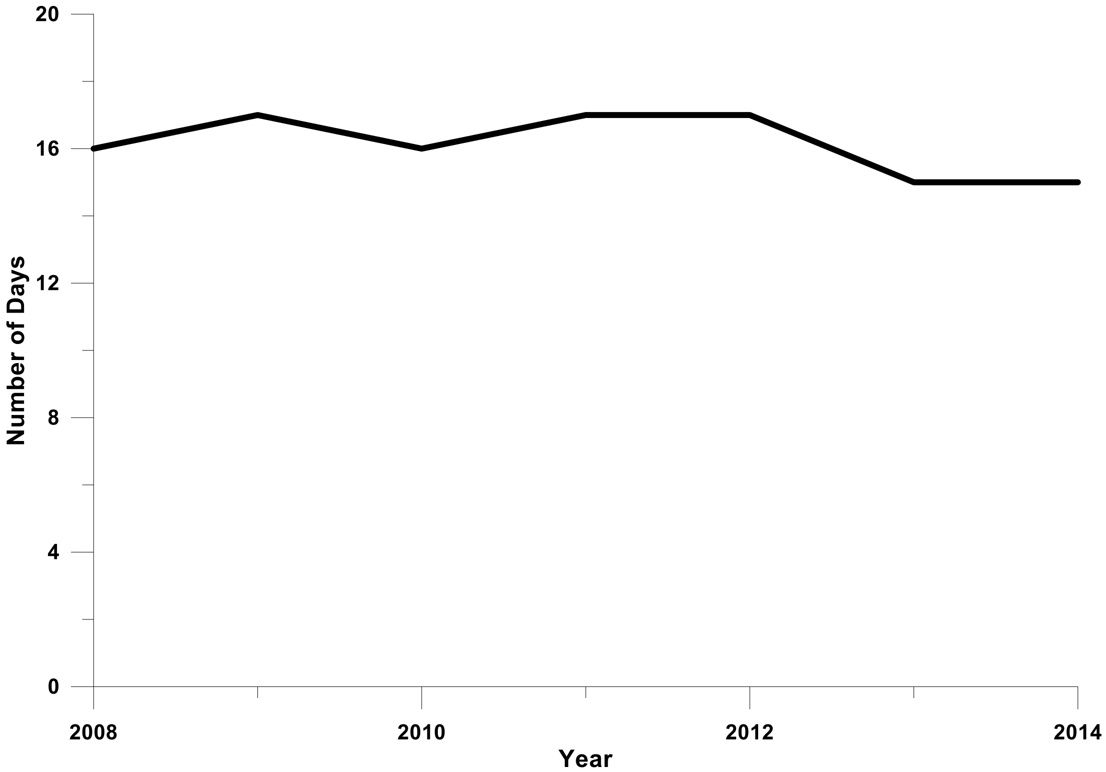

Figure 2.1.2.4.2.4: Variation in the number of days trawl sampling in each year over the course of the Northern Irish first quarter Irish Sea Survey.

Over the course of the whole Northern Ireland first quarter Irish Sea Survey, 19 ICES rectangles were sampled, while in any one year, between 16 and 19 rectangles were sampled (Figure 2.1.2.4.2.5a). One rectangle was sampled in just one year and the remaining 18 were sampled in over 50% of the years that the survey was in operation. These 18 rectangles, therefore, constituted the standard survey area (Figure 2.1.2.4.2.6), and in most years all 18 of these rectangles were actually sampled (Figure 2.1.2.4.2.5b).

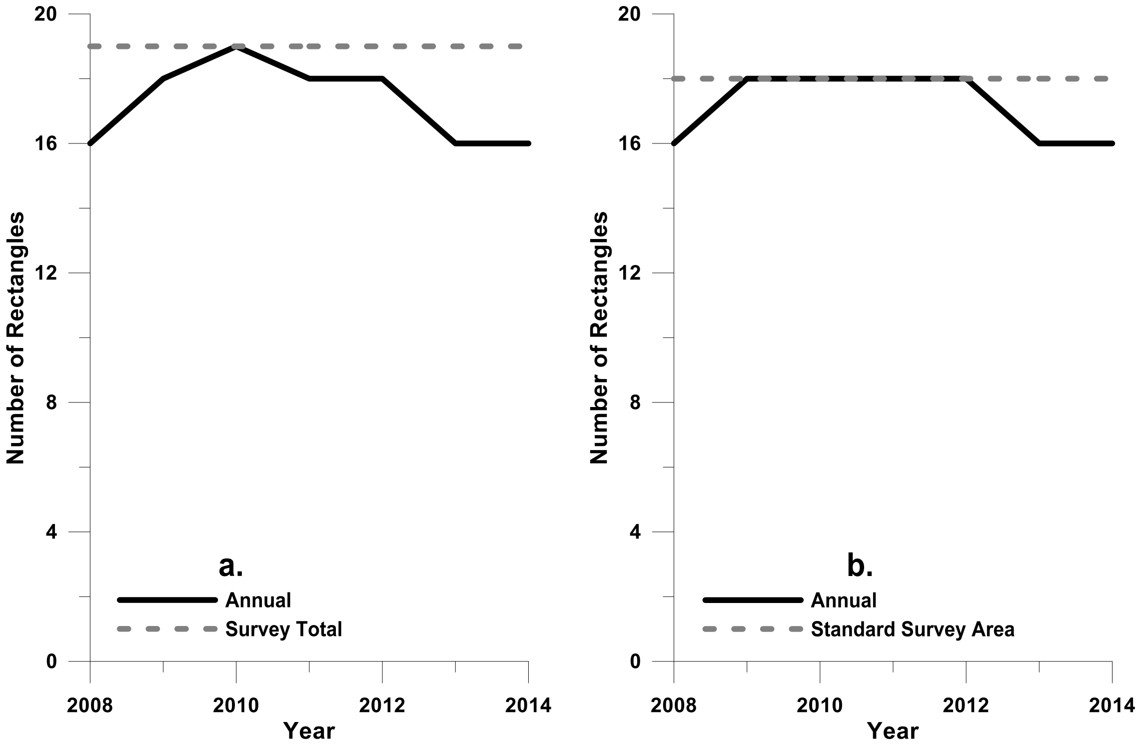

Figure 2.1.2.4.2.5: Trends in the number of ICES statistical rectangles sampled in each year of the Northern Irish first quarter Irish Sea Survey (a) in all rectangles sampled and (b) in a standard survey area consisting only of the 18 rectangles sampled in ≥50% of years of the survey time span.

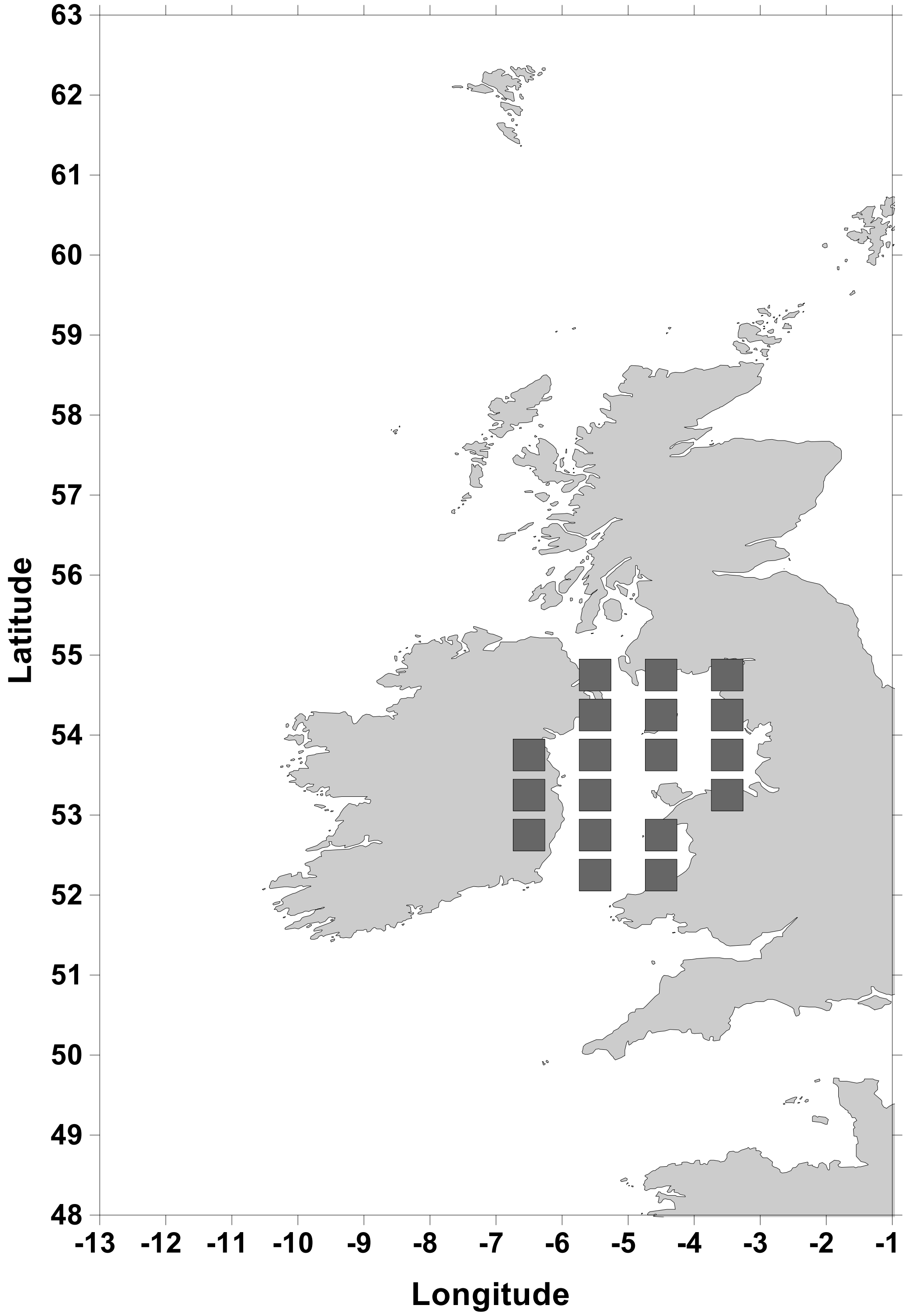

Figure 2.1.2.4.2.6: Chart showing the standard survey area covered by the Northern Irish first quarter Irish Sea Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

2.1.2.5. The Fourth Quarter Northern Irish Groundfish Survey (CSNIrOT4)

2.1.2.5.1. Survey History

See section 2.1.2.4.1 for fourth quarter Northern Irish Groundfish survey history, both Quarter 1 and Quarter 4 surveys follow the same pattern.

2.1.2.5.2. Defining the Standard Monitoring Programme

Description of the Northern Ireland Irish Sea survey data provided in the previous section is again germane to this section. Analyses presented in this section relate to the 356 valid fourth quarter records.

The Northern Irish fourth quarter Irish Sea survey was primarily undertaken in October, although in 2011 some survey was carried out in November (Figure 2.1.2.5.2.1). The majority of trawl samples collected in the first quarter survey were of 20 minutes duration (Figure 2.1.2.5.2.2), although a range of durations from 17 minutes to 30 minutes was evident. Trawl durations of 13 minutes to 66 minutes were considered valid, so no samples were excluded from the monitoring programme data product on the basis of haul duration.

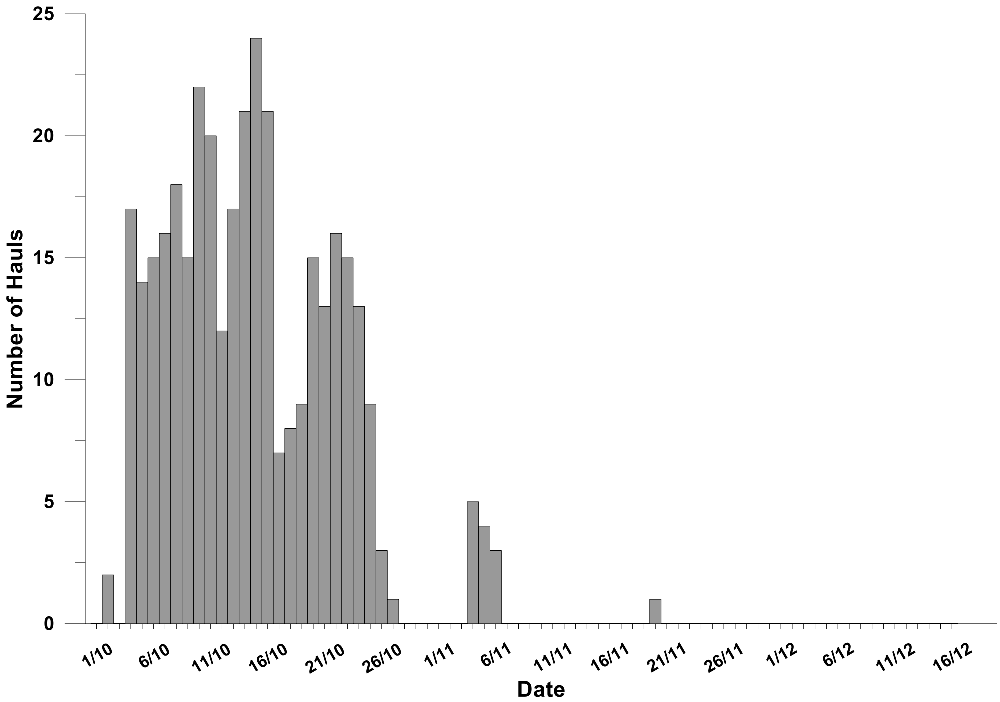

Figure 2.1.2.5.2.1: Frequency distribution of hauls over all years of the Northern Irish fourth quarter Irish Sea Survey by date (day/month).

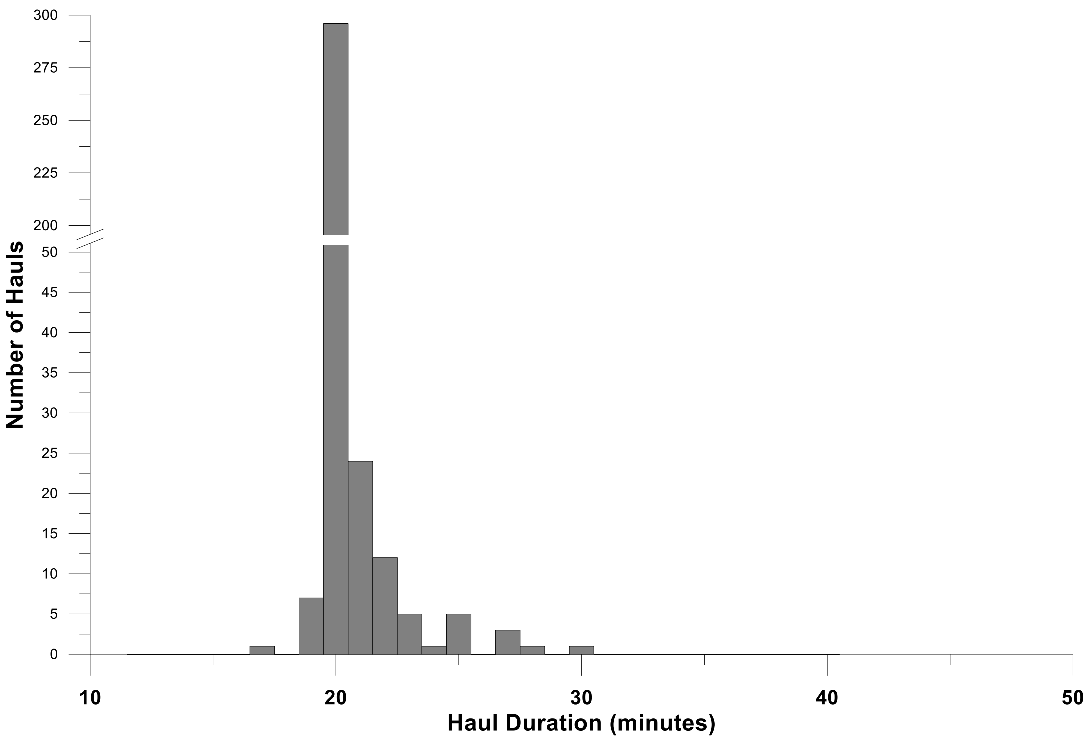

Figure 2.1.2.5.2.2: Frequency distribution for hauls durations for ROT otter trawl samples collected by the Northern Irish fourth quarter Irish Sea Survey.

Figure 2.1.2.5.2.3 shows trends in annual sampling effort in the Northern Ireland fourth quarter Irish Sea survey. The database contains records for single trawl samples collected in each year 2006 and 2007. On their own, these single samples could not be considered to be part of an effective monitoring programme so they were excluded leaving survey with an effective start date of 2009. Variation in sampling effort was minimal over the period 2009 to 2014 and no systematic trend was apparent. Cruise duration over this survey period was also relatively constant at around 11-14 days (Figure 2.1.2.5.2.4).

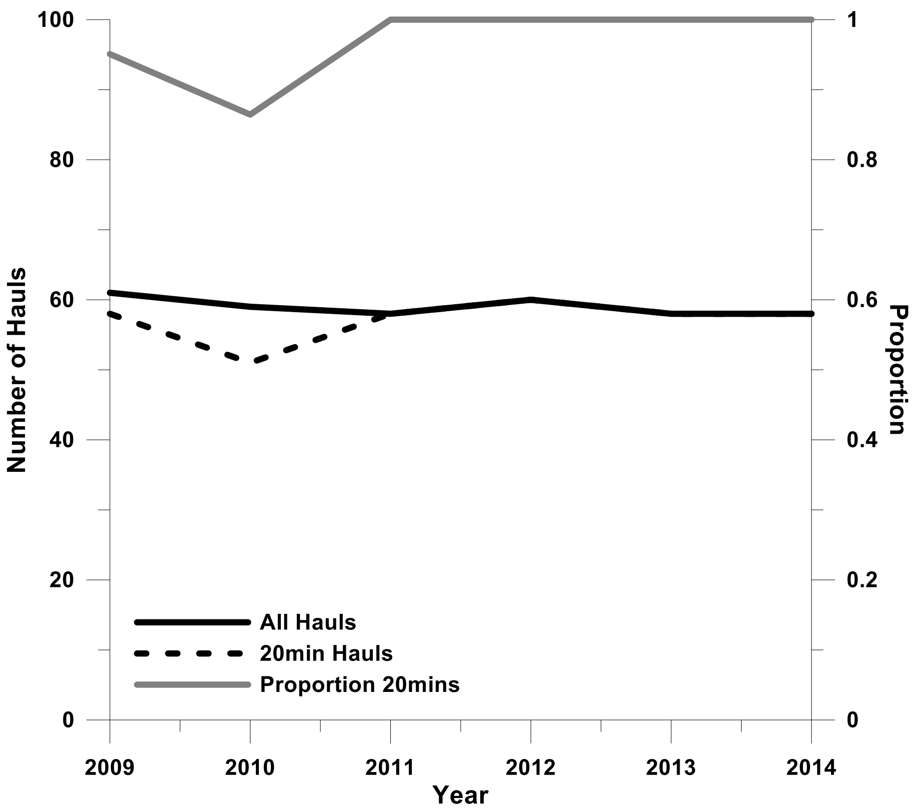

Figure 2.1.2.5.2.3: Trends in the number of all ROT trawl samples collected during the Northern Irish fourth quarter Irish Sea Survey in each year, and the number of these hauls that were a nominal 20 ± 3 minutes duration. The proportion of all hauls in each year that was of nominal 20 minutes duration is also shown.

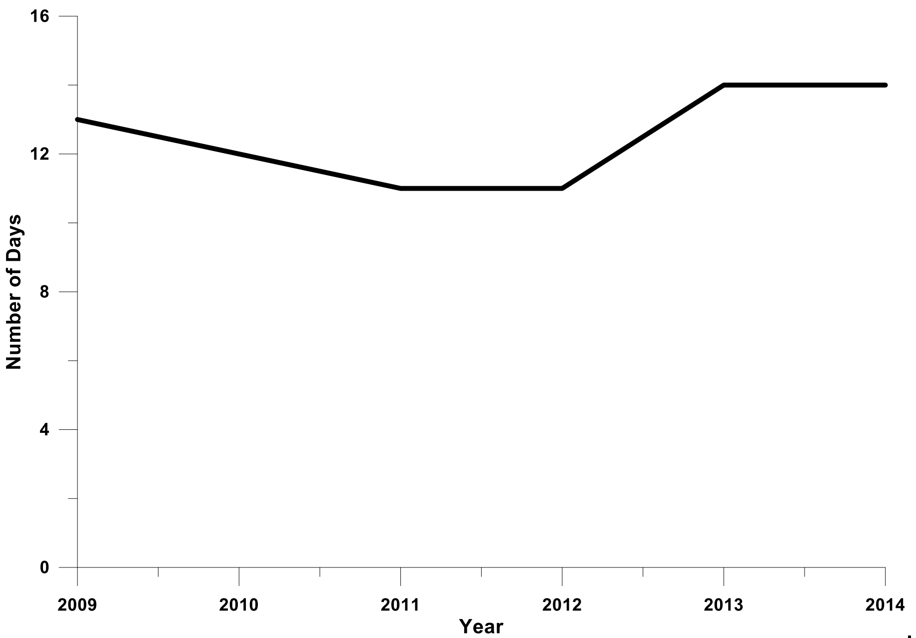

Figure 2.1.2.5.2.4: Variation in the number of days trawl sampling in each year over the course of the Northern Irish fourth quarter Irish Sea Survey.

Over the course of the whole Northern Ireland Quarter 4 Irish Sea Survey, 19 ICES rectangles were sampled, while in any one year, between 17 and 18 rectangles were sampled (Figure 2.1.2.5.2.5a). One rectangle was sampled in just one year and the remaining 18 were sampled in over 50% of the years that the survey was in operation. These 18 rectangles, therefore, constituted the standard survey area (Figure 2.1.2.5.2.6), and in many years all 18 of these rectangles were actually sampled (Figure 2.1.2.5.2.5b).

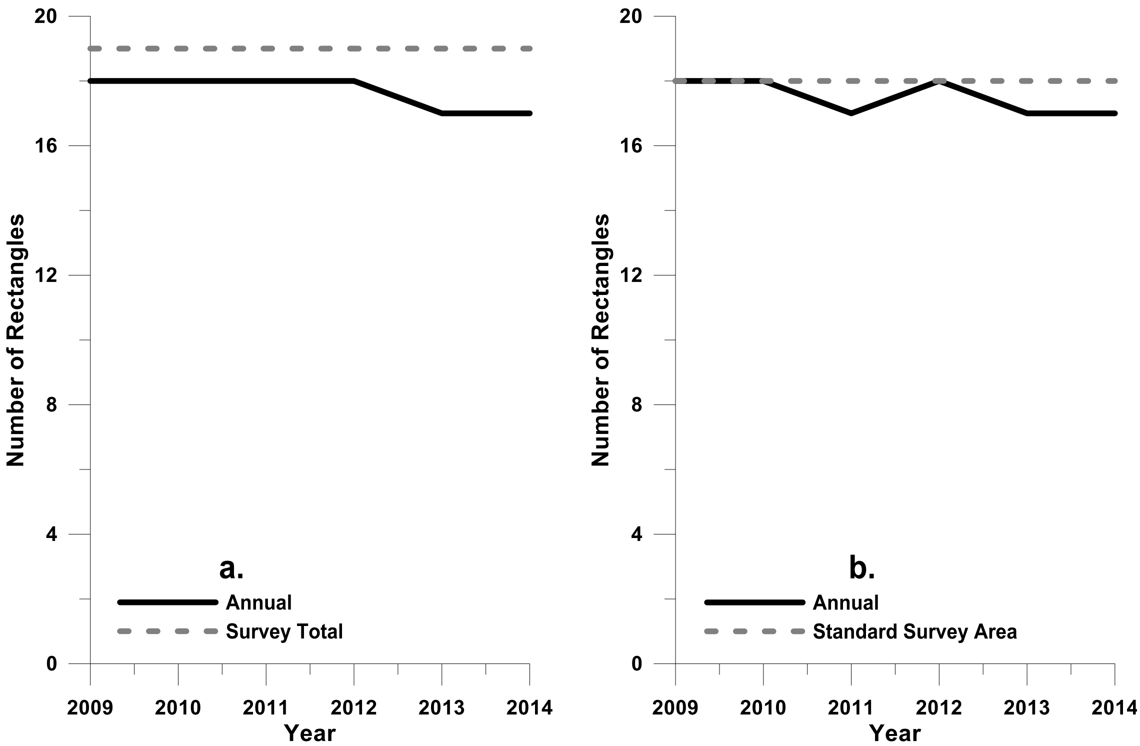

Figure 2.1.2.5.2.5: Trends in the number of ICES statistical rectangles sampled in each year of the Northern Irish fourth quarter Irish Sea Survey (a) in all rectangles sampled and (b) in a standard survey area consisting only of the 18 rectangles sampled in ≥50% of years of the survey time span.

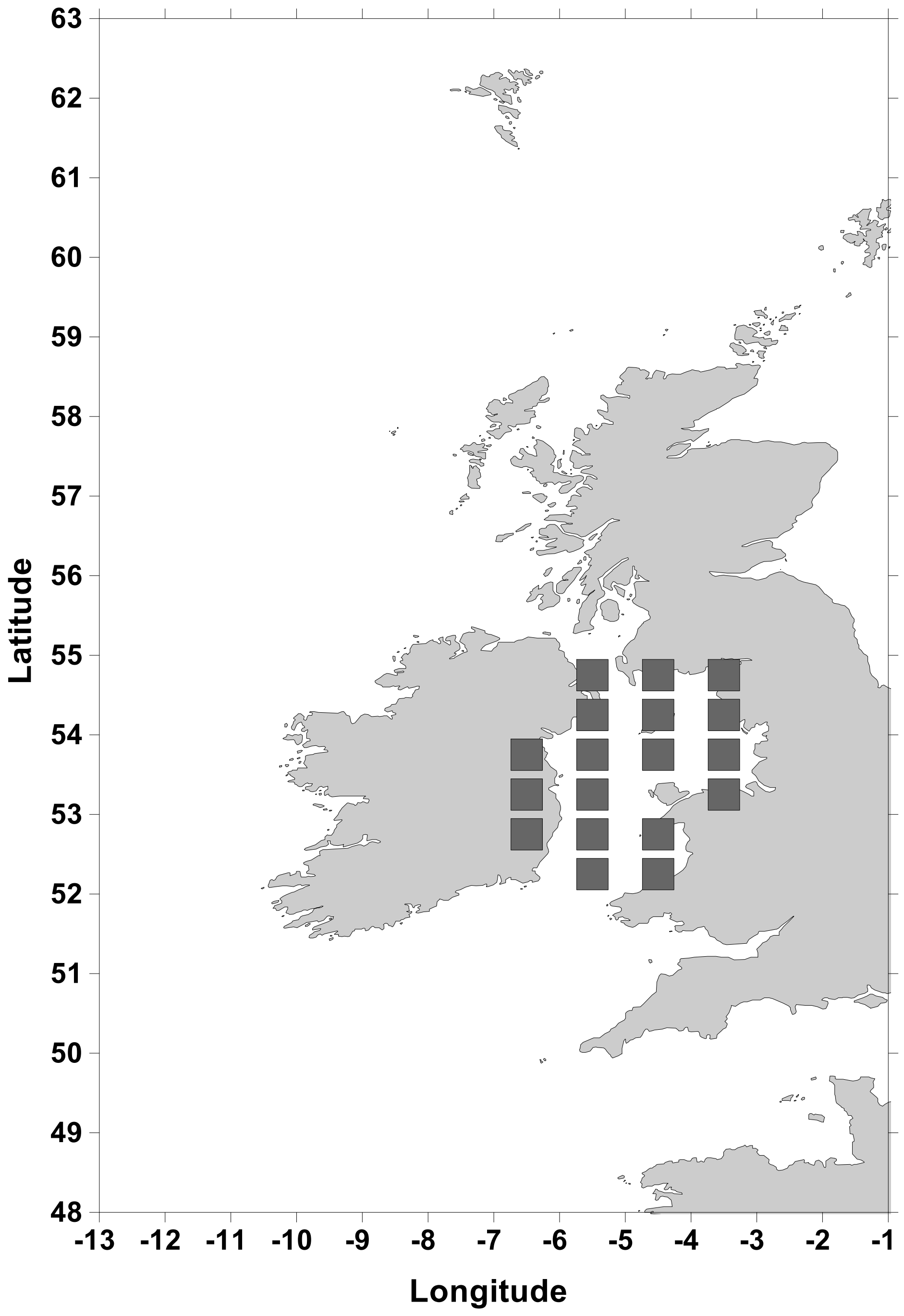

Figure 2.1.2.5.2.6: Chart showing the standard survey area covered by the Northern Irish fourth quarter Irish Sea Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

2.1.2.6. The Fourth Quarter French EVHOE Groundfish Survey (CSBBFraOT4)

2.1.2.6.1. Survey History

The EVHOE survey operates in both the Celtic Seas and the Bay of Biscay and Iberian Coast subregions (see Figure 2.1). In the Celtic Seas, the survey operates across ICES Divisions VII(f), VII(g), VII(h), and VII(j), and it also covers the French part of the Bay of Biscay, ICES Divisions VIII(a) and VIII(b). Since this is a single survey, for convenience we include it here in the Celtic Seas section. The survey is conducted from 15 m to 600 m depths, with sampling following a stratified random design based on both geography, in that Bay of Biscay is partitioned into two areas and the Celtic Sea into three, and depth with six depth strata (ICES, 2010a). The number of trawl samples per stratum is determined following an optimized Neyman allocation based on numbers variance averaged across the four most important commercial species (hake, the two species of angler fish, and megrim) and ensuring a minimum of at least two stations per stratum. 140 trawl samples are planned every year and this number is subsequently adjusted according to the actual time at sea available. The EVHOE is carried out by the RV "Thalassa" using the GOV 36/47 trawl as described in the IBTS Survey manual (ICES 2010a), except that the exocet Kite is replaced by additional buoyancy, 66 floats instead of 60, and the weight of the Marport sensors, placed in the middle of the headline, has been balanced by adding 21 4l floats. Generally, the gear has a horizontal opening around 20 m and a vertical opening of 4 m. The doors are plane oval of 1350 Kg. The net is fitted with a 20 mm codend liner.

2.1.2.6.2. Defining the Standard Monitoring Programme

The French fourth quarter EVHOE survey covers an 18 year period from 1997 to 2014. A single vessel, the RV *Thallassa II*, was used for the entire period and only the GOV trawl was used. A single ground gear, the D gear, was used, but two sweep lengths were deployed, with a change-over from the shorter sweep (50 m) to the longer sweep (100 m) occurring at a depth of approximately 120 m. The fields DoorType, Rigging, Tickler and WarpDen all held only -9 null values. WarpDia was recorded as either 24 or 26 and it seems unlikely that both were used as this would entail changes to the winches on the vessel. DoorSurface, Buoyancy, KiteDim and WgtGroundRope had either null values of -9 or values of 4.5, 145, 0.7 or 210 respectively recorded.

The database held records for 2495 trawl samples, all with a valid V code recorded in the HaulVal field. The survey primarily took place between mid-October and early-December (Figure 2.1.2.6.2.1). The majority of trawl samples were of 30 minutes haul duration. No other modal haul durations were obvious, but haul duration ranged from 10 minutes to 40 minutes (Figure 2.1.2.6.2.2). Considering the range of haul durations deemed valid in other surveys, the single 10 minutes duration sample was omitted from the standard monitoring programme.

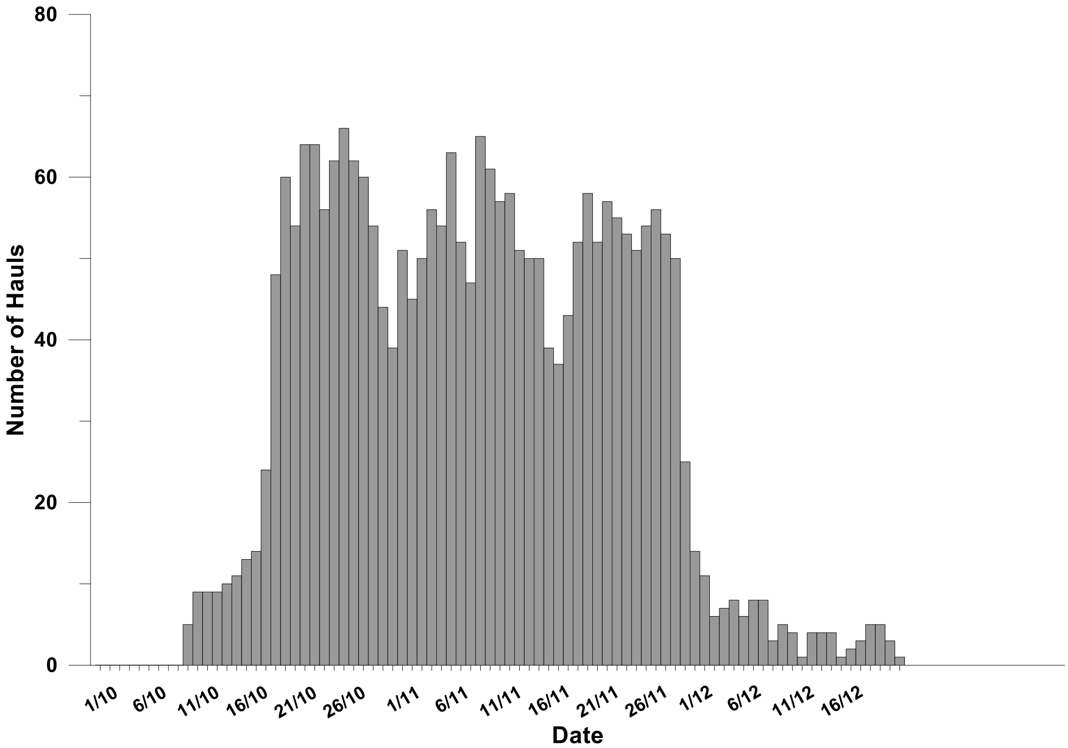

Figure 2.1.2.6.2.1: Frequency distribution of hauls over all years of the French fourth quarter EVHOE Survey by date (day/month).

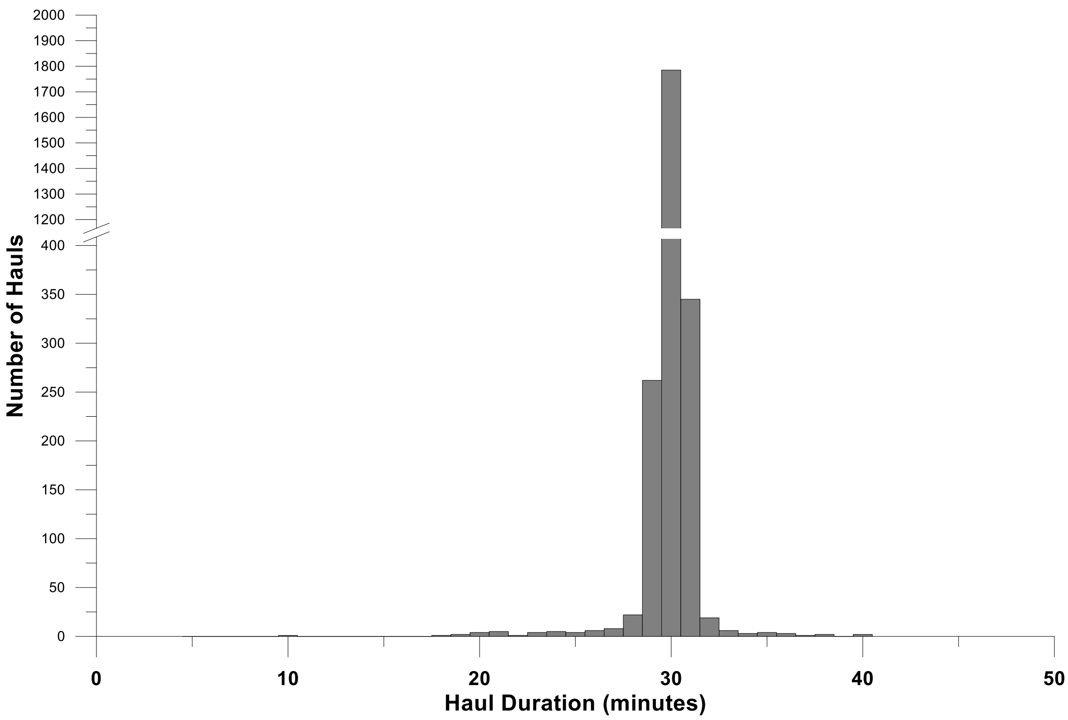

Figure 2.1.2.6.2.2: Frequency distribution for hauls durations for GOV otter trawl samples collected by the French fourth quarter EVHOE Survey.

There was some suggestion that after the first four years of the survey, the number of trawl samples collected each year may have increased by approximately 15 on average, but the proportion of trawls samples with a 30 minutes duration was relatively constant over the course of the entire time series (Figure 2.1.2.6.2.3). A slight increase in vessel time allocation may have accounted for this increase in sampling effort (Figure 2.1.2.6.2.4).

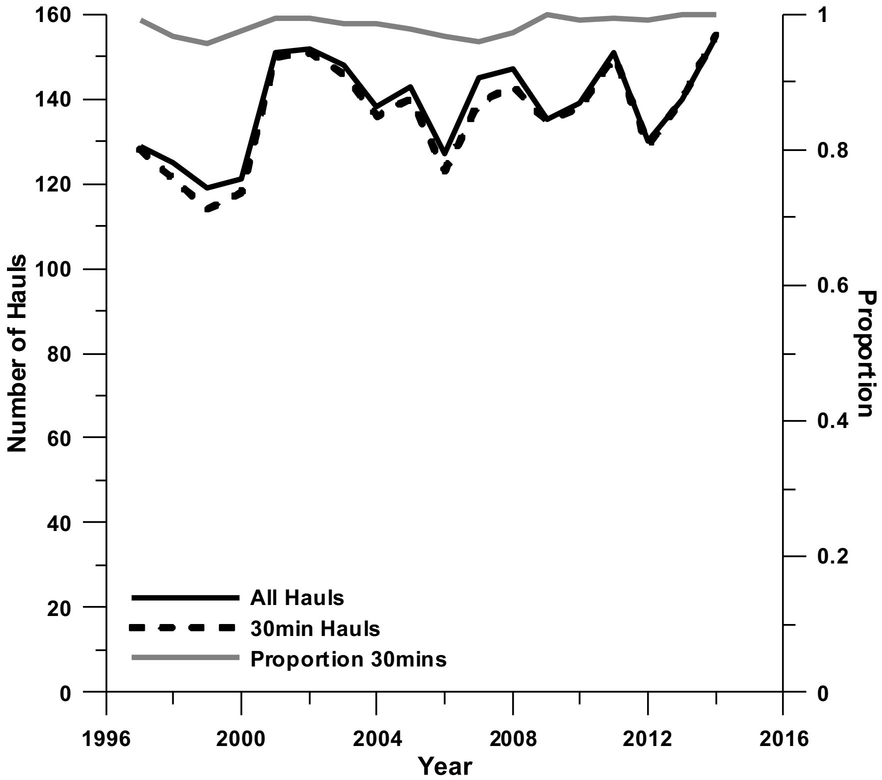

Figure 2.1.2.6.2.3: Trends in the number of all GOV trawl samples collected during the French fourth quarter EVHOE Survey in each year, and the number of these hauls that were a nominal 30 ± 4 minutes duration. The proportion of all hauls in each year that was of nominal 30min duration is also shown.

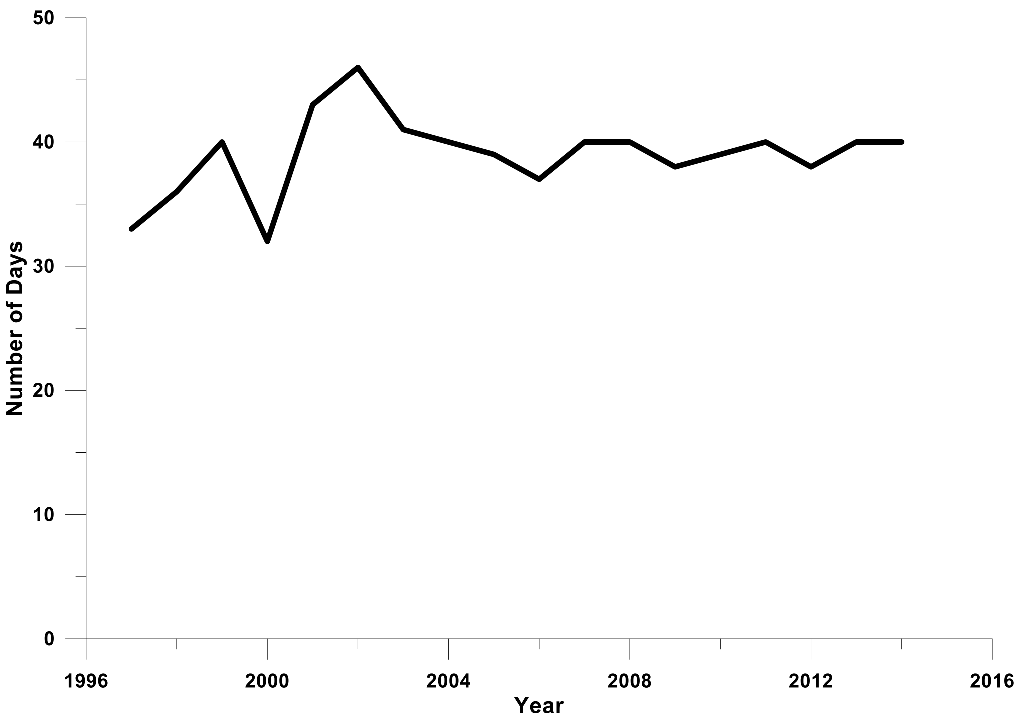

Figure 2.1.2.6.2.4: Variation in the number of days trawl sampling in each year over the course of the French fourth quarter EVHOE Survey.

Over the course of the full time series a total of 74 ICES statistical rectangles were sampled at one time or another, but the number of rectangles sampled in any one year varied between 54 and 62 (Figure 2.1.2.6.2.5a); this was due more to the sampling strata not corresponding to ICES statistical rectangles and, therefore, did not provide evidence of systematic year-to-year variation in spatial coverage. Nevertheless, as already mentioned, although 140 trawl samples were planned every year following an optimized Neyman design, year to year variation in the amount of sea time available inevitably caused some inter-annual variation in survey spatial coverage. Furthermore, since the optimized Neyman design was based on variability in the abundance of just four commercial fish species, and not on environmental or broader fish community characteristics, in order to derive a monitoring programme that addressed the full fish community, and to avoid potential edge effects on community-based indicators, it was still deemed desirable to determine a standard survey area for the French fourth quarter EVHOE Survey. Only 64 ICES statistical rectangles were sampled in 50% or more (≥9y) of the years of the survey and these rectangles constitute the standard survey area covered by the French fourth quarter EVHOE survey (Figure 2.1.2.6.2.6). Between 52 (81%) and 60 (94) of these standard survey area rectangles were fished each year and there was no evidence of any trend in the proportion of the standard survey area covered each year (Figure 2.1.2.6.2.5b).

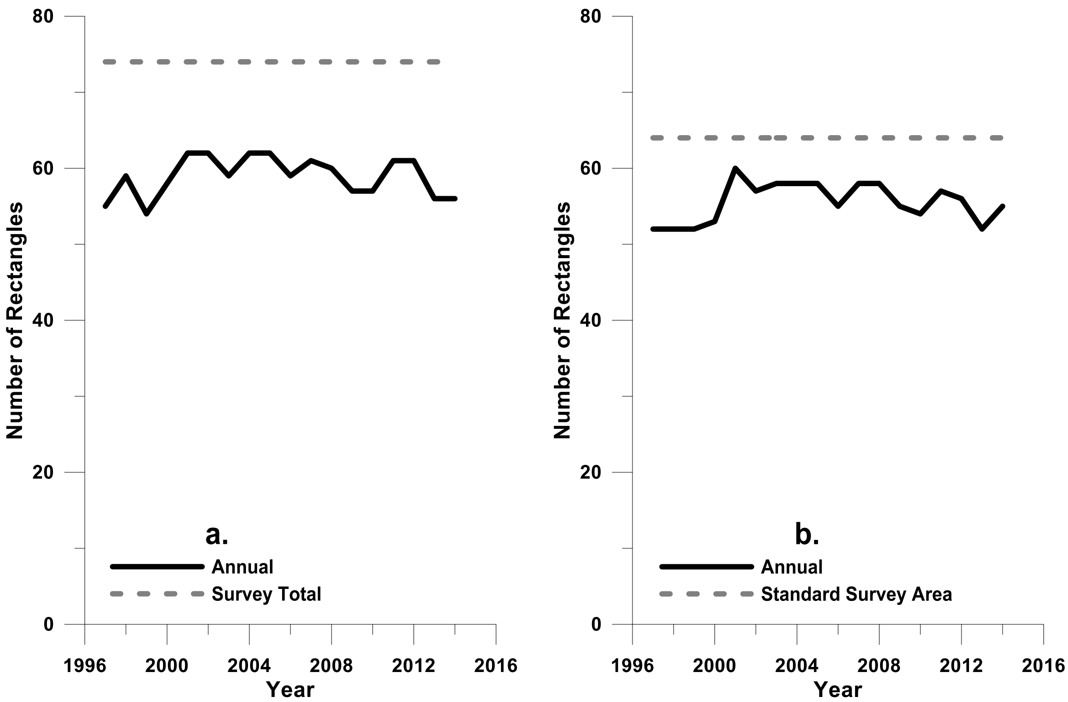

Figure 2.1.2.6.2.5: Trends in the number of ICES statistical rectangles sampled in each year of the French fourth quarter EVHOE Survey (a) in all rectangles sampled and (b) in a standard survey area consisting only of the 64 rectangles sampled in ≥50% of years of the survey time span.

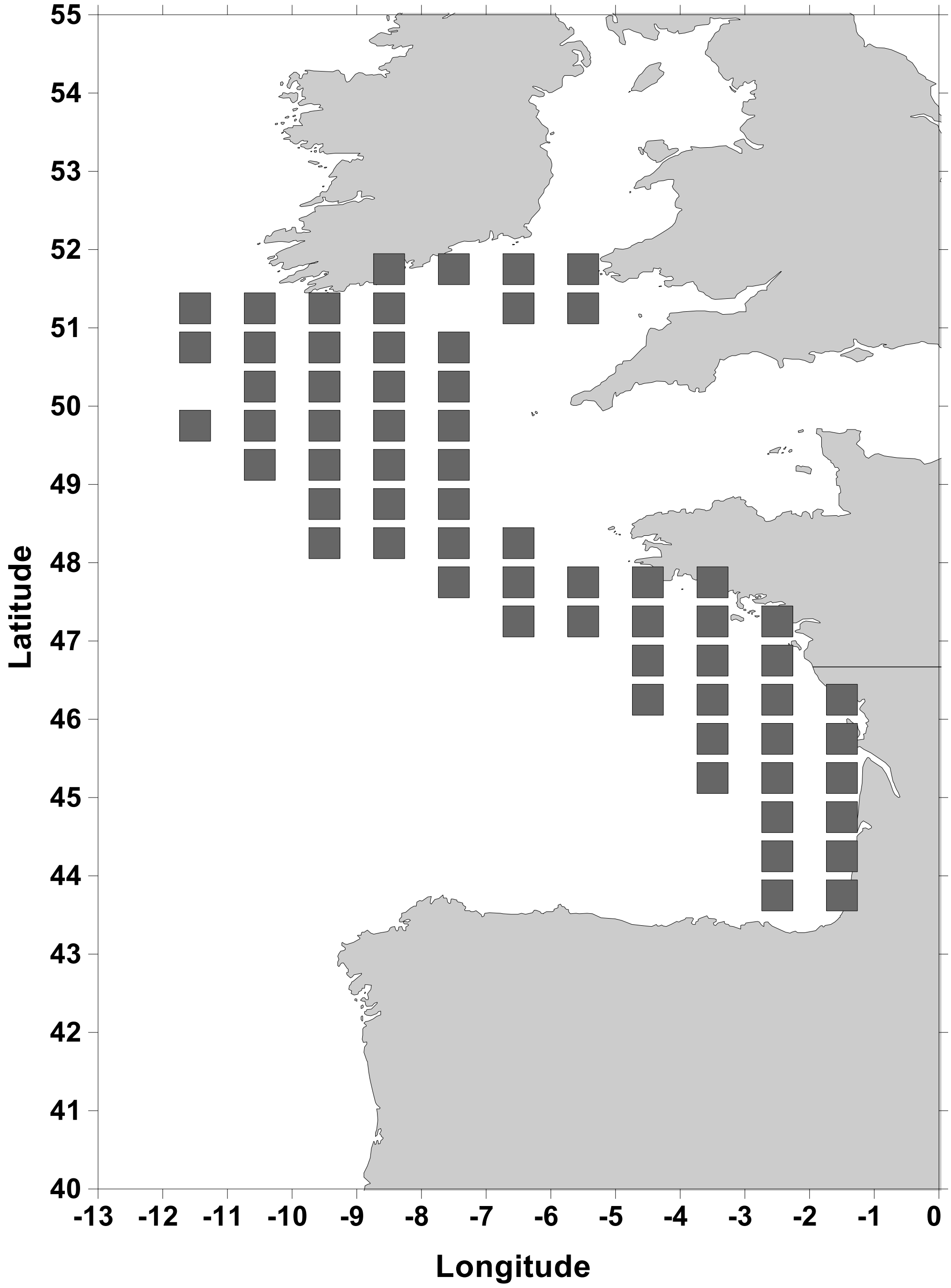

Figure 2.1.2.6.2.6: Chart showing the standard survey area covered by the French fourth quarter EVHOE Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

2.1.3. The Bay of Biscay and Iberian Coast

2.1.3.1. The Fourth Quarter French EVHOE Groundfish Survey (CSBBFraOT4)

2.1.3.1.1. Survey History

This survey operates in both the Celtic Seas and the Bay of Biscay and Iberian Coast subregions (see Figure 2.1). For convenience the history of this single survey has been described in Section 2.1.2.6.1 above.

2.1.3.1.2. Defining the Standard Monitoring Programme

This survey operates in both the Celtic Seas and the Bay of Biscay and Iberian Coast subregions (see Figure 2.1). For convenience derivation of the standard monitoring programme from this single survey time series has been described in section 2.1.2.6.2 above.

2.1.3.2. The Fourth Quarter Spanish Northern Shelf Survey (BBIC(n)SpaOT4)

2.1.3.2.1. Survey History

The Instituto Español de Oceanografía (Spanish Institute of Oceanography: IEO) has performed bottom-trawl sampling in the Atlantic northern continental shelf waters of the Iberian Peninsula since 1974, but only since 1980 has the full area included within ICES Divisions VIII(c) and northern IX(a) been covered and only since 1983 have homogenous sampling protocols been implemented across this area. Two survey series, one in Spring and the second in Autumn, commenced in the 1980s. The latter time series survives to the present day as the Spanish Northern Groundfish Survey. This still covers the continental shelf waters around the north of Spain, including the Cantabrian Sea, and the waters off Galicia, lying mainly in ICES Division VIII(c) and the northern part of IX(a). The survey is primarily carried out in the fourth quarter of the year, but often starts at the end of the third quarter. Hydrographic sampling started in 1993 and has been carried out ever since at each fishing station sampled. In some years radial CTD sampling perpendicular to the coast has been carried out.

The survey uses a standard Baka trawl 44/60 gear with a 43.6 m footrope and a 60.1 m headline. Sweep length was 200 m. Initially, a 20 mm mesh codend cover of was used to prevent the escape of small individuals, but since 1985 this has been replaced by an inner 10 mm mesh codend liner (ICES, 2010a). The usual trawl doors were made of wood, rectangular, weigh 650 Kg and have a surface of 3.6 m² (2.67×1.34 m). The warp diameter is 22 mm (1.9 Kg/m).

The survey has usually been undertaken by the RV "*Cornide de Saavedra*". In 1989 this vessel was renovated from her original length of 56 m and displacement of 990GRT, to the present 67 m and 1133GRT. Because of this renovation there was no survey in 1987 and in 1989 the survey was carried out in the RV "*Francisco de Paula Navarro*"; a smaller stern trawler with reduced fishing power compared to the rest of the time series. Between vessel inter-calibration trials were included in the 1990 survey, and the 1989 abundance indices were subsequently corrected. In 2014, the RV *Miguel Oliver* replaced the RV *Cornide de Saavedra*. The trawl gear used remained the same except that the otter doors were switched to the same Thyboron doors used in the Gulf of Cadiz (see section 2.1.3.3). Inter-calibration work was carried out by both vessels in 2012 and 2013. However, some caution is necessary in interpreting the 2013 data because different sweeps were used and there was some indication that this resulted in larger catches of benthic species.

The survey follows a stratified semi-random design. Stratification involves five geographical zones between the Portuguese border at the Miño river and the French border at the Bidasoa river, followed by further bathymetric depth stratification. Initially depth strata of 30–100 m, 101–200 m, 200– 500 m were used, but following the results of the SESITS project (Sánchez, 1997), these were changed in1997 to 70–120 m, 121–200 m, 201–500 m. This new stratification fitted better the depth distribution of the main fish assemblages in the area. The number of stations per stratum is allocated *pro rata* with stratum area, with an approximate sampling effort of 5.4 hauls for every 1000 km², based on achieving approximately 120 hauls per survey. Following the adoption of the new depth stratification scheme in 1997, haul allocation across all the strata was adjusted to maintain this consistency of sampling effort across the strata. When time permits, further stations are sampled to cover two additional depth strata between 30–70 m and between 500 and 800 m. Surveyed depths, therefore, range from 30 to 800 m. The semi-random design of the survey is intended to ensure adequate coverage of hake nursery areas in different parts of the northern Spanish shelf. Samples taken from water shallower than 70 m were not included in the stratified abundance estimates used in stock assessments (ICES 2013b).

2.1.3.2.2. Defining the Standard Monitoring Programme

Spain does not lodge their complete groundfish survey data sets on the ICES DATRAS portal, reporting only data for the major commercial species required under DCF regulations. For constructing the Standard Monitoring Programme data set, complete data for all fish species sampled were supplied directly by the national data centre, the IEO.

By 12 August 2016, the final version of the survey data had not been received from the IEO so, at this point, it was not possible to analyse data for the BBIC(n)SpaOT4 survey to define the Standard Monitoring Programme or Standard Survey Area. This analysis will be performed once the data are received and the results presented in a subsequent document (Greenstreet and Moriarty 2017), which will include a description of the full groundfish survey monitoring and assessment data product. However, an approach identical to the one adopted for all other otter trawl surveys covered in this document for identifying a standard monitoring programme, in terms of including only standard haul durations (13 minutes to 66 minutes) and establishing the time period over which a standard survey protocol was adopted, and determining a standard survey area for this Spanish survey will again be applied.

2.1.3.3. The First Quarter Spanish Gulf of Cadiz Survey (BBIC(s)SpaOT1)

2.1.3.3.1. Survey History

In 1992, the IEO started a spring series of bottom-trawl surveys in the Gulf of Cádiz, covering an area of approximately (7200 Km^2), with depth ranging from 15 m to 800 m, in the southern part of ICES Division IX(a). The survey used the RV "*Cornide de Saavedra*" up until the change in 2014 to the new vessel, the RV *Miguel Oliver*. No survey was carried out in 2003 because the research vessel was involved in the operation to assess the impact of the "Prestige" oil spill which took place in November 2002 (ICES 2013a). The survey uses a standard Baka trawl 44/60 with a 43.6 m footrope and a 60.1 m headline. In 2008, the traditional wooden rectangular, 650 Kg and 3.6 m^2 trawl doors, used since 1992, also used on the northern shelf survey, were replaced by new Thyboron doors (330 Kg and 1.8 m^2). A sweep length of 200 m was used, except when water depth was shallower than 30 m, when sweep lengths of 100 m were employed. The warp diameter is 22 mm (1.9kg/m) and an 10 mm mesh codend liner is used to prevent the escape of small individuals. Hauls last 60 minutes, timed from the locking of the winches following shooting the net and warp to the start of retrieving the gear. The length of warp shot is based on a power relationship with the depth (warp= $9.062 \times Depth^{0.783}$). Trawl speed is three knots. SCANMAR sensors are fitted to monitor net geometry. Vertical net opening generally varies around 1.8–2 m, horizontal opening around 17–21 m, and door-spread is approximately 107 m; all varying with depth. Since 2004, depth, water temperature and salinity have been recorded by CTD situated on the net. The sampling design is random stratified based on five depth strata (15–30 m, 31–100 m, 101–200 m, 201–500 m and 501–800 m). Forty-two fishing stations are allocated pro rata across the five strata relative to the area of each stratum (ICES 2013b).

2.1.3.3.2. Defining the Standard Monitoring Programme

Spain does not lodge their complete groundfish survey data sets on the ICES DATRAS portal, reporting only data for the major commercial species required under DCF regulations. For constructing the Standard Monitoring Programme data set, complete data for all fish species sampled were supplied directly by the national data centre, the IEO.

By 12 August 2016, the final version of the survey data had not been received from the IEO so, at this point, it was not possible to analyse data for the BBIC(s)SpaOT1 survey to define the Standard Monitoring Programme or Standard Survey Area. This analysis will be performed once the data are received and the results presented in a subsequent document (Greenstreet and Moriarty 2017), which will include a description of the full groundfish survey monitoring and assessment data product. However, an approach identical to the one adopted for all other otter trawl surveys covered in this document for identifying a standard monitoring programme, in terms of including only standard haul durations (13 minutes to 66 minutes) and establishing the time period over which a standard survey protocol was adopted, and determining a standard survey area for this Spanish survey will again be applied.

2.1.3.4. The Fourth Quarter Spanish Gulf of Cadiz Survey (BBIC(s)SpaOT4)

2.1.3.4.1. Survey History

Data are available from 1997 for the fourth quarter Gulf of Cadiz. The survey uses the same vessel as Quarter 1 described in Section 2.1.3.3.1 above. Survey is essentially the same as described above for the first quarter survey (ICES 2013b).

2.1.3.4.2. Defining the Standard Monitoring Programme

Spain does not lodge their complete groundfish survey data sets on the ICES DATRAS portal, reporting only data for the major commercial species required under DCF regulations. For constructing the Standard Monitoring Programme data set, complete data for all fish species sampled were supplied directly by the national data centre, the IEO.

By 12 August 2016, the final version of the survey data had not been received from the IEO so, at this point, it was not possible to analyse data for the BBIC(s)SpaOT4 survey to define the Standard Monitoring Programme or Standard Survey Area. This analysis will be performed once the data are received and the results presented in a subsequent document (Greenstreet and Moriarty 2017), which will include a description of the full groundfish survey monitoring and assessment data product. However, an approach identical to the one adopted for all other otter trawl surveys covered in this document for identifying a standard monitoring programme, in terms of including only standard haul durations (13 minutes to 66 minutes) and establishing the time period over which a standard survey protocol was adopted, and determining a standard survey area for this Spanish survey will again be applied.

The area covered by the Spanish northern shelf survey and the two Gulf of Cadiz surveys is illustrated in Figure 2.1.3.4.2.1

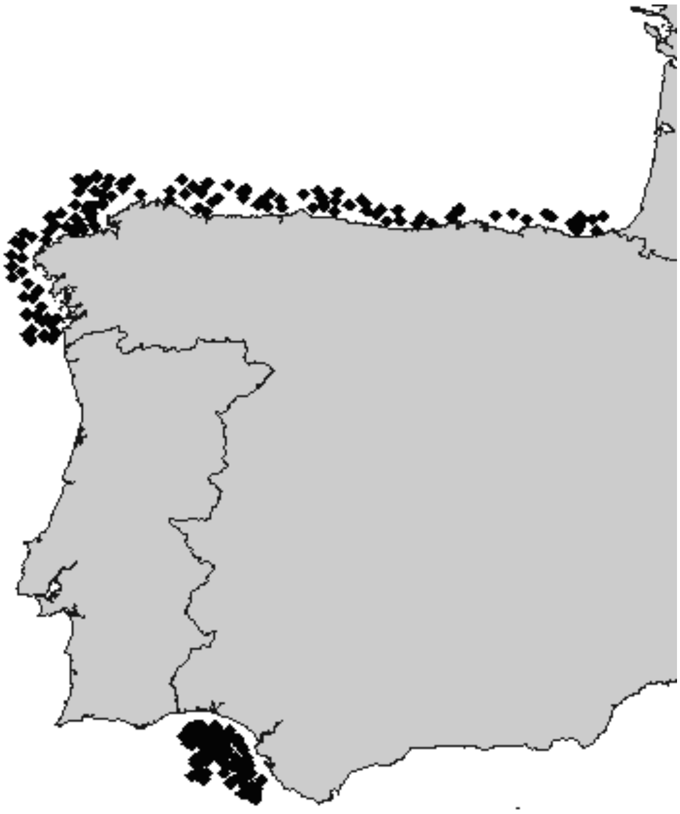

Figure 2.1.3.4.2.1: Spatial coverage of the three surveys carried out by Spain using the Standard Baca Trawl Surveys in the Cantabrian Sea and Off Galicia and Gulf of Cadiz.

2.1.3.5. The Fourth Quarter Portuguese Groundfish Survey (BBICPorOT4)

2.1.3.5.1. Survey History

Portugal has carried out ground fish trawl sampling in Portuguese continental waters, in ICES Division IX(a), since 1979, but the current survey protocol has only been in place since 2005. The area surveyed extends from latitude 41°20'N to 36°30'N, with depths ranging from 20 to 500 meters. The surveys, mainly conducted in October at the beginning of the fourth quarter of the year, are carried by the RV "*Noruega*", a stern trawler of 47.5 m length, 1500 hp and 495 GTR, using a Norwegian Campell Trawl (NCT) 1800/96 bottom otter trawl fitted with a 20 mm mesh size codend. This gear is characterised by having a ground-rope with bobbins. The mean vertical net opening is 4.6 m and the mean horizontal distance between the net wings and the otter doors is 15.1 m and 44.4 m respectively. Polyvalent trawl doors are used; these are rectangular (2.7 m x 1.58 m) with an area of 3.75 m^2 and weigh 650 kg. The DATRAS portal includes data for samples collected in 2003 and 2004, but in these years a different vessel and trawl gear (bottom trawl FGAV019) was used. These data were excluded from the data product. Data were also collected in 2002, but in this year, the same vessel and trawl gear was used as in 2005 and all subsequent years. These 2002 data were, therefore, included in the data product.

The present sampling design, implemented in 2005, uses a combination of systematic and stratified random sampling, aimed at facilitating geostatistical modelling and improved estimation of variance. The current strata permit comparison with the 48 strata used formerly. The new sampling scheme includes depths from 20 m to 500 m, the main objective of the survey being to derive estimate recruitment indices for hake and horse mackerel. A mixed sampling scheme composed of 66 trawl positions distributed over a fixed 5' by 5' NM grid which correspond to earlier trawl positions and 30 additional random trawl positions. Tow duration is 30 minutes. Survey design in 2002 was similar enough to the design adopted from 2005 onwards as to still retain the 2002 data as part of the standard monitoring programme.

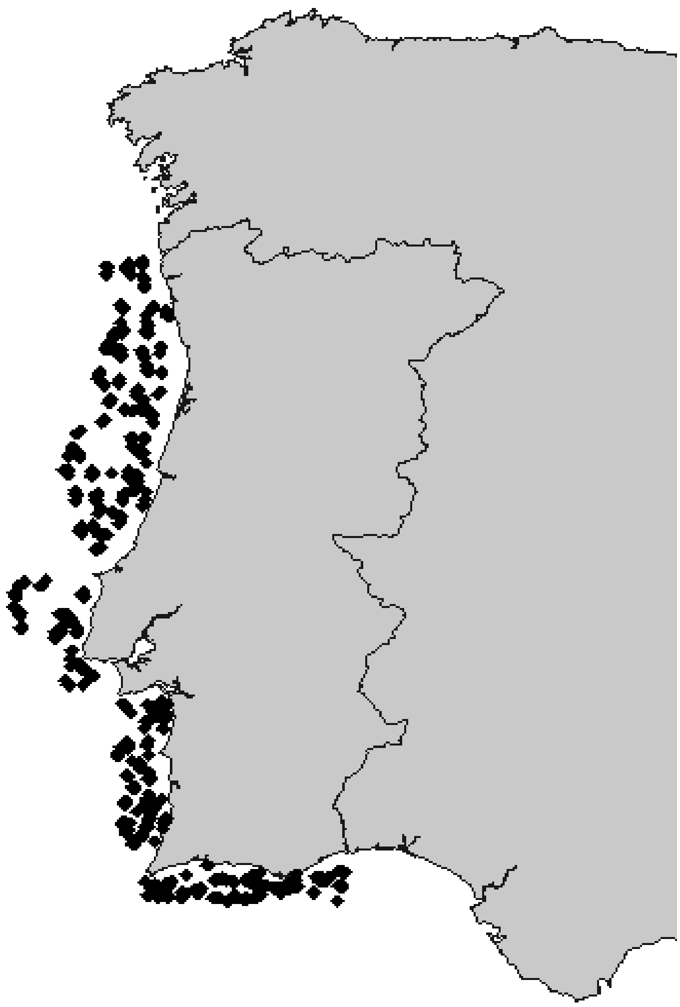

Figure 2.1.3.5.1.1: Spatial coverage groundfish surveys carried out by Portugal Portuguese Atlantic continental shelf waters using Norwegian Campbell otter trawl.

2.1.3.5.2. Defining the Standard Monitoring Programme

Although ostensibly a fourth quarter survey, some sampling occurred in September, i.e. in the third quarter (Figure 2.1.3.5.2.1). In 2008 all the survey was carried out in September, while in 2006 and 2007 approximately one third of the survey was undertaken in September. For these records, following the approach described previously, the quarter field was changed to four, to refect the ‘naming’ of the survey rather than the time of year when the samples were actually collected. Minimum haul duration was 15 minutes and maximum was 35 minutes; 91% of all trawl samples were 30 minutes duration (Figure 2.1.3.5.2.2). No samples were excluded from the standard monitoring programme on the basis of being out-of-bounds in terms of haul duration. The proportion of nominal 30 minutes duration hauls showed no trend over the survey time series (Figure 2.1.3.5.2.3) and survey sampling effort, both in terms of the number of trawl samples collected each year (Figure 2.1.3.5.2.3) and the number of days allocated to the survey (Figure 2.1.3.5.2.4), also remained relatively consistent over the period. This having been said, survey duration was relatively short, and the number of samples collected less, in 2002; the year when the survey was prosecuted by the RV “*Noruega*” and using the Norwegian Campell Trawl prior to the establishment of the full survey protocol and the routine use of this vessel and gear.

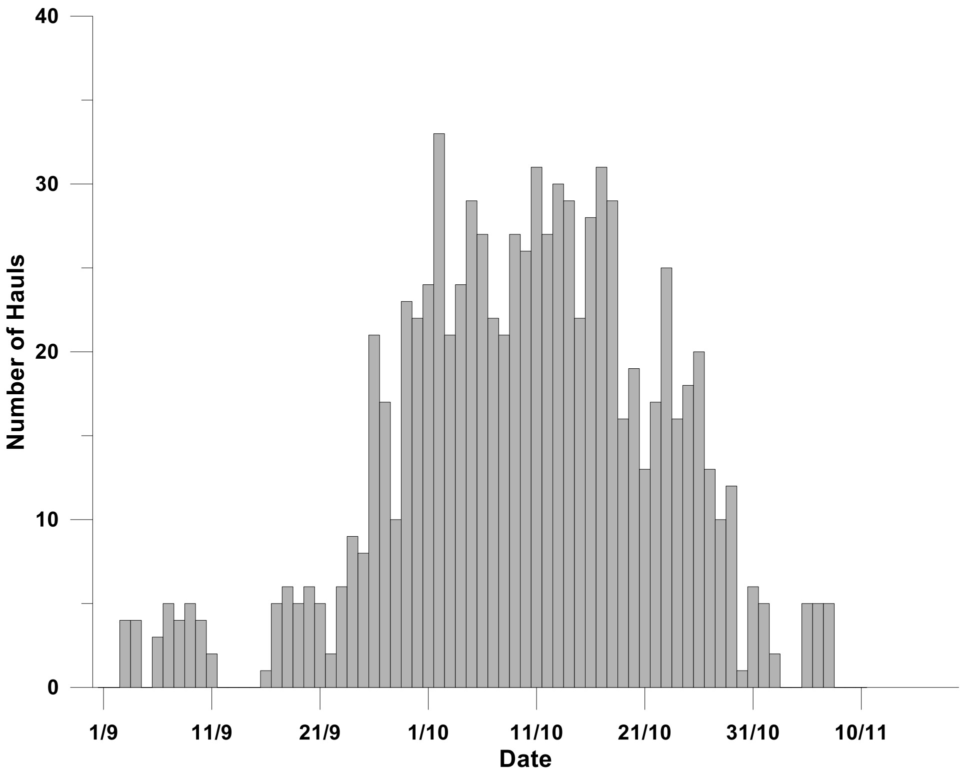

Figure 2.1.3.5.2.1: Frequency distribution of hauls over all years of the Portuguese forth quarter Atlantic continental shelf Survey by date (day/month).

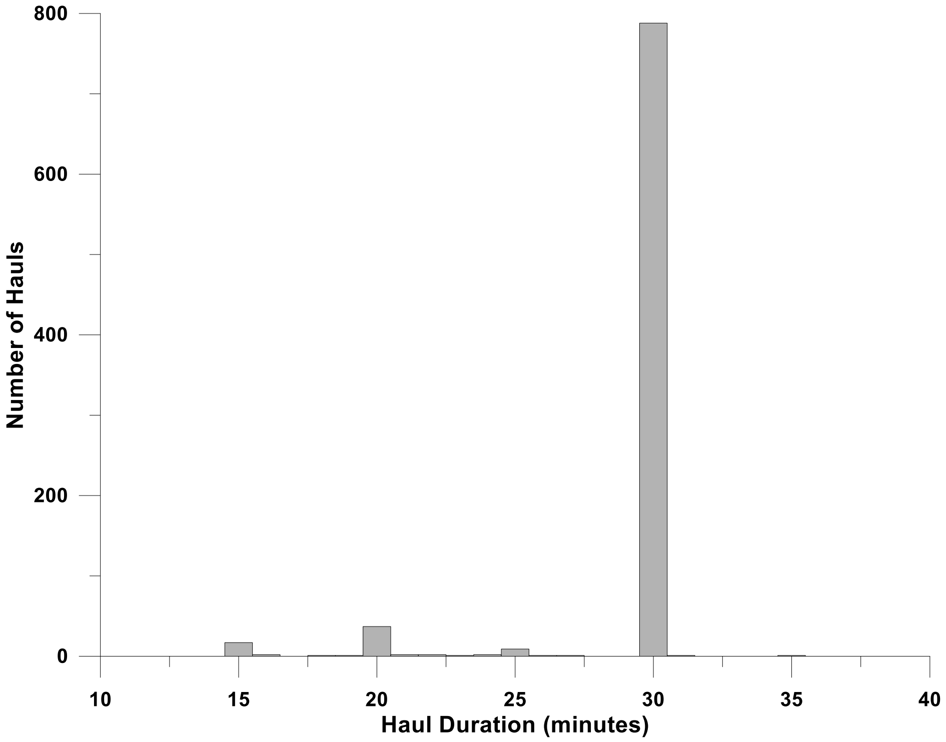

Figure 2.1.3.5.2.2: Frequency distribution for hauls durations for NCT otter trawl samples collected by the Portuguese forth quarter Atlantic continental shelf Survey.

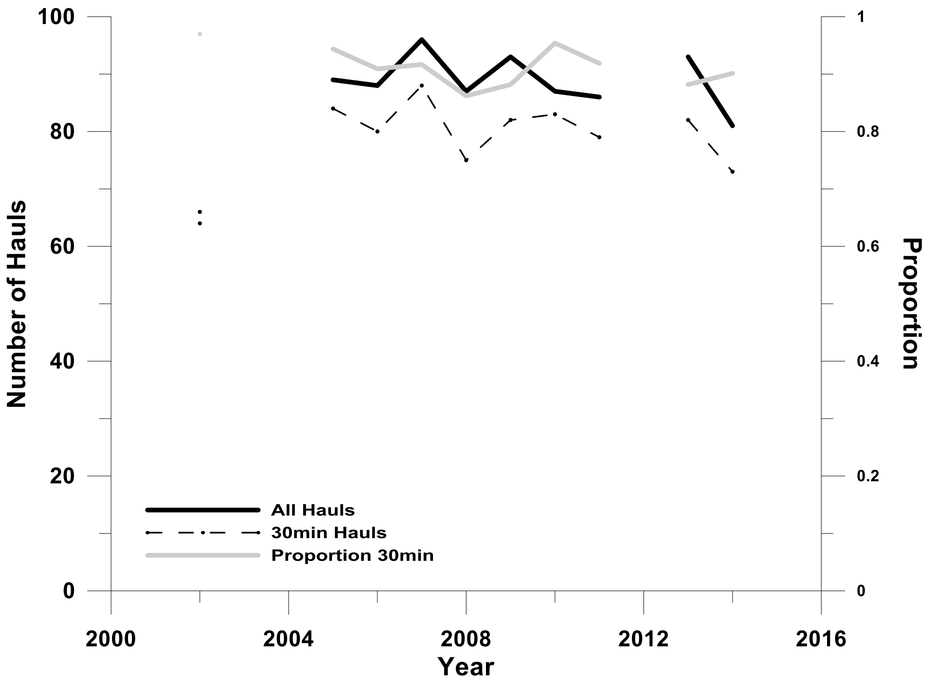

Figure 2.1.3.5.2.3: Trends in the number of all NCT trawl samples collected during the Portuguese forth quarter Atlantic continental shelf Survey in each year, and the number of these hauls that were a nominal 30 ± 4 minutes duration. The proportion of all hauls in each year that was of nominal 30 minutes duration is also shown.

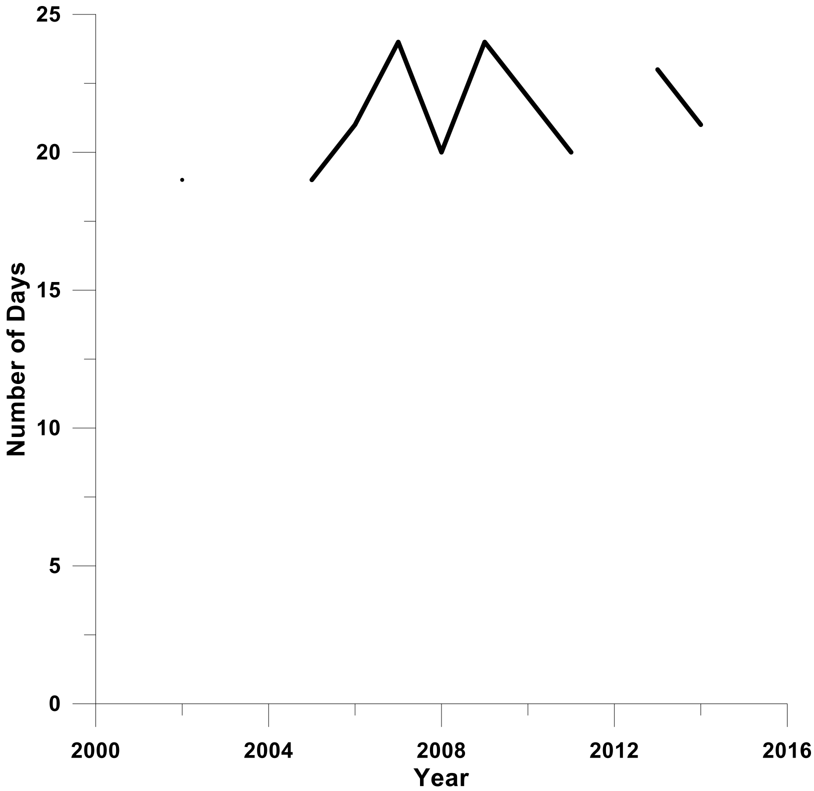

Figure 2.1.3.5.2.4: Variation in the number of days trawl sampling in each year over the course of the Portuguese forth quarter Atlantic continental shelf Survey.

Over the full course of the survey, 22 ICES statistical rectangles were sampled in total, but only 20 of these were sampled in at least 50% of years that the survey was carried out, and the majority of these 20 rectangles were sampled every year (Figure 2.1.3.5.2.5). These 20 rectangles, therefore, constituted the BBICPorQ4 standard survey area and their locations are charted in Figure 2.1.3.5.2.6.

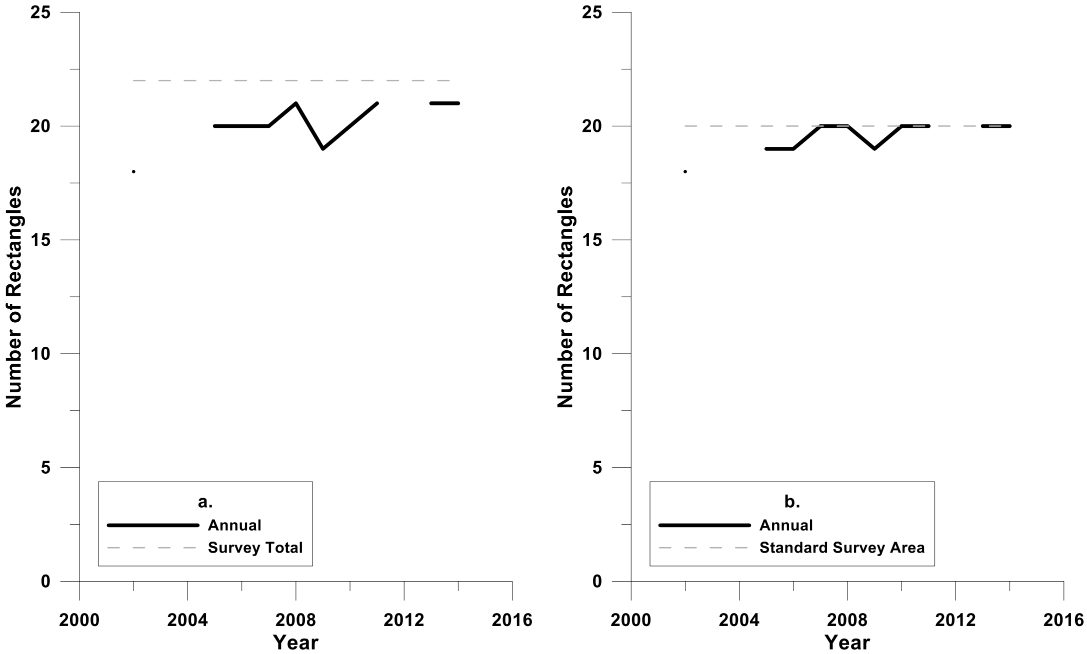

Figure 2.1.3.5.2.5: Trends in the number of ICES statistical rectangles sampled in each year of the Portuguese forth quarter Atlantic continental shelf Survey (a) in all rectangles sampled and (b) in a standard survey area consisting only of the 20 rectangles sampled in ≥50% of years of the survey time span.

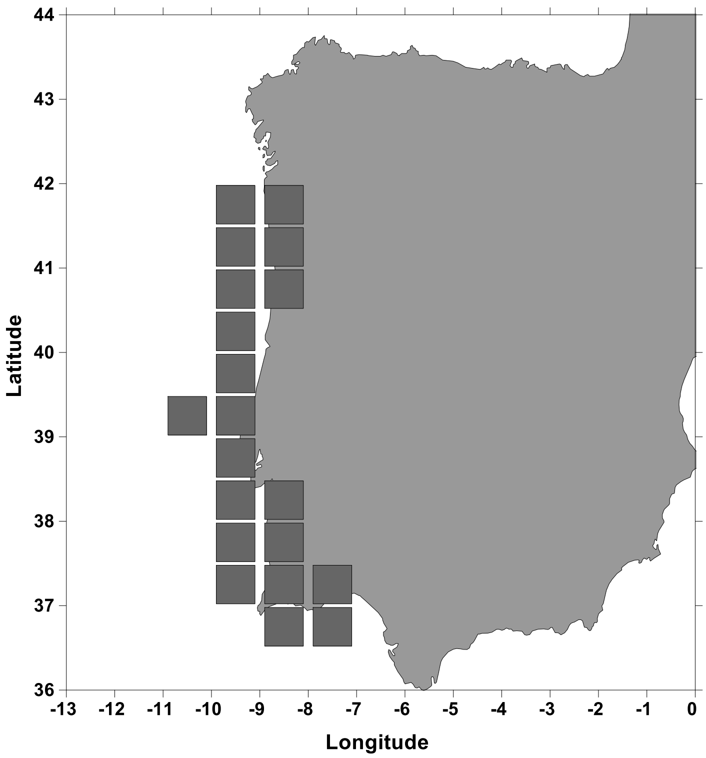

Figure 2.1.3.5.2.6: Chart showing the standard survey area covered by the Portuguese forth quarter Atlantic continental shelf Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

2.1.4. The Wider Atlantic

2.1.4.1. The Third Quarter Scottish Rockall Survey (WAScoOT3)

2.1.4.1.1. Survey History

The Scottish Rockall Survey covers a relatively small area within approximately eight ICES statistical rectangles. Trawl stations are on known clear tows and vary between two and eight per rectangle depending on the proportion of the area inside 250 m. Initially survey was undertaken biennially, more recently it is undertaken annually. The gear deployed on all the Scottish surveys is the 36/47 GOV trawl fitted with heavy groundgear 'C' and a 20 mm internal liner. The vessel undertaking this survey changed to *Scotia III* in March 1999 from the previous *Scotia II*. The gear includes a full suite of SCANMAR sensors; headline height, wing and door spread and speed through the water (ICES 2013b). Trawl duration is nominally 30 minutes at a nominal trawl speed of 4 knots.

2.1.4.1.2. Defining the Standard Monitoring Programme

This survey has always operated between 25 August and 16 September, so all samples have been collected in the first half of the third quarter (Figure 2.1.4.1.2.1). All trawl samples were between 14 minutes and 52 minutes duration with 93% being 30 minutes long (Figure 2.1.4.1.2.2). No other duration modes were apparent and no samples were excluded from the standard monitoring programme on the basis of abnormal duration. Over the course of the survey time series there has been no trend in the number of trawl samples collected annually (Figure 2.1.4.1.2.3), the proportion of these that were of nominal 30 minutes duration (Figure 2.1.4.1.2.3), or in the number of days allocated to the survey (Figure 2.1.4.1.2.4). However, in 2003, an extra day or two was allocated to the survey and this was reflected in the number of samples collected (Figure 2.1.4.1.2.3), but not in the number of ICES statistical rectangles sampled (Figure 2.1.4.1.2.5).

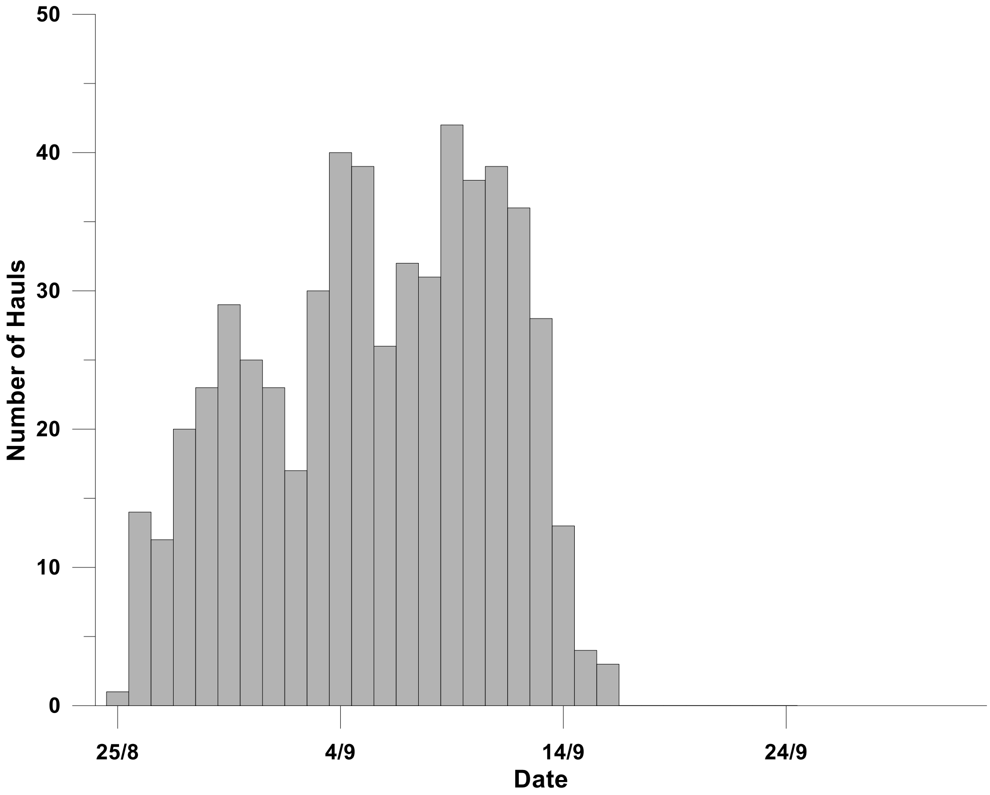

Figure 2.1.4.1.2.1: Frequency distribution of hauls over all years of the Scottish third quarter Rockall Survey by date (day/month).

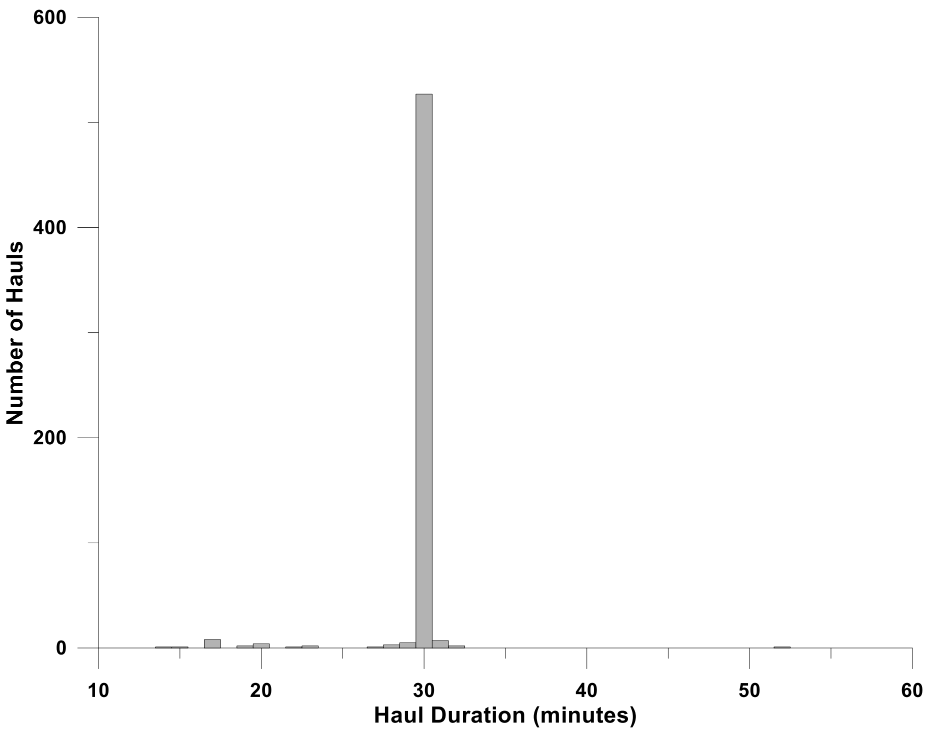

Figure 2.1.4.1.2.2: Frequency distribution for hauls durations for GOV otter trawl samples collected by the Scottish third quarter Rockall Survey.

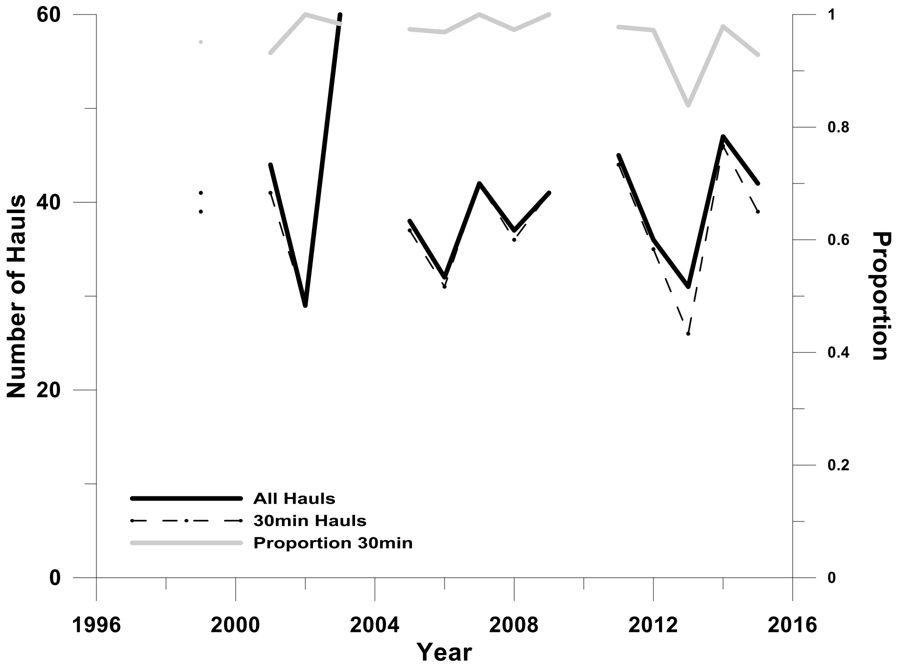

Figure 2.1.4.1.2.3: Trends in the number of all GOV trawl samples collected during the Scottish third quarter Rockall Survey in each year, and the number of these hauls that were a nominal 30 ± 4 minutes duration. The proportion of all hauls in each year that was of nominal 30 minutes duration is also shown.

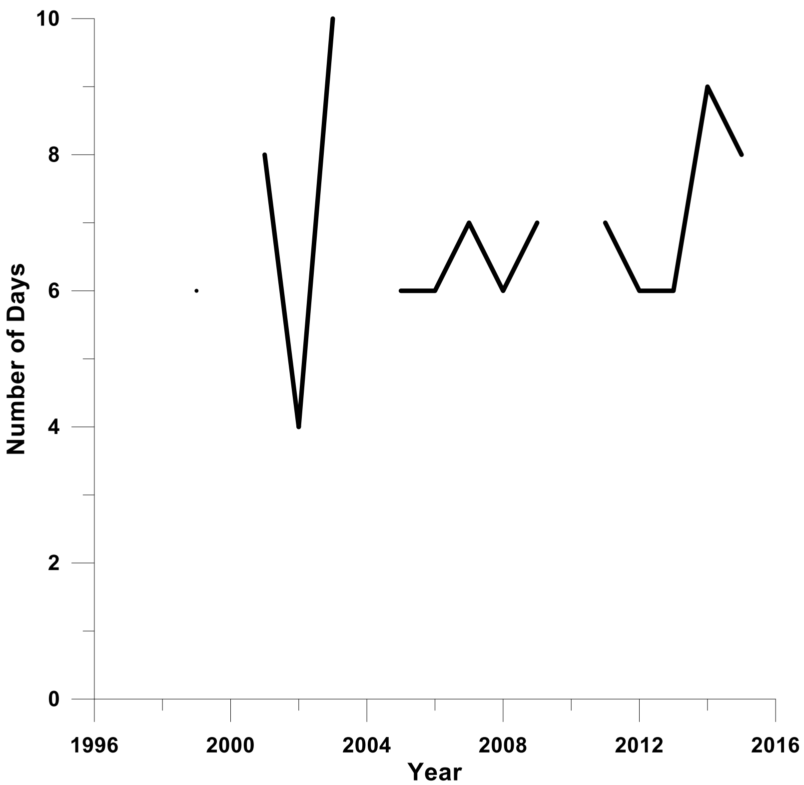

Figure 2.1.4.1.2.4: Variation in the number of days trawl sampling in each year over the course of the Scottish third quarter Rockall Survey.

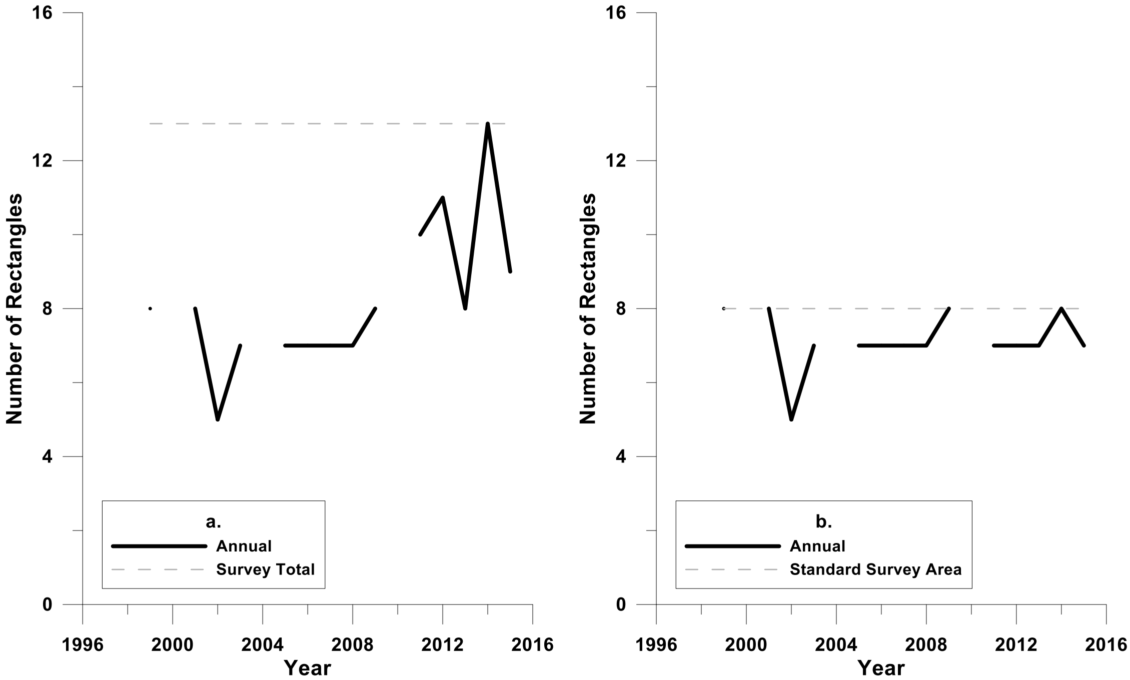

Figure 2.1.4.1.2.5: Trends in the number of ICES statistical rectangles sampled in each year of the Scottish third quarter Rockall Survey (a) in all rectangles sampled and (b) in a standard survey area consisting only of the eight rectangles sampled in ≥50% of years of the survey time span.

Over the course of the survey period a total of 13 ICES statistical rectangles was sampled, but the number sampled in any one year was much less (Figure 2.1.4.1.2.5). Only eight rectangles met the 50% of years criterion, so constituting the standard survey area for the WAScoOT3 survey (Figure 2.1.4.1.2.5). These eight rectangles are charted in Figure 2.1.4.1.2.6 and were mostly sampled every year that the survey operated. Figure 2.1.4.1.2.5 suggests a tendency in latter years for more ICES statistical rectangles to be sampled.

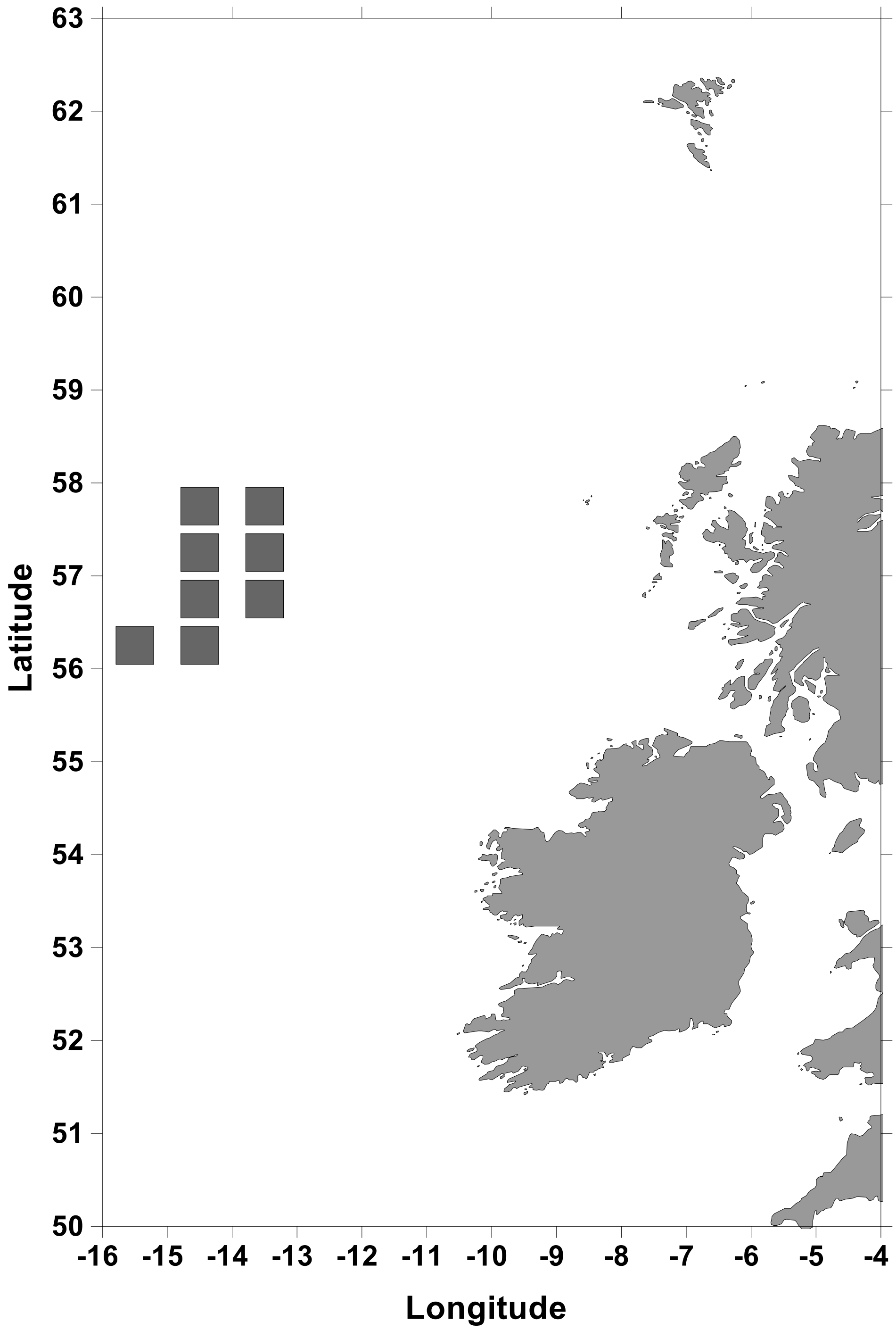

Figure 2.1.4.1.2.6: Chart showing the standard survey area covered by the Scottish third quarter Rockall Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

2.1.4.2. The Third Quarter Spanish Porcupine Bank Survey (WASpaOT3)

2.1.4.2.1. Survey History

In 2001 the IEO commenced a series of bottom-trawl surveys in the Porcupine Bank to address the lack of scientific information regarding the state of the stocks in an area that was included in the IBTS Western Area. This has become known as the Spanish Porcupine Bank groundfish survey, and it is carried out at the end of the third quarter of the year and into the start of the fourth quarter. The survey covers the Porcupine Bank and adjacent area in western Irish waters from longitude 12°W to 15°W and from latitude 51°N to 54°N, in ICES Division VII(c2), VII(k2), and in depths of between 180 m and 800 m. The survey is carried out by the RV "*Vizconde de Eza*", a stern trawler of 53 m length, 13.5 m beam and gross tonnage of 1400 t, using a Porcupine Baca 40/52 with 250 m length sweeps, a 39.46 m footrope and a 51.96 m headline. The otter boards are oval weighing 800 kg and have a 4.5 m^2 surface area. The warp diameter is 20 mm, sweep diameter is 55 mm and the groundrope diameter is 98 mm with a double synthetic coat. The codend mesh size is 20 mm (ICES 2013b).

The original stratification on which the sampling design was based was determined from commercial catch observer data collected in the previous years. This stratification combined two geographical sectors, one in the outer part (W-NW) of the bank and the other in the inner part (E-SW) surrounding the Porcupine Seabight, with three depth strata <200 m, 200–400 m and 400–800 m. However, taking account of the data obtained from the first two surveys in the area (Velasco and Serrano, 2003), a new stratification was adopted in 2003 that better reflected observed bottom-trawl faunal assemblages in the area. The whole area, covering (45,880 Km^2, is now divided into two geographical sectors and three depth strata, <300 m, 300–450 m and 450–800 m. Given that the southern geographical sector has no water shallower than 300 m, this gives rise to five strata. Sampling follows a stratified random design, with the 80 samples collected each year allocated across the strata *pro rata* to stratum area constrained by a buffered random sampling procedure (Kingsley et al., 2004) to avoid selection of adjacent 5×5 nm rectangles and ensure a minimum of two stations per stratum (ICES 2013b).

2.1.4.2.2. Defining the Standard Monitoring Programme

Spain does not lodge their complete groundfish survey data sets on the ICES DATRAS portal, reporting only data for the major commercial species required under

DCF regulations. For constructing the Standard Monitoring Programme data set, complete data for all fish species sampled were supplied directly by the national data centre, the IEO.

By 12 August 2016, the final version of the survey data had not been received from the IEO so, at this point, it was not possible to analyse data for the WASpaOT3 survey to define the Standard Monitoring Programme or Standard Survey Area. This analysis will be performed once the data are received and the results presented in a subsequent document (Greenstreet and Moriarty 2017), which will include a description of the full groundfish survey monitoring and assessment data product. However, an approach identical to the one adopted for all other otter trawl surveys covered in this document for identifying a standard monitoring programme, in terms of including only standard haul durations (13 minutes to 66 minutes) and establishing the time period over which a standard survey protocol was adopted, and determining a standard survey area for this Spanish survey will again be applied.

2.2. The Beam Trawl Surveys

In this section the various beam trawl based surveys are described, along with the process used to determine the subset of data that constitutes ‘the standardised monitoring programme’ for each survey. The surveys are considered subregion by subregion. No beam trawl survey data are available for the Bay of Biscay and Iberian Coast and Wider Atlantic subregions. Five countries, the Netherlands, Germany, England, France and Belgium, undertake beam trawl survey in the Greater North Sea and Celtic Seas subregions, but only the first three submit their data to the DATRAS portal; the French and Belgian data are only available from their respective national data centres. Currently French and Belgian data are not included in the MSFD Groundfish Survey Monitoring and Assessment data product, and only the Dutch, German and English surveys are described here. Spatial coverage by these three beam trawl surveys combined is illustrated in Figure 2.2.1. All the major beam trawl surveys were initially intended to address fisheries management and commercial stock assessment issues.

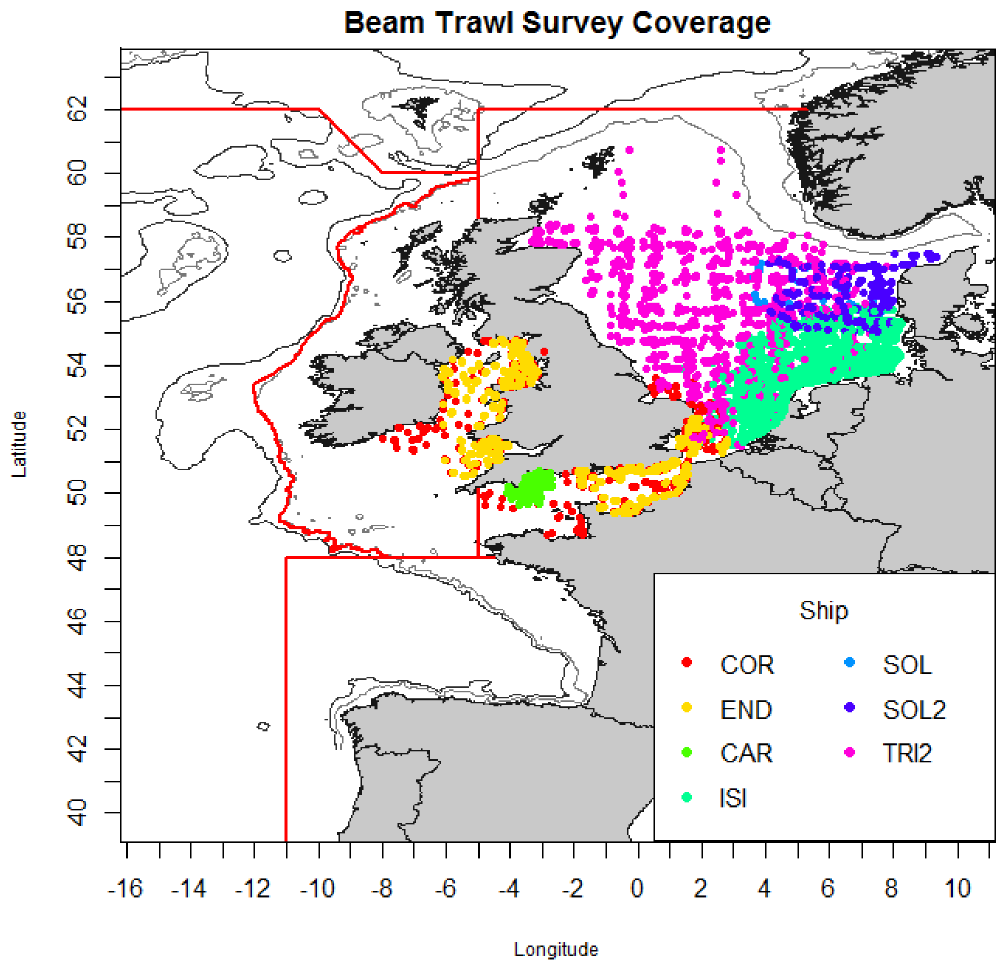

Figure 2.2.1: Spatial coverage by the four national beam trawl surveys operating in the North Sea, English Channel Celtic Sea, St George's Channel and the Irish Sea. Colour coding indicates the research vessels involved (Germany: *Solea I* (SOL) and *Solea II* (SOL2); The Netherlands: *Tridens II* (TRI2) and *Isis* (ISI); England : *Corystes* (COR) *Endevour* (END) and *Carhelmar* (CAR)) (ICES, 2009a).

2.2.1. The Greater North Sea

2.2.1.1. The Third Quarter Netherlands Beam Trawl Survey (GNSNetBT3)

2.2.1.1.1. Survey History

The Dutch offshore beam trawl survey started in 1985 with RV "*Isis*". At this time the sampling distribution was predominantly coastal in the Dutch EEZ. In 1996, *Tridens II* started carrying out a beam trawl survey with stations located much further into the Central North Sea. Originally, *Tridens* had been involved in the quarterly IBTS surveys undertaken through the early 1990s (see Section 2.1.1.2), but when this level of survey effort could no longer be sustained, and the second and fourth quarter surveys ceased, it seemed more appropriate for the Dutch research vessel to continue third quarter survey effort using a beam trawl to better sample the flatfish species that are the mainstay of the Dutch fishing industry. In 1996 and 1997 part of the IBTS Q3 was, therefore, given up to fish with a beam trawl in the Central North Sea. From 1998 onwards, the entire third quarter Dutch survey effort consisted of beam trawl survey and the area covered has expanded to include as much of the North Sea that can reasonably be sampled by a beam trawl (i.e. with suitable seafloor characteristics) as possible.

The principal goal of the Dutch survey was to determine fisheries independent indices for plaice and sole in the Southeastern North Sea, with a secondary objective to collect abundance at length data on all fish species sampled. More recently data from the epifaunal benthic invertebrate bycatch has also been recorded to support broader ecosystem research (ICES, 2009a). The fisheries independent indices for plaice and sole from this survey are used by the ICES North Sea demersal working group (WGNSSK) (ICES, 2009a).

2.2.1.1.2. Defining the Standard Monitoring Programme

The HH file for the Beam Trawl Survey, downloaded from the DATRAS portal on 29/10/2015 at 11:59 hours contained a total of 7,897 records. The single database on DATRAS contains data collected by three different countries, The Netherlands, Germany and England, each using a different beam trawl and ground-gear set up. Determining the extent to which these individual data sets can be combined to derive a single monitoring data product is, therefore, a key issue that needs to be addressed. The data were examined to define specific monitoring programme data time-series. The database held records for 3919 Dutch, 3364 English and 614 German samples.

Many fields in the Beam Trawl HH database appear superfluous. The fields SweepLngt, GearExp, DoorType, Stratum, WarpDen, DoorWgt, WingSpread, Buoyancy, KiteDim, WgtGroundRope, Thermocline, ThClimeDepth held -9 null values in all records, while the fields WarpDia, DoorSurface, DoorSpread, BotCurDir, and BotCurSpeed held either the same -9 null value or a value of one in all records. In the case of the latter, the value one was mistakenly entered as a null value. These redundant fields in the beam trawl survey data base reflect the fact that this data structure was originally that used for the IBTS data. Two other fields, StdSpecRecCode and BycSpecRecCode hold the value onr in all records. This value holds meaning, but since all the values are the same, these two fields are also redundant. This reflects the WGBEAM decision to sort the full catch and report on all species (ICES, 2009a)

Dutch data are available for the period 1987 to 2015, but in reality these data consist of two separate time series. The first, from 1987 to 2015 (29y) collected by the research vessel "*Isis*", consists of relatively high spatial intensity data (average of 2.9 trawl samples per ICES statistical rectangle in each year) collected from a relatively limited area in the southeastern North Sea. A total of 44 ICES statistical rectangles were sampled at some point in time by the RV "*Isis*" over the whole time series, but the maximum number of rectangles sampled in any one year was 39. In 2010, RV "*Isis*" broke down after collecting only 16 rectangles and RV "*Tridens*" completed the RV "*Isis*" survey programme using the same ground gear that RV *Isis* would have used. The second time series, from 1996 to 2015 (20y) collected by the RV "*Tridens II*", consists of lower spatial intensity data (average of 1.0 trawl samples per ICES statistical rectangle in each year) collected from a much wider area covering the central and southern North Sea. A total of 114 ICES statistical rectangles were sampled at some point in time by the RV "*Tridens II*" during the entire time series, but the maximum number of rectangles sampled in any one year was 75, while in 1996 and 1997 only 44 and 43 rectangles respectively were sampled. In both these years, RV "*Tridens*" was also involved in the third quarter IBTS (GNSIntOT3).

Both time series used the same eight-metre beam trawl (in fact two 8 m beam trawls were deployed, but data were only recorded from one). It is likely that the same ground gear (eight tickler chains and a flip rope) was always used in both time series. The Tickler field only contained the value eight, whereas the rigging code contained the values F or -9 (a null entry). RV *Isis* records always had -9 entries except in 2002 when all entries were F, while RV *Tridens II* records held -9 from 1996-2001, and again in 2003 and 2010, and F in 2002-2015. Thus *RV Tridens II* records held both and 'F' entries in 2003 and 2010. However, the RV "*Tridens*", when fishing its usual stations, had a flip up rope fitted to the beam trawl, whilst this was not the case in the stations sampled by RV "*Isis*". ICES (2009a) suggest that these two seemingly separate time series can be combined to derive a single North Sea scale monitoring programme data product, but some catchability comparisons would be useful to confirm this.

- The Dutch beam trawl surveys consist of 2,547 RV "*Isis*" samples and 1,372 RV "*Tridens" II* samples.

The predominant trawl duration on both Dutch RVs was 30 minutes, but modes at other time spans, for example 15 minutes, 20 minutes and 25 minutes, were also evident (Figure 2.2.1.1.2.1). Figure 2.2.1.1.2.2 shows temporal variation in both the total number of hauls, and the number of nominal 30 ± 4 minutes trawl samples collected each year by each vessel. The standard tow duration was clearly 30 minutes, but a sufficient number of shorter and longer duration hauls was also collected as to cause potential problems were these samples to be excluded from the Greater North Sea Quarter 3 Dutch Beam Trawl Monitoring Programme. Furthermore, distinct year-to-year variation in the proportion of hauls of nominal 30 minute duration meant that such problems would have been especially prevalent in certain years.

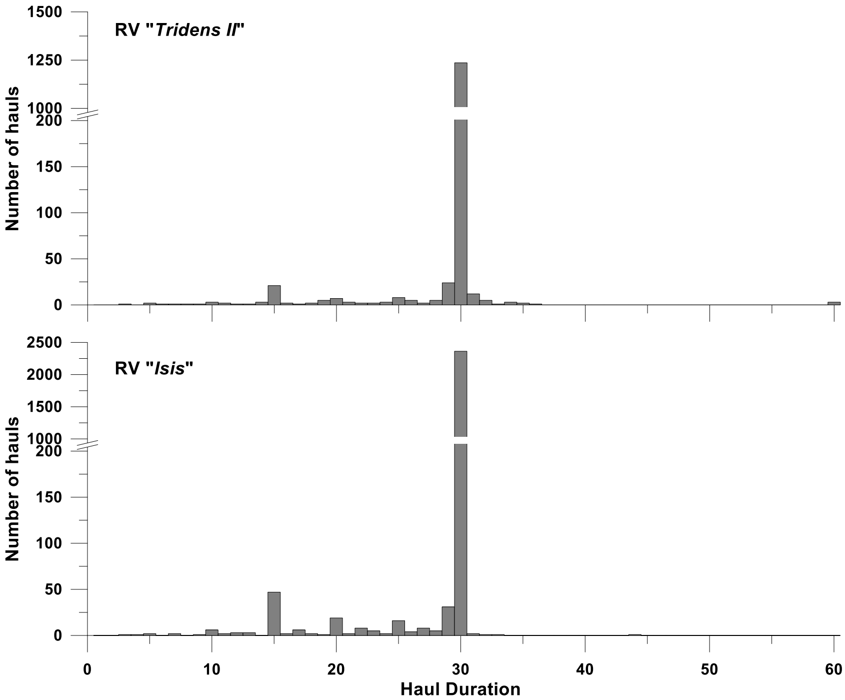

Figure 2.2.1.1.2.1: Frequency distribution of haul durations for beam trawl samples collected by the Dutch research vessels *Isis* and *Tridens II*.

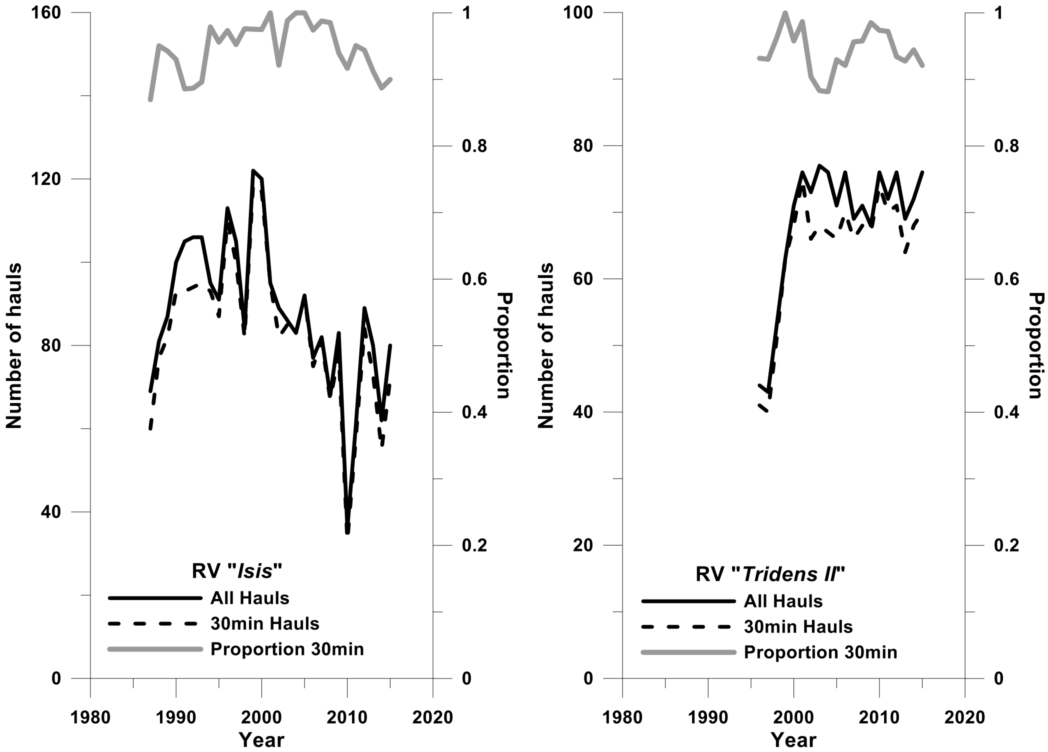

Figure 2.2.1.1.2.2: Trends in the number of all beam trawl samples collected by the Dutch research vessels "*Isis*" and "*Tridens II*" in each year, and the number of these hauls that were a nominal 30 minutes (±4 minutes) duration. The proportion of all hauls in each year that were of nominal 30 minutes duration is also shown.

- A range of haul durations must be accepted, including hauls of between 13 minutes and 66 minutes duration. Thus extreme short- and long-duration hauls would be excluded. The rule applied is essentially that hauls of nominal 15 minutes to 60 minutes duration, allowing a range of ±10% of these values to take account of operational variability, are deemed acceptable. Excluding all extreme long- and extreme short-duration hauls from the Greater North Sea Quarter 3 Dutch Beam Trawl Monitoring Programme data product further reduces the number of available trawl samples to 2,529 records for RV "*Isis*" and 1,359 records for RV "*Tridens II*".

The minimum number of ICES statistical rectangles sampled with hauls of this valid duration range by RV *Isis* was 16 in 2010, while the maximum was 38 in 1992 and 1993. Similarly, RV *Tridens* II sampled only 42 rectangles in 1997 and a maximum of 75 rectangles in 2012 and 2015. Over the full span of each time series, 44 rectangles were sampled by RV *Isis* and 114 were sampled by RV *Tridens II* (Figure 2.2.1.1.2.3). These data suggest appreciable year-to-year variation in spatial coverage; variation that was closely linked to year-to-year variation in total survey effort (Figure 2.2.1.1.2.2). Figures 2.2.1.1.2.2 and 2.2.1.1.2.3 suggest that total sampling effort and overall spatial coverage both increased during the first two to three years of each research vessel time series. Both factors can critically affect metric values in indicators of biodiversity, and so this begs the question as to which year in each survey time series should be actually be considered as the effective start date of a monitoring programme intended to support MSFD monitoring and assessment?

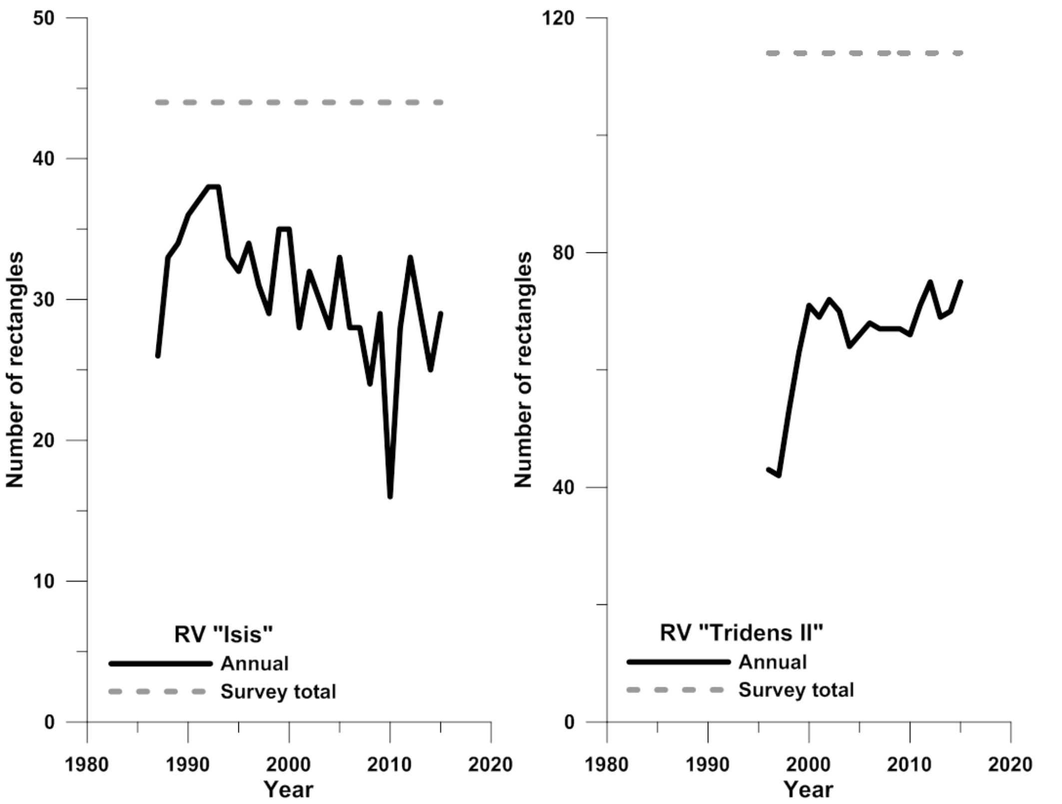

Figure 2.2.1.1.2.3: Trends in the number of ICES statistical rectangles sampled by RV "*Isis*" and RV "*Tridens II*" in each year. In both plots the total number of rectangles ever sampled by each RV is also shown.

Since assessment of the state of fish communities at the scale of the whole North Sea is the principal concern, the RV *Tridens II* time series is considered first. Figure 2.2.1.1.2.4 suggests that the RV *Tridens II* survey covered a large fraction of the North Sea, but that consideration of the effective survey start data held implications regarding the extent of the standard survey area. The largest area, extending to 70 ICES statistical rectangles, was attained when the survey was deemed to have effectively started in 2000. But because sampling effort and the area covered was so much less in the first few years of the survey, if the full time series of data available was considered the standard survey area, those rectangles sampled in ≥ 50% of years in the time series, was reduced to only 65 rectangles. Furthermore, the rectangles lost were located at the northerly and southerly extremes of the standard survey area where, because of boundary effects, they would be most likely to have the most effect on biodiversity indicator values. This initial assessment suggests that only data for the years 2000 to 2015 from the Dutch RV *Tridens II* beam trawl survey should be used for North Sea scale assessment of the state of fish communities aimed at meeting MSFD requirements, thus enabling such assessment to be made for the full area shown in Figure 2.2.1.1.2.4.

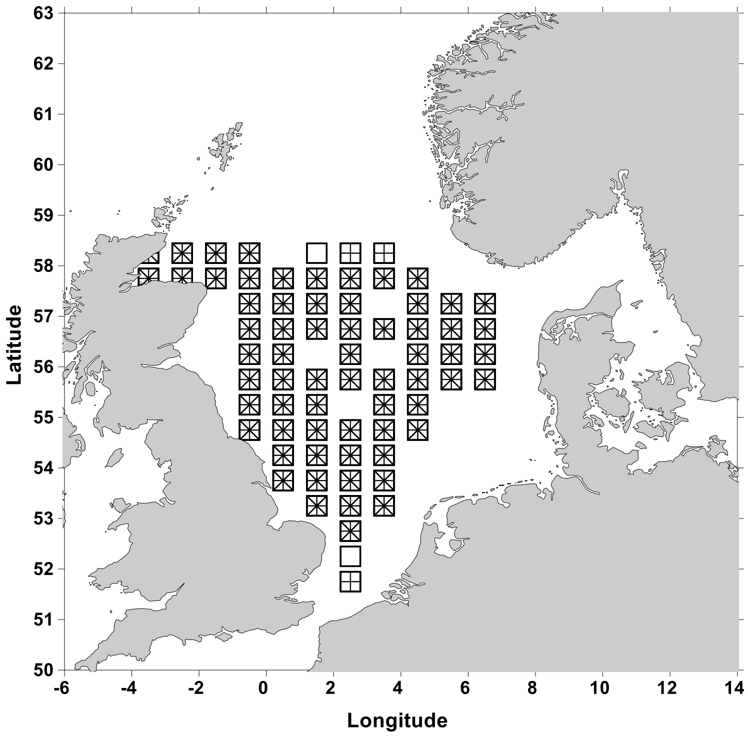

Figure 2.2.1.1.2.4: The standard survey area covered by the RV "*Tridens II*", defined as ICES statistical rectangles sampled in ≥50% of the survey time span. The effect of variation in effective survey start date is illustrated. Square symbols indicate the extent of the standard survey area if the survey is deemed to start in 2000; the 70 rectangles sampled in eight or more years of the 16 years time series. Horizontal/vertical cross-hatch only symbols indicate three rectangles sampled in less than 9 years of the resulting 17 years time series if 1999 is deemed the start date, and so lost from the standard survey area. Square symbols with no hatch indicate two further rectangles lost from the standard survey area if 1996 is considered the survey start date, since these were sampled in <10 years in the resulting 20 years time series. Square symbols with both horizontal/vertical and diagonal cross-hatch indicate rectangles included in the standard survey area regardless of assumed survey start date.

Compared with RV *Tridens II*, RV *Isis* covered a much smaller fraction of the North Sea; the RV *Isis* time series on its own cannot, therefore, be considered suitable to support assessments at the scale of the whole North Sea. The RV *Tridens* survey was introduced to address this problem. Nevertheless, there are two reasons for considering the RV *Isis* time series here. Firstly the data could be useful for national monitoring, assessment and reporting purposes and secondly, should the data from the two surveys prove compatible, RV *Isis* data could be used to extend the RV *Tridens II* standard survey area into the areas not otherwise covered, particularly off the Dutch, Danish and German coasts (Figure 2.2.1.1.2.5). Even though both vessels use the same beam trawl, the RV *Tridens* fishes with a 'flip-up' rope to deal with the rougher seabed terrain across the majority of the area covered by the vessel (ICES, 2009a). For the purposes of full North Sea scale monitoring and assessment, the RV Isis data would need to be combined with the RV *Tridens II* data, so again the three potential start dates of 1996, 1999, and 2000 were considered to explore the effect of choice of start date on the extent of the RV Isis standard survey area. For national scale monitoring, the full RV *Isis* time series has potential value, so the standard survey area for the full time series was also considered. In fact start date had no effect on standard survey area, and regardless of start date and resulting time series duration, the same 28 ICES statistical rectangles met the criterion of having been sampled on ≥ 50% of occasions (Figure 2.2.1.1.2.5).

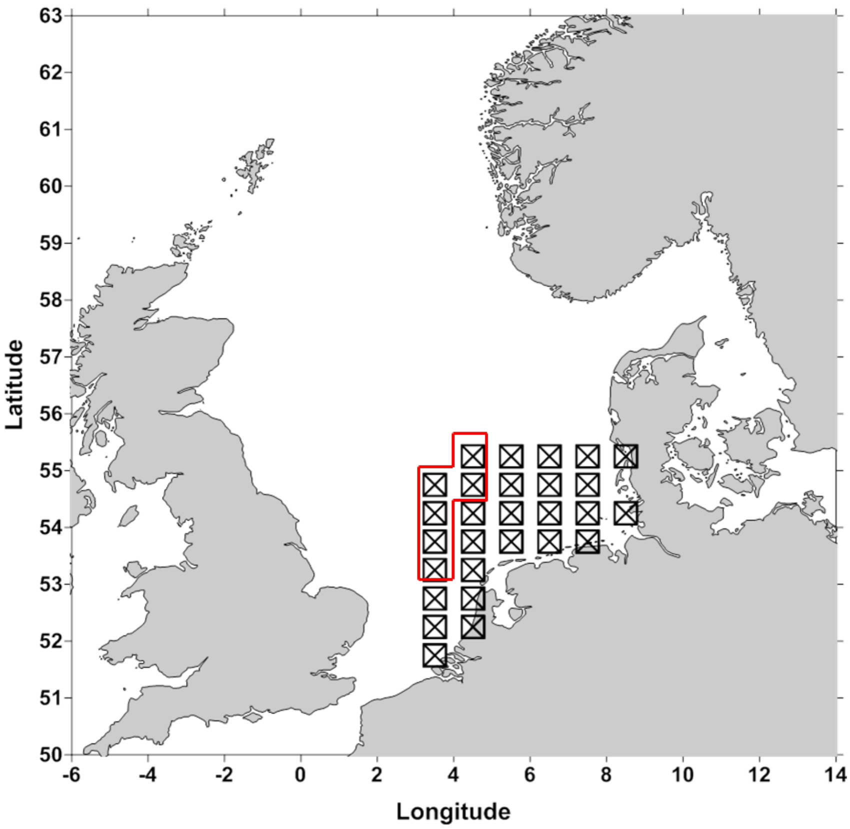

Figure 2.2.1.1.2.5: The standard survey area covered by the RV Isis, defined as ICES statistical rectangles sampled in ≥50% of the survey time span. Time series start dates of 1987, 1996, 1999 and 2000 had no effect on standard survey area. Six ICES rectangles covered by both the RV *Isis* and RV *Tridens* surveys are indicated by red polygon.

Comparison of Figures 2.2.1.1.2.4 and 2.2.1.1.2.5 clearly shows that the two Dutch research vessels operate in different parts of the North Sea, and if the two data sets can be merged, then the combined coverage across the North Sea would be considerably more extensive. Figures 2.2.1.1.2.4 and 2.2.1.1.2.5 also indicate an overlap of six ICES rectangles between the RV *Isis* and RV *Tridens II* standard survey areas, which is shown in Figure 2.2.1.1.2.5. Instances where both research vessels sampled the same ICES rectangle in the same year provide the opportunity to compare catch rates for specified size classes of given species between the two research vessels. There were 118 such instances involving 264 RV *Isis* hauls and 131 RV *Tridens II* hauls (Table 2.2.1.1.2.1). Only hauls of nominal 30 minutes (± 4 minutes) duration should be considered for this analysis. For the purposes of creating the data product, catchability between the *Isis* and *Tridens* surveys is assumed to be equivalent, and the two data sets are combined into a single third quarter Dutch beam trawl survey data product. However, this assumption should be tested and any differences in catchability taken into account in interpreting the results of any analysis of these data.

Year	StatSq	"*Isis*"	"*Trid*"	Year	StatSq	"*Isis*"	"*Trid*"	Year	StatSq	"*Isis*"	"*Trid*"
1996	37F3	3	1	2004	38F4	2	1	2011	38F3	2	1
1996	38F3	3	1	2004	39F4	2	1	2011	38F4	2	1
1996	38F4	1	1	2005	35F2	2	1	2011	39F4	1	1
1996	39F4	1	1	2005	35F3	3	1	2011	40F5	1	1
1996	40F6	4	1	2005	36F2	2	1	2011	40F6	1	1
1997	35F2	1	1	2005	36F3	3	1	2012	32F3	4	1
1998	38F3	3	1	2005	37F3	2	2	2012	35F2	2	1
1998	38F4	2	1	2005	38F3	2	1	2012	35F3	3	1
1998	39F4	3	1	2005	38F4	2	1	2012	35F4	3	1
1998	39F5	3	1	2005	39F4	2	1	2012	36F2	2	1
1998	40F6	1	1	2005	40F5	2	1	2012	36F3	3	1
1999	37F3	1	1	2005	40F6	2	1	2012	37F3	2	1
1999	38F3	3	1	2006	33F4	3	1	2012	37F4	2	1
1999	38F4	3	1	2006	35F3	2	1	2012	38F3	2	1
1999	39F4	3	1	2006	36F3	3	1	2012	38F4	2	1
2000	35F3	4	1	2006	37F3	2	2	2012	39F4	2	1
2000	37F3	3	1	2006	38F3	2	1	2012	40F5	2	1
2000	38F3	3	1	2006	38F4	2	1	2012	40F6	3	1
2000	38F4	3	1	2006	39F4	2	1	2013	35F3	3	1
2000	39F4	3	1	2007	35F3	3	1	2013	36F3	3	1
2001	36F3	1	4	2007	36F3	3	1	2013	37F3	2	1
2001	37F3	1	2	2007	37F3	2	1	2013	38F3	2	1
2001	38F3	3	1	2007	38F3	2	1	2013	38F4	2	1
2001	38F4	2	1	2007	38F4	2	1	2013	39F4	2	1
2001	39F4	3	1	2007	39F4	2	2	2014	35F3	3	1
2002	34F4	4	1	2008	35F3	1	2	2014	36F3	4	1
2002	36F4	3	1	2008	38F4	2	1	2014	37F3	2	1
2002	37F3	2	1	2008	39F4	2	1	2014	38F3	2	1
2002	38F3	2	1	2009	35F3	3	1	2014	38F4	2	1
2002	38F4	2	1	2009	36F3	3	1	2014	39F4	2	1
2002	39F4	2	1	2009	37F3	2	1	2015	35F3	3	1
2003	35F2	2	1	2009	38F3	2	1	2015	36F3	3	1
2003	36F2	2	1	2009	38F4	2	1	2015	37F3	2	1
2003	37F3	2	1	2009	39F4	2	1	2015	37F4	1	1
2003	38F3	2	1	2010	38F7	2	1	2015	37F5	2	1
2003	38F4	2	1	2010	39F5	1	1	2015	38F3	2	1
2003	39F4	2	1	2010	39F8	1	1	2015	38F4	2	1
2003	39F5	2	1	2011	35F3	3	1	2015	39F4	2	1
2004	37F3	2	6	2011	36F3	1	1	2015	40F6	2	1
2004	38F3	2	1								

Table 2.2.1.1.2.1: Catalogue of 118 instances where the same ICES statistical rectangle was sampled by both RV "*Isis*" and RV "*Tridens II*" in the same year. In each case the number of samples collected by each vessel is shown.

2.2.1.2. The Third Quarter English Beam Trawl Survey (GNSEngBT3)

2.2.1.2.1. Survey History

England has carried out an annual summer Eastern English Channel Beam Trawl Survey since 1989 using a commercial 4 m beam trawl. Since a primary focus of the survey has been to provide estimates of the abundance of pre recruit plaice and sole in ICES Division VIId to support stock assessments, most of the sampling was carried out in areas that are nursery grounds for these species. In 1995 the survey was extended to include the southern North Sea in order to sample the whole population of plaice and sole. More recently additional stations have been fished off the Belgium coast in order to start a time-series of stations for comparison purposes. The English Eastern English Channel Beam Trawl Survey provides fisheries independent abundance indices of all age classes of sole and plaice on the east channel grounds and, in particular, provides an index of recruitment of young (1-3 year old) sole prior to full recruitment to the fishery (ICES, 2009a).

The Western English Channel Beam Trawl Survey in ICES Division VII(e) commenced following complaints from the fishing industry in the southwest concerning a lack of scientific knowledge and investigation of the local sole stock. Following enquiries of the local fishery officers and normal tendering procedures, a skipper-owned 300 hp beam trawler the *Bogey 1* was selected. Survey started in 1984 and in this first year simply consisted of a collection of tows on the main sole grounds. For the period 1984 to 1988 the vessel was unchanged, but in 1989 the *Bogey 1* was replaced by the latest design 24 m 300 hp (220 kw) beam trawler FV "*Carhelmar*". Between 1989 and 2001, the survey continued using the FV "*Carhelmar*" and then in 2002 the survey moved onto the RV "*Corystes*". It was reinstated back to the FV "*Carhelmar*" in 2005. The English beam trawl survey in the Western English Channel provides fisheries-independent abundance indices of all age groups of sole and plaice on the west channel grounds, and an index of recruitment of young (1-3 year old) sole prior to full recruitment to the fishery (ICES, 2009a).

This Western English Channel Beam trawl Survey is not appropriate for the MSFD monitoring data product. The survey mainly took place on a fishing vessel where space was limited, and as a result the full range of species was not sampled consistently which could lead to errors in species richness estimates. This survey was discontinued and a new survey in the area which aims to address a range of ecosystem related questions has taken over. However the survey sampling protocols are are inappropriate for the current groundfish monitoring and assessment data product.

2.2.1.2.2. Defining the Standard Monitoring Programme

The English research vessel data held in the DATRAS Beam Trawl database were primarily collected from the eastern English Channel; these data are examined here. Three vessels were involved, 'CAR', 'END' and 'COR'. CAR only collected data from six ICES statistical rectangles in October (fourth quarter) during the period 2006 to 2013. These data were not considered useful as part of a region-wide long-term monitoring programme, particularly since the time series appears to have ceased. They were, therefore, excluded from the MSFD groundfish monitoring programme data product. The vessels COR and END appear to have conducted a single 10 to 14 day survey each year mainly in July, but sometimes bridging into August (third quarter); 'COR' was used from 1990 to 2007, while 'END' operated from 2008 to 2015. A total of 31 ICES statistical rectangles were sampled at some point by these two vessels over the combined time period. The English Beam trawl survey deploys a 4 m beam trawl, considerably smaller than the gear used by the Dutch and German surveys. Data were available on DATRAS for the period 1990 onwards; any data collected in 1989, the first year of the survey, were not therefore available for analysis.

- The Beam Trawl database contains 3,364 English trawl sample records; excluding the October 'CAR' records reduces this to 2,447 records, comprising the eastern English Channel survey data.

The majority of English beam trawl hauls were of 30 minutes duration, but other modal durations were apparent at 15 minutes and 20 minutes duration. Across the time series, however, 86.8% of all samples were of nominal 30 ± 4 minutes duration (Figure 2.2.1.2.2.1). Following previous precedent, therefore, trawls of 13 minutes to 66 minutes duration were deemed valid, resulting in the exclusion of four trawl records with durations deemed to be too short.

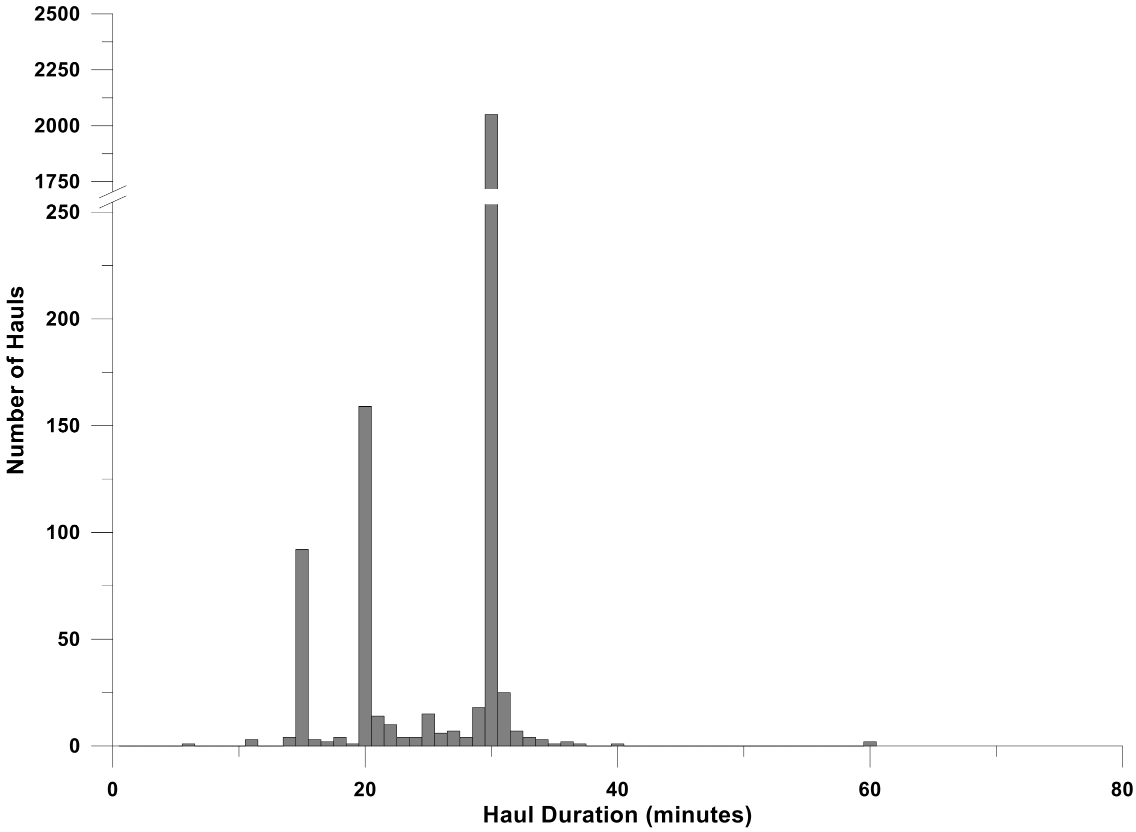

Figure 2.2.1.2.2.1: Frequency distribution for haul durations for beam trawl samples collected by English research vessels in the eastern English Channel.

The total number of beam trawl samples collected by England each year was quite variable, but no trend in was apparent. However, the number of these trawls that were of nominal 30 minutes duration showed a marked decline in the second half of the time series giving rise to a negative trend in the fraction of English beam trawl sampling consisting of nominal 30 minutes duration hauls across the span of the time series (Figure 2.2.1.2.2.2).

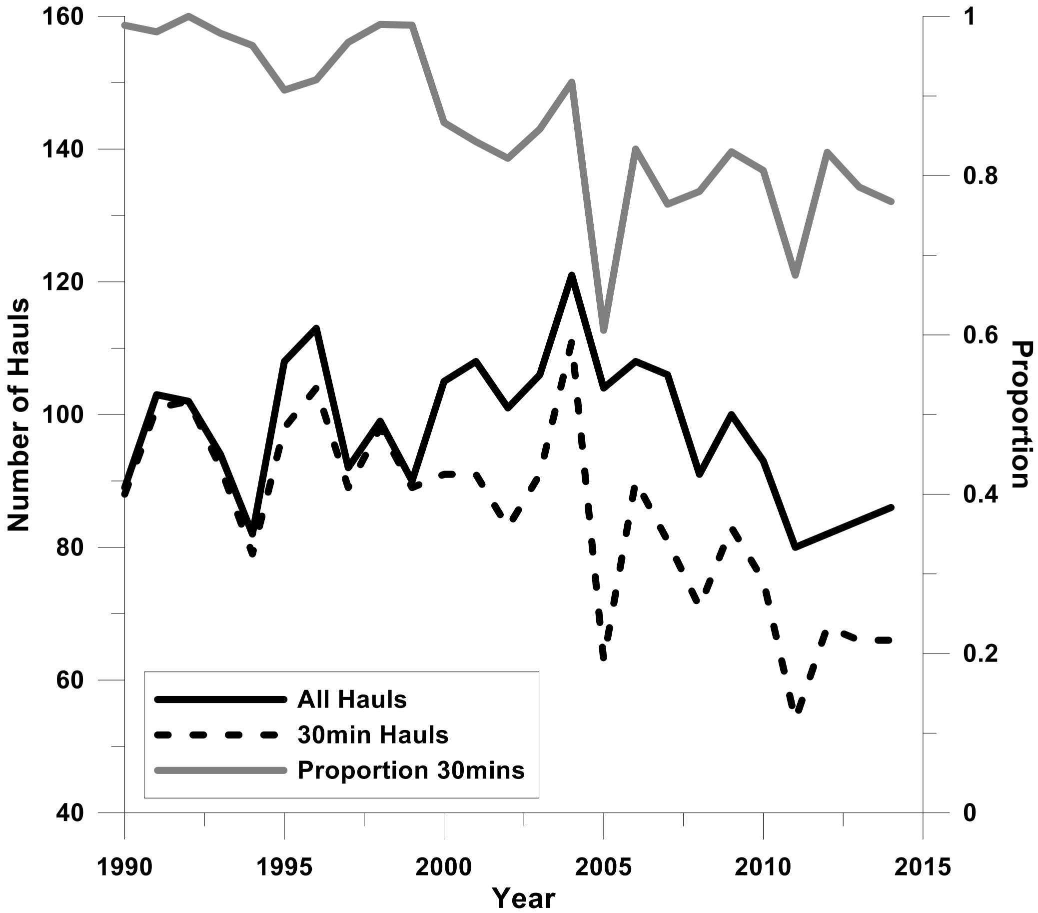

Figure 2.2.1.2.2.2: Trends in the number of all beam trawl samples collected by the English research vessel in each year, and the number of these hauls that were a nominal 30 minutes (±4 minutes) duration. The proportion of all hauls in each year that was of nominal 30 minutesduration is also shown.

The number of ICES statistical rectangles sampled in each year of the English Beam Trawl Survey varied between 14 and 21, with no trend apparent across the span of the time series (Figure 2.2.1.2.2.3). However, the total number of rectangles ever sampled was 31; the fraction of this overall total sampled in any one year varied between 45% and 68%, indicative of considerable year-to-year variation in spatial coverage. The standard survey area, defined as rectangles sampled in ≥50% of years of the time series extended to only 15 ICES statistical rectangles. However, all but two of these (32F1 sampled in 24 years and 33F1 sampled in 22 years) were sampled in all 25 years of the survey time span, suggesting that the English survey covered a core area of 15 ICES statistical rectangles, and if time was available, additional rectangles were sampled on an ad hoc basis. The 16 additional rectangles sampled by the English Beam Trawl Survey were sampled in between one (9 rectangles) and eight years.

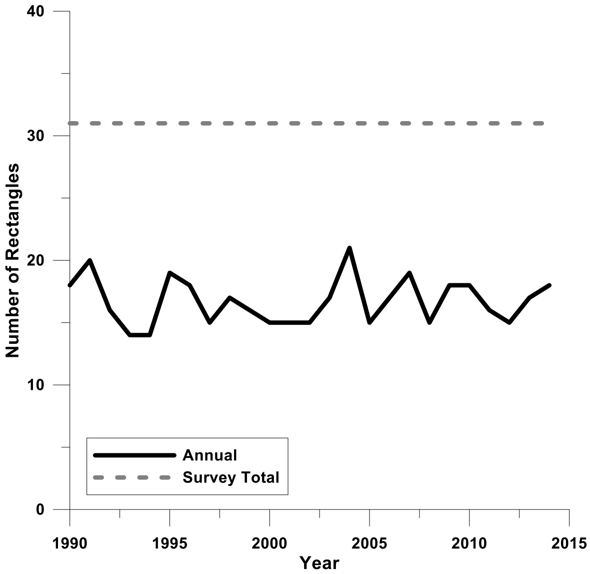

Figure 2.2.1.2.2.3: Trends in the number of ICES statistical rectangles sampled by England in each year. The number of rectangles ever sampled is also shown.

Figure 2.2.1.2.2.4 shows the English Beam Trawl Survey standard survey area of 15 ICES statistical rectangles. These essentially covered the eastern English Channel with three rectangles actually extending into the extreme southwest of the North Sea (ICES area IV). Unfortunately, overlap between the English and Dutch Beam Trawl Surveys was minimal and insufficient to allow any meaningful comparison of catchability between the two gears.

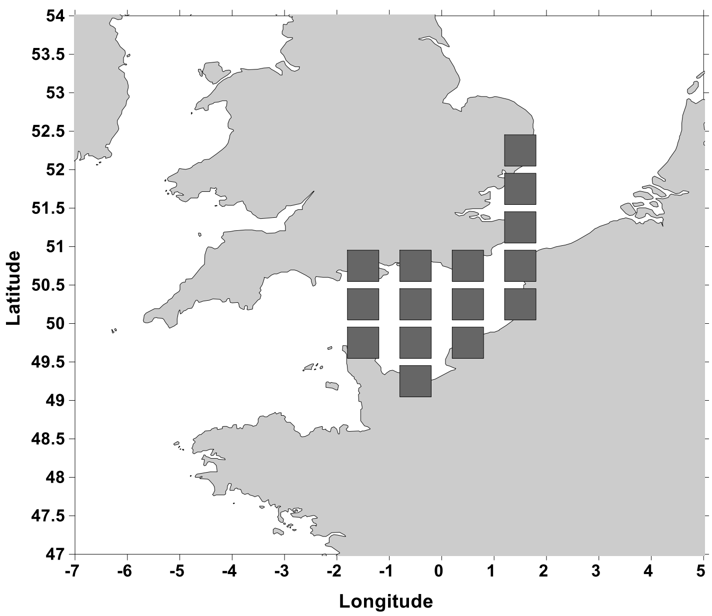

Figure 2.2.1.2.2.4: The standard survey area covered by the English Beam Trawl Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

2.2.1.3. The Third Quarter German Beam Trawl Survey (GNSGerBT3)

2.2.1.3.1. Survey History

The German survey started in 1991, covering areas off the Jutland coast that were not sampled by the Netherlands North Sea offshore survey. The gear is a 7 m light beam trawl. In 1991 an 80 mm mesh gear was used, but from 1992 a 40 mm liner in the codend has been the standard. Some years are missing in the series as a result of technical failures. The survey started with RV "*Solea*" (I) which was replaced in 2004 with the newly build "*Solea*" (II) (ICES, 2009). The German survey was initiated to increase spatial coverage and to include more coastal areas which would not otherwise be sampled as intensively (ICES, 2009a).

2.2.1.3.2. Defining the Standard Monitoring Programme

Germany has collected beam trawl survey data using two vessels: SOL in 2003 and SOL2 (the research vessel that replaced SOL) in every year subsequently to 2015 with the exception of 2006 when no data are present; a result of mechanical issues with the research vessel (ICES, 2007c). The time series thus spans the period 2003 to 2015 with a one-year gap in 2006. Data collected prior to 2003 have not been submitted to the DATRAS portal. All German data have been collected using a 7 m Beam Trawl with a 'T' "Rigging" code and '5' "Tickler" chains. The vast majority (96.4%) of the 614 German hauls were of a nominal 30 ± 4 minutes duration. The shortest was 10 minutes (n=1) and the longest was 60 minutes (n=1) (Figure 2.2.1.3.2.1). Following previous precedent, and considering all trawls 13 minutes to 66 minutes duration to be valid, resulted in only two German hauls being excluded.

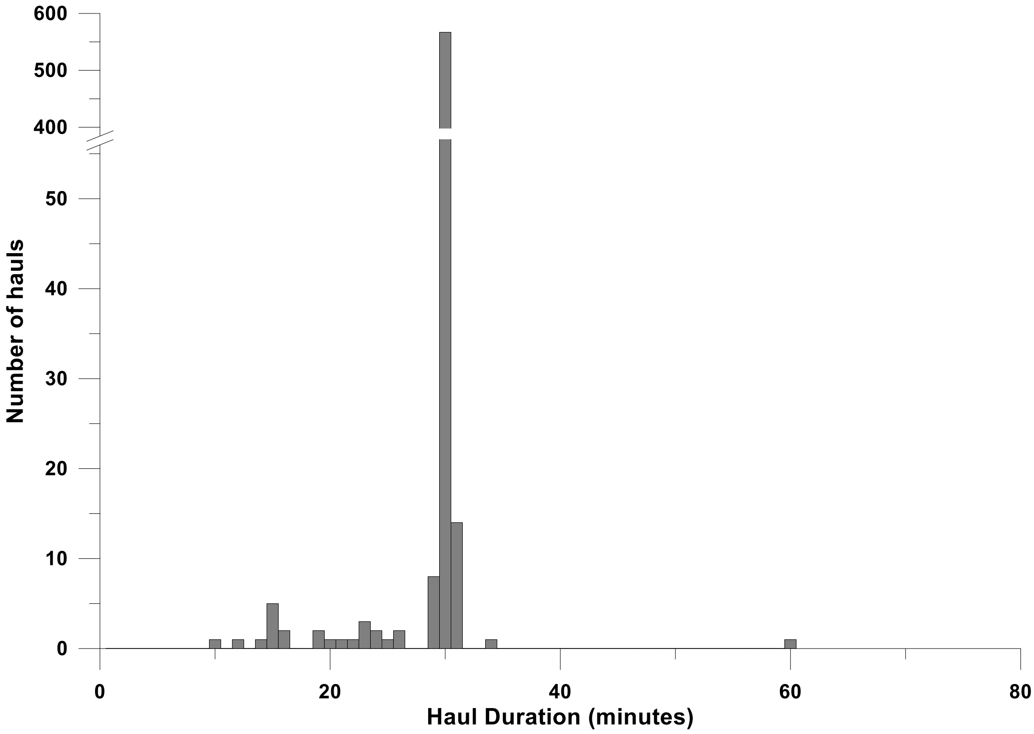

Figure 2.2.1.3.2.1: Frequency distribution for haul durations for beam trawl samples collected by the German research vessels.

- Only hauls of 13 minutes to 66 minutes duration were deemed valid. Only two hauls fell outside these parameters reducing the Greater North Sea Quarter 3 German Beam Trawl Monitoring Programme data set to 612 samples.

The number of beam trawl samples collected each year by German research vessels was relatively constant. No trend was discernible, but a dip in sampling effort was apparent in 2014 due to bad weather (ICES, 2016). The proportion of hauls that was of nominal 30 minutes duration was also reasonably steady, though a dip was again apparent, but this time in 2012 (Figure 2.2.1.3.2.2). The number of ICES statistical rectangles sampled each year was relatively constant throughout the time series, although again the total number of rectangles sampled at any time during the time series was appreciably higher than the number sampled in any given year; indicative of year-to-year variation in spatial coverage (Figure 2.2.1.3.2.3). Of the 26 ICES rectangles sampled over the course of the German Beam Trawl Survey, 20 met the criterion of having been sampled in ≥50% of occasions, giving the standard survey area indicated in Figure 2.2.1.3.2.4.

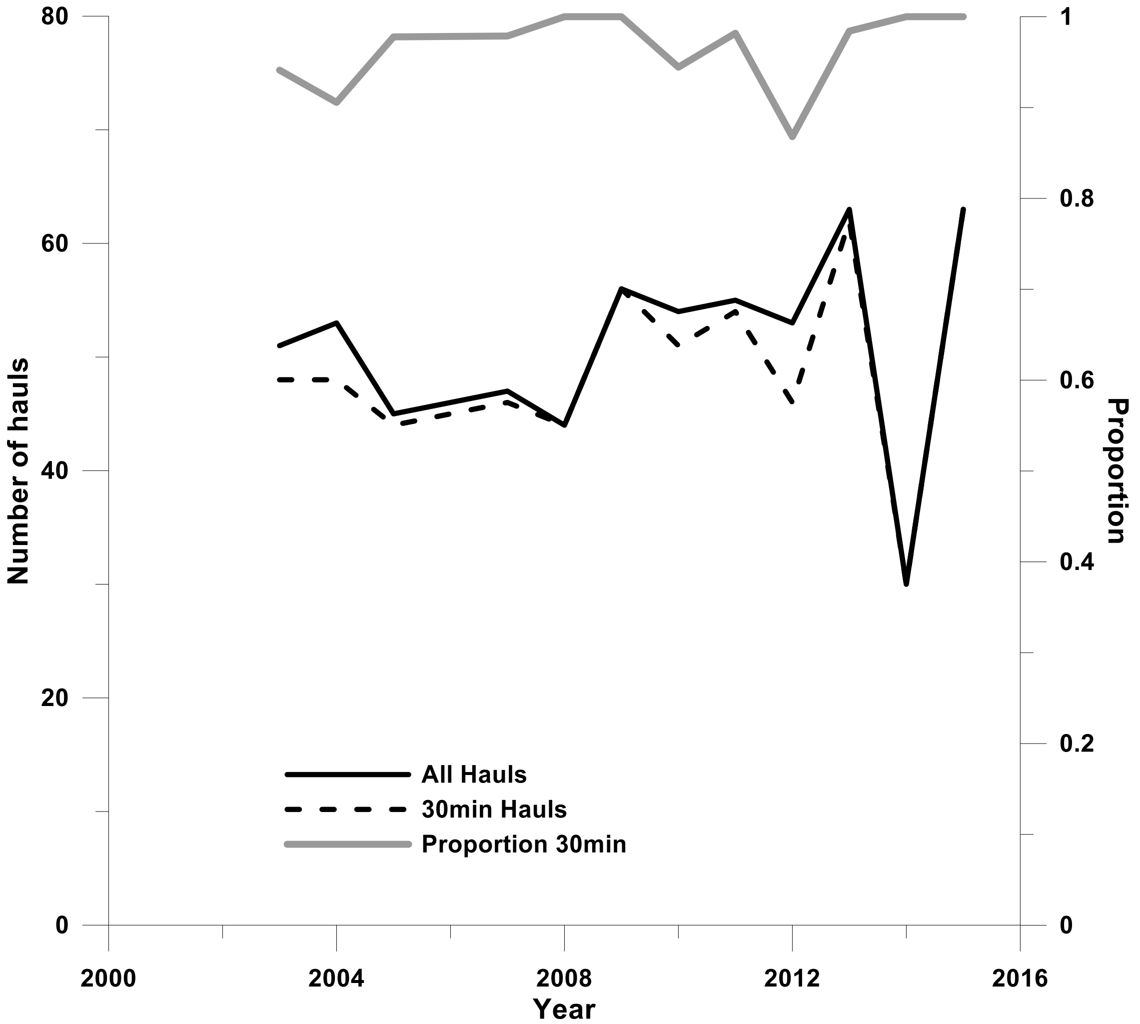

Figure 2.2.1.3.2.2: Trends in the number of all beam trawl samples collected by the Germany research vessel in each year, and the number of these hauls that were a nominal 30 minutes ± 4 minutes duration. The proportion of all hauls in each year that were of nominal 30 minutes duration is also shown.

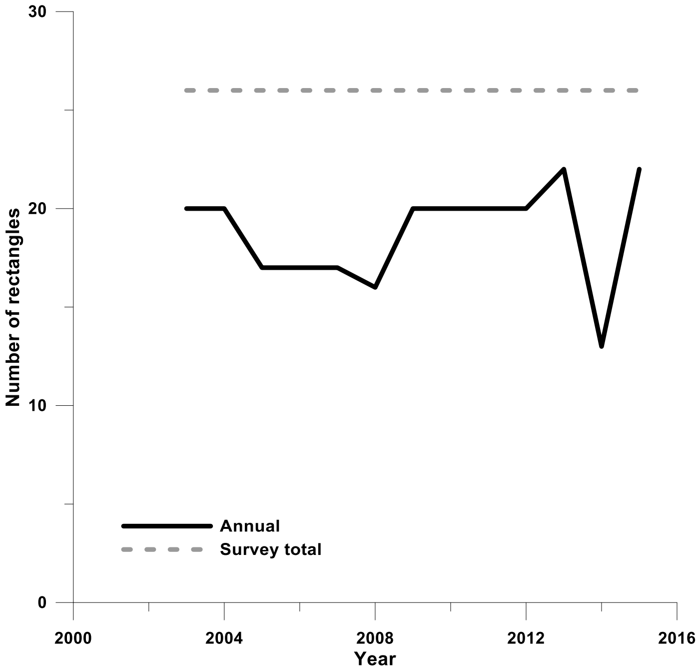

Figure 2.2.1.3.2.3: Trends in the number of ICES statistical rectangles sampled by Germany in each year. The total number of rectangles ever sampled is also shown.

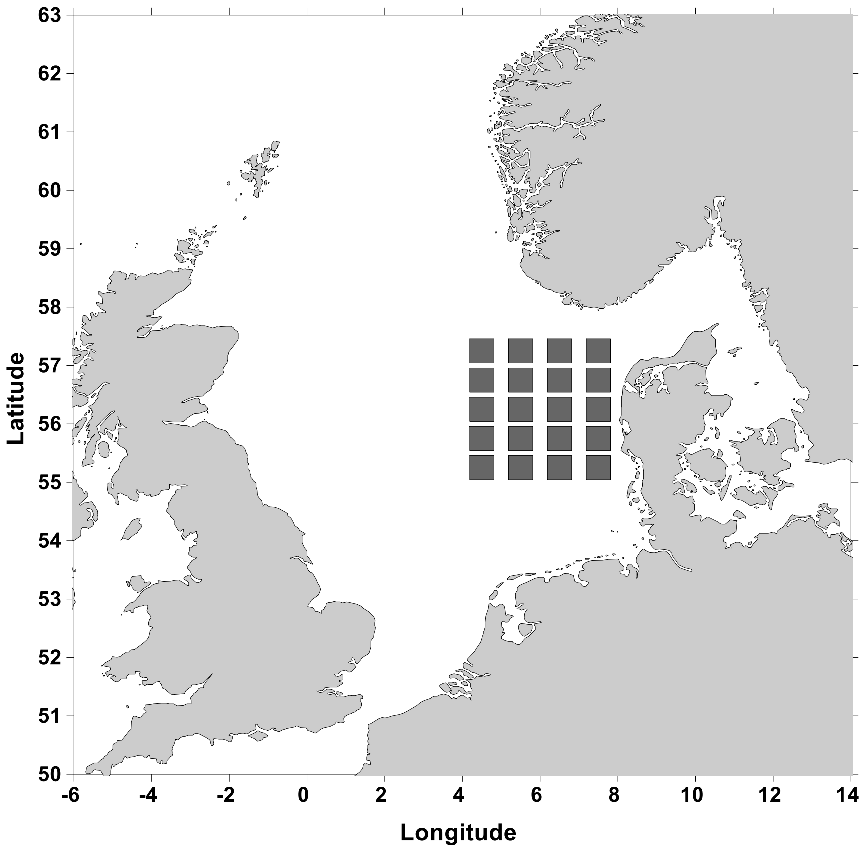

Figure 2.2.1.3.2.4: The standard survey area covered by the German Beam Trawl survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

On its own, the German standard survey area is again too small for the German beam trawl survey to constitute a monitoring programme capable of supporting assessment at the scale of the entire North Sea, although it could still support assessment at the scale of national waters. More importantly though, it includes four coastal ICES statistical rectangles not covered by the combined Dutch RV *Isis* and RV *Tridens II* standard survey areas. If catchabilities in the beam trawls used by the two countries are similar, then this offers the opportunity of merging the German and Dutch survey data sets to provide a combined Greater North Sea third Quarter Beam Trawl Survey Monitoring Programme based on a larger standard survey area covering 96 ICES statistical rectangles (Figure 2.2.1.3.2.5). The German standard survey area overlapped the RV Isis standard survey area in four ICES statistical rectangles and the RV *Tridens II* standard survey area in 13; one ICES statistical rectangle was included in all three standard survey areas (Figure 2.2.1.3.2.5). Density estimates for samples collected by the different gears in these rectangles should be compared to assess whether the German and Dutch surveys could be merged to provide an overall combined beam trawl monitoring programme. In total, data from 137 German samples and 118 Dutch RV *Isis* samples, and from 341 German samples and 151 Dutch RV *Tridens II* samples, were available to compare species and size class catch rates between the two gears (Tables 2.2.1.3.2.1 and 2.2.1.3.2.2). For now this catchability comparison analysis has not been done and, because the Dutch and German surveys used different beam trawl gears, these two surveys are kept as separate data products.

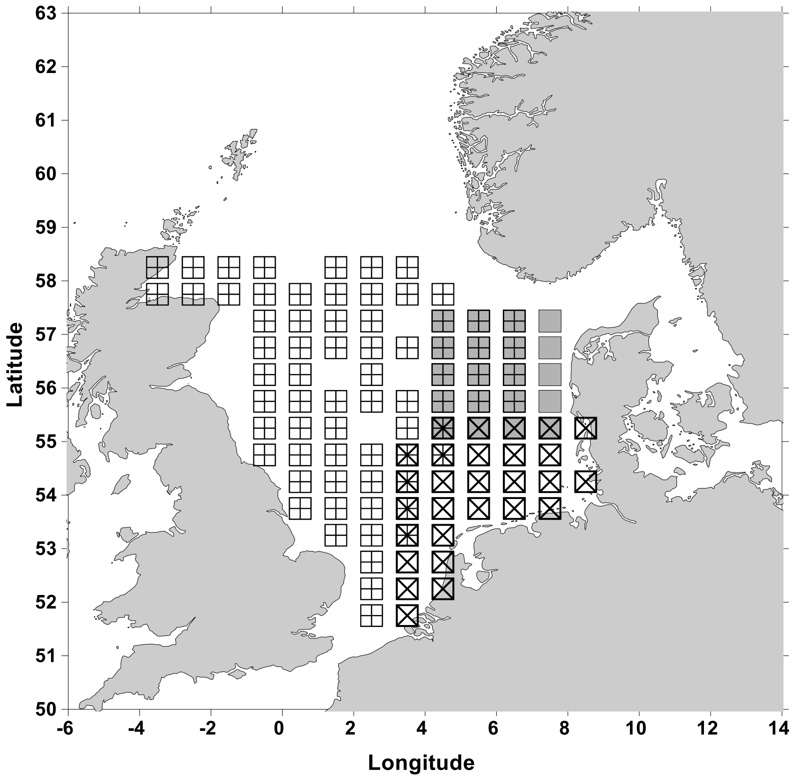

Figure 2.2.1.3.2.5: Chart showing the standard survey areas for all three beam trawl surveys carried out in the North Sea (German beam trawl survey – grey filled squares; Dutch RV *Isis* beam trawl survey – diagonal hatch squares; Dutch RV *Tridens II* beam trawl survey – vertical/horizontal hatch squares).

Year	StatRec	GFR	NED/Isis	Year	StatRec	GFR	NED/Isis	Year	StatRec	GFR	NED/Isis
2004	39F4	2	2	2009	39F7	4	4	2012	40F7	4	3
2004	39F5	2	2	2009	40F7	4	3	2013	39F4	2	2
2004	39F6	3	3	2010	39F5	2	1	2013	39F5	2	2
2004	39F7	4	4	2011	39F4	2	1	2013	39F6	3	3
2005	39F4	2	2	2011	39F5	2	1	2013	39F7	4	4
2005	39F5	2	2	2011	39F6	3	2	2013	40F7	4	3
2005	39F6	3	3	2011	39F7	4	3	2014	39F4	2	2
2005	39F7	3	4	2011	40F5	2	1	2014	39F5	2	2
2005	40F5	2	2	2011	40F6	3	1	2014	39F6	3	2
2005	40F6	2	2	2011	40F7	4	1	2014	39F7	4	3
2005	40F7	4	2	2012	39F4	2	2	2015	39F4	2	2
2007	39F6	3	3	2012	39F5	2	2	2015	39F5	2	2
2008	40F7	4	3	2012	39F6	2	2	2015	39F6	3	3
2009	39F4	2	2	2012	39F7	5	4	2015	39F7	4	4
2009	39F5	2	2	2012	40F5	2	2	2015	40F6	3	2
2009	39F6	3	3	2012	40F6	3	3	2015	40F7	4	3

Table 2.2.1.3.2.1: Catalogue of 48 instances where the same ICES statistical rectangle was sampled by both the German research vessel and the Dutch RV *Isis* in the same year. In each case the number of samples collected by each country is shown.

Year	StatRec	GFR	NED/Tri2	Year	StatRec	GFR	NED/Tri2	Year	StatRec	GFR	NED/Tri2
2003	40F3	2	1	2008	40F5	2	1	2011	42F6	3	1
2003	40F4	2	1	2008	40F6	3	1	2011	43F4	2	1
2003	40F5	2	1	2008	41F4	2	1	2011	43F5	2	1
2003	40F6	3	1	2008	41F5	2	1	2011	43F6	3	1
2003	41F4	2	1	2008	41F6	3	1	2012	39F4	2	1
2003	41F5	2	1	2008	42F4	2	1	2012	40F4	2	1
2003	41F6	3	1	2008	42F5	2	1	2012	40F5	2	1
2003	42F3	2	1	2008	42F6	3	1	2012	40F6	3	1
2003	42F4	2	1	2008	43F4	2	1	2012	41F4	2	1
2003	42F5	2	1	2008	43F5	2	1	2012	41F5	2	1
2003	42F6	3	1	2008	43F6	3	1	2012	41F6	3	1
2003	43F4	2	1	2009	39F4	2	1	2012	42F4	2	1
2003	43F6	3	1	2009	40F4	2	1	2012	42F5	2	1
2004	39F4	2	1	2009	40F5	2	1	2012	42F6	1	1
2004	40F4	2	1	2009	40F6	3	1	2012	43F4	2	1
2004	40F5	2	1	2009	41F4	2	1	2012	43F5	2	1
2004	40F6	3	1	2009	41F5	2	1	2012	43F6	3	1
2004	41F4	2	1	2009	41F6	3	1	2013	39F4	2	1
2004	41F5	2	1	2009	42F4	2	1	2013	40F4	2	1
2004	41F6	3	1	2009	42F5	3	2	2013	40F5	2	1
2004	42F5	2	1	2009	42F6	3	1	2013	40F6	3	1
2004	42F6	3	1	2009	43F4	2	1	2013	41F4	2	1
2004	43F4	2	1	2009	43F5	2	1	2013	41F5	2	1
2004	43F5	2	1	2009	43F6	3	1	2013	41F6	3	1
2004	43F6	3	1	2010	39F4	2	2	2013	42F4	2	1
2004	43F7	4	1	2010	39F5	2	1	2013	42F5	2	1
2005	39F4	2	1	2010	39F6	3	2	2013	42F6	3	1
2005	40F4	2	1	2010	39F7	3	2	2013	43F4	2	1
2005	40F5	2	1	2010	40F4	2	1	2013	43F5	2	1
2005	40F6	2	1	2010	40F5	2	1	2013	43F6	3	1
2005	41F4	2	1	2010	40F6	3	1	2014	39F4	2	1
2005	41F5	2	1	2010	40F7	4	1	2014	40F4	2	1
2005	41F6	3	1	2010	41F4	2	1	2014	40F6	3	1
2005	42F5	2	1	2010	41F5	2	1	2014	41F6	2	1
2005	42F6	3	1	2010	41F6	3	1	2014	42F6	2	1
2005	43F6	1	1	2010	42F4	2	1	2014	43F6	2	1
2007	40F4	2	1	2010	42F5	2	1	2015	39F4	2	1
2007	40F5	2	1	2010	42F6	3	1	2015	40F4	2	1
2007	40F6	3	1	2010	43F5	2	1	2015	40F5	2	1
2007	41F4	2	1	2010	43F6	3	1	2015	40F6	3	1
2007	41F5	2	1	2011	39F4	2	1	2015	41F4	2	1
2007	41F6	3	1	2011	40F4	2	1	2015	41F5	2	1
2007	42F4	2	1	2011	40F5	2	1	2015	41F6	3	1
2007	42F5	2	1	2011	40F6	3	1	2015	42F4	2	1
2007	42F6	3	1	2011	41F4	2	1	2015	42F5	2	1
2007	43F4	2	1	2011	41F5	2	1	2015	42F6	3	1
2007	43F5	2	1	2011	41F6	3	1	2015	43F4	2	1
2007	43F6	3	1	2011	42F4	2	1	2015	43F5	2	1
2008	40F4	2	1	2011	42F5	2	1	2015	43F6	3	1

Table 2.2.1.3.2.2: Catalogue of 147 instances where the same ICES statistical rectangle was sampled by both the German research vessel and the Dutch RV *Tridens II* in the same year. In each case the number of samples collected by each country is shown.

2.2.2. The Celtic Seas

2.2.2.1. The Third Quarter English Beam Trawl Survey (CSEngBT3)

2.2.2.1.1. Survey History

An Autumn Irish Sea groundfish survey has been carried out annually by MAFF/DEFRA since 1979 in the Irish Sea and Bristol Channel. Until 1987 a Granton otter trawl was used, the current commercial 4 m beam was introduced in 1988. From 1988 to 1992 the main survey effort was concentrated in the northeast Irish Sea and the Bristol Channel and since 1993 a standard survey covering the whole of ICES Divisions VIIa, f, and g, has been undertaken. Only these data, collected from 1993 onwards, were available for download from the DATRAS portal. In 2002, the survey was extended to cover the survey area in ICES Division VIIe, previously undertaken by the charter vessel MV "*Carhelmar*" that had been used since 1988. In 2005 the VIIe survey was moved back to the "*Carhelmar*". Data collected by the "*Carhelmar*" were not available for download from the DATRAS portal. The English beam trawl survey in the Irish Sea and Bristol Channel English Channel provides fisheries-independent abundance indices of all age groups of plaice, sole, cod and Whiting in the Irish Sea, Bristol Channel and Western English Channel. It also provides an index of recruitment of juvenile plaice and sole prior to full recruitment to the fishery for other ICES working groups (ICES, 2009a).

Some data downloaded from the DATRAS for this survey related to samples collected in the western English Channel, i.e. part of the Greater North Sea region, not the Celtic Seas. These data were deleted from the CSEngBT3 data product. These excluded samples were too few in number to constitute a useful monitoring programme for this part of the Greater North Sea region.

2.2.2.1.2. Defining the Standard Monitoring Programme

All trawl samples collected by this survey were collected between 25 August and 5 October (Figure 2.2.2.1.2.1), so primarily towards the latter third of the third quarter. However, samples collected in October, were actually taken in the fourth quarter. Following the previously established protocol, the "quarter" field for these samples was altered from 4 to 3 to reflect the survey name rather than the precise data that the samples in question were collected. This date information is still retained in the data product in the "year", "month" and "day" fields. The majority of trawl samples was 30 minutes in duration, but modes at 15 minutes and 20 minutes were also apparent. One sample of only 10 minutes duration was excluded from the standard monitoring programme (Figure 2.2.2.1.2.2). The proportion of trawl samples that were of nominal 30 minutes duration declined steadily over the course of the survey time series, but was nevertheless stll 80% in 2015 (Figure 2.2.2.1.2.3). Survey effort declined in the early years of the survey, both in terms of the number of samples collected (Figure 2.2.2.1.2.3) and the number of daya allocated to the survey (Figure 2.2.2.1.2.4), but then stabilised from 1998 onwards.

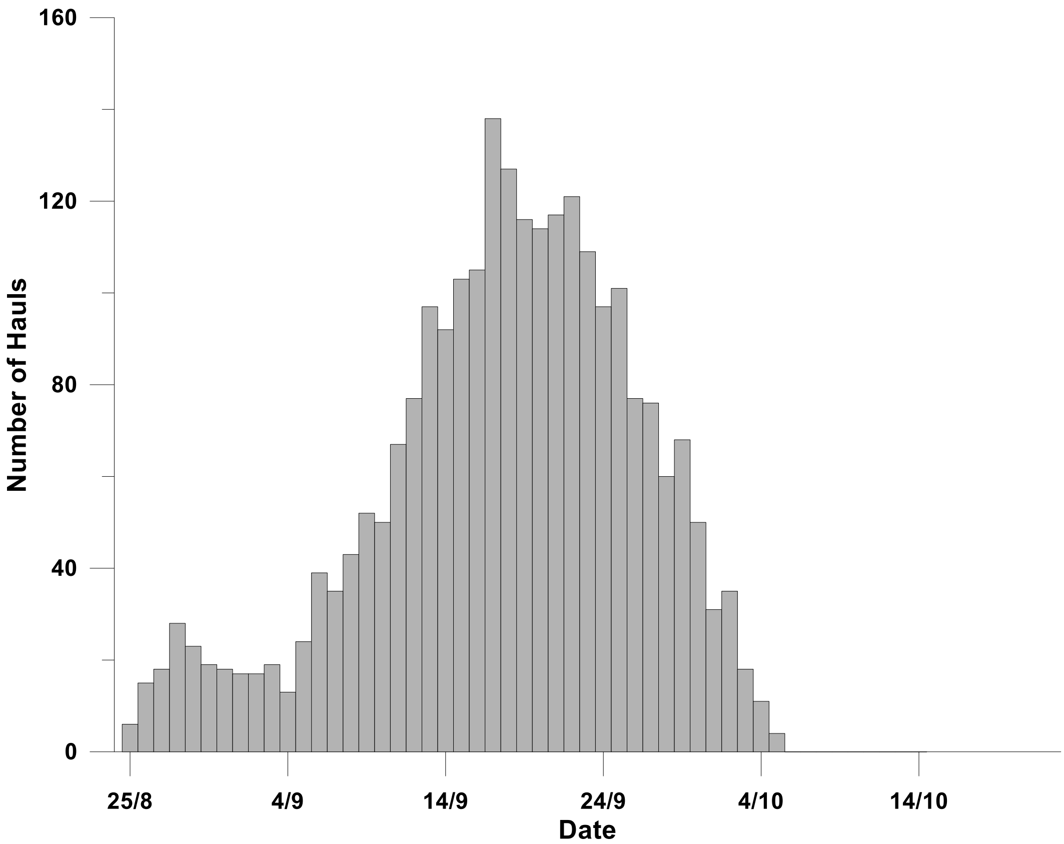

Figure 2.2.2.1.2.1: Frequency distribution of hauls over all years of the English third quarter Beam Trawl Survey by date (day/month).

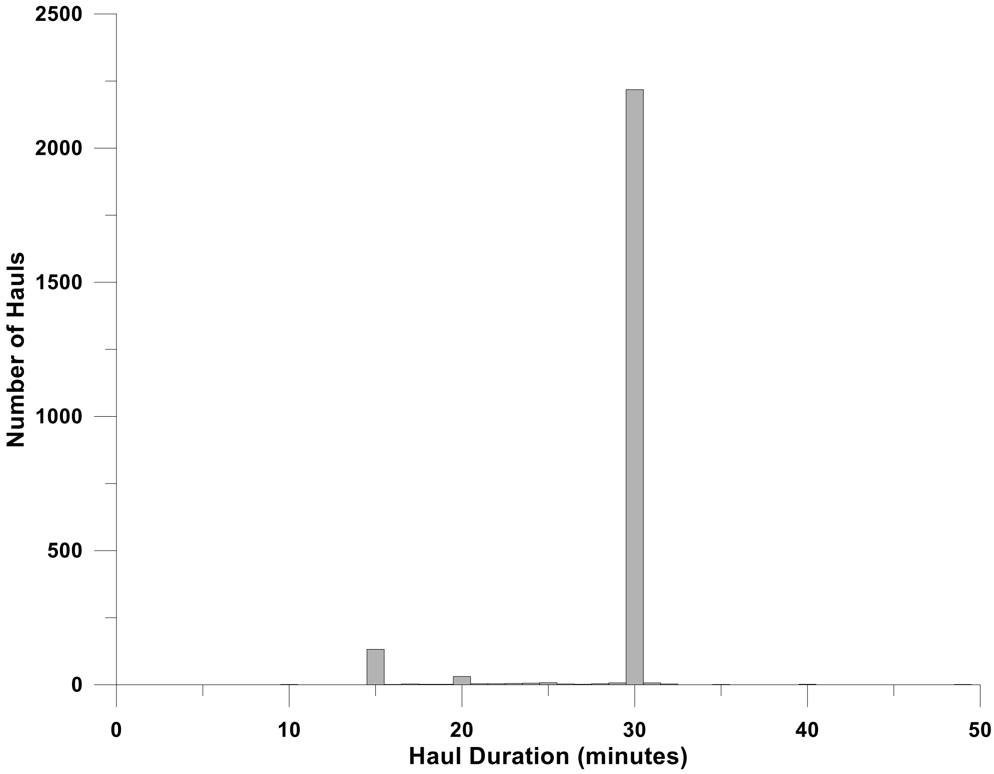

Figure 2.2.2.1.2.2: Frequency distribution for hauls durations for trawl samples collected by the English third quarter Beam Trawl Survey.

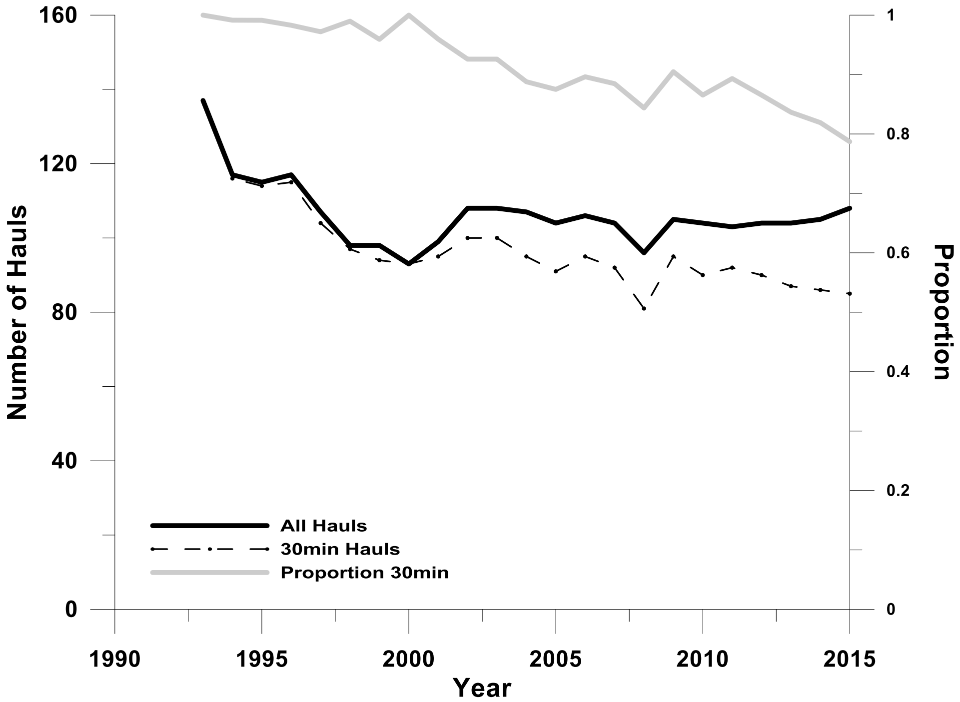

Figure 2.2.2.1.2.3: Trends in the number of all GOV trawl samples collected during the English third quarter Beam Trawl Survey in each year, and the number of these hauls that were a nominal 30 ± 4 minutes duration. The proportion of all hauls in each year that was of nominal 30 minutes duration is also shown.

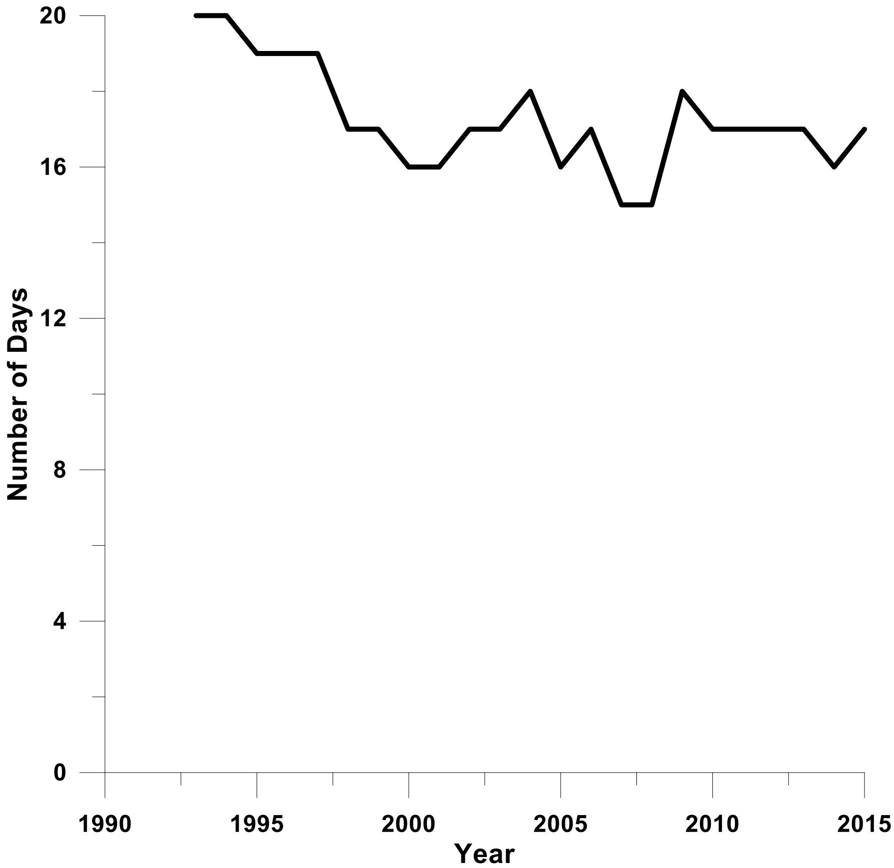

Figure 2.2.2.1.2.4: Variation in the number of days trawl sampling in each year over the course of the English third quarter Beam Trawl Survey.

Reflecting the reduction in survey effort over the first five years of the survey, the number of ICES statistical rectangles sampled also declined over the same period. Over the 23 year that the survey has operated, a total of 32 ICES statistical rectangles were sampled but, especially since 1998, rarely was more than 25 rectangles sampled in any one year. Indeed only 23 of these rectangles met the criterion of having been sampled in at least 50% of the years that the survey has operated and, with the clear exception of the period 1998 to 2000, the majority of these 23 rectangles were sampled in every year (Figure 2.2.2.1.2.5). These 23 ICES statistical rectangle therefore constituted the standard survey area for the CSEngBT3 survey, shown in (Figure 2.2.2.1.2.6).

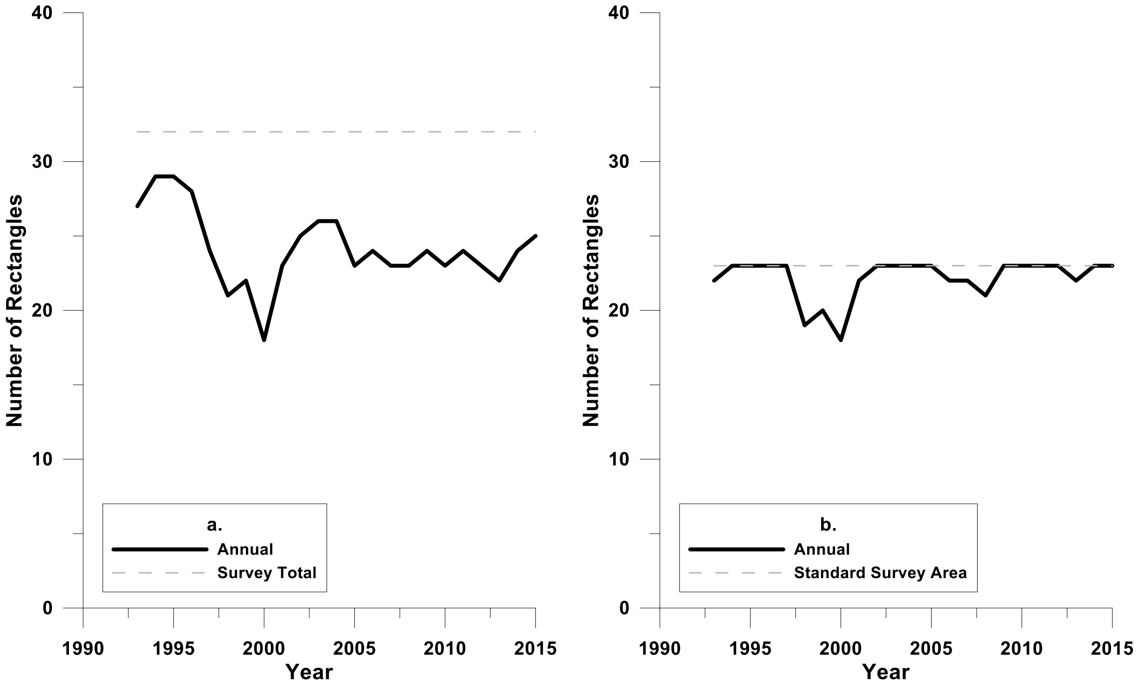

Figure 2.2.2.1.2.5: Trends in the number of ICES statistical rectangles sampled in each year of the English third quarter Beam Trawl Survey (a) in all rectangles sampled and (b) in a standard survey area consisting only of the 23 rectangles sampled in ≥50% of years of the survey time span.

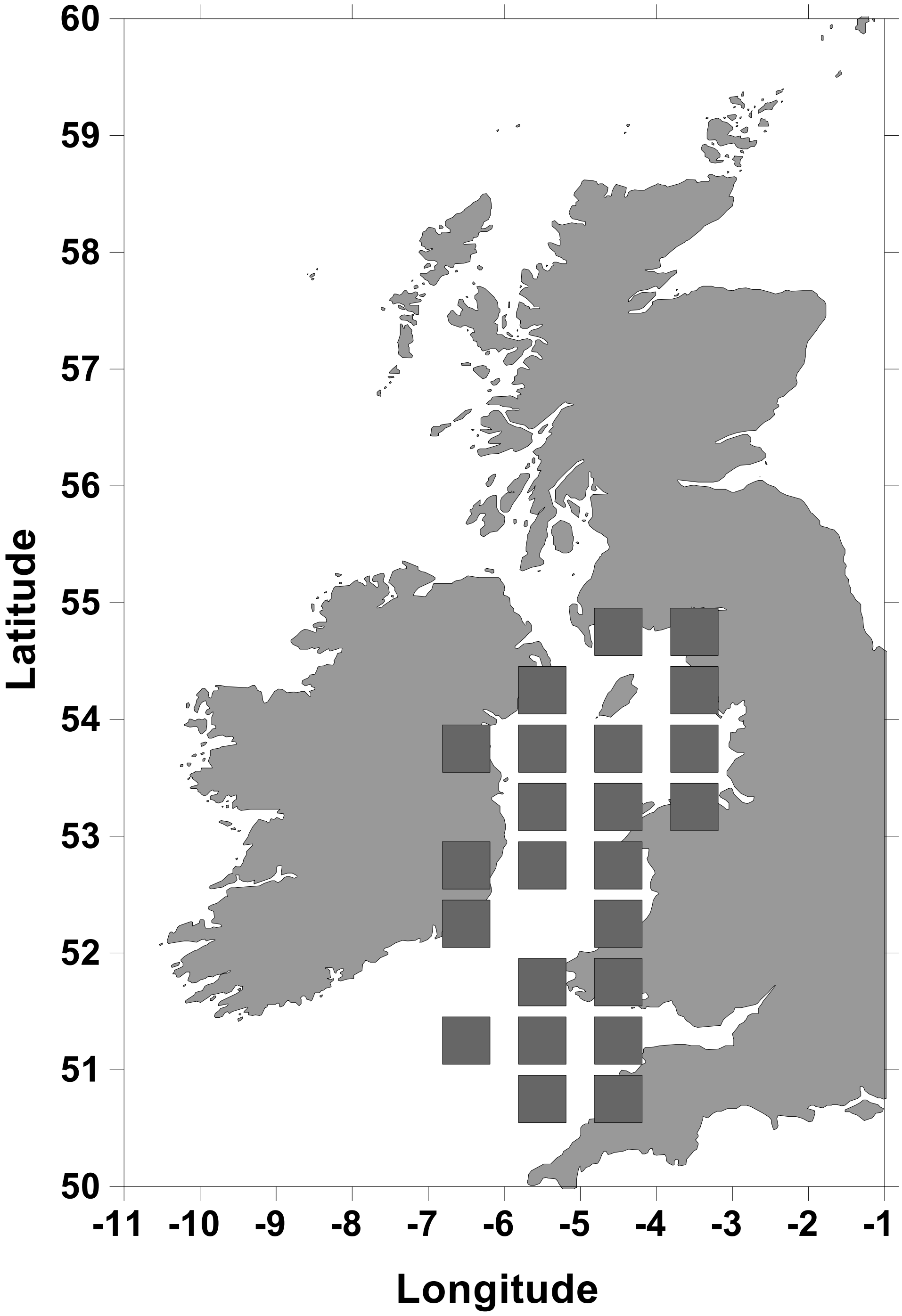

Figure 2.2.2.1.2.6: Chart showing the standard survey area covered by the English third quarter Beam Trawl Survey, defined as ICES statistical rectangles sampled in ≥50% of the survey time span.

3. General Sampling Protocols

Although the text for this section has been largely drawn from the WGIBTS manuals, WGIBTS considers the standard protocol devised for the GOV otter trawl surveys in the North Sea to form an adequate basis for use in surveys where different gears are employed and to be suitable for all parts of the Northeastern Atlantic area (ICES 2010b). The WGIBTS manual for the North Eastern Atlantic Area (ICES 2013b) outlines differences in gears in each survey (as does Section 2 of this document). Fundamentals, such as the standard haul durations and speed over ground as well as handling the catch, remain consistent in the North Sea and across the North Eastern Atlantic region. Beam trawl surveys carried out in the same regions have endorsed the practises of the WGIBTS and they have a standardised haul duration and speed over ground comparable to the otter trawls. They also handle the catch similarly although the composition of species will be different due to the inherent differences in the catchability of each species in the two quite different types of gear (ICES 2009a).

3.1. Trawling Parameters

The 36/47 GOV-trawl is the standard rigged GOV. There are numerous check sheets to insure correct specification and rigging of the gear. For example the lining of the codend should consist of 400 stretched meshes of 20 mm each, giving a total length of 8 m. The total circumference of the lining should be 600 meshes. A standard fishing method is undertaken (ICES, 2012). Gear deployment and ground contact are monitored. Trawl sensors are used to collect additional information and insure net geometry is within the tolerances set out in the manual (IBTS, 2012). The standard tow should be 30 minutes duration at a standard fishing speed of 4 ± 0.5 knots.

The GOV-trawl is used in the majority of otter trawl surveys, excluding the Northern Irish who use a rockhopper, the Spanish who use a baka trawl and the Portuguese who use a Norwegian Campbell Trawl. Further details on these trawls can be found in Sections 2.1.2.4.1, 2.1.3.2.1, 2.1.3.3.1, 2.1.3.4.1 and 2.1.3.5.1 respectively. The beam trawls vary by country. This is due to the type of ground being fished in the different areas. Despite the differences in gear types a standard tow durations of 30 minutes and a standard fishing speed of 4 ± 0.5 knots is consistent across all of the surveys, with the exception that Spanish and Portuguese surveys appear to have a nominal two speed of 3 knotst or 3.5 knots.

3.2. Biological Data

Standardized data collection for fish is well established in IBTS protocols, and these data are submitted to DATRAS. The on-board process is outlined in Figure 3.2.1, (ICES 2012b, ICES 2013a). Where practicable, the entire catch from valid hauls should be fully sorted with fish and shellfish species identified to the most fully resolved taxonomic level possible (i.e. ideally to species level). For larger catches, where full sorting of the entire catch is deemed impractical, a selection of species, or specific size categories of particular species, may be identified as being sufficiently abundant that they can be sub-sampled appropriately, with only the subsample worked-up and the resulting data raised to reflect the proportion of the whole represented by the subsample. If the entire catch cannot be sorted through then the data should be flagged accordingly when submitted to the DATRAS database. In the IBTS Manual 2012 (ICES 2012b) the Appendices VI and VII show tables of catch processing procedures carried out in Quarter 1 North Sea and Quarter 3 North Sea respectively (updated from ICES, 2002).

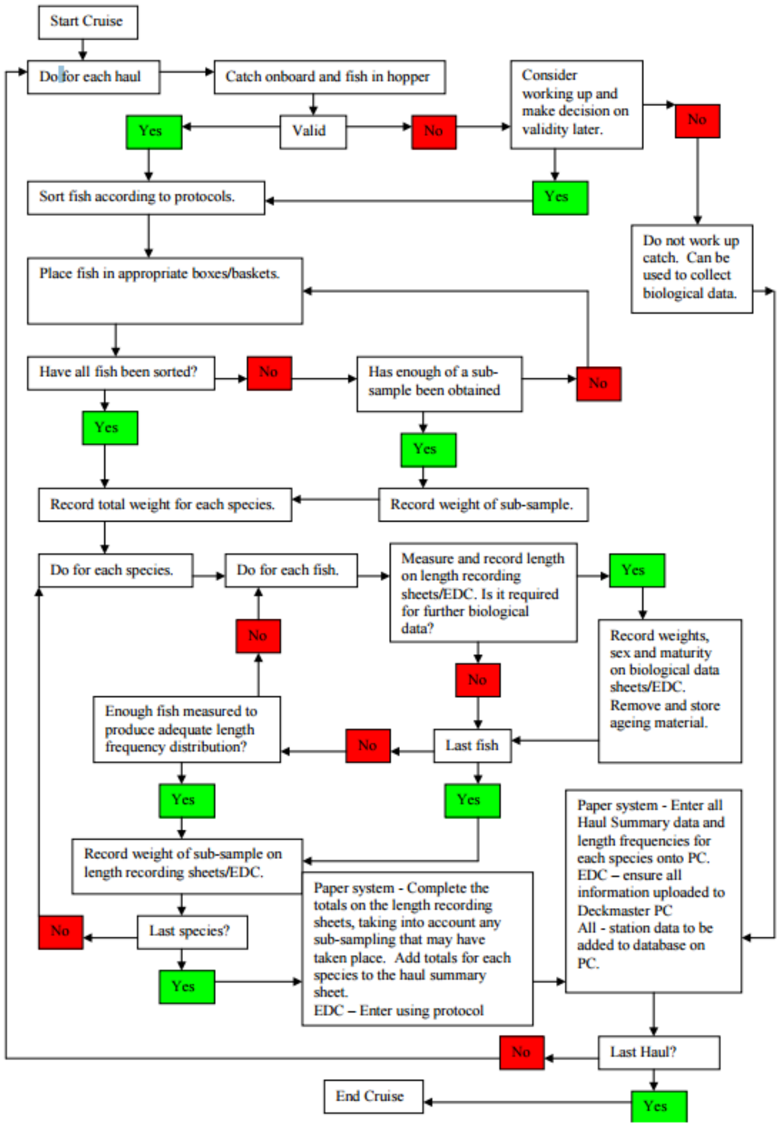

Figure 3.2.1: Flow diagram outlining the standard catch processing for all of the surveys within WGIBTS and WGBEAM. (ICES 2012b, ICES 2013a).

There is no standardized approach for the submission of abundance and size data for cephalopods and shellfish. Some national laboratories record abundance data for invertebrate species (benthos), although no agreed protocols for the collection and submission of these data exist, as the levels of taxonomic expertise on board vessels can be variable. Given the size and set up of their ground-gears, and the mesh size of their nets and codends, otter trawls generally, and the GOV in particular, are not effective gears for quantitatively sampling benthic invertebrates. However, it has been suggested that such data could be used to provide relatively crude distribution information. Such information can be recorded as presence/absence or as weights or numbers; it is left to the discretion of the institute collecting the data to decide which is most appropriate. Given the level of variation in the extent to which benthic invertebrate data are recorded, and in the type of information recorded when such data are actually collected, none of the benthic invertebrate data available on the DATRAS data portal have been retained in the groundfish survey monitoring and assessment data product. The data product, therefore, focuses solely on providing the means to assess the status of the fish community across the Northeast Atlantic region.

4. Data Quality Assurance Procedures

The data normally derived from groundfish survey data usually quantifies fish catch abundance (C) by species (s) and size category (l) at each sample (h) location, as numbers of fish caught per hour of trawl effort ($CPUE$). Thus, $CPUE_{s,l,h} = N_{s,l,h}/T_h$ where T_h is the haul duration in hours. For a half-hour trawl, therefore, this simply means raising each species' catch abundance at length by a factor of two. Two key assumptions are implicit in the use of such data:

i. That the vessels involved in the surveys trawl with consistent speed over the ground, so that for any given amount of trawling effort in terms of time spent fishing, the distances trawled in each sample are more or less equivalent;
ii. The width of the gear whilst trawling does not vary systematically; that any variation in gear width is random and thus simply contributes 'noise' to CPUE data, and that there is, therefore, nothing in the way that the trawl gear fishes that might impart bias to CPUE data.

For beam trawl surveys the width of the gear is fixed absolutely, but assumption (i) may frequently be violated; despite survey manuals defining strict operational trawls speeds, in practice it is frequently difficult to maintain sufficient control over trawling speed because of having to contend with tidal, weather and sea conditions. For otter trawl surveys, neither of these assumptions holds. Because of the greater size of the fishing gear, otter trawl operations may be even more subject to tidal, weather and sea conditions. It has been previously demonstrated that in the ICES North Sea IBTSs, the distance towed in 30 minutes can vary by almost a factor of two (Greenstreet et al., 2007), rendering CPUE data extremely noisy. Furthermore there is also a direct relationship between water depth and the width of the trawl gear (Fraser et al., 2007). With the requirement for a longer trawl warp at deeper depths, the action of the otter doors tends to pull the net wider than is the case in shallower water and shorter trawl warps. This variation in the performance of the net with increasing depth imparts a direct bias to CPUE data; all else being equal, CPUE values for deeper samples will be greater than equivalent data from shallower samples. Both these assumptions are examined further in later sections.

Violation of these two assumptions presents serious problems with using CPUE data, with effort measured as time spent fishing. Several authors have commented on the apparent low power of ecological indicators that use groundfish survey data to detect change in fish community composition and structure (Nicholson and Jennings, 2004; Maxwell and Jennings 2005). The noise associated with the CPUE data undoubtedly contributes to this lack of statistical power and any change that can reduce this noise can only benefit the use of ecological indicators to support environmental assessment. Therefore, following previous precedent in studies using ecological indicators to describe change in fish communities (Greenstreet and Rogers, 2006; Greenstreet et al., 2011; Greenstreet et al, 2012b; Greenstreet et al., 2012c), the groundfish survey monitoring and assessment data product described here to support the OSPAR IA2017 and MSFD assessments uses an alternative measure of trawling effort, the area swept by the trawl on each sampling occasion. The abundance-at-length statistic is, therefore, an estimate of the density of fish, by species and length, at each sampling location: the number of fish per square kilometre of seabed swept by the gear on each occasion. This statistic takes direct account of variation in the distance towed, brought about by either trawling for a longer or shorter period of time, or by variable trawl speed, and variation in the width of the gear whilst trawling. In order to derive accurate estimates of the area swept by the fishing gear, good estimates of both these parameters, the distance trawled and the width of the gear, are necessary.

For beam trawl surveys, the width of the gear is predetermined, being simply the width of the beam. For otter trawl surveys, the distance between the wings of the net would seem to be the obvious ‘width’ parameter, but the otter doors and sweeps can have a herding effect on some species pushing them into the path of the net from an area much wider than the area swept by the net alone. However, in their study of species catchability, Fraser et al (2007) suggest that the number of species that are prone to significant herding is relatively limited, just haddock and whiting among the 40 or so demersal species that they considered. The groundfish survey monitoring and assessment data product described here, therefore, focuses on a single species density-at-length statistic, the density of fish along the path fished by the net, determined as the product of the towed distance and the distance between the wings of the otter trawl. However, conversion multipliers are also provided should the density along the path swept between the otter doors need to be considered. Conversion factors are also provided that take acount of the height of the gear headline or beam, and so allow volumetric densities to be calculated, the number of fish sampled per cubic kilometre of water filtered by the gear. Such densities could, for example, be considered to be more appropriate for pelagic, or benthopelagic species.

In deriving a quality assured data product from the data stored in the DATRAS data portal, two types of data error were defined: 'erroneous data' and 'incorrect data'. Erroneous data were considered to be the consequence of a breakdown in the data archiving procedure. At some point a 'mistake' occurs during the archiving process such that the datum value in the database no longer matches the original value recorded at source. Such errors are easily corrected simply by editing the archived data values in the database. Incorrect data are more difficult to rectify; in these instances the archived values do match the original values recorded at source. If a mistake has occurred, it happened at source and it is, therefore, now not possible to establish absolutely that the outlier value in question is in fact a data error, and if so what the correct value should be. In these instances a judgement must be made as to whether the data value under scrutiny has sufficient credibility as to be possible, or whether the recorded value is so unlikely that it must be deemed to be wrong. In making these judgements, guidelines or criteria, need to be established. Where 'incorrect data', are deemed to be such extreme outliers as to not be possible, and so *wrong*, these data values are essentially deleted and a missing value procedure employed to replace them with more likely data.

The data products for each survey consist of two types of file. Firstly, essential information regarding each sampling event is contained in the "SamplingInfo" files. These consist of one record per sample with fields holding data on date, time of shooting, duration and position of the the tow, speed of trawling, depth of water, distance towed, and gear width and headline height above the seabed, area of seabed swept and volume of water filtered by the gear, etc. Secondly, the

“BiologicalInfo” files hold information on the catch taken in each sample with one record for each 1 cm length class of every species sampled. These catch data are recorded as number of fish caught per square kilometre of seabed swept between the wings of the gear. For both types of data, the protocols followed to check the veracity of the data, and the procedures used to estimate missing values, or to replace incorrect values, are described in full.

4.1. HH Data – Haul Summary Information

Figure 4.1.1. provides an overview of the process applied to derive the quality assured SampingInfo data product files.

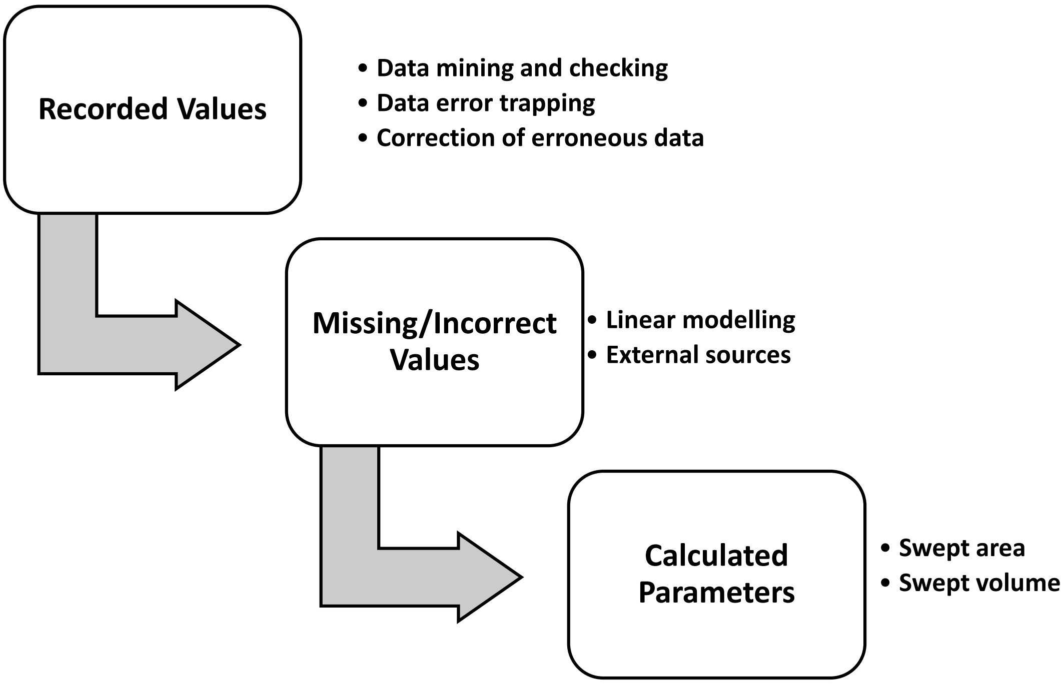

Figure 4.1.1: Summary of the protocol for quality assurance and estimation of missing gear parameters within a standardised survey area which addresses the need for estimation of some gear parameters for the MSFD monitoring programme data set.

4.1.1. Sample Location

In all instances a shoot position was provided, but frequently no haul position was given. In many cases where a haul position was recorded, this was often found to be identical to the shoot position. The common explanation for this was that, in reality, only the shoot position was actually recorded, and the same position was then entered into both sets of fields in the DATRAS data entry system. However, it is also conceivable that on occasion these duplicate positions could represent an average location for the trawl sample in question; the mean of the shoot and haul positions. Where both shoot and haul positions were identical, the haul position was deleted leaving this field blank. Thus haul position data was only retained where this differed from the shoot position. For the purposes of geo-referencing each trawl sample, shoot positions provided the most consistent tag.

As a first check, both the shoot and haul (where available) positions were examined to ensure that both corresponded to the ICES statistical rectangle stated for each sample. Where discrepancies were found, data providers were asked to verify which information was correct. Generally, and particularly early on in survey time series, the ICES statistical rectangle recorded in the data set was the more reliable parameter value, and any error lay in the recorded shoot/haul positions. Where archived values were simply erroneous, these errors were corrected. If just one of the shoot/haul positions was incorrect, then this was simply deleted leaving just the single correct value to provide a geo-reference for the trawl sample in question. Invariably it was the haul position that was located in another ICES statistical rectangle. Where both shoot/haul positions were either missing or incorrect, and the data provider was unable to provide a likely haul position then these data were replaced with the ICES statistical rectangle mid-point position to provide a geo-reference for the trawl sample in question. If the ICES statistical rectangle was thought to be the erroneous or incorrect parameter value, and the shoot/hauls positions deemed reliable, then the recorded ICES rectangle was changed to the rectangle corresponding with the recorded shoot/haul positions.

4.1.2. Depth

The reliability of depth values recorded in the depth field (D_{rec}) was assessed by deriving estimated 'depth check' values (D_{est}) for each recorded trawl location from ocean bathymetry map data (http://maps.ngdc.noaa.gov/viewers/bathymetry/) provided by the National Oceanic and Atmospheric Administration (NOAA) (Figure 4.1.2.1). If both shoot and haul position information was available then a depth transect along the straight line between these two positions was generated and the mean depth along this transect used as the 'depth check' value. If only the shoot position was available, then the depth at that location was used as the 'depth check' value. If no reliable shoot/haul position data were available, then depth at the mid-point location of the ICES statistical rectangle was used as the 'depth check' value.

Figure 4.1.2.1: Example of the National Oceanic and Atmospheric Administration (NOAA) Ocean Bathymetry map covering the area -15 to 10 degrees longitude and 35 to 63 degrees latitude was used to estimate depth for trawl samples collected in this area where depth was either a missing value or deemed to be incorrect.

A 'depth deviation' statistic (D_{dev}) was calculated as $D_{dev} = \sqrt{(D_{rec} - D_{est})^2}$ and all instances where D_{dev} was >50% of D_{rec} (i.e. $D_{dev}/D_{rec} > 0.5$) were referred back to the data providers for checking. Erroneous values in the DATRAS database (i.e. where the recorded depth value in the database did not match the value recorded at source) were corrected and the HH records involved then passed through the checking procedure again. In the majority of cases, data providers asserted that apparently aberrant depth values were in fact correct. Plotting a spatial map of the D_{dev}/D_{rec} values revealed that in all cases, unexpectedly large D_{dev} values were associated with trawl samples obtained close to the continental shelf edge (Figure 4.1.2.2). The recorded depths were, therefore, deemed credible and the high deviations likely to have arisen as minor mapping errors in regions of sharply changing depth (that D_{est} was, therefore, unreliable). Where depth data were missing, the estimated depth at the location, D_{est}, was inserted to fill the missing value. Across all surveys examined, only in 527 cases were such depth estimates necessary, amounting to approximately 1% of the samples.

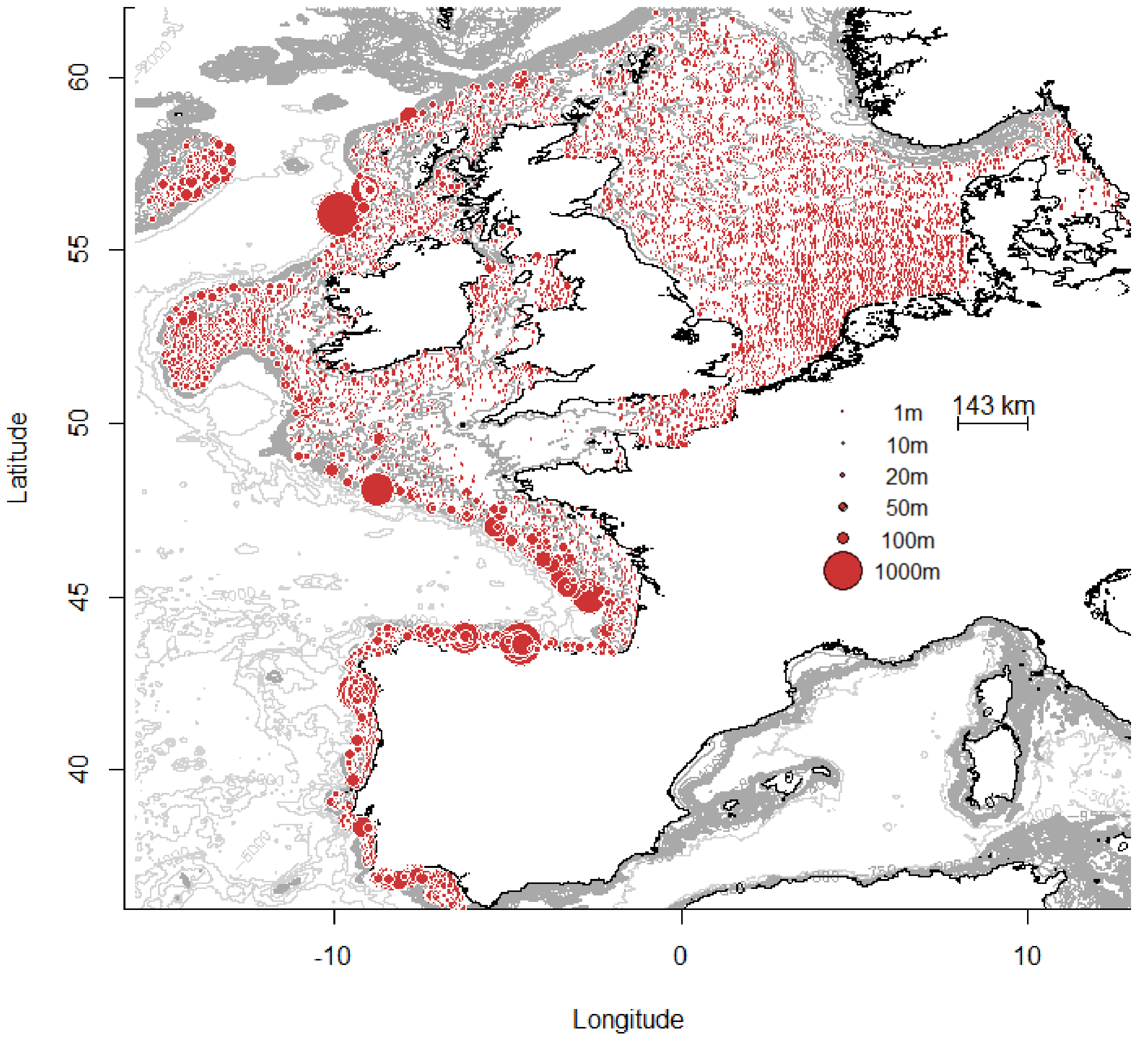

Figure 4.1.2.2: Spatial plot of the depth deviation statistic, D_{dev}.

The code to carry out the depth checks is available within the R Script number 6 “Haul_QA” line 104-178 housed on Marine Scotland Science’s Github (Moriarty, 2017a).

4.1.3. Sweep Length

Sweep length values are missing in 40% of the data across Europe (19512 out of 48487 values). Sweep length is prescribed by the IBTS Manual, which stipulates that different lengths of sweep should be used depending on water depth at the sample location. Since each survey has a different set of prescribed protocols, they are dealt with individually.

Standard methodology for the first quarter North Sea IBTS is to change the sweep length from the short (50 m sweep plus a 10 m back-strop) to a long sweep length (100 m sweep plus a 10 m back-strop) at depths in excess of 70 m (ICES 1992, ICES 1994, ICES 1997, Heessen et al 1997, ICES2006, ICES 2007a, ICES 2010a, ICES 2011, ICES 2012a, ICES 2013a, ICES 2014, ICES 2015). This protocol had become generally established by 2001, but it was not clear how widely these guidelines had been adhered to prior to this (ICES 2001). Furthermore, evidence of some deviation from these recommendations has been documented. For example, between 15 February and 14 March 2012, long sweep lengths were not used at all deeper stations in Norway's first Quarter North Sea IBTS (ICES 2012a), and again in 2013, Scotland only used long sweeps on the first 12 tows of their first quarter North Sea IBTS (ICES 2013a). Since IBTS manual guidelines not been strictly followed by all parties involved in the first quarter IBTS, simply applying the protocol to infill missing values in the sweep length field was not appropriate. Instead, a comprehensive review of the history of the IBTS protocols and known deviations was undertaken and used to provide the basis for addressing missing values.

Because of doubts regarding the extent to which sweep lengths were actually changed when operating at depths greater or less than 70 m, when the third quarter North Sea IBTS became established WGIBTS recommended that only the short sweep length (60 m length in total including 10 m backstrop) be used at all depths (ICES, 1992). However, to preserve the first quarter survey time series, this recommendation was not implemented for the Q1 survey. The 60 m total sweep-backstrop length was chosen because this was the preferred rigging used in earlier surveys (ICES, 1992). Again, deviations away from this prescribed methodology are known to have occurred. For example, a 20 m sweep was used on all samples collected by the English vessel RV Endeavour during the third quarter IBTS in 2006 (ICES, 2007a).

GOV-based otter trawl groundfish surveys carried out in waters to the west of the UK and Europe all started independently with the result that each country/vessel combination has developed its own protocol regarding sweep lengths. Only more recently has some degree of coordination been attempted. Thus, France used both short (60 m sweep plus backstrop) and long (110 m sweep plus backstrop) sweep lengths, with the change-over meant to take place at a depth of 125 m, while Ireland and Scotland used only a 60 m (sweep plus backstrop) sweep length regardless of depth. England used a sweep of 18.28 m (ICES 2013b). More recently, since 2011, a more coordinated approach has seen the use of 60 m sweep lengths at depths up to 80 m and sweep lengths of 110 m at depths greater than this (ICES, 2012a, ICES 2013a). Portugal and Spain do not use a GOV trawl, but for completeness, Portugal's gear has no sweep, while Spain uses a 200 m sweep with their gear (ICES, 2001).

Over the past two decades several analyses have occurred to address the question of how varying the sweep length affects the catchability of key species. In 1994, Germany obtained data to evaluate the difference in catch rates between a GOV rigged with short (60 m sweeps plus back-strops) and long (110 m sweeps plus back-strops) to help to decide whether there was actually any need to use the longer sweeps in depths over 70 m in Quarter 1 surveys (ICES, 1994). Analysis of the effect of the 20 m sweep used by the Cefas Endeavour in the 2006 survey concluded that whilst gear parameters were on the low side, they were still within the limits defined in IBTSWG manual revision VII and, for the key target species cod, haddock, whiting, saithe, herring, no effect was detectable within the natural variation in the recorded data (ICES, 2007a). Further analysis of the Quarter 1 North Sea IBTS data concluded that both Scotland and Sweden could use longer short (60 m) sweeps, and Denmark, Germany and Sweden, might use shorter long (110 m) sweeps to ensure gear geometry parameters that were closer to the recommended values, so long as proper contact with the seabed was maintained (ICES, 2012a).

Tables 4.1.3.1, 4.1.3.2 and 4.1.3.3 below summarise the sweep length practices used over the time series of the first quarter North IBTS, third quarter North Sea IBTS and the otter trawl surveys carried out in waters to the west of the UK and Europe respectively. Where recorded values matched either of the stipulated sweep lengths, but were inappropriate given the depth at which the sample was collected, the recorded sweep length was retained on the assumption that a mistake occurred whilst the survey was in progress; the incorrect sweep length was actually used, rather than it being a data recording error. The information provided in these tables indicates the sweep length values assumed where values were missing. These tables have been checked by the relevant Data Providers.

Year	Denmark	England	France	Germany	Netherlands	Norway	Scotland	Sweden
1983	60/110	60/110	60/110	60/110	60/110	60/110	60/110	60/110
1984	60/110	60/110	60/110	-9/80	60/110	60/110	60/110	60/110
1985	60/110	18/60/110	60/110	60/110	60/110	60/110	60/120	60/110
1986	60/110	60/110	60/110	60/110	60/110	60/110	60/110	60/110
1987	60/110	60/110	60/110	60/110	60/110	60/110	60/110	60/110
1988	60/110	60/110	60/110	60/110	60/110	60/110	60	60/110
1989	60/110	60/110	60/110	60/110	60/110	60/110	60	60/110
1990	60/110	60/110	60/110	60/110	60	60/110	60	60/110
1991	60/110	60	60/110	60/110	60/110	60/110	60/110	60/110
1992	60/110	60	60/110	60/110	60/110	60/110	60	60/110
1993	60/110	60	60	60/110	60	60/110	60	60/110
1994	60/110	60	60	60/110	60	60/110	60	60/110
1995	60/110	60	60	60/110	60	60/110	60	60/110
1996	60/110	60	60	60/110	60	60/110	60	60/110
1997	60/110	60	60	60/110	60	60/110	60	60/110
1998	60/110	60	60	60/110	60	60/110	60	60/110
1999	60/110	60	60	60/110	60	60/110	60	60/110
2000	60/110	60	60	60/110	60	60/110	60	60/110
2001	60/110	60	60	60/110	60	60/110	60	60/110
2002	60/110	60	60	60/110	60	60/110	60	60/110
2003	60/110	60	60	60/110	60	60/110	60	60/110
2004	60/110	X	60	60/110	60	60/110	60	60/110
2005	60/110	X	60	60/110	60	60/110	60	60/110
2006	60/110	X	60	60/110	60	60/110	60	60/110
2007	60/110	X	60	60/110	60	60/110	60	60/110
2008	60/110	X	60	60/110	60	60/110	60	60/110
2009	60/110	X	60	60/110	60	60/110	60	60/110
2010	60/110	X	60	60/110	60	60/110	60	60/110
2011	60/110	X	60	60/110	60	60/110	60	60
2012	60/110	X	60	60/110	60	60/110	60	60/110
2013	60/110	X	60	60	60	60/110	60/110	60/110
2014	60/110	X	60	60	60	60/110	60	60/110
2015	60/110	X	60	60	60	60/110	60	60/110
2016	60/110	X	60		60	60/110		60/110

Table 4.1.3.1: Summary of sweep length practices used by different nations participating in the first quarter North Sea IBTS. Where two depths are indicated (e.g. 60/110) this denotes the change from a short to a long sweep length at a depth of 70 m (ICES 2010). Green cells indicate where the WGIBTS recommendations for sweep length have been adhered to. Yellow cells indicate where the WGIBTS recommendations for sweep length have not been adhered to, but where sweep length has been recorded in the data base. Grey cells indicate where data in the sweep length field are missing, but a value can be inferred from the ICES manuals and WGIBTS reports. X in a cell indicate no survey undertaken by the country in the year.

Year	Denmark	England	France	Germany	Netherlands	Norway	Scotland	Sweden
1991	60/110	50	X	60	60	60	60	60
1992	60/110	50	60	60	0/60	60	60	60
1993	60/110	50	60	60	0/60	60	60	60
1994	60/110	50	60	60	0/60	60	60	60
1995	60/110	50	60	60	60	60	60	60
1996	60/110	50	60	60	60	60	60	60
1997	X	50	X	60	60	60	60	60
1998	60/110	50	X	60	X	60	60	60
1999	60/110	50	X	60	X	60	60	60
2000	110	50	X	60	X	60	60	60
2001	60/110	50	X	60	X	60	60	60
2002	60/110	50	X	60	X	60	60	60
2003	60/110	50	X	60	X	60	60	60
2004	60	40	X	60/110*	X	60	60	60
2005	60	40	X	60/110*	X	60	60	60
2006	60	20	X	60/110*	X	60	60	60
2007	60	40	X	60/110*	X	60	60	60
2008	60	40	X	60	X	60	60	60
2009	60	40	X	60/110*	X	X	60	60
2010	60	40	X	60/110*	X	60	60	60
2011	60	40	X	60	X	60/110	60	60
2012	60	40	X	60	X	110	60	60
2013	60	40	X	60	X	60/110	60	60
2014	60	40	X	60	X	60	60	60
2015	60	40	X	60	X	60	60	60
2016			X		X			

Table 4.1.3.2: Summary of sweep length practices used by different nations participating in the third quarter North Sea IBTS. Where two depths are indicated (e.g. 60/110) this denotes the change from a short to a long sweep length at a depth of 70 m (ICES 2010). Green cells indicate where the WGIBTS recommendations for sweep length have been adhered to. Yellow cells indicate where the WGIBTS recommendations for sweep length have not been adhered to, but where sweep length has been recorded in the data base. Grey cells indicate where data in the sweep length field are missing, but a value can be inferred from the ICES manuals and WGIBTS reports. X in a cell indicate no survey undertaken by the country in the year.

Year	Scotland WAScoOT3	Scotland CSScoOT1 CSScoOT4	France CSFraOT4	France DNSFraOT4	Ireland	Spain
1985	X	60	X	X	X	X
1986	X	60	X	X	X	X
1987	X	60	X	X	X	X
1988	X	60	X	50	X	X
1989	X	60	X	50	X	X
1990	X	60	X	50	X	X
1991	X	60	X	50	X	X
1992	X	60	X	50	X	X
1993	X	60	X	50	X	X
1994	X	60	X	50	X	X
1995	X	60	X	50	X	X
1996	X	60	X	50	X	X
1997	X	60	50/100	50	X	X
1998	X	60	50/100	50	60/-	X
1999	60	60	50/100	50	60/-	X
2000	60	60	50/100	50	60/-	X
2001	60	60	50/100	50	60/-	200
2002	60	60	50/100	50	60/-	200
2003	60	60	50/100	50		200
2004	60	60	50/100	50	55/110	200
2005	60	60	50/100	50	55/110	200
2006	60	60	50/100	50	55/110	200
2007	60	60	50/100	50	55/110	200
2008	60	60	50/100	50	55/110	200
2009	60	60	50/100	50	55/110	200
2010	-	60	50/100	50	55/110	200
2011	110	60/110	50/100	50	55/110	200
2012	110	60/110	50/100	50	55/110	200
2013	110	60/110	50/100	50	55/110	200
2014	110	60/110	50/100	50	55/110	200
2015	110	60/110	50/100	50	55/110	200
2016	110	60/110	50/100	50	55/110	

Table 4.1.3.3: Summary of sweep length practices used by different nations participating in surveys undertaken in waters to the west of the UK and Europe. Where two sweep lengths are indicated (e.g. 60/110) this denotes the change from a short to a long sweep length at a depth of 80 m (Scotland and Ireland) or 120 m (France) depending on the country (ICES 2010). Green cells indicate where the WGIBTS recommendations for sweep length have been adhered to. X in a cell indicate no survey undertaken by the country in the year.

4.1.4. Haul Duration

Haul duration was a key parameter used to define the standard monitoring programmes for each survey (Section 2), such that extreme long (>66) and short (<13) duration hauls were excluded from the standard survey monitoring programmes. These samples with extreme haul duration were all referred to the

Data Providers to check the reliability of the recorded values; in a couple of instances the haul duration values were found to be erroneous and could be corrected. If the corrected haul duration was between 13 and 66 minutes, then the haul sample was retained as part of the standard monitoring programme. Remaining extreme haul duration samples were all excluded from the standard monitoring programmes. There were no missing haul duration values.

Only time of shooting the net is recorded, hauling time is not, so it was not possible to check haul duration directly be comparing these two times.

In Section 4.1.6 haul duration, ground speed and distance towed are compared to examine the degree of consistency between the three values.

4.1.5. Groundspeed

In instances where the required field tow distance ($D_{tow,h}$) holds either no data or data deemed to be incorrect, an estimate of tow distance might be derived as the product of haul duration (T_h) and haul groundspeed ($V_{ground,h}$), thus $D_{tow,h} = T_h V_{ground,h}$. Figure 4.1.5.1 shows the process used to assess the reliability of recorded groundspeed data and the approach used to estimate missing values. The field Groundspeed is recorded in knots (nautical miles per hour). This value was missing in 38% of samples.

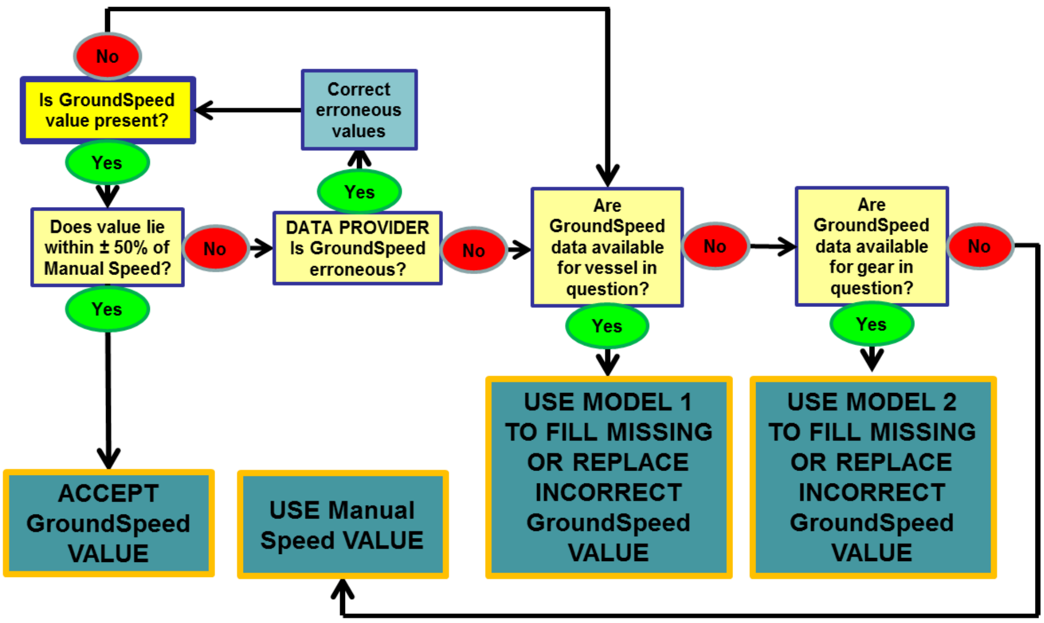

Figure 4.1.5.1: Flow chart depicting the process used to either accept or reject a groundspeed value and to estimate missing values.

For the beam trawl surveys, all recorded groundspeed values were within 4 knots ± 1.0 knots; recorded groundspeed tended to be slightly slower in the German beam trawl survey. For the otter trawls, recorded speed over ground was more variable. Spanish and Portuguese otter trawl surveys recorded slower groundspeeds, generally within 3 knots ± 1 knot. The remaining otter trawl surveys generally recorded groundspeed values of between 4 knots ± 2.0 knots, which was considered to be within acceptable bounds for the type of gear (usually a GOV) used (Figure 4.1.5.1). Just two recorded groundspeed values were found to exceed the first error trap range of ±50% of the recommended manual speed: one of 8.4 knots was recorded in the CSIreOT4 survey and a second of just over 6 knots recorded in the GNSIntOT3 (Table 4.1.5.1). To conclude, in the 62% of instances where groundspeed was recorded, recorded values almost invariably fell within the bounds stipulated in the relevant survey manuals (ICES 2009a).

Survey	Tow speed (knots)							Total
	2-2.9	3-3.9	4-4.9	5-5.9	6-6.9	7+	NA	
GNSIntOT1	14	3231	3776	25	0	0	6470	13516
GNSIntOT3	20	3146	1399	1	1	0	1305	5872
GNSFraOT4	0	0	0	0	0	0	2398	2398
CSScoOT1	0	1021	207	2	0	0	565	1795
CSScoOT4	7	1068	181	2	0	0	267	1525
CSIreOT4	27	1103	979	8	0	1	95	2213
CSNIrOT1	0	0	0	0	0	0	1172	1172
CSNIrOT4	0	0	0	0	0	0	1180	1180
CS/BBFraOT4	2	1585	782	1	0	0	271	2641
BBIC(n)SpaOT4	462	2366	0	0	0	0	0	2828
BBIC(s)SpaOT1	20	757	0	0	0	0	3	780
BBIC(s)SpaOT4	15	684	0	0	0	0	1	700
BBICPorOT4	1	865	0	0	0	0	0	866
WAScoOT3	0	504	58	0	0	0	3	565
WASpaOT3	2	1102	0	0	0	0	0	1104
GNSNetBT3	0	0	3657	0	0	0	0	3657
GNSEngBT3	0	89	77	0	0	0	2223	2389
GNSGerBT3	0	575	89	0	0	0	0	664
CSEngBT3	0	62	151	0	0	0	2409	2622
Total	570	18158	11356	39	1	1	18362	**48487**

Table 4.1.5.1: Number of hauls in each groundfish survey with given recorded speed over ground. NA indicates hauls where speed-over-ground data were absent, amounting 38% of the total number. Numbers highlighted in red indicate the hauls trapped in the error trap process shown in Figure 4.1.5.1.

The error trap shown in Figure 4.1.5.1 does not actually assess the reliability of recorded towing groundspeed; rather it establishes whether or not the values recorded either complied (within stated bounds) or did not comply with the speeds recommended for the various surveys in their respective manuals. Section 4.1.4 established that all haul samples retained in the survey standard monitoring programmes had valid haul duration values recorded. Approximately 90% of HH records where groundspeed was recorded also had values recorded in the tow distance field enabling calculation of a "realised" groundspeed ($V_{ground,h,realised} = D_{tow,h}/T_h$). Comparison of these "realised" groundspeeds with the groundspeed values actually recorded suggested considerable inconsistency between the three variables ($V_{ground,h}$, $D_{tow,h}$ and T_h) within the recorded data (Figure 4.1.5.2).

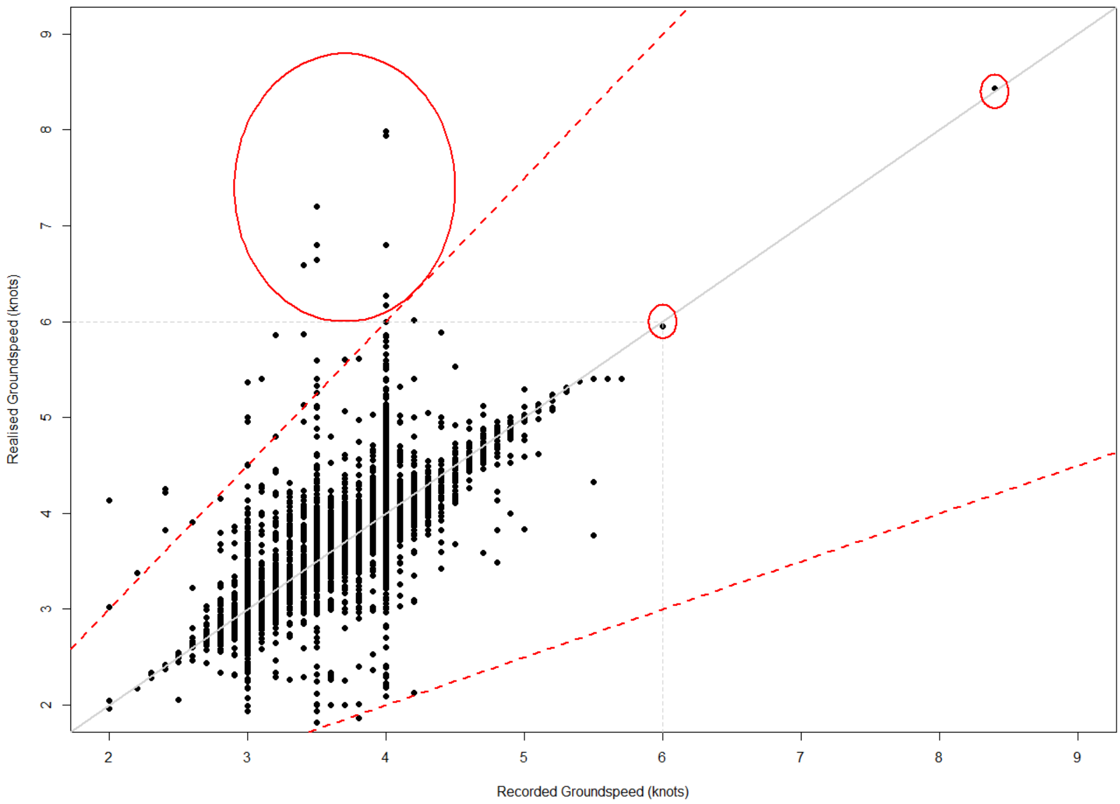

Figure 4.1.5.2: Comparison of calculated realised groundspeed values with groundspeed values actually recorded. Two data points circled in red indicate the two trawl samples caught by the non-compliance with recommended manual speeds error trap illustrated in Figure 4.1.5.1. Solid grey line shows the anticipated relationship for a perfect match between realised and recorded groundspeed values. Red dashed lines bound the data where the realised groundspeed is within ± 50% of the recorded groundspeed value. Data highlighted by the large red circle indicate instances where, although the recorded Groundspeed was within the error trap limits, the realised Groundspeed actually exceeded the upper error trap limit.

Referral to the data providers suggested that recorded tow duration values were likely to be reliable; inconsistency between “realised” and recorded groundspeed was more likely to be attributable to errors in recorded groundspeed or recorded distance towed. Distinct vertical bands are evident in Figure 4.1.5.2 corresponding with recorded groundspeeds of 4 knots, 3.5 knots and 3 knots, which are the mean, or manual recommended, groundspeeds for the GOV otter trawl and Dutch beam trawl surveys, the German and English beam trawl surveys, and the Spanish and Portuguese otter trawl surveys respectively. This suggests that in many cases “standard” trawling speeds, e.g. the speed stipulated in the pertinent manual, had been recorded in the database rather than actual measured groundspeeds; implying that the groundspeed values recorded were perhaps the less reliable. Few of the data points shown in Figure 4.1.5.2 fell below the lower bound. Generally, recorded tow distances were either too long given the groundspeed recorded, or alternatively trawling speed was actually faster than the groundspeed recorded. However, if recorded tow distance were deemed the more reliable, then in at least nine instances, the tow distance recorded would infer a groundspeed that exceeded the upper bound of the error trap illustrated in Figure 4.1.5.1 of +50% of the manual groundspeed; over five times more than the number of such errors actually detected. Furthermore, it was also clear that in several cases, the realised Groundspeed exceeded the recorded Groundspeed by a factor of >1.5.

It is not possible, therefore, to reach any conclusion regarding which are the more reliable data, groundspeed or distance towed. However, as stated at the start of this section, distance towed is the key variable needed to estimate the area swept by the gear when collecting each sample. If we use towed distance to estimate groundspeed, inserting the calculated “realised” groundspeed where groundspeed data are missing, or where the recorded distance might be erroneous or incorrect, then this would tend to preclude our use of groundspeed as part of the procedure to assess the reliability of the recorded towed distance data (see Section 4.1.6); the process would become circular.

Two alternative models to estimate missing groundspeed data were, therefore, developed instead, neither of which included towed distance as an explanatory variable. Essentially each model provided an estimate of groundspeed that still included all the vagaries inherent in the actual recorded groundspeed data. Choice of model depended on the data available (Figure 4.1.5.1). If any groundspeed data were available for the vessel in question, then an interaction term model that included vessel identity, season and fishing gear (Model 1 in Figure 4.1.5.1) could be used,

$$V_{ground} = 3.41585 + Quarter{:}Vessel{:}Gear$$ Equ. 4.1.5.1.

This model was statistically significant ($P < 0.0001$) with an adjusted $R^2 = 0.7414$ and where numerical values for the Quarter:Vessel:Gear interaction term are provided in Table 4.1.5.2. However, if no groundspeed data were recorded at all for a particular vessel, then a second interaction term that only included season and fishing gear (Mmodel 2 in Figure 4.1.5.1) had to be used instead,

$$V_{ground} = 3.41585 + Quarter{:}Gear$$ Equ. 4.1.5.2.

This second model was again highly significant ($P < 0.0001$), and still had an adjusted $R^2 = 0.6734$. Numerical values for the Quarter:Gear interaction term are given in Table 4.1.5.3. If no groundspeed data were available for a vessel and this was the only vessel participating in the survey, then the groundspeed stipulated in the relevant manual was assumed. Where data for Groundspeed were missing, 31% of records were estimated using Equation 4.1.5.1, 44% were estimated using Equation 4.1.5.2, and the remaining 25% were simply filled with the value recommended in the relevant manual.

Interaction term (*Quarter : Vessel : Gear*)	Numerical value
1 : *Miguel Oliver* : BAK	-0.40335145
4 : *Miguel Oliver* : BAK	-0.44069422
1 : *Cornide de Saavedra* : BAK	-0.41612282
4 : *Cornide de Saavedra* : BAK	-0.39361195
3 : *Endeavour* : BT4A	0.55802718
3 : *Solea 1* : BT7	0.56376020
3 : *Solea 2* : BT7	0.24225907
3 : *Isis* : BT8	0.58414855
3 : *Tridens* 2 : BT8	0.58414855
1 : G. O. *Sars* : GOV	0.45894194
1 : *Argos* : GOV	0.33337382
3 : *Argos* : GOV	0.32000441
4 : *Celtic Explorer* : GOV	0.45841673
1 : *Dana 2* : GOV	0.51011540
3 : *Dana 2* : GOV	0.50030501
1 : *Dana* (Sweden) : GOV	0.26961111
3 : *Dana* (Sweden) : GOV	0.28059300
1 : *Eldjarn* : GOV	0.41377818
3 : *Endeavour* : GOV	0.48615301
1 : *Endeavour* : GOV	0.58414855
3 : *Johan Hjort* (new): GOV	0.26142128
1 : *Mimer* : GOV	0.28182297
1 : *Scotia 2* : GOV	0.92863016
4 : *Scotia 2* : GOV	0.51211465
1 : *Scotia 3* : GOV	0.30212090
3 : *Scotia 3* : GOV	0.28457368
4 : *Scotia 3* : GOV	0.26485031
1 : *Thalassa* : GOV	0.55772368
1 : *Thalassa 2* : GOV	0.53310253
4 : *Thalassa 2* : GOV	0.44091785
1 : *Tridens 2* : GOV	0.58414855
1 : *Walter Herwig 3* : GOV	0.56017643
3 : *Walter Herwig 3* : GOV	0.61340166
4 : *Noruega* : NCT	0.01555733

Table 4.1.5.2: Numerical values to substitute into the Quarter:Ship:Gear interaction term in Equation 4.1.5.1 to predict missing groundspeed values where data are available for the vessel in question.

Interaction term (*Quarter : Gear*)	Numerical value
1 : BAK	-0.41546535
4 : BAK	-0.39784975
3 : BT4A	0.55802718
3 : BT7	0.29213048
3 : BT8	0.58414855
1 : GOV	0.46292179
3 : GOV	0.37796801
4 : GOV	0.41390321
4 : NCT	0.01555733

Table 4.1.5.3: Numerical values to substitute into the Quarter:Gear interaction term in Equation 4.1.5.2 to predict missing groundspeed values where no data are available for the vessel in question.

The code to generate the linear models used to estimate ground speed is available within the R Script "Haul_QA" line 301-466 housed on Marine Scotland Science's Github (Moriarty, 2017a).

4.1.6. Towed Distance

Figure 4.1.6.1. illustrates the protocol used to assess the reliability of recorded Towed distance values, correct erroneous values, replace incorrect values and estimate values where this information was missing.

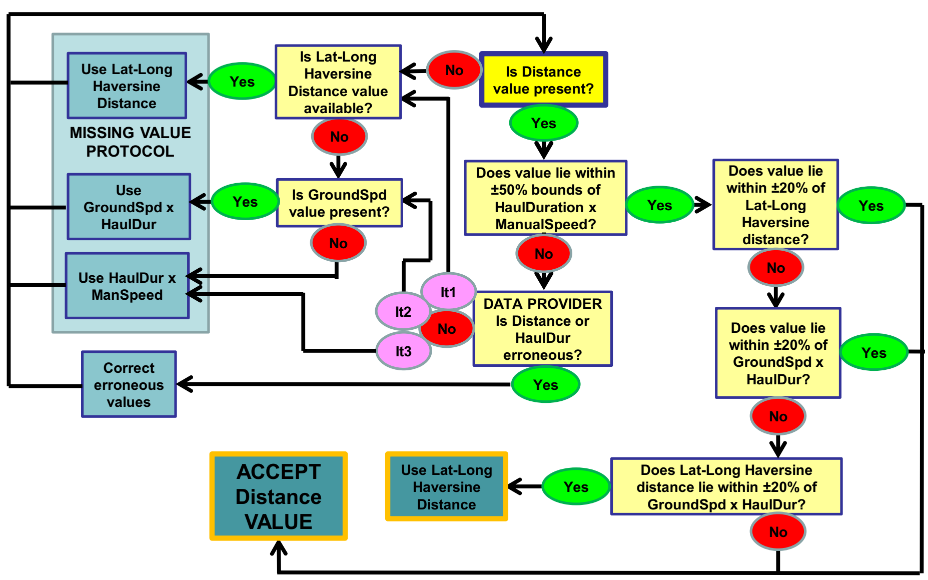

Figure 4.1.6.1: Flow chart illustrating the steps involved in assessing the validity of recorded Towed distance values and to estimate missing and replace incorrect data.

If the Towed distance field held no value, then an estimate of the missing value was necessary since this information was critical to deriving an estimate of the area of seabed swept by the gear when collecting the sample. If valid shoot and haul positions were available, then the great circle distance between these two positions on a sphere, calculated using the Haversine equation ($D_{Haversine}$), provided one possible estimate of the Towed distance. The Haversine equation is

$$D_{Haversine} = 12742 \sin^{-1}\left(\sqrt{\sin^2\left(\frac{\Delta\varphi}{2}\right) + \cos(\varphi_{Shoot})\cos(\varphi_{Haul})\sin^2\left(\frac{\Delta\omega}{2}\right)}\right) \quad \text{Equ. 4.1.6.1,}$$

where 12742 is two times the radius of the earth, assumed to be 6371km, and where $\Delta\varphi$ and $\Delta\omega$ are the differences between the two latitudes and the two longitude respectively and φ_{Shoot} and φ_{Haul} are the shoot and haul latitudes respectively, all with degrees converted to radians. If Groundspeed data were provided, then an alternative estimate for missing Towed distance data could be obtained from the product of Groundspeed and Haul duration. If both options were possible then initial preference was given to the Haversine approach simply because of the frequent, and often quite considerable, discrepancy between recorded Groundspeed and "realised" Groundspeed discussed above in Section 4.1.5. If neither option was available, then an estimate of Towed distance could always be determined simply as the product of the towing speed recommended by the relevant manual for the survey in question and Haul duration. In this way, using one of these three approaches, an estimate of Towed distance could always be determined for any HH record where data for this field were missing.

Next the reliability of all Towed distance records, whether recorded or estimated following one of the three approaches described above, had to be assessed. The primary error trap depended on whether each Towed distance value lay within the bounds of ±50% of the product of the Haul Duration and the towing speed recommended in the appropriate manual relevant to the particular survey. Where values failed this trap, then HH records were referred to the data providers to determine whether the Towed distance value (or indeed the Haul duration value) were erroneous. Where this was the case, the records were simply corrected and then passed through the protocol illustrated in Figure 4.1.6.1 once more. Where no error was found, the recorded Distance towed value was deemed to be incorrect and treated as a missing value and the missing value protocol, as described above, was applied. If a Haversine distance could be calculated, this was substituted for the "incorrect" recorded value. If this was not possible the product of Groundspeed and Haul duration was applied to replace the "incorrect" recorded value, or failing this, the product of the manual recommended towing speed and Haul duration was applied. These records were passed through the full protocol once more.

All records where Towed distance was either missing, or deemed to be “incorrect” and so treated as a missing value, had eventually to pass the primary error trap. If the preferred fill in estimate, the Haversine distance failed the trap, then on the second iteration this was replaced by the Groundspeed – Haul duration product, and if this subsequently failed the trap, then on the third iteration, this was replaced by the Manual recommended speed – Haul duration product, and by definition, this last replacement value was bound to meet the trap condition.

A secondary reliability process to assess internal consistency then commenced. If the Towed distance value was within ± 20% of the Haversine distance, the value was accepted. If it was outside ± 20% of the Haversine distance, but within ± 20% of the Groundspeed – Haul duration product the value was accepted. If neither of these conditions held, the Towed distance value lay outside the ± 20% bounds of both the Haversine distance and the Groundspeed – Haul duration product, but these two check parameters corroborated one another, then the Towed distance value was replaced by the Haversine distance. If this third condition did not hold either, then internal consistency between these three parameters was low, so the Towed distance value was simply accepted. Essentially this part of the protocol ensured that Towed distance values that passed the primary error trap were automatically accepted, except under circumstances where the value differed in excess of ± 20% from both the Haversine distance and the Groundspeed – Haul duration product, and the Groundspeed – Haul duration product corroborated the alternative use of the Haversine distance.

The consequence of following the protocol illustrated in Figure 4.1.6.1 was that all Towed distance values in the resulting groundfish survey monitoring and assessment data product were forced to be within the bounds of ± 50% of the product of the towing speed recommended in the manuals pertinent to each survey and Haul duration (Figure 4.1.6.2). Consultation with the data providers, and with fishing gear technologists suggest that this is reasonable. Towing speeds faster than the upper bound would have been difficult to achieve and speeds both faster than the upper bound and slower than the lower bound would have resulted in the fishing gear not fishing properly. Fishing masters in charge of fishing operations on the research vessels, and scientists in charge of the surveys, would have been aware of this so that, if such a situation had arisen, the haul in question should have been declared invalid. Where such situations appear to have occurred, the records in question have been deemed to be erroneous, and the towed distance corrected according to the procedures described. Following implementation of the protocol illustrated in Figure 4.1.6.1, and described above, the actual recorded Towed distance value was used in 77.4% of cases, the Haversine distance was used in 15.1% of cases, the Groundspeed by Haul duration product was used in 7.3% of cases and the recommended manual speed by Haul duration product was used in 0.2% of cases.

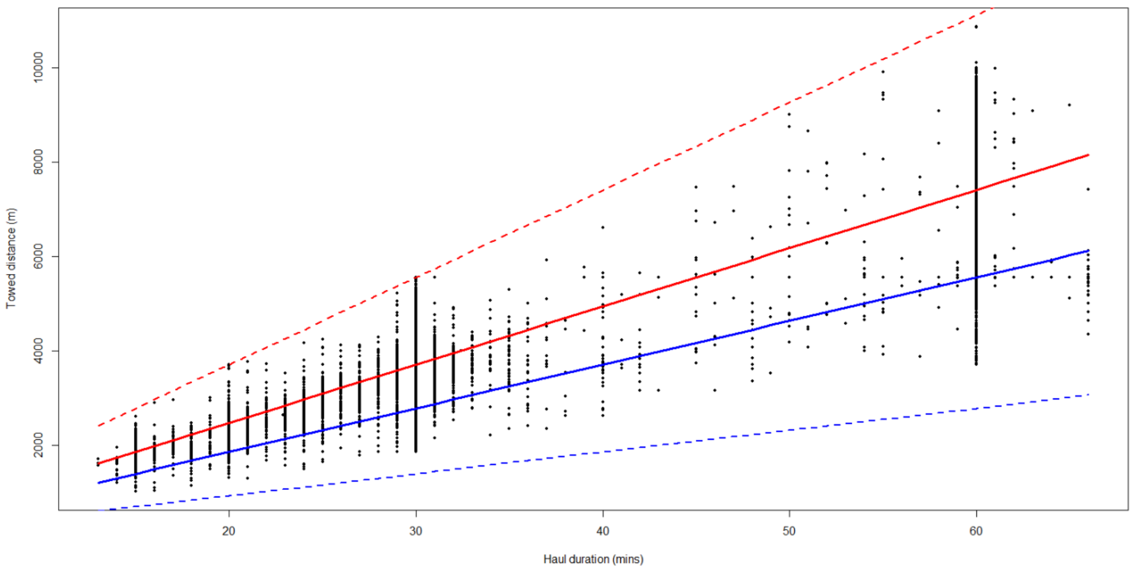

Figure 4.1.6.2: Plot of Towed distance against Haul duration. Upper dashed red line illustrates the upper bound assuming a Groundspeed of 6 knots (+50% of the fastest recommended towing speed of 4 knots) and lower dashed red line illustrates the lower bound assuming a Groundspeed of 1.5 knots (-50% of the slowest recommended towing speed of 3 knots). Solid lines show the relationship given a Groundpeed of 4 knots (red) or 3 knots (blue).

The code to generate the linear models used to estimate towed distance is available within the script 6 “Haul_QA” line 468-601 housed on Marine Scotland Science’s Github (Moriarty, 2017a).

4.1.7. Otter Trawl Net Geometry Parameters

The second key parameter required to derive fish density estimates is a measure of the width of the towed path. As already discussed, two potential width measures could be used: the width delimited by the distance between the wings of the net, the Wing spread, or the width delimited by the distance between the otter doors, the Door spread. In addition a third set of density values might also be derived based on the volume of water filtered by the net, determined by the inclusion of a third parameter, the height of the net headline, or the Net opening. Where recorded values for these three parameters were either absent, or deemed to be incorrect, then appropriate estimates were necessary.

Fishing gear and net geometry interactions are too complex to be modelled by single-factor randomized designs (e.g. one-way ANOVA) and the use of inappropriate statistical models to analyse and estimate missing gear geometry values could lead to serious errors in inference. Mixed models are appropriate for modelling gear geometry parameter values because of the different covariance structures among non-independent observations. Simple linear mixed-effects models were, therefore, used to estimate missing wing spread, door spread and net opening parameters. The models were implemented in R, using the "lme4" package.

Final models were reached after extensive data and model exploration. Potential explanatory variables that might be used to model haul geometry parameters were plotted against one another and Pearson's correlation testing was undertaken to explore the correlations between them; for example, Figure 4.1.7.1 provides these correlations for the GOV trawl).

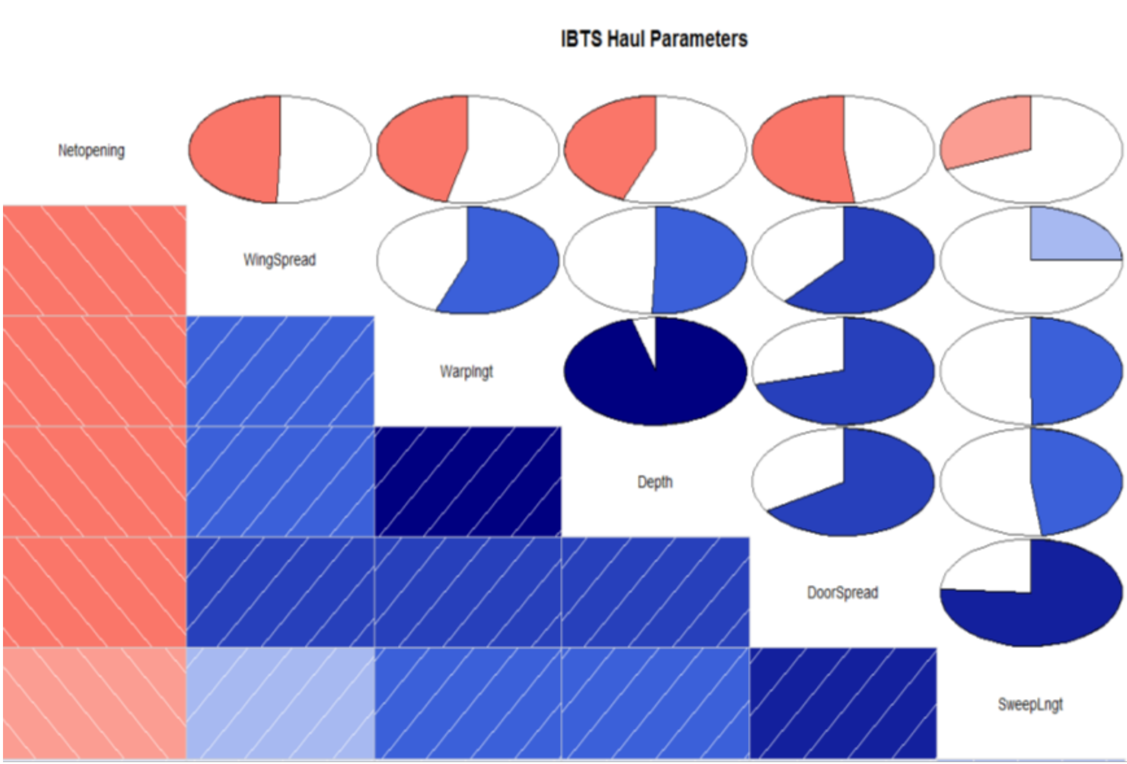

Figure 4.1.7.1: The relationships and correlations between the different GOV gear parameters. Red presents a negative relationship, and blue is a positive relationship, the stronger the correlation the deeper the colour. The coloured section of the pie chart shows the Pearson's correlation coefficient e.g. the relationship between Depth and Warp length is 0.97.

The rockhopper otter trawl is used by only one country in the IBTS working group, Northern Ireland. Compared with the other types of otter trawl, there were far fewer WingSpread and NetOpening data points from which to develop models for these two net geometry parameters. This was because, most of the time, the vessel involved didn't have the capacity to measure these parameters. Until 2015, WingSpread data had never been recorded in the survey. However, the Northern Irish research team carried out gear trials using the full suite of net geometry sensors, and these have provided the few data available with which to develop net geometry models (Table 4.1.7.1.).

Mean Depth	Mean Net Opening	Mean Warp Out	Mean Door Spread	Mean Wing Spread
12.03	2.433	51.7	25.067	11.900
82.27	2.567	273.0	39.467	15.700
53.40	2.467	191.0	36.667	14.800
82.37	2.567	270.3	35.167	14.867
64.83	2.733	214.3	38.000	14.967
79.83	2.433	260.0	41.100	16.200
20.73	3.133	95.0	27.100	12.767
41.00	2.300	150.0	36.433	15.233
41.10	3.033	136.7	33.400	13.933
37.43	2.400	135.0	35.300	15.200
37.57	2.867	140.0	35.600	15.133
53.57	2.633	185.0	39.067	15.967
31.77	2.533	120.0	31.333	13.867
85.50	2.300	267.0	38.100	15.433
84.27	2.633	270.0	41.400	16.500
42.63	2.533	143.3	32.967	14.433
63.23	2.700	202.0	37.800	15.500
63.63	2.567	220.3	40.500	16.533
69.47	2.633	230.0	38.267	15.700
72.20	2.567	261.0	39.467	16.100
81.83	2.567	273.7	35.833	15.133
68.07	2.800	233.7	38.900	16.167
72.23	2.800	244.0	40.833	16.133
33.30	2.700	122.3	29.867	12.667

Table 4.1.7.1: Raw data provided by the Northern Ireland gear trials for net geometry modelling.

Similar approaches to those used estimate missing gear geometry parameter values in the GOV data were applied to develop models to estimate missing BAK gear net geometry parameters. For each parameter, AIC scores were again used to assess which models best explained the observed data, and these models were then applied as appropriate to estimate missing parameter values. Although mixed effects models were explored, comparison of the AIC scores suggested that simple linear models could be used to estimate missing BAK gear wing spread, door spread and net opening parameters for in the Spanish surveys. Final models were determined after extensive data exploration where fixed variables where plotted against one another and Pearson's correlation testing was undertaken. Considerably fewer data were available to support the BAK models compared with the GOV analyses.

No trawl geometry sensors have ever been used during the Portuguese surveys using the Norwegian Campbell Trawl. The DATRAS database, therefore, held no values for WingSpread, DoorSpread, or NetOpening for the NCT gear. For the purposes of developing the groundfish survey monitoring and assessment data product, theoretical values estimated from net drawings (ICES 2010) have been assumed until further empirical data become available.

4.1.7.1. Wing Spread

Figure 4.1.7.1.1 illustrates the protocol used to assess the reliability of recorded WingSpread values, correct erroneous values, replace incorrect values and estimate values where this information was missing. By this point in the development of the data product, Depth data were present for every record where a WingSpread value was available, allowing the relationship between water Depth and WingSpread to be determined. If the WingSpread value recorded fell within the upper and lower 95% confidence limits defined by this relationship, then the value was deemed reliable and simply accepted. All statistically significant outliers, those WingSpread values lay outside the 95% confidence limits of the depth on WingSpread relationship, were referred back to the data providers to determine whether the value was erroneous or potentially incorrect. Where values were found to be erroneous, i.e. the WingSpread value recorded in the database did not match the value recorded at source, these recording errors were corrected and the replacement value passed through the check procedure again. Statistically significant WingSpread outliers that were not found to be erroneous, i.e. the recorded outlier value matched the value note at source, were deemed to be incorrect and subsequently treated as a missing value All such statistically significant outliers were, therefore, substituted by a modelled estimate.

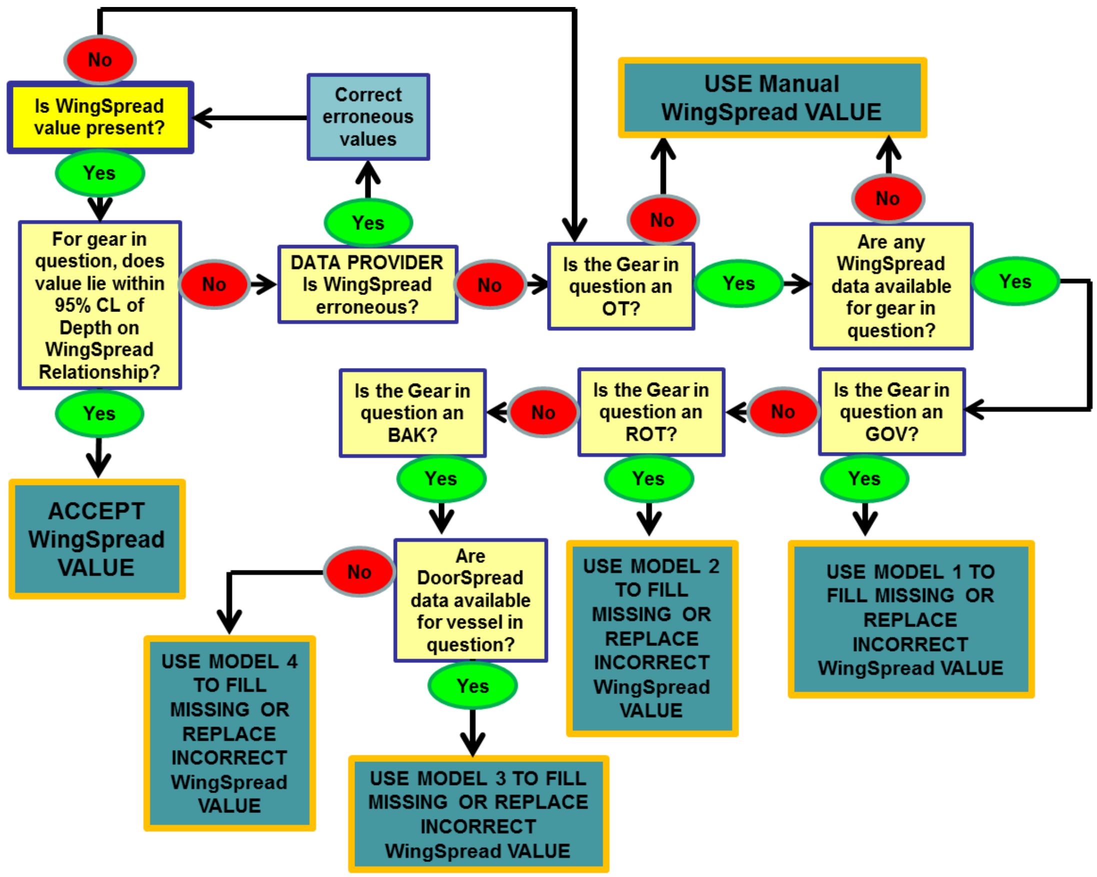

Figure 4.1.7.1.1: Flow chart illustrating the steps involved in assessing the validity of recorded WingSpread values and to estimate missing and replace incorrect data.

The first step in the procedure to estimate WingSpread values where these were either missing or treated as incorrect was to determine whether the gear in question was in fact an otter trawl. If it was not, then it must be a beam trawl and the missing gear width parameter could simply be infilled with the beam width value given in the relevant survey manual. If the gear was indeed an otter trawl, then the next step was to determine whether any WingSpread data were available at all for the gear in question. If the answer to this question was no, then it was not possible to model WingSpread for that particular gear and again the only option available was to use the gear width information provided in the relevant survey manual. Where WingSpread data were available for the gear in question then linear mixed-effects models could be developed for the gear and used to derive appropriate estimates for missing or incorrect WingSpread values.

4.1.7.1.1. The GOV Otter Trawl (Model 1)

Wing spread data were available for less than 40% of all the GOV trawl sample records and, therefore, needed to be estimated in over 60% of records. The IBTS working group has been working on defining models to estimate wingspread for each survey-ship combination. These models were evaluated, but ultimately were not used to estimate missing/incorrect wingspread data for the groundfish survey monitoring and assessment data product. Each country had adopted their own individual approach to modelling wingspread with the result that a variety of different methods, including lowess smoothers and linear models had been used. By treating each country/vessel independently, there was an implicit assumption that a significant country/vessel effect existed, but this had never actually been tested. Instead a single linear mixed models approach was adopted. Vessel/country effects were not simply assumed to exist, but this possibility was examined, and only if the effect was significant was it built into the model. Linear mixed models account for the fact that multiple responses from the same ship are more similar than responses from other ships. Such models, therefore, control for non-independence among the repeated observations for each ship, by adding random effects for the ships to the model.

Depth, SweepLength, NetOpening, DoorSpread, Year, Vessel, Country, ICES Statistical Rectangle were all considered as potential explanatory variables in a model to estimate WingSpread. Survey had no significant effect – variables affecting WingSpread appeared to operate universally regardless of the survey involved. Other parameters, such as WarpLength were also considered but due to the high correlation between Depth and WarpLength, the inclusion of both parameters in the model was not useful; the inclusion of WarpLength rendered the contribution of Depth non-significant, and *vice versa*. The inclusion of Depth was deemed preferable because this parameter varied continuously, whereas WarpLength tended to vary as a ‘stepped’ value. In some instances, certain variables (e.g. NetOpening or DoorSpread) were not available to inform a model to estimate WingSpread. For example, of those records where WingSpread was absent or incorrect and needed to be estimated, DoorSpread data were also missing in 35% and NetOpening in 20% of cases, so models that required these explanatory variable could not have been used. Variables such as Depth, Vessel, and SweepLength were always available to inform any model used to estimate WingSpread.

The linear mixed model was fitted using maximum likelihood t-tests with degrees of freedom determined using Satterthwaite approximations (Figure 4.1.7.1.1.1). The final model used to estimate WingSpread considered the interaction between Depth and SweepLength category ('long' or 'short') as the fixed effect and used Vessel as the single random effect to account for the fact that WingSpreads from the same Vessel may be more similar than WingSpreads from different Vessels. WingSpead (D_{wing}) was, therefore, modelled as

$$D_{wing} = \exp\left(\tau + \left(\ln D_{depth} - \ln \overline{D_{depth}}\right)\sigma\right) \qquad \text{Equ. 4.1.7.1.1.1.}$$

where τ is the numerical parameter to account for the Vessel effect where Vessel could be used to inform the mode, with a single value for all other Vessels where no individual Vessel effect could be determined, and σ is the numerical parameter for the SweepLength category, equal to 0.1368142 for a 'short' SweepLength and equal to 0.07253764 for the 'long' SweepLength category. The term $\left(\ln D_{depth} - \ln \overline{D_{depth}}\right)$ is essentially the centred natural-logged depth where $\overline{D_{depth}}$ is the mean depth across all records equal to 95.23m.

Vessel	τ
G.O. Sars	2.922359
Celtic Explorer	3.029118
Cirolana	3.064204
Dana 2	3.089823
Dana (Sweden)	3.117058
Endeavour	3.033285
Endeavour (Netherlands)	3.036859
Scotia 2	2.961087
Scotia 3	2.939403
Thalassa	2.969002
Thalassa 2	2.951269
Walter Herwig 3	3.027502
All other Vessels	3.011747

Table 4.1.7.1.1.1: Numerical "Vessel" parameter (τ) values for substitution into Equation 4.1.7.1.1.1.

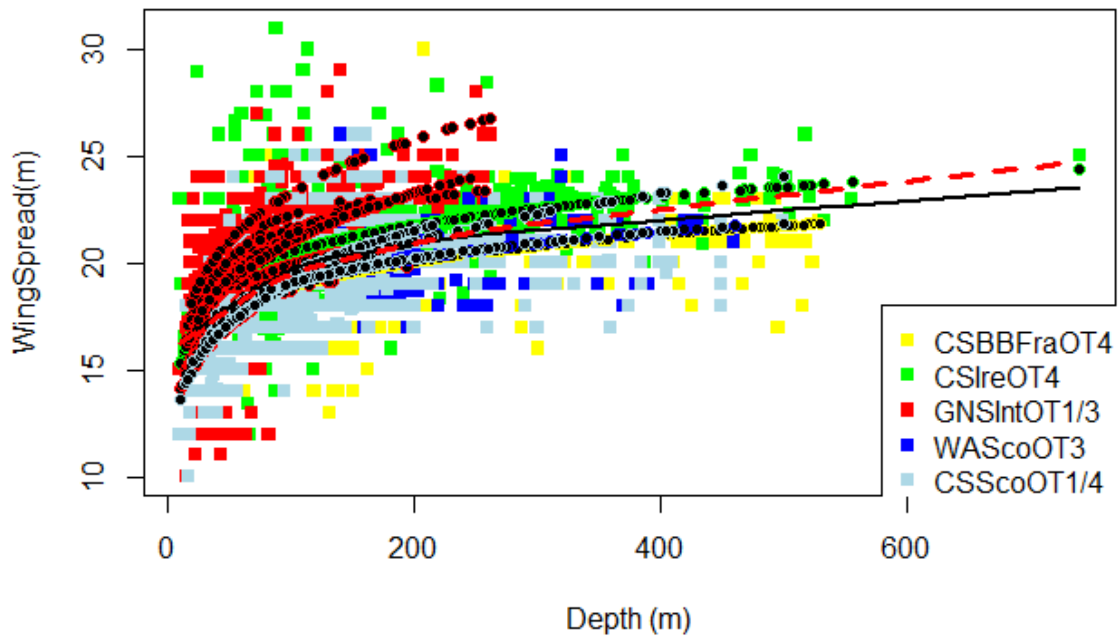

Figure 4.1.7.1.1.1: Output of the model (Equation 4.1.7.1.1.1) for estimating WingSpread for all GOV trawl samples. Solid black line shows the single best fit relationship between WingSpread and Depth, dotted red line shows the modelled data fit. Black dotted curves show individual modelled Vessel and SweepLength category relationships.

4.1.7.1.2. The ROT Trawl (Model 2)

Until 2015, WingSpread was not recorded during the two Northern Irish surveys and must, therefore, be estimated for all samples collected prior to this from the gears trials data. Although only 25 data records were available from the gear trials (see Section 4.1.7), the relationship between DoorSpread (D_{door}) and WingSpread (D_{wing}) was close and highly significant (Figure 4.1.7.1.2.1). Since DoorSpread data were available for all but one of the Northern Irish samples, the relationship obtained could be used to estimate the missing WingSpread data. AIC scores for other models that included additional explanatory variable suggested that this simple linear regression model was adequate to estimate missing WingSpread data. WingSpread was therefore estimated as

$$D_{wing} = \exp\left(\alpha + \beta(\ln D_{door})\right) \qquad \text{Equ 4.1.7.1.2.1,}$$

where α is the intercept equal to 0.3859096 and β is the slope of the linear regression equal to 0.6483112.

For the single sample where a DoorSpread value was missing, this was estimated using equation 4.1.7.2.2.1, and this value then used in equation 4.1.7.1.2.1 to estimate the missing WingSpread. This was deemed the only viable approach given the minimal data available for WingSpread estimates.

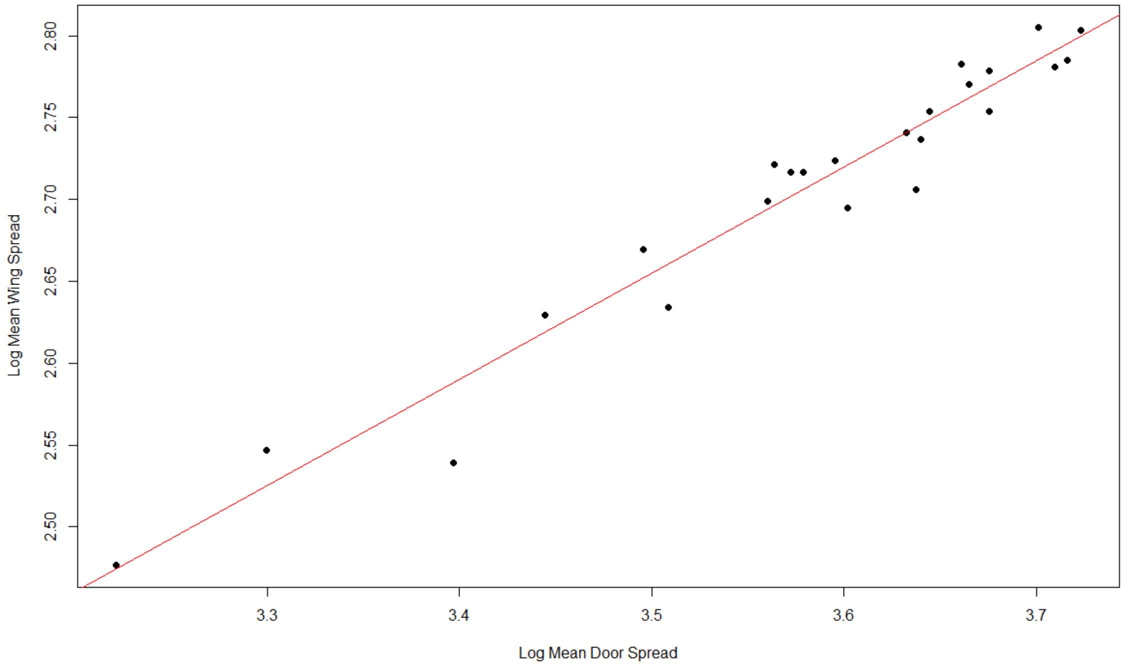

Figure 4.1.7.1.2.1: Trial data provided by Northern Ireland from their wing sensor trails. Log Mean wing spread shows the expected linear relationship with logged door spread.

4.1.7.1.3. The BAK Trawl (Model 3 and Model 4)

When DoorSpread (D_{door}) data were available, the best performing model (Model 3 in Figure 4.1.7.1.1) incorporated this information as an explanatory variable to estimate missing WingSpread data. Thus WingSpread in the BAK gear could be estimated as

$$D_{wing} = \exp(2.6132495 + (\ln D_{door} - \ln \overline{D_{door}})\sigma) \qquad \text{Equ. 4.1.7.1.3.1.}$$

Where σ = 0.5402047 when the SweepLength category is 100m, σ = 0.6654865 when the SweepLength category is 200m, and σ = 0.7820882 when the SweepLength category is 250m. The term $(\ln D_{door} - \ln \overline{D_{door}})$ is essentially the centred logged DoorSpread where $\overline{D_{door}}$ is equal 59.8m (Figure 4.1.7.1.3.1).

Where DoorSpread data were also missing, WingSpread was estimated using an alternative model, which incorporated Depth as the principal explanatory variable (Model 4 in Figure 4.1.7.1.1). Thus WingSpread in the BAK gear could be estimated as

$$D_{wing} = \exp\left(2.8209005 + \left(\ln D_{depth} - \ln \overline{D_{depth}}\right)\sigma\right) \qquad \text{Equ. 4.1.7.1.3.2.}$$

Where σ = 0.1289007 when the SweepLength category is 100m, σ = 0.1059284 when the SweepLength category is 200m, and σ = 0.3216203 when the SweepLength category is 250m. The term $(\ln D_{depth} - \ln \overline{D_{depth}})$ is essentially the centred logged Depth where $\overline{D_{depth}}$ is equal 95.23m (Figure 4.1.7.1.3.2).

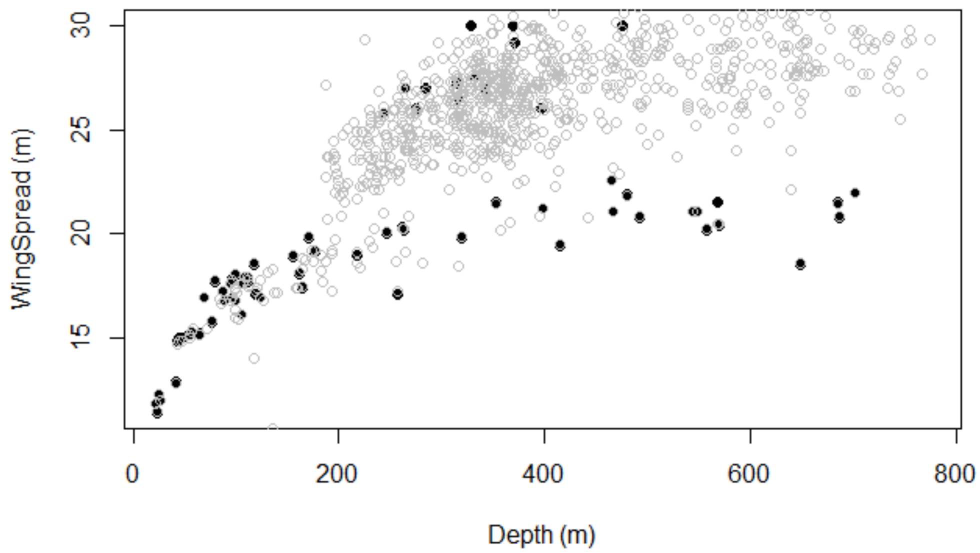

Figure 4.1.7.1.3.1: Model 3 used to estimate missing WingSpread data for vessels where DoorSpread data were available (adjusted R squared 0.9913, with a p-value of<0.0001). For consistency with other plots shown throughout Section 4.1.7, the figure shows the plot of WingSpread against Depth, even though the modelled WingSpread values (shown as grey dots) were estimated using Equation 4.1.7.1.3.1, which used DoorSpread as the explanatory variable. Black dots are recorded data.

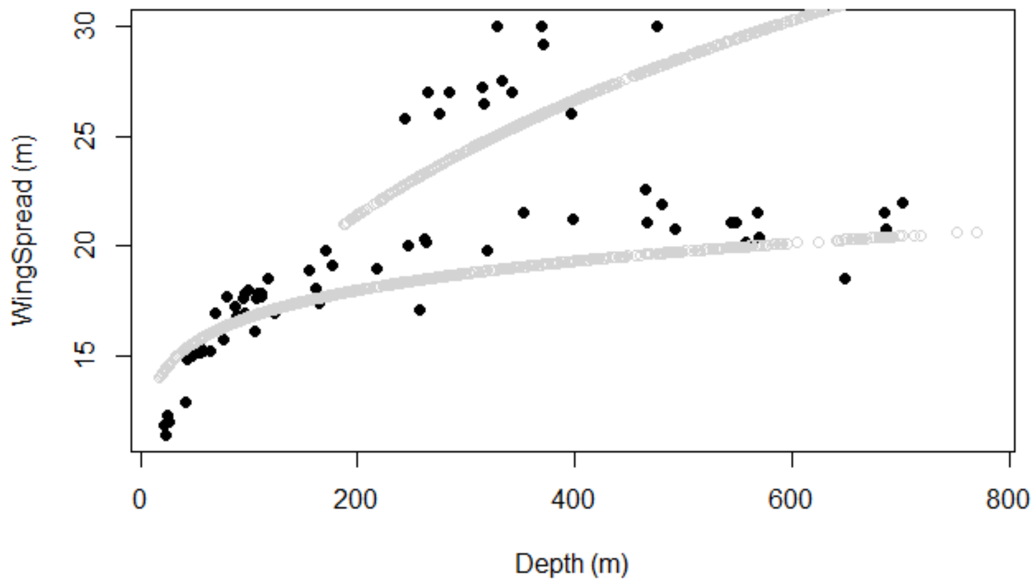

Figure 4.1.7.1.3.2: Model 4 used to estimate missing WingSpread data for vessels where DoorSpread data were not available (adjusted R squared 0.601, with a p-value of<0.0001), and so where the model (Equation 4.1.7.1.3.2) used Depth as the explanatory variable. Black dots are recorded data.

The code to generate the linear models used to estimate otter trawl net geometry parameters is available within the R Script number 6 “Haul_QA” line 603-1206 housed on Marine Scotland Science’s Github <https://github.com/MarineScotlandScience/MSFD-QA-GFSM-A-DP/blob/master/6_Haul_QA>.

4.1.7.1.4. The NCT Gear

Net drawings suggested a theoretical WingSpread value for the NCT gear of 15.1 m.

4.1.7.2. Door Spread

Figure 4.1.7.2.1 illustrates the protocol used to assess the reliability of recorded DoorSpread values, correct erroneous values, replace incorrect values and estimate values where this information was missing. As with WingSpread described above, by this point in the development of the data product, Depth data were present for every record where a DoorSpread value was available, allowing the relationship between water Depth and DoorSpread to be determined. If the DoorSpread value recorded fell within the upper and lower 95% confidence limits defined by this relationship, then the value was deemed reliable and simply accepted. All statistically significant outliers, those DoorSpread values lying outside the 95% confidence limits of the depth on DoorSpread relationship, were referred back to the data providers to determine whether the value was erroneous or potentially incorrect. Where values were found to be erroneous, i.e. the DoorSpread value recorded in the database did not match the value recorded at source, these recording errors were corrected and the replacement value passed through the check procedure again. Statistically significant DoorSpread outliers that were not found to be erroneous, i.e. the recorded outlier value matched the value note at source, were deemed to be incorrect and subsequently treated as a missing value. All such statistically significant outliers were, therefore, substituted by a modelled estimate.

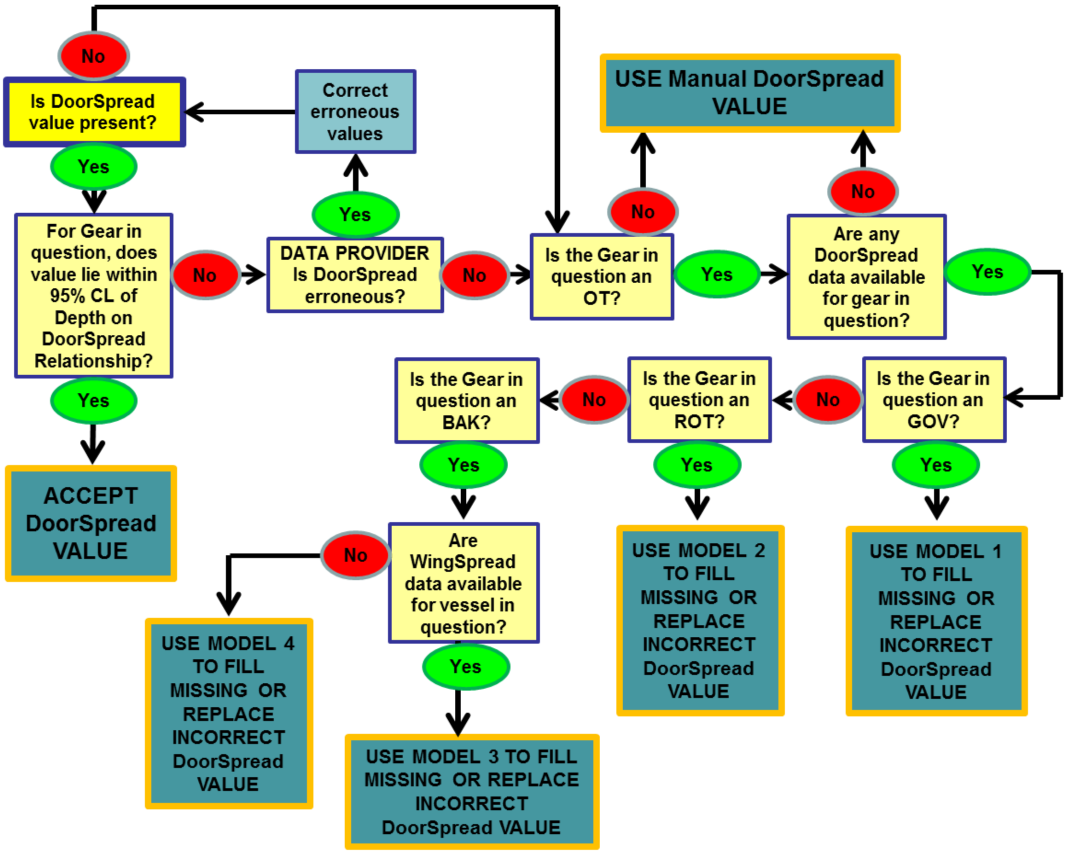

Figure 4.1.7.2.1: Flow chart illustrating the steps involved in assessing the validity of recorded Door spread values and to estimate missing and replace incorrect data.

The first step in the procedure to estimate DoorSpread values where these were either missing or treated as incorrect was to determine whether the gear in question was in fact an otter trawl. If it was not, then it must be a beam trawl and the missing gear width parameter could simply be infilled with the beam width value given in the relevant survey manual. For beam trawl surveys, only a single gear width parameter was possible, the width of the beam. For beam trawl surveys, therefore, WingSpread and DoorSpread values were identical. If the gear was indeed an otter trawl, then the next step was to determine whether any DoorSpread data were available at all for the gear in question. If the answer to this question was no, then it was not possible to model DoorSpread for that particular gear and again the only option available was to use the gear width information provided in the relevant survey manual. Where DoorSpread data were available for the gear in question then linear mixed-effects models could be developed for the gear and used to derive appropriate estimates for missing or incorrect DoorSpread values.

4.1.7.2.1. The GOV Otter Trawl (Model 1)

The approach to estimating missing DoorSpread parameter values was similar to that described in Section 4.1.7.1.1 for WingSpread. The final model for estimating Door-Spread used the interaction between Depth and SweepLength category (‘long’ or ‘short’) as a fixed effect variable and the interaction between Vessel and SweepLength category (‘long’ or ‘short’) as a single random effect variable to account for the fact that DoorSpreads from the same Vessel may be more similar than DoorSpreads from different Vessels, and that the interaction between Vessel and SweepLength might also vary from Vessel to Vessel. Again the linear mixed model was fitted using maximum likelihood t-tests with degrees of freedom determined using Satterthwaite approximations (Figure 4.1.7.2.1.1). DoorSpead (D_{door}) was, therefore, modelled as

$$D_{door} = \exp\left((\tau : \sigma) + \left(\ln D_{depth} - \ln \overline{D_{depth}}\right)\sigma\right) \quad \text{Equ. 4.1.7.2.1.1.}$$

where $(\tau : \sigma)$ is the numerical parameter to account for the Vessel :SweepLength category interaction effect where both could be used to inform the model, with a single value for all other Vessels where no individual Vessel effect could be determined, and σ is the numerical parameter for the SweepLength category, equal to 0.207424 for a ‘short’ SweepLength and equal to 0.140676 for the ‘long’ SweepLength category. The term $\left(\ln D_{depth} - \ln \overline{D_{depth}}\right)$ is essentially the centred logged depth where $\overline{D_{depth}}$ is the mean depth across all records equal to 95.23 m.

Vessel : SweepLength	$(\tau : \sigma)$
G.O. *Sars* : short	4.393767
G.O. *Sars* : long	4.566618
Celtic Explorer : short	4.478885
Celtic Explorer : long	4.692524
Cirolana : short	4.480698
Dana 2 : short	4.369519
Dana 2 : long	4.410523
Dana (Sweden) : short	4.526824
Dana (Sweden) : long	4.673256
Endeavour : short	4.369753
Endeavour (Netherlands) : short	4.402162
Scotia 2 : short	4.434618
Scotia 3 : short	4.371144
Scotia 3 : long	4.528643
Thalassa : short	4.446317
Thalassa 2 : short	4.307403
Thalassa 2 : long	4.467133
Walter Herwig 3 : short	4.443779
Walter *Herwig 3* : long	4.675431
All other Vessels : All SweepLengths	4.473635

Table 4.1.7.2.1.1: Numerical Vessel : SweepLength category ('long' or 'short') interaction parameter $(\tau : \sigma)$ values for substitution into Equation 4.1.7.2.1.1.

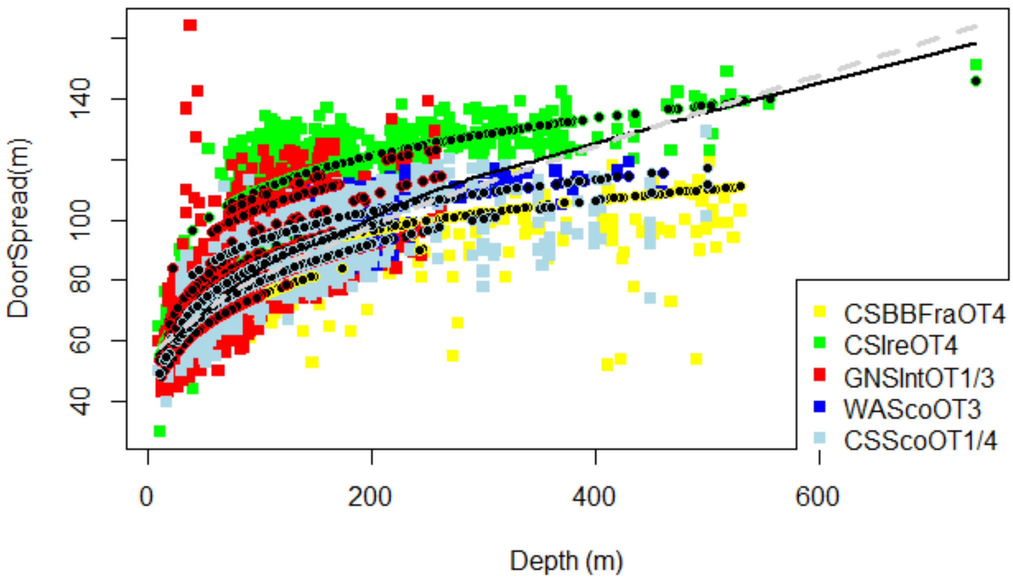

Figure 4.1.7.2.1.1: Output of the model (Equation 4.1.7.2.1.1) for estimating DoorSpread for all GOV trawl samples. Solid black line shows the single best fit relationship between DoorSpread and Depth, dashed grey line shows the modelled data fit. Black dotted curves show individual modelled Vessel and SweepLength category relationships.

4.1.7.2.2. The ROT Trawl (Model 2)

From 2008 to 2015, DoorSpread was consistently recorded in the Northern Irish surveys with only one value missing. However, of the 1480 samples collected between 1992 and 2007, DoorSpread data were missing on 64% of occasions. In total 1397 records with DoorSpread available could be used to develop an ROT DoorSpread model. A simple linear model using Depth (D_{depth}) as the explanatory variable explained 67% of the variance in DoorSpread (D_{door}) (Figure 4.1.7.2.2.1). The AIC scores associated with more complex models that included additional explanatory variables suggested that this model was the most appropriate.

$$D_{door} = \exp\left(\alpha + \beta\left(\ln D_{depth}\right)\right) \qquad \text{Equ 4.1.7.2.2.1,}$$

where α is the intercept equal to 2.6267584 and β is the slope of the linear regression equal to 0.2480771.

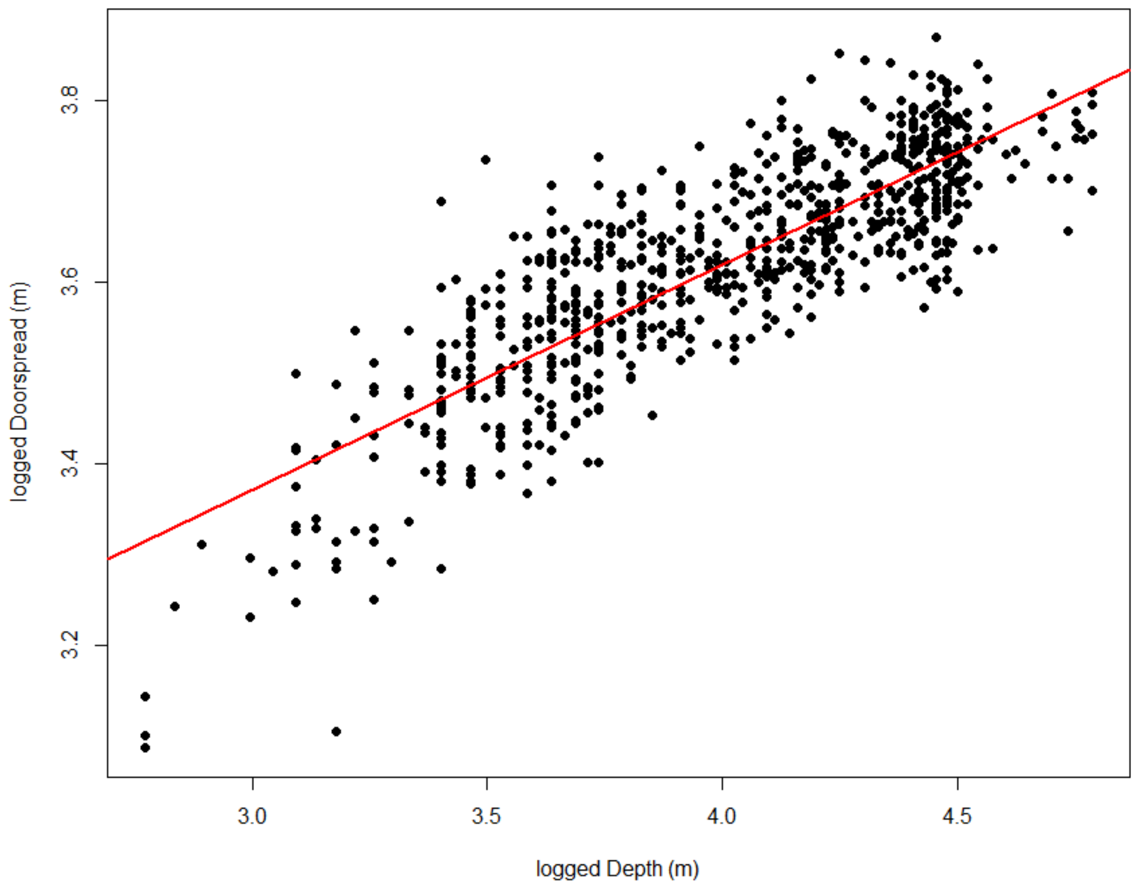

Figure 4.1.7.2.2.1: Northern Irish DATRAS dataset, log Door-Spread shows a linear relationship with log Depth.

4.1.7.2.3. The BAK Trawl (Model 3 and Model 4)

When WingSpread (D_{wing}) data were available, the best performing model (Model 3 in Figure 4.1.7.2.1) incorporated this information as an explanatory variable to estimate missing DoorSpread data. Thus DoorSpread in the BAK gear could be estimated as

$$D_{door} = \exp\left(4.103014 + \left(\ln D_{wing} - \ln \overline{D_{wing}}\right)\sigma\right) \qquad \text{Equ. 4.1.7.2.3.1.}$$

Where σ = 1.688265 when the SweepLength category is 100m, σ = 1.511456 when the SweepLength category is 200m, and σ = 1.278481 when the SweepLength category is 250 m. The term $\left(\ln D_{wing} - \ln \overline{D_{wing}}\right)$ is essentially the centred logged WingSpread where $\overline{D_{wing}}$ is equal 13.79 m (Figure 4.1.7.2.3.1).

Where WingSpread data were also missing, DoorSpread was estimated using an alternative model, which incorporated Depth as the principal explanatory variable (Model 4 in Figure 4.1.7.2.1). Thus DoorSpread in the BAK gear could be estimated as

$$D_{door} = \exp\left(4.4688055 + \left(\ln D_{depth} - \ln \overline{D_{depth}}\right)\sigma\right) \qquad \text{Equ. 4.1.7.2.3.2.}$$

Where σ = 0.5217405 when the SweepLength category is 100m, σ = 0.1363721 when the SweepLength category is 200 m, and σ = 0.3329973 when the SweepLength category is 250 m. The term $\left(\ln D_{depth} - \ln \overline{D_{depth}}\right)$ is essentially the centred logged Depth where $\overline{D_{depth}}$ is equal 95.23m (Figure 4.1.7.2.3.2).

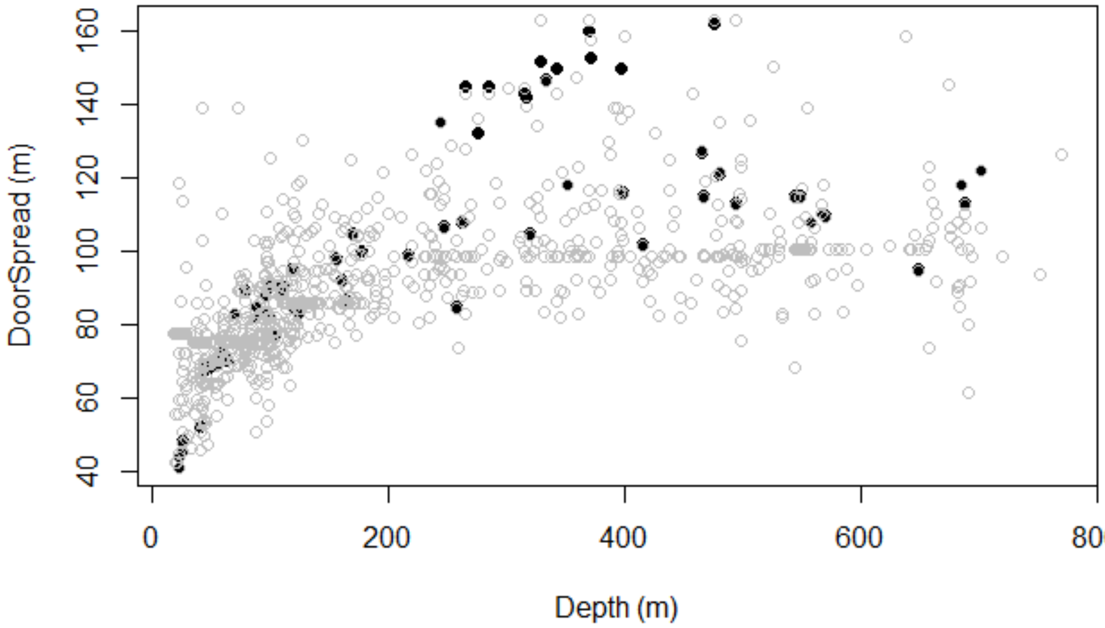

Figure 4.1.7.2.3.1: Model 3 used to estimate missing DoorSpread data for vessels where WingSpread data were available (adjusted R squared 0.9913, with a p-value of<0.0001). For consistency with other plots shown throughout Section 4.1.7, the figure shows the plot of WingSpread against Depth, even though the modelled DoorSpread values (shown as grey dots) were estimated using Equation 4.1.7.2.3.1, which used WingSpread as the explanatory variable. Black dots are recorded data.

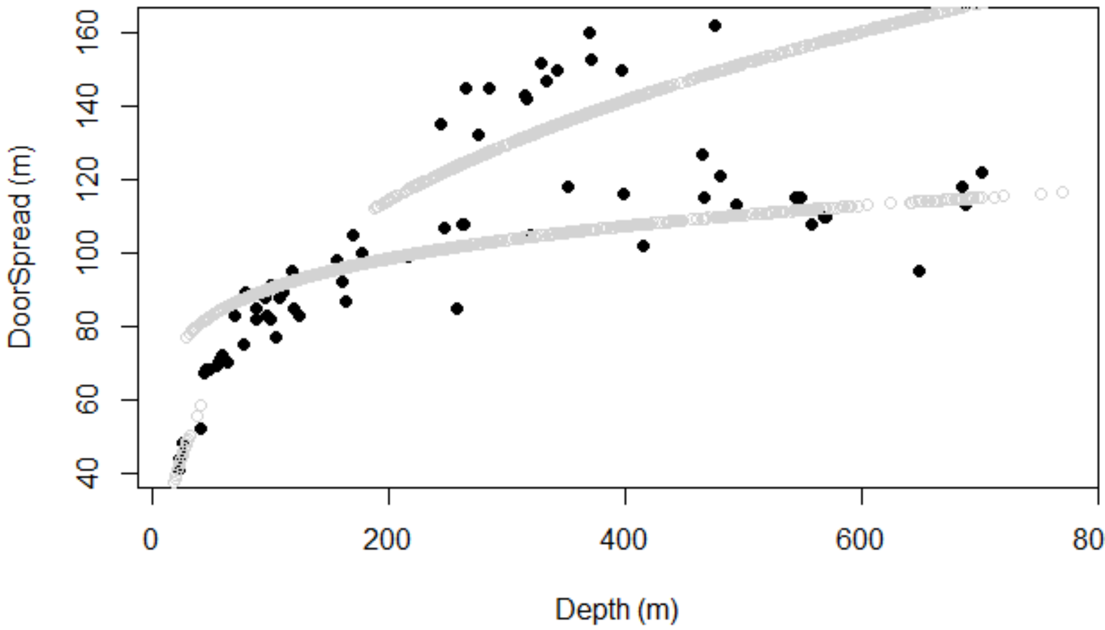

Figure 4.1.7.2.3.2: Model 4 used to estimate missing DoorSpread data for vessels where WingSpread data were not available, and so where the model (Equation 4.1.7.2.3.2) used Depth as the explanatory variable. Black dots are recorded data.

4.1.7.2.4. The NCT Gear

Net drawings suggested a theoretical DoorSpread value for the NCT gear of 44.4 m.

4.1.7.3. Net Opening

Figure 4.1.7.3.1 illustrates the protocol used to assess the reliability of recorded NetOpening values, correct erroneous values, replace incorrect values and estimate values where this information was missing. As with WingSpread and DoorSpread described above, by this point in the development of the data product, Depth data were present for every record where a NetOpening value was available, allowing the relationship between water Depth and NetOpening to be determined. If the NetOpening value recorded fell within the upper and lower 95% confidence limits defined by this relationship, then the value was deemed reliable and simply accepted. All statistically significant outliers, those NetOpening values lying outside the 95% confidence limits of the depth on NetOpening relationship, were referred back to the data providers to determine whether the value was erroneous or potentially incorrect. Where values were found to be erroneous, i.e. the NetOpening value recorded in the database did not match the value recorded at source, these recording errors were corrected and the replacement value passed through the check procedure again. Statistically significant NetOpening outliers that were not found to be erroneous, i.e. the recorded outlier value matched the value note at source, were deemed to be incorrect and subsequently treated as a missing value. All such statistically significant outliers were, therefore, substituted by a modelled estimate.

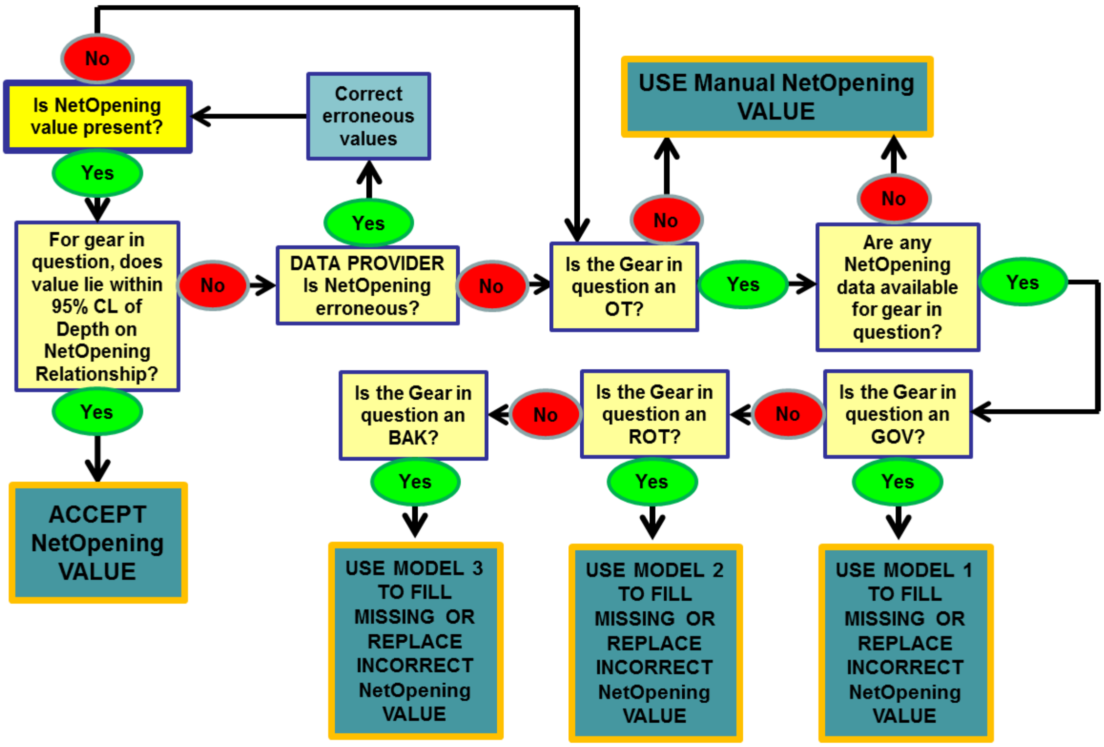

Figure 4.1.7.3.1: Flow chart illustrating the steps involved in assessing the validity of recorded NetOpening values and to estimate missing and replace incorrect data.

The first step in the procedure to estimate NetOpening values where these were either missing or treated as incorrect was to determine whether the gear in question was in fact an otter trawl. If it was not, then it must be a beam trawl and the missing gear width parameter could simply be infilled with the beam height value given in the relevant survey manual. If the gear was indeed an otter trawl, then the next step was to determine whether any NetOpening data were available at all for the gear in question. If the answer to this question was no, then it was not possible to model NetOpening for that particular gear and again the only option available was to use the gear headline height information provided in the relevant survey manual. Where NetOpening data were available for the gear in question then linear mixed-effects models could be developed for the gear and used to derive appropriate estimates for missing or incorrect NetOpening values.

4.1.7.3.1. The GOV Otter Trawl (Model 1)

The approach to estimating missing NetOpening parameter values was similar to that described in Section 4.1.7.1.1 for WingSpread and identical to that described in Section 4.1.7.2.1 for DoorSpread. The final model for estimating NetOpening used the interaction between Depth and SweepLength category (‘long’ or ‘short’) as a fixed effect variable and the interaction between Vessel and SweepLength category ('long' or 'short') as a single random effect variable to account for the fact that NetOpenings from the same Vessel may be more similar than NetOpenings from different Vessels, and that the interaction between Vessel and SweepLength might also vary from Vessel to Vessel. Again the linear mixed model was fitted using maximum likelihood t-tests with degrees of freedom determined using Satterthwaite approximations (Figure 4.1.7.3.1.1). NetOpening (D_{net}) was, therefore, modelled as

$$D_{net} = \exp\left((\tau : \sigma) + \left(\ln D_{depth} - \ln \overline{D_{depth}}\right)\sigma\right) \qquad \text{Equ. 4.1.7.3.1.1.}$$

where $(\tau : \sigma)$ is the numerical parameter to account for the Vessel : SweepLength category interaction effect where both could be used to inform the model, with a single value for all other Vessels where no individual Vessel effect could be determined, and σ is the numerical parameter for the SweepLength category, equal to -0.145476 for a 'short' SweepLength and equal to -0.062117 for the 'long' SweepLength category. The term $\left(\ln D_{depth} - \ln \overline{D_{depth}}\right)$ is essentially the centred logged depth where $\overline{D_{depth}}$ is the mean depth across all records equal to 95.23m.

Vessel : SweepLength	$(\tau : \sigma)$
G.O. *Sars* : short	1.246688
G.O. *Sars* : long	1.212898
Celtic Explorer : short	1.429033
Celtic Explorer : long	1.473072
Cirolana : short	1.588651
Dana 2 : short	1.565542
Dana 2 : long	1.575401
Dana (Sweden) : short	1.338802
Dana (Sweden) : long	1.423355
Endeavour : short	1.550711
Endeavour (Netherlands) : short	1.570606
Scotia 2 : short	1.514447
Scotia 3 : short	1.580827
Scotia 3 : long	1.604966
Thalassa : short	1.691653
Thalassa 2 : short	1.515216
Thalassa 2 : long	1.344804
Walter Herwig 3 : short	1.513395
Walter *Herwig 3* : long	1.688193
All other Vessels : All SweepLengths	1.496224

Table 4.1.7.3.1.1: Numerical Vessel : SweepLength category ('long' or 'short') interaction parameter $(\tau : \sigma)$ values for substitution into Equation 4.1.7.3.1.1.

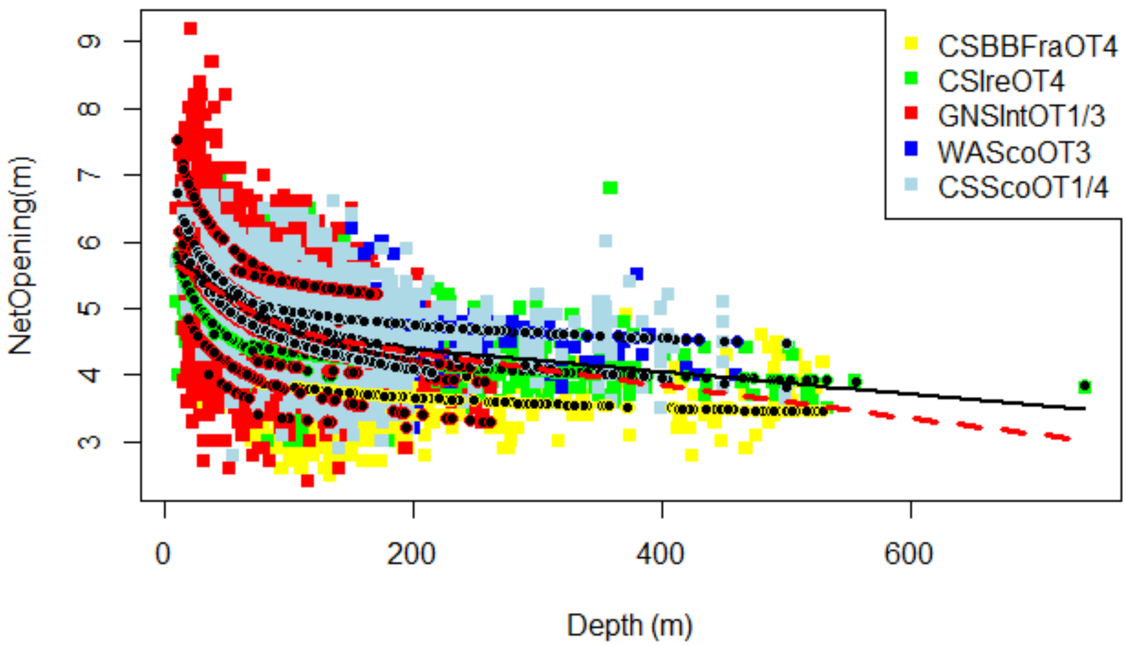

Figure 4.1.7.3.1.1: Output of the model (Equation 4.1.7.3.1.1) for estimating NetOpening for all GOV trawl samples. Solid black line shows the single best fit relationship between DoorSpread and Depth, dotted red line shows the modelled data fit. Black dotted curves show individual modelled Vessel and SweepLength category relationships.

4.1.7.3.2. The ROT Trawl (Model 2)

NetOpening was difficult to model for the ROT gear, as data availability was low. Furthermore, no significant relationships between NetOpening and any potential explanatory variables could be found. Until more data become available, the headline height value of 3 m, given in the relevant manual, was substituted and used to infill all missing NetOpening values.

4.1.7.3.3. The BAK Trawl (Model 3)

NetOpening (D_{net}) was estimated using a single model, which incorporated Depth (D_{depth}) as the principal explanatory variable (Model 3 in Figure 4.1.7.3.1). Thus NetOpening in the BAK gear could be estimated as

$$D_{net} = \exp\left(0.772164355 + \left(\ln D_{depth} - \ln \overline{D_{depth}}\right)\sigma\right) \qquad \text{Equ. 4.1.7.3.3.1.}$$

where σ = -0.051233707 when the SweepLength category is 100 m, σ = -0.006829265 when the SweepLength category is 200 m, and σ = 0.294157415 when the SweepLength category is 250 m. The term $\left(\ln D_{depth} - \ln \overline{D_{depth}}\right)$ is essentially the centred logged Depth where $\overline{D_{depth}}$ is equal 95.23 m (Figure 4.1.7.3.3.1).

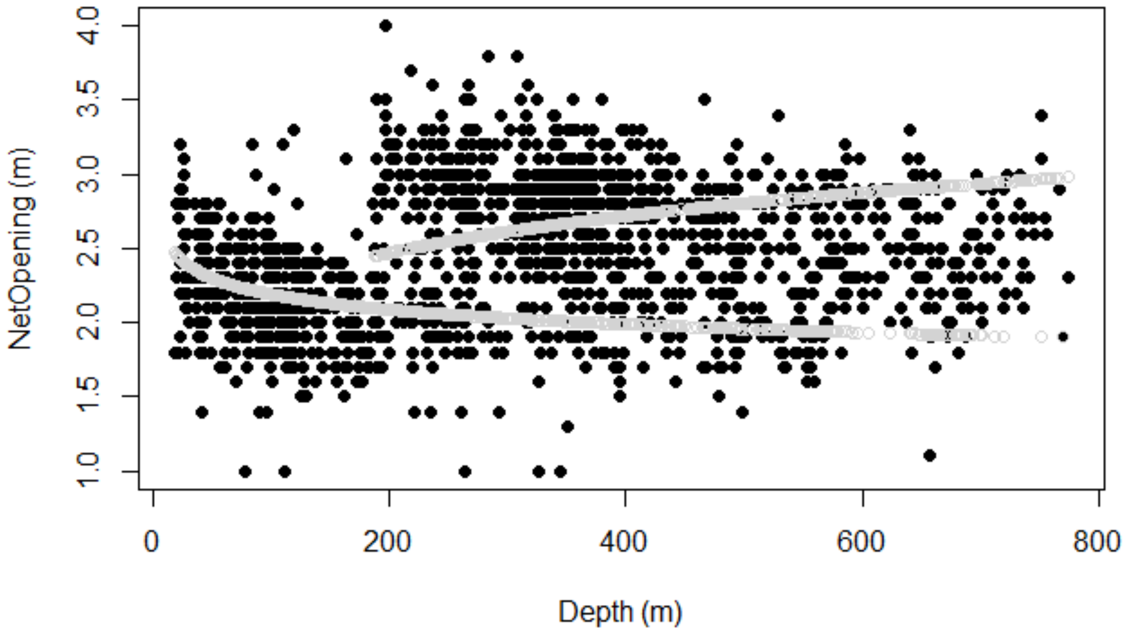

Figure 4.1.7.3.3.1: Model 3 used to estimate missing NetOpening data where the model (Equation 4.1.7.3.3.1) used Depth as the explanatory variable. Black dots are recorded data

4.1.7.3.4. The NCT Gear

Net drawings suggested a theoretical NetOpening value for the NCT gear of 4.6 m.

4.1.8. Calculation of the Area/Volume Swept by the Trawl

Estimates of the area swept by the trawl on each sampling occasion are values derived specifically for the groundfish survey monitoring and assessment data product. These parameters are necessary for deriving the required fish density-at-length data (numbers per square kilometre by species and length category) needed to support the ecological indicators used in the assessments of the status of fish communities across the Northeast Atlantic. Swept area can be calculated in two ways:

$$A_{wing} = D_{wing} \times D_{towed} \qquad \text{Equ 4.1.8.1}$$

$$A_{door} = D_{door} \times D_{towed} \qquad \text{Equ 4.1.8.2}$$

where A_{wing} is the area of the towed path swept between the wings of the net and A_{door} is the area of the towed path swept between the otter doors; D_{wing}, and D_{door} are the distances between the net wings and the otter doors respectively, and D_{towed} is the distance towed between the shoot and haul positions. The data product only gives wing-swept densities, but multiplier conversion factors are provided to convert the wing-swept densities to door-swept densities, which are simply determined as A_{wing}/A_{door}.

For pelagic species, volumetric density-at-length data could be considered to be more appropriate, that is to say numbers of fish, by species and length category, per cubic kilometre of water filtered through the net or between the otter doors. The volume of water filtered can again therefore be calculated in two ways:

$$V_{wing} = D_{wing} \times D_{towed} \times D_{net} \qquad \text{Equ 4.1.8.3}$$
$$V_{door} = D_{door} \times D_{towed} \times D_{net} \qquad \text{Equ 4.1.8.4}$$

where V_{wing} is the volume of water filtered between the wings of the net along the towed path and V_{door} is the volume of water along the towed path between the otter doors.

The code to generate the linear models used to calculate swept area and filtered volume parameters is available on Marine Scotland Science's Github Script 6 "Haul_QA" line 1211-1211 (Moriarty, 2017a).

4.2. HL Data – Biological Information

The biological data used for the MSFD data product are the catch total species abundance-at-length data collected on-board the surveys. The preparation process for biological data differs from the process undertaken to prepare the haul data as the issues are more complex and more open to interpretation. A clear rational to underpin each decision is therefore necessary. Further calculations are also needed involving the swept area (or swept volume) values determined for each haul, and therefore part of the HL data set (see Section 4.1.8), in order to convert catch total species abundance-at-length data to species density-at-length (nos km^{-2} or nos km^{-3}) estimates at each sample location, which are the data required to calculate the MSFD indicators. This section outlines the processes and the logic used to derive fully quality assured sets of species biological data for each survey.

The problems in DATRAS are extensive. Over 470 species are included in the data generated from the surveys undertaken across European Northeast Atlantic waters. However, there are a number of taxonomic issues apparent in these data, including:

1. WoRMS Aphid identification codes that are not to species level.
2. Apparently different species suites being reported by countries participating in the same survey, or surveying in the same area at similar times.
3. Apparently different species-specific length-frequency distributions being reported by countries participating in the same survey, or surveying in the same area at similar times.
4. Lengths being reported that exceed the known maximum length of the species in question.
5. Species recorded from areas that lie outwith the known geographic range of the species in question.
6. Catch abundance reported for species known to be rare in the area surveyed that are higher than would therefore be expected.

Many of these issues would appear to imply a degree of taxonomic identification error. Such problems could be due to insufficient taxonomic expertise, and this could be especially apparent early on, particularly in some of the longer time series (Daan, 2001). Inconsistencies could also arise as a consequence of species coding errors, particularly since a number of different species coding protocols have been used during the time period that several of the surveys have been in operation. Translation errors could easily have arisen as successive coding protocols have been introduced. Simple data archiving errors could also have contributed to species identification inconsistencies, such as typographical errors resulting in erroneous species codes being electronically archived for species that had been correctly identified. These inconsistencies still arise, even in recent years, despite attempts to resolve the problem such as the the 2007 Workshop on Taxonomic Quality issues in the DATRAS database (WKTQD), (ICES 2007b). These issues have caused difficulties in fish community studies in the North Sea and in other regions; erroneous species records can easily distort species diversity analyses for example (Greenstreet et al., 1999).

It would appear that many of WKTQD’s recommendations have not been implemented within the DATRAS database (ICES 2007a). Although many of the inconsistencies and errors are obvious, determining definitive, logical and scientifically defensible remedies is problematic. Nevertheless, these issues now need to be addressed in order to develop a fully quality assured groundfish survey monitoring and assessment data product. Here we present a series of protocols to address these fundamental problems.

It was not simply assumed that every fish identified to a family or genus level belonged to a single species; in some cases a coarser taxonomic level identification could potentially be resolved to a number of different species. For analyses of species richness indicators it is necessary to either aggregate all fish up to the lowest common dominator available across Europe, which in some cases could be the family level, or to use a probabilistic approach to assign an unknown sample identified at a low taxonomic level to the most likely species or species that make up that group. Such estimation processes to assign fish that are not adequately identified to the most likely species cannot provide a perfect solution, but this is the most optimal solution to minimising variability in the data product and facilitating its use to support analyses involving species richness and species diversity indicators. This approach reduces the use of lower resolution and less informative taxonomic ID codes, by using the surrounding data to inform on the most likely solution for a fish, using relevant biological, spatial and temporal parameters. In other indicators, such as the LFI which is based on fish biomass, knowing the species of fish in the sample is important as this allows the most appropriate weight at length relationships to be applied.

In order to derive the most standardised data product possible, and one that can support the widest range of ecological indicators imaginable, as far as is possible, the issue of multiple ID codes all relating to a single species needs to be addressed. The two options are:

1. To ‘lump’ all species (or genus or family, etc) IDs together into a single coarser taxonomic level ID code, that nevertheless represents the finest taxonomic resolution possible to include all ID levels.
2. To ‘split’ the coarser taxonomic resolution ID codes into the constituent species-level ID codes.

The advantage of the former approach is that it only uses information provided by the data; no inference of unknown information is involved. The disadvantage of the former approach is that, because the use of coarse taxonomic resolution ID codes is so common, and involving almost all families of fish, the loss of species-level information would be considerable and certainly sufficient to preclude any sort of species diversity analysis. The advantage of the second approach is that is generates a data set that is amenable to any conceivable sort of species-based ecological indicator analysis, but the disadvantage is that the outcome from such analyses could be questioned if doubt over the species-level identifications is sufficient. In deriving the groundfish monitoring and assessment data product a combination of the two approaches is used, where the selection of the most appropriate approach in each instance is informed by statistical analysis and an *a priori* defined protocol (see Section 4.2.4).

4.2.1. Identification Codes

The WoRMS Aphia codes aim to provide the most authoritative list of names of all marine species ever published globally. Currently there are 245,233 accepted species of which 229,212 (93%) have been checked. The WoRMS database currently houses 559,017 taxon names from species to kingdom level, of which 451,048 are species level names, which clearly includes numerous miss-spelt species names and synonyms. (WoRMS Editorial Board, 2016).

4.2.2. Initial Screening

The initial screening process, summarised in Figure 4.2.2.1, rationalises the WoRMSs taxa identification codes found in the source DATRAS database. The first step aimed at ensuring that the groundfish survey monitoring and assessment data product contained a consistent uniform set of WoRMS Aphia ID codes within each individual survey and, where possible and appropriate, across all surveys incorporated within the data product. There are several reasons for a WoRMS code to be “unaccepted”, such as: species reclassification, species name misspellings, synonyms of current species names, etc. The first step, therefore, insured that only “accepted” WoRMS Aphia ID codes were used in the groundfish monitoring and assessment data product; all synonym and misspelt species name codes were converted to the appropriate “accepted” species name code using R script generated for this purpose. The specific code can be found on lines 43-50 in Moriarty (2017b).

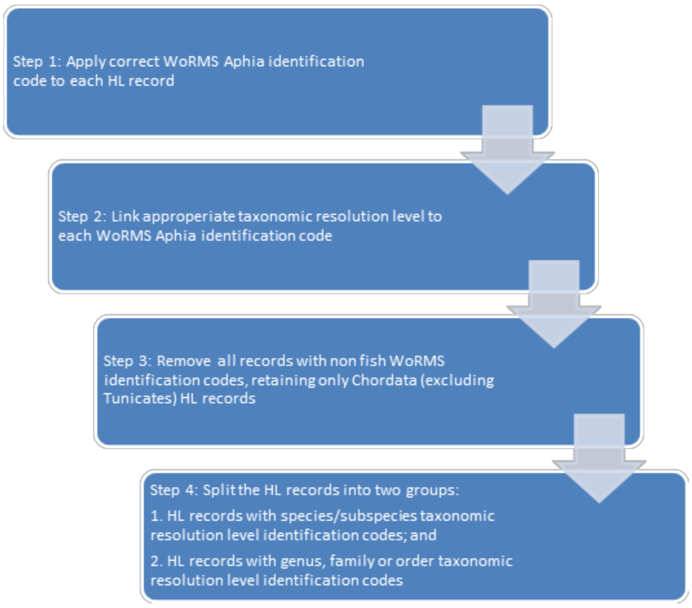

Figure 4.2.2.1: Overview of the process followed to apply the correct WoRMS codes to the species in the DATRAS database.

In some instances, up three different codes could relate to a single species, e.g., a family level, a genus level and a species level code. Such situations could arise for a number of reasons. In some cases the coarser taxonomic resolution level code was applied by mistake due to confusion using the original three letter codes. For example 'EEL' is the three letter code for Anguilidae, and this in the past was mistakenly used instead of ELE for *Anguila anguila*. Following consultation with the data providers, all records with the family taxonomic level identification Anguilidae could in fact be corrected to a species taxonomic level identification *Anguila anguila*. In a second situation, one particular survey labelled all grey gurnards *Eutrigla gurnardus* with the genus taxonomic level identification of Eutrigla, and all piper gurnards *Trigla lyra* with the genus taxonomic level identification of Trigla. In both these instances, the genus taxonomic level identification could be reliably resolved to the single species taxonomic level identification code in each genus. If in any given genus or family, only one species was ever recorded, then all the coarser level ID codes were simply substituted by the single species-level identification code. Table 4.2.2.1 provides examples of genus, family and order taxonomic resolution level identification codes that, following consultation with the data providers, could be resolved to a species taxonomic resolution level.

Rank	Scientific Name	Comments
Family	Anguillidae	Family with 1 species recorded
Genus	Anguilla	Genus with 1 species recorded
Species	*Anguilla anguilla*	Bring genus and family records to species
Family	Congridae	
Genus	Conger	Genus with 1 species recorded
Species	*Conger conger*	Bring genus records to species
Family	Engraulidae	
Genus	Engraulis	Genus with 1 species recorded
Species	*Engraulis encrasicolus*	Bring genus records to species
Family	Notacanthidae	Family with 1 species
Species	*Notacanthus chemnitzii*	
Family	Argentinidae	Family with 1 genus
Genus	Argentina	Use k-NN to estimate likely species. Distinctive geographical distribution
Genus	Lampetra	Valid taxon *L. fluviatilis*
Species	*Lampetra fluviatilis*	
Genus	Petromyzon	Valid taxon *Petromyzon marinus*
Species	*Petromyzon marinus*	
Genus	Microchirus	Genus with 1 species recorded in NS/SWC Valid taxon SWC/NS Microchirus variegatus
Species	*Microchirus variegatus*	
Species	*Scomberesox saurus saurus*	Previously known as *Scomberesox saurus*
Genus	Pegusa	Genus with 1 species recorded
Species	*Pegusa lascaris*	
Genus	Dicentrarchus	In NS and SWC: genus with 1 species: *Dicentrarchus labrax*
Species	*Dicentrarchus labrax*	
Genus	Solea	*Solea solea* only found in NS/SWC
Species	*Solea solea*	Previously *Solea vulgaris*
Genus	Eutrigla	Genus with 1 species recorded in surveys
Species	*Eutrigla gurnardus*	
Genus	Lepidotrigla	
Genus	Trigla	Genus with 1 species recorded in surveys
Species	*Trigla lyra*	*Trigla lucerna* - inconsistencies among countries
Genus	Trigloporus	Genus with 1 species recorded in surveys
Species	*Trigloporus lastoviza*	
Family	Caproidae	Valid taxon is *Capros aper*
Species	*Capros aper*	Family with 1 species recorded in surveys

Table 4.2.2.1: List of genus and family taxonomic resolution level identifications that could be resolved to a single species taxonomic resolution level..

In developing the data product, the intent was, as far was possible, to resolve identification to the finest resolution, i.e. to species or subspecies. If such fine resolution identification was deemed to be generally unreliable, then all identification codes, at least within a survey, were conflated uniformly to the resolution level where confidence in the identification was deemed acceptable. Determining what this acceptable level might be was achieved through extensive consultation with the data providers. In order to do this, each WoRMS identification code had to be tagged with the appropriate taxonomic level label (e.g. species/subspecies, genus, family, order, etc), and this constituted the second step in the initial screening process (Figure 4.2.2.1).

For example, the DATRAS data included information for 12 species of goby, three belonging to the genus Gobius, four belonging to the genus Lesueurigobius and six belonging to the genus Pomatoschistus. In each case a high proportion of records were tagged with a genus taxonomic level identification code. Furthermore, the number of records with the genus taxonomic level Gobius far exceeded the number that might be expected given the fraction of records with species taxonomic level identifications that were assigned to one of the three Gobius species. This raised concern that the genus level identification Gobius had been used in situations where the family level identification Gobiidae was more appropriate, i.e. the fish in question could in fact have been a species belonging to any of the three genus, and was not necessarily a Gobius species. Given all these issues, and taking account of the fact that over 40% of all goby records were given only a genus or family taxonomic resolution level identification code, the decision was taken, following consultation with the data providers, to assign the family taxonomic resolution level Gobiidae identification code to all goby records. Table 4.2.2.2 provides a list of species where it was deemed more reliable to conflate the species level identifications to identifications at a genus, family or order level.

Rank	Scientific Name	Comments
Family	Ammodytidae	Report all taxon to family level Ammodytidae
Genus	Ammodytes	Report all taxon to family level Ammodytidae
Species	*Ammodytes marinus*	inconsistencies among countries (and >Lmax)
Species	*Ammodytes tobianus*	inconsistencies among countries (and >Lmax)
Species	*Gymnammodytes semisquamatus*	inconsistencies among countries (and >Lmax)
Genus	Hyperoplus	Report all taxon to family level Ammodytidae
Species	*Hyperoplus immaculatus*	inconsistencies among countries
Species	*Hyperoplus lanceolatus*	inconsistencies among countries
Family	Gobiidae	All taxon reported as Gobiidae
Species	*Aphia minuta*	inconsistencies (>Lmax) - SWE
Species	*Buenia jeffreysii*	
Species	*Crystallogobius linearis*	
Species	*Deltentosteus quadrimaculatus*	
Genus	Gobius	Too many… input error (Pomatoschistus or Gobiidae)
Species	*Gobius gasteveni*	
Species	*Gobius niger*	
Species	*Gobius paganellus*	
Genus	*Lesueurigobius*	
Species	*Lesueurigobius friesii*	
Species	*Lesueurigobius sanzi*	
Genus	Pomatoschistus	
Species	*Pomatoschistus lozanoi*	
Species	*Pomatoschistus microps*	identification ?
Species	*Pomatoschistus minutus*	identification ? flagged lmax
Species	*Pomatoschistus norvegicus*	
Species	*Pomatoschistus pictus*	

Table 4.2.2.2: Taxon which have been grouped to family, this includes the Gobiidae and Ammodytidae. The comments section highlights problems identified with some of the species listed.

The groundfish survey monitoring and assessment data product was specifically developed to assess the status of fish communities across the Northeast Atlantic region. Benthic invertebrate data were not consistently sampled and the fishing gears used in the surveys are not good samplers of either infauna or epibenthos (Callaway et al., 2000). The third step in the initial screening process was, therefore, to exclude all records that did not relate to fish (Figure 4.2.2.1). This was primarily achieved by selecting WoRMS identification codes related to the phylum Chordata, but excluding the subphylum Tunicata.

Step 4 in the initial screening process shown in Figure 4.2.2.1 essentially provides the link to the next stages in the process to derive the HL records data product. This essentially aims at ensuring that every HL record was tagged with the most appropriate, reliable, taxonomic identification code, and then splitting the HL records into two categories: HL records with a species/subspecies taxonomic resolution level identification code and HL records with either a genus, family or order taxonomic resolution level identification code.

Figure 4.2.2.2 provides a flowchart illustrating the procedures applied to achieve Steps 3 and 4 in Figure 4.2.2.1 above. Step 3 involved checking taxonomic identifications to ensure that the WoRMS identification codes for all retained records related only to fish, and that all non-fish records were excluded from the data product (Figure 4.2.2.2). The first question in this process, therefore, was to establish whether or not the WoRMS identification code related to a fish. If it didn’t then the record was referred to the data providers to check whether the identification was erroneous. If the identification was found to be an error, then the identification code was corrected accordingly. The corrected records then passed through the initial error trap loop a second time, now to ensure that the corrected identification code related to a fish. Any records with corrected/checked identification codes that did not relate to fish were excluded from the data product.

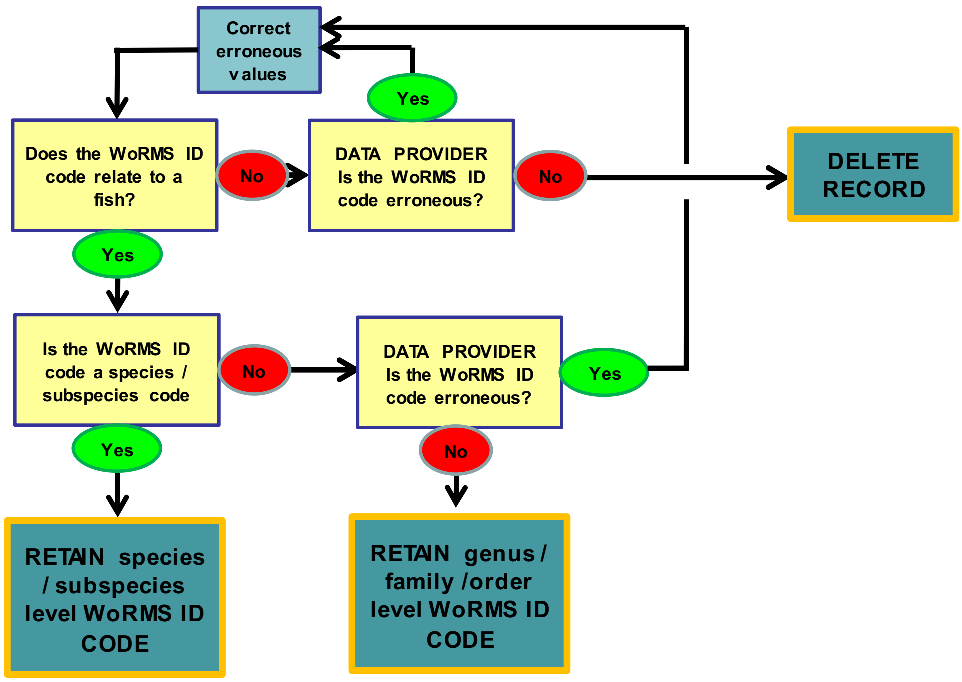

Figure 4.2.2.2: Flowchart illustrating the procedures used to ensure that all WoRMS identification codes for records retained in the data product were correct, and related to the most appropriate taxonomic resolution level: Steps 3 and 4 in Figure 4.2.2.1.

Only records with WoRMS identification codes related to fish passed through to Step 4. This part of the process determined the taxonomic resolution level of the WoRMS identification code (Figure 4.2.2.2). All records with identification codes that were linked to a species/subspecies resolution level were simply retained in the data product. Records with WoRMS identification codes linked to a genus, family or order taxonomic resolution level were referred back to the data providers. The purpose of this was two-fold. Firstly, data providers were asked to check the code to ensure that it was correct. All corrected records than passed through both error trap checks again. If the corrected code now related to a non-fish taxon, then the record was deleted. If the corrected code record now related to fish identified to the species/subspecies taxonomic resolution then the record, in its corrected state, was simply retained in the data product. Secondly data providers were asked to check that the most appropriate identification code had been assigned to each record in question. Where it was deemed appropriate, any genus, family or order taxonomic resolution level codes that could be were replaced with a species/subspecies level code, and the altered record retained in the data product but now with the desired species/subspecies taxonomic resolution level identification code. Where this was not possible, or appropriate, data providers were asked to ensure that each record was tagged with the most appropriate WoRMS identification code at the finest taxonomic resolution possible; i.e., a genus level code to replace a family level code if this was considered plausible, or a family level code to replace an order level code if again this was plausible.

4.2.3. HL Records with Species/Subspecies Identification Codes

In this section, the various procedures applied to check, correct or estimate parameter values in the HL records with species/subspecies taxonomic resolution identification codes are described. The focus first was in assessing the reliability of the species/subspecies identification codes themselves. So, for each HL record where species/subspecies taxonomic resolution level codes were retained having passed through the process illustrated in Figure 4.2.2.2 above, the sampling location was checked to determine whether or not the species/subspecies identification code represented a taxon within its recognised geographic range (Figure 4.2.3.1). Recognised geographic ranges for each species/subspecies identification code were obtained with reference to FishBase to identify the OSPAR regions (MSFD subregions) where each species might be expected to be encountered. Where the recorded species/subspecies identification code inferred species within their recognised geographic range then the records involved were simply further retained in the data product. Where the recorded species/subspecies identification code inferred species ouside their recognised geographic range then the records involved were referred back to the relevant data providers to check whether the identification code was erroneous. Where errors were found, the species/subspecies identification code was corrected and the record passed through the error-trap loop again (Figure 4.2.3.1).

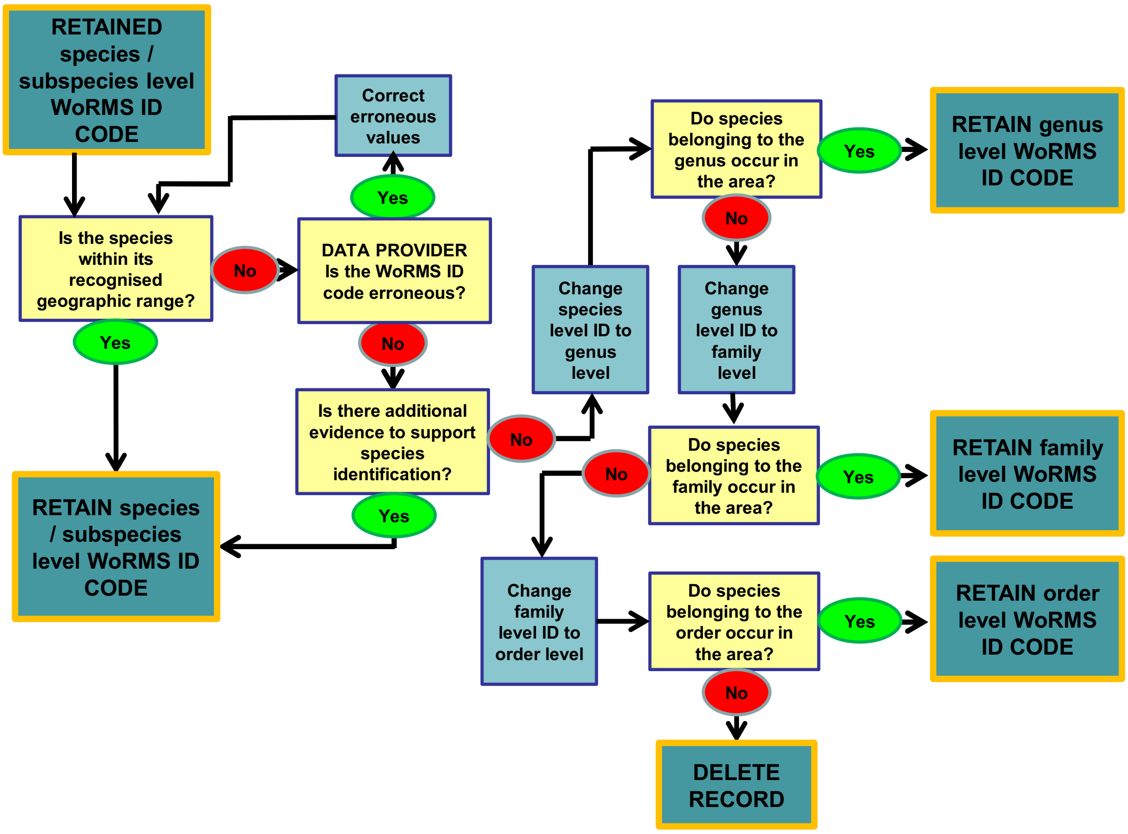

Figure 4.2.3.1: Flowchart to illustrate the procedure used to assess the reliability of species/subspecies taxonomic resolution level identifications based on the known geographic range of each species, and the process adopted where there wasinsufficient evidence to support the species identification.

Where species/subspecies identification, which apparently implied a taxon outside the species' normal geographic range, were not found to be erroneous, these were accepted provided the data providers could produce additional information to support what would otherwise be an exceptional record, such as photographic evidence or documentary evidence to show the application of a formal identification procedure. Where this evidence was lacking the identification was treated as being incorrect and an alternative coarser taxonomic resolution level identification code substituted depending on whether species belonging to the same genus, family or order were encountered in the OSPAR region (MSFD subregion) in question. If no species belonging to the same order occurred in the area, then the record was simply deleted on the basis that it was so corrupted, that no reasonable alternative could be applied (Figure 4.2.3.1). Table 4.2.3.1 provides a list of species recorded in one or other of the survey databases, but which should not occur in the Northeast Atlantic. In the some cases, these were found to be instances of miss-coding, which have now been corrected at source. In cases where species have been verified by supporting photographic or taxonomic procedural evidence, these have been retained.

Scientific Name	Solution
Bathyraja brachyurops	Code translation error *Raja brachyura*
Scomber japonicus	Coding typographic error *Scomber colias*
Leucoraja lentiginosa	Missing data protocol: family level ID assigned and subsequently assigned to species by KNN process
Lycodes vahlii	Supporting evidence: retained
Benthodesmus elongatus	Missing data protocol: family level ID assigned and subsequently assigned to species by KNN process
Nezumia bairdii	Missing data protocol: genus level ID assigned and subsequently assigned to species by KNN process
Spratelloides lewisi	Missing data protocol: genus level ID assigned and subsequently assigned to species by KNN process

Table 4.2.3.1: Species recorded in the survey database which were deemed to be outside of their known geographical range, and which shouldn't occur within the four MSFD subregions within the MSFD assessment: the Greater North Sea, Celtic Seas, Bay of Biscay and Iberian Coast, and Wider Atlantic.

Anarrhichthys ocellatus is a species with a North Pacific distribution and *Hippocampus histrix*, the thorny seahorse, has an indo pacific distribution. Both species were unlikely to occur in the Northeast Atlantic and would, therefore, have been deemed to be species outside their normal geographic range. Resolutions to these two indentification issues were, however, not necessary because the trawl sample in which they were encountered were excluded from the standard groundfish monitoring and assessment data product. These samples were either of too short or too long tow duration, collected in an early part of the survey times series deemed to be outside the standard survey period, or taken from areas deemed to be outside the standard survey area.

Species abundance-at-length data have been recorded using several different types of length categories (Table 4.2.3.2), with little consistency in the length categories used either within species with in any given survey, between species in any given survey, or between surveys. This renders the use of these data by scientists, who may not be aware of all these issues, fraught with risk. In order to derive a single standardised data product for all surveys undertaken across the Northeast Atlantic area, length categories recorded in the DATRAS database were rationalised to **a single standard length category of "*to the cm below*"**. Thus, all fish of length 11.0 to 11.9 cm, or 110 to 119 mm, would be assigned a length category of 11 cm.

Length Code	Definition	Retained in Data Product
-9	Missing value	No
.	To the nearest 1mm below: e.g. 87mm	No
0	To the nearest 5mm below: e.g. 87mm recorded as 85mm	No
1	To the nearest cm below: e.g. 8.7cm recorded as 8cm	Yes
2	To the nearest 2cm below: e.g. 8.7cm recorded as 8cm	No
5	To the nearest 5cm below: e.g. 8.7cm recorded as 5cm	No
9	A 'plus' size clas: e.g. all fish over 60cm recorded as 60cm	No

Table 4.2.3.2: Length codes assigned by DATRAS to the biological data. In the DATRAS database, the field that describes what sort of length measurement is present is called the Length Code. This is a confusing name, and so in this text this field has been referred to as "the measurement type" field. Note that in DATRAS, where measurements are to the nearest 5mm below, the length should be recorded in mm.

While the length categories listed above assume that all fish are measured to "Total Length" (TL) this was not always the case, certain species in some years and countries are treated differently. Smoothheads and Searsids (Alepocephalidae and Searsidae) are measured to the "Standard Length" (SL). Grenadiers (Macrouridae) are measured to the "Pre Anal Fin Length" (PAFL) and Chimaeridae (Rabbitfish) are measured to the "Pre Supra Caudal Fin Length" (PSCFL). This is not made clear in any of the fields in the DATRAS database, but is reported in ICES 2013a *(*ICES 2013b). A conversion factor must be applied to address this and bring all such length measurement types for these fish to the standard "TL" length measurement used for all other species in the DATRAS database. (Table 4.2.3.3).

Species Name	Measurement Type	Conversion Factor	Reference
Coelorinchus caelorhincus	PAFL	Length *2.82	Mindel et al 2016
Malacocephalus laevis	PAFL	Length*4.57	Mindel et al 2016
Macrourus berglax	PAFL	5.2320+2.3455*Length	Atkinson 1991
Coryphaenoides rupestris	PAFL	Length*4.7399	Atkinson 1981
Coelorinchus labiatus	PAFL	Length*2.5	Mindel et al 2016
Hymenocephalus italicus	PAFL	Length*1	Mindel et al 2016
Nezumia aequalis	PAFL	Length*3.78	Mindel et al 2016
Nezumia bairdii	PAFL	Length*3.78	Mindel et al 2016
Trachyrincus murrayi	PAFL	Length*3.1	Mindel et al 2016
Trachyrincus scabrus	PAFL	Length*3.1	Mindel et al 2016
Xenodermichthys copei	SL	Length*1.155	Mindel et al 2016
Chimaeridae	PSCFL	Length*1.31	Mindel et al 2016
Hydrolagus mirabilis	PSCFL	Length*1.28	Mindel et al 2016

Table 4.2.3.3: Conversion factors to "Total Length" (TL) from "Standard Length" (SL), "Pre Anal Fin Length" (PAFL) and "Pre Supra Caudal Fin Length" (PSCFL).

On occasion length category information was absent. Where this involved only a single fish of the species in the sample, the missing length parameter could be estimated using the reversed weight at length relationship, thus $Length\ (cm) = \exp\left(\frac{\ln(Weight(g) - \ln\alpha}{\beta}\right)$ where α and β are respectively the constant and exponent for the weight at length relationship for the species in question. Where more than one fish was involved, a more complex procedure was necessary involving a k-Nearest-Neighbour (k-NN) analysis (see Section 4.2.5). The species weight at length length relationship was applied to the length frequency distribution outcome from such k-NN analysis to derive estimates of catch biomass at length, which when summed across all length categories, could be compared with the reported total catch weight.

Length frequency distributions for a suite of species recorded by different countries operating in the same MSFD subregions, for example the various countries participating in the North Sea IBTSs, were examined to look for between-country differences. Any such inconsistencies could potentially suggest a systematic difference in species identification between the countries involved. Two examples are provided: presented here. Dragonets are identified to one of three species, or alternatively to genus or family level. Trends for *Callionymus lyra* were consistent across the wider surveyed area. *C. reticulatus* tends to be the smallest of the three species. However, *C. maculatus* was on occasion recorded well above its known maximum length (Figure 4.2.3.2a). This observation from the GOV otter trawl surveys contrasts markedly with data derived from the beam trawl surveys where excessively large *C. maculatus* were not recorded. Checking the GOV records with the Data Providers suggested that excessively large *C. maculatus* recorded in the GOV surveys were in fact more likely to be misidentified *C. lyra*. These changes were made in the data set prior to the data being used in the k-NN protocol to classify the genus and family level to the most appropriate species, since these errors, if left in the data, would have an effect on model parameter training (see Sections 4.2.4 and 4.2.5.) Figure 4.3.2.2 illustrates the effects of these changes to the three Callionymus species' length frequency distributions and Figure 4.3.2.3 illustates the effects of a similar approach applied to gurnard species of the genus Chelidonichthys.

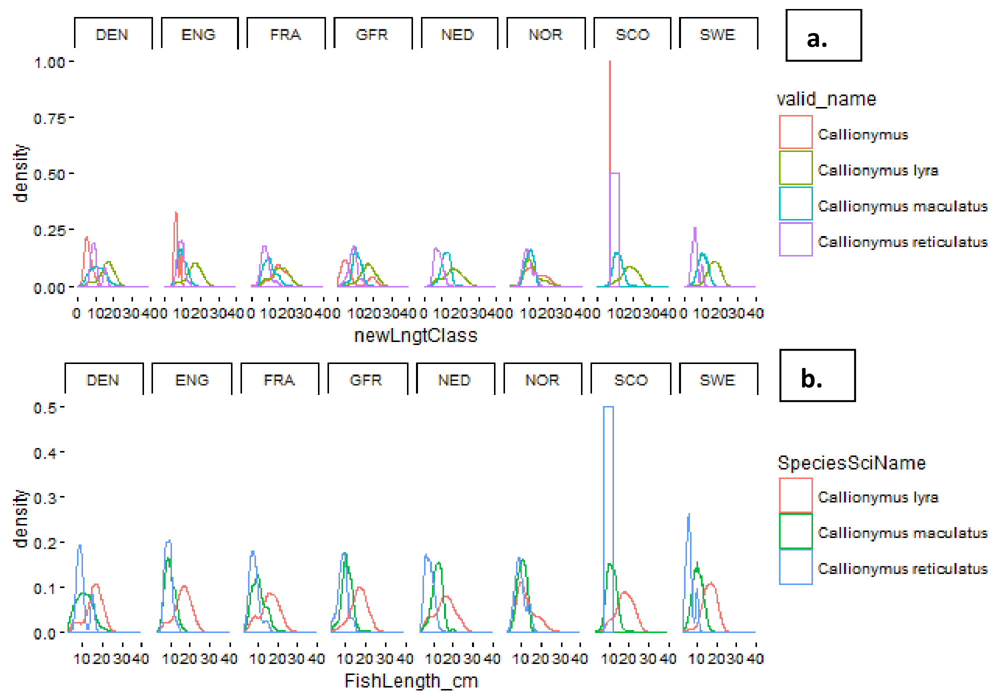

Figure 4.2.3.2: Sample of relative length frequency distributions reported for all species in the genus Callionymus among countries participating in the North Sea Quarter 1 survey (GNSIntOT1) a. represents the raw data collected, where samples are not always identified to species levels and species lengths occasionally are higher than the Lmax. Part b shows the quality assured information from the same data set, where unknown species are estimated to species level and length information is checked, verified and corrected where necessary.

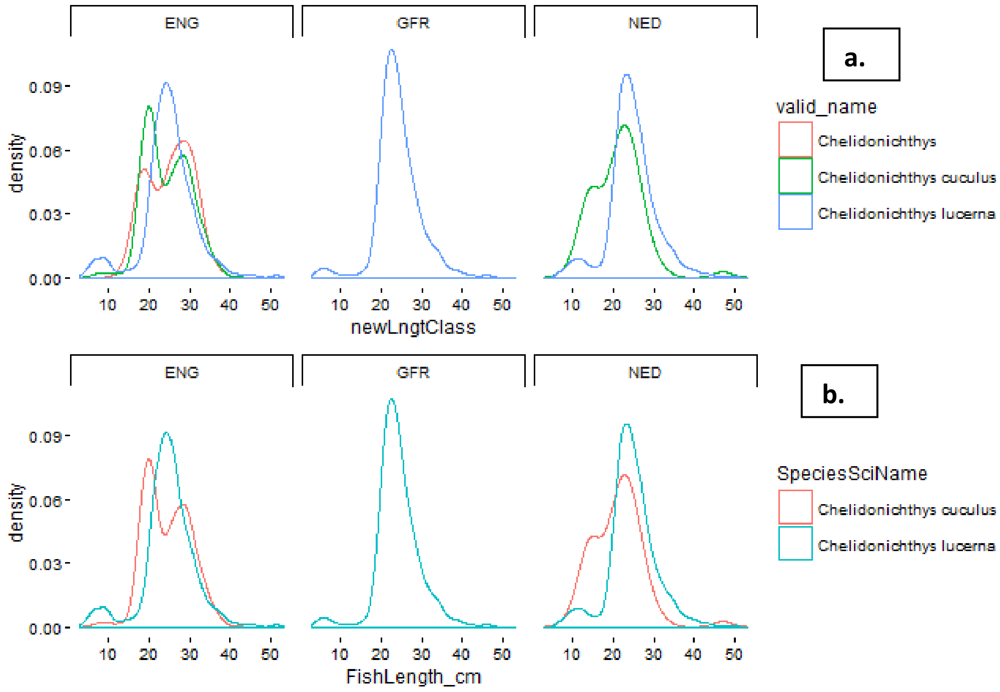

Figure 4.2.3.3:. Illustration of the different practises among countries participating in surveys in similar areas; showing (a) the raw data collected for Chelidonichthys spp., where samples are not always identified to species level, and (b) the quality assured information from the same data set, where unknown species are estimated to species level and length information is checked, verified and corrected where necessary.

Having rationalised all lengths recorded in HL records to the cm below, the actual lengths recorded with each species/subspecies taxonomic resolution level identification code in HL records retained in the data product were examined following the procedure illustrated in Figure 4.2.3.4. If the length lay within permitted bounds of the species' known Lmax (obtained from FishBase) and Lmin (defined as the birth or hatch length of elasmobranch species or the length at metamorphosis out of the larval phase for actinopterid species (S P R Greenstreet, Marine Scotland, unpublished data), then both the species identification code and the length parameter value were retained in the data product (Figure 4.2.3.4). If the length value lay outside these bounds, then the records in question were referred back to the data providers to check both the species identification and the length parameter value. Any erroneous data were corrected and the HL records again passed through the error trap. Table 4.2.3.4 provides examples of the type of issue that was caught by the error trap causing HL records to be referred back to the data providers.

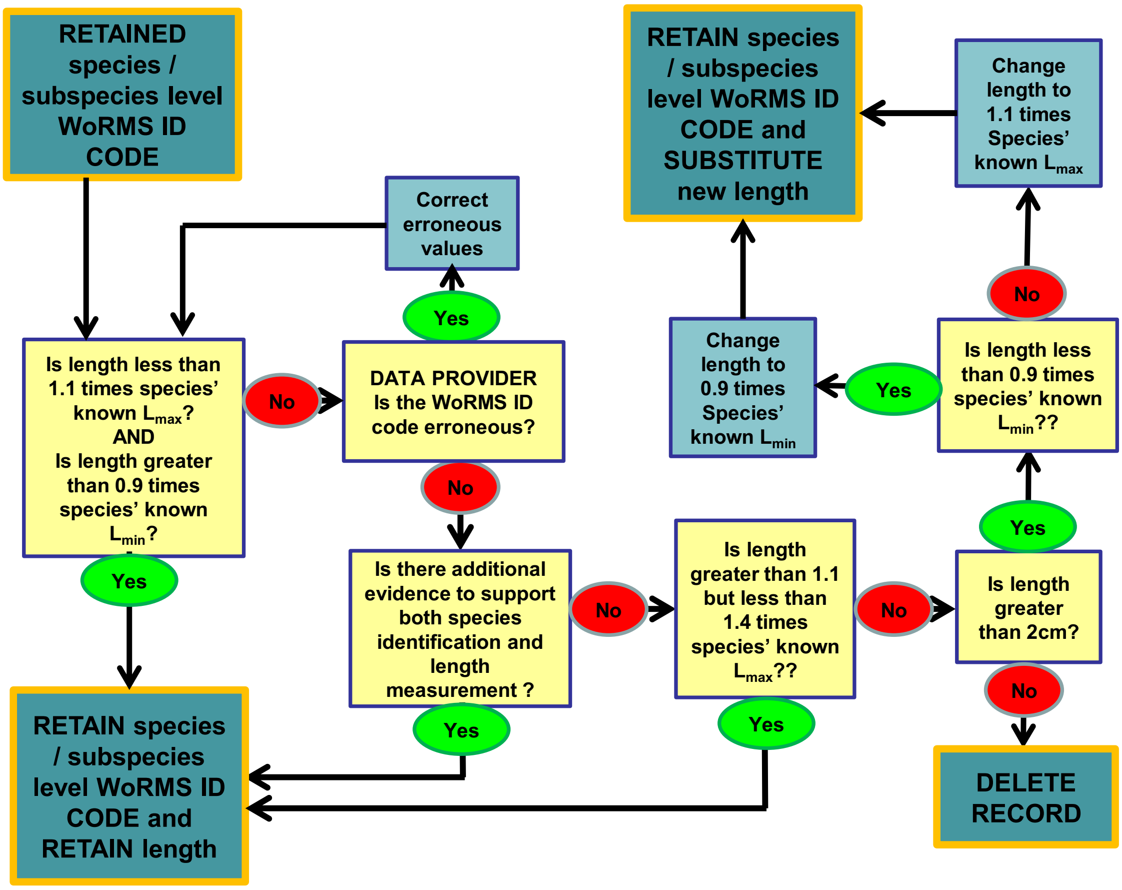

Figure 4.2.3.4: Flowchart to illustrate the procedure used to assess the reliability of species/subspecies taxonomic resolution level identifications against their recorded length parameter values. Unusually large or unusually small records were all referred back to the data providers for checking. Because exceptionally large specimens turn up occasionally, records of fish of upto 1.4 times their L_{max} were considered acceptable. Records of fish less than 2 cm in length were deleted because their poor catchability in the trawl gear. In records of species where the length parameter was either unacceptably large or small, the recorded length was substituted with a more acceptable value.

Rank	Scientific Name	Comments
Species	*Alosa fallax*	Flagged Lmax
Species	*Sprattus sprattus*	Flagged Lmax
Species	*Gadiculus argenteus*	Flagged Lmax
Species	*Trisopterus minutus*	Flagged LMax
Species	*Gaidropsarus mediterraneus*	Flagged Lmax
Species	*Spinachia spinachia*	inconsistencies (>Lmax) - DEN
Genus	Lepadogaster	(>Lmax) - FRA
Species	*Argentina silus*	Flagged Lmax
Species	*Callionymus maculatus*	inconsistencies (>Lmax)
Species	*Callionymus reticulatus*	inconsistencies (>Lmax)
Species	*Pholis gunnellus*	Flagged Lmax
Species	*Leptoclinus maculatus*	id. errors >Lmax - Lumpenus? Den, Eng, Nor, Sco
Species	*Echiichthys vipera*	Flagged Lmax
Species	*Limanda limanda*	Flagged Lmax NED 1984
Species	*Zeugopterus punctatus*	identification? inconsistencies among countries Rare! Flagged Lmax
Species	*Buglossidium luteum*	Flagged Lmax
Species	*Taurulus bubalis*	inconsistencies (>Lmax) – DEN, ENG, FRA, SCO
Species	*Liparis liparis liparis*	Previously Liparis liparis: inconsistencies (>Lmax) - NED
Species	*Liparis montagui*	inconsistencies (>Lmax)
Species	*Sebastes viviparus*	Lmax flagged
Species	*Maurolicus muelleri*	Flagged Lmax
Species	*Nerophis ophidion*	identification error (>Lmax) – FRA, NOR
Species	*Mustelus mustelus*	uncertain identification criteria Denmark has reported 96 unrealistically small Mustelus mustelus of 3-13 cm, whereas the reported minimum size at birth is about 35cm!
Family	Chimaeridae	
Species	*Chimaera monstrosa*	Not measured to TL need to be converted
Species	*Leucoraja naevus*	inconsistencies (>Lmax) - SCO

Table 4.2.3.4: Species recorded in the survey database which were deemed to be outside of their known length range.

Corrected records now passing the error trap were retained in the data product. Otherwise, where an issue still persisted, if further evidence could be provided to support both the identification coding and the length measurement, then the record was considered to be reliable and retained in the data product. For example, in addition to the type of photographic or taxonomic procedural evidence discussed above, if the catch weight reported for the species, compared with the reported number of fish caught, implied the inclusion of unusually large fish, then this could indeed suggest that the reported length value in question, whilst exceptional, was indeed reliable. Furthermore records where the length measurement, whilst exceeding $1.1L_{max}$ for the species, was nevertheless still less than $1.4L_{max}$ were also retained on the basis that exceptionally large specimens do occasionally turn up. For example, a particularly large sunfish (*Mola mola*) turned up in Malta in 2016 (Figure 4.2.3.5). This fish, at 4.2 m long, exceeded the previous known Lmax of 3.3 m by a factor of 1.3. Here a factor of 1.4 was adopted to take account of the fact that fish of such exceptional size were possible. A confirmed record of a *Rajella bathyphila* at 110 cm, approximately 1.2 times its known maximum length at the time of 90 cm, provides one example of an unusually large fish recorded in the DATRAS data base that was retained in the data product.

Figure 4.2.3.5: Image of the exceptionally large, 4.2 m long, sunfish (*Mola mola*) recorded off Malta in 2016.

This left a number of HL records where the recorded length was either less than the likely minimum length for the species, or was greater than 1.4 times the species' Lmax. Firstly all records where length was ≤2 cm were deleted on the basis that the sampling of fish of such length by the trawl gears used in the surveys was inadequate (Fraser et al., 2007). Next lengths less than 0.9 times the likely L_{min} were all substituted by the appropriate species-specific 0.9L_{min} value. In both these situations, where the exceptionally small length category involved was subsequently found to be a consequence of the systematic error associated with the date entry process for fish measured to the ½ cm below, the record was retained and the length category corrected as described below (see Table 4.2.3.5 and associated text). Finally all lengths ≥1.4 times the species Lmax were substituted by the appropriate species-specific 1.1L_{max} value, i.e. the error-trap values used in Figure 4.2.3.4. This was particularly important in respect of unacceptably large fish to prevent such records having an undue influence on the Large Fish Indicator, which being biomass-based (Greenstreet et al., 2011), would be highly susceptible to the inclusion of fish of extreme body-length.

Unless informed otherwise by the data providers as part of the error trap phase, the process depicted in Figure 4.2.3.4 implicitly assumes that the species identification code is correct. Where the species identification code and the reported length parameter do not match, it is the length parameter that is deemed to be unreliable and subsequently adjusted. In the majority of cases where data providers were able to correct an erroneous record, it was indeed the length parameter that had been incorrectly recorded/archived.

However, instances where the species identification was erroneous were observed and these often occurred when a small number of fish were presented in the sample at an outlying length, e.g. *Buglossidium luteum* (solenette) recorded at 28 cm which were considered much more likely to have been *Solea solea* (Dover Sole) by the relevant data provider. Such mistakes often arose because of the old three letter species ID codes that were used early on in survey time series. For example SOL was the code used for solenette, but could easily have been mistakenly used for sole, which actually had the code DSO. Where such situations were considered more likely, rather than strictly adhering to the process depicted in Figure 4.2.3.4, the appropriate change was made to the species ID code instead.

Generally, instances where the recorded length was erroneous but the species ID code was correct were more common. Where this occurred, the problem frequently affected the length class in the records of every fish of that species or family in the haul, and often many hauls, and sometimes across several years. This was because the problem arose as a systematic error in the DATRAS upload process associated with mistakenly entering a length measured in cm for a species where the measurement type code indicated fish measured to the ½ cm below. For example, *Hyperoplus lanceolatus* recorded at 490 mm in the DATRAS database, when the actual length in the national database was 26.5 cm. Where this occurred appropriate changes were made to the recorded length category. This DATRAS data upload issue is described in more detail below (see Table 4.2.3.5).

Occasionally records were found to be a complete mistake, simply requiring removal. This usually occurred as a result of an accidental ‘swipe’ on an electronic measuring board, therefore, recording a length values for totally non-existent fish belonging to the species previously being measured, as was found to be the case for a *Sebastes viviparous* at a length of 50 cm for example.

Three types of abundance-at-length data were recorded in the survey databases:

1. ‘C’: catch per unit effort data (CPUE) where the data were standardised to numbers per hour; so, for example, all observed abundance-at-length values for a half-hour trawl sample were simply multiplied by two;
2. ‘R’: actual raw catch totals-at-length;
3. ‘S’: sub-sampled data, where a known fraction of the total catch was quantified, and all subsequent totals-at-length multiplied by the reciprocal of the subsample fraction. In this last case, the remaining fraction of the sample was not examined at all.

As with the recording of length category described above, there is little consistency in the way that species abundance-at-length data have been recorded, either within species within any given survey, between species in any given survey, or between surveys. This again renders the use of these data by scientists, who may not be aware of all these issues fraught with risk. In order to derive a single standardised data product for all surveys undertaken across the Northeast Atlantic area, the different types of abundance data recorded in the DATRAS database were rationalised to **a single standard density estimate as number-at-length per square kilometre.** This essentially required the second type of abundance information, the actual raw catch totals-at-length, which could then be divided by the area swept by the trawl to derive the required values. Where data were recorded as either of the first or third abundance types these values were first converted back to actual raw catch totals-at-length.

If data was recorded as “C”, i.e. CPUE data (hr^{-1}), then the equation used to change it to “R” i.e. actual raw catch total data, was $R = \frac{C * T_{tow}}{60}$ where T_{tow} is the haul duration measured in minutes. Thus for a half-hour tow, CPUE data were simply multiplied by a factor of 0.5. For HL records with 'S' type abundance at length categories, both the total catch number and the total catch weight for the species in question take account of the sub-sample subfactor, and so represent the total number and total weight of fish in the catch. However, the abundance at length data do not take the subfactor into account; the reported abundance values simply indicate the number of fish in each length category that was actually measured. To convert sub-sample abundances (*S*) to actual raw catch at length (*R*) data the following equation was applied $R = S * subfactor$. In DATRAS the subfactor is reported as the reciprocal of the fraction of the catch sampled. Thus if 25% of the catch is sampled and measured, then the subfactor is four.

The species abundance at length data reported in the DATRAS data were checked using a number of different approaches. Firstly, weight at length relationships were applied to convert species catch number at length data to species biomass at length data. Summing the latter across all weight classes recorded for the species in question for the trawl sample in question provided a theoretical total catch weight for the species in that sample. This could then be compared directly with the total catch weight reported in the DATRAS database. A perfect one-to-one relationship would be the anticipated result, but given the numerous sources of variation, a discrepancy of up to ±25% was considered acceptable. Any records where the theoretical summed biomass at length deviated from the reported catch weight by a factor of <75% or >125% were referred back to the data providers for checking. Secondly the estimated densities at length could be summed across all length classes to derive an estimated total density of each particular in each trawl samples. Again a direct relationship between reported catch weight and the summed densities at length would be anticipated, although in this instance the relationships would vary from species to species in accordance with variation in the mean body length of the different species. Once again records with a deviance of >±25% of the expected summed density at length value were referred back to the data providers for checking. Differences between plots provided clear diagnostic evidence as to where any errors might lie.

Figure 4.2.3.6 shows both plots for a set of hypothetical data. In Figure 4.2.3.6a, the reported catch weight on summed biomass at length plot, five types of outlier are obvious, shown as different coloured dots. However, in all these outliers, it is not clear what the problem is; the reported densities could be erroneous, or the reported length categories could be incorrect. In Figure 4.2.3.6b, the reported catch weight on summed densities at length plot, three of the types of outlier are no longer apparent; the red, yellow and light blue data points now all fall within the acceptable data range. This is because, for these hypothetical records, it is the length parameter that is incorrect. Thus for the light blue datum, one or more length categories have reported values that are smaller than they should be. Application of the weight at length relationship to these erroneous values gives individual mean weighs that are lighter than they should be, leading to underestimation of the biomass at length in these length classes. This in turn means that the summed biomass at length across all length classes is less than it should be, leading to negative outliers in the the reported catch weight on summed biomass at length plot (Figure 4.2.3.6a). Similarly, for the yellow datum, one or more length categories have reported values that are larger than they should be. Application of the weight at length relationship to these erroneous values gives individual mean weighs that are heavier than they should be, leading to overestimation of the biomass at length in these length classes. This in turn means that the summed biomass at length across all length classes is greater than it should be, leading to positive outliers in the the reported catch weight on summed biomass at length plot (Figure 4.2.3.6a). In both cases, reported densities at length are accurate, so in the reported catch weight on summed densities at length plot these data do not appear as outliers (Figure 4.2.3.6b). The blue and green data points appear as outliers in both plots because, for these two hypothetical HL records, it is the abandance data that are erroneous. If abundance data are erroneously high (blue datum) or erroneously low (green datum) then this affects both the summed densities at length and the summed biomass at length. Depending on the direction of the error, the datum will be a positive outlier (densities erroneously high) or a negative outlier (densities erroneously low) in both plots (Figure 4.2.3.6).

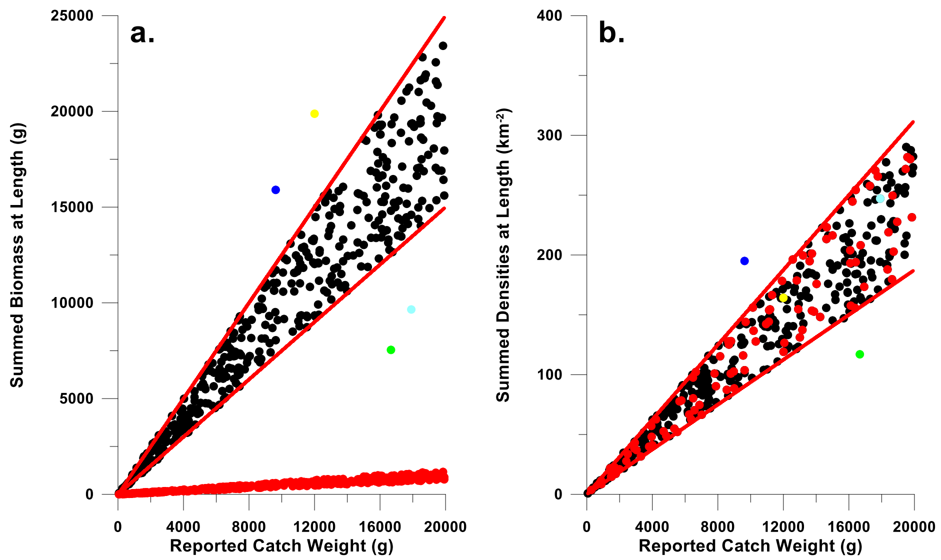

Figure 4.2.3.6: Hypothetical relationships between reported catch weight and the summed biomass at length across all length classes (a) and between reported catch weight and the summed densities at length across all length classes (b). Black data points depict data lying within acceptable ±25% bounds defined by the solid red lines. Blue and green data points depict records where error in the reported abundance values may be present. Light blue, yellow and red data points depict records where error in the reported length categories may be present. See text for further details.

The red data points in Figure 4.2.3.6 illustrate a particular type of systematic error that was fairly common throughout the DATRAS database, where the summed biomass at length estimate deviated hugely from the reported catch weight (by a factor of between -95% to -98%). Since the red data only fall as outliers in the summed biomass at length plot (Figure 4.2.3.6a), and not in the summed densities at length plot (Figure 4.2.3.6b), it is immediately obvious that the problem lay with the length categories reported in the DATRAS data. Examination of the data revealed that this type of problem was restricted only to records where the fish had been measured to the half cm below, which is a common practice for many pelagic species such as herring, sprats, and sandeels. A further clue was the fact that records where this error was observed were also characterised by having unusually, and in many instances unbelievably, low reported length categories,

Table 4.2.3.5 illustrates a typical herring sample, in which the fish would have been measured to the ½ cm below. Columns 1 and 2 illustrate the typical data that would have been recorded; the number of fish caught and measured at each given ½c m length category. The fact that ½ cm length categories have been used is recorded in the DATRAS measurement type field. But critically, when this is the case, DATRAS expects the length information to be entered in mm not cm, thus 200 mm, 205 mm, 210 mm, etc., not 20.0 cm, 20.5 cm, 21.0 cm, and so on, as shown in Columns 3 and

2 respectively (Table 4.2.3.5). The data entry format requires the first length category to be entered, followed by the abundance of fish in that category, then followed by the abundance of fish in each subsequent category. Knowing that the categories are ½ cm (5 mm), and given the first length category, the data entry system automatically assigns each subsequent length category for each abundance value provided. Thus in the example shown in Table 4.2.3.5, the data entry stream would look like:

200,19,22,27,35,42,39,40,35,32,26,20,15,12,8,0,2 .

The resulting DATRAS database would then hold 16 records with the length categories shown in Column 3 (Table 4.2.3.5) and the abundance values shown in Column 1 (Table 4.2.3.5). If this was done correctly, then in constructing the groundfish survey monitoring and assessment data product, these mm length categories (Table 4.2.3.5 Column 3) would correctly be altered to their equivalent lengths in cm (Table 4.2.3.5 Column 2).

	Number	Length (cm)	Correct Length (mm)	Erroneous Length (mm)	Erroneous Length (cm)	Indivual Weight	Erroneous Ind. Wt.	Biomass at Length	Erroneous Biom. at
	19	20	200	20	2	62.23	0.057	1182.32	1.08
	22	20.5	205	25	2.5	67.08	0.112	1475.72	2.46
	27	21	210	30	3	72.18	0.195	1948.77	5.26
	35	21.5	215	35	3.5	77.53	0.311	2713.50	10.89
	42	22	220	40	4	83.14	0.467	3491.91	19.60
	39	22.5	225	45	4.5	89.02	0.668	3471.75	26.04
	40	23	230	50	5	95.17	0.920	3806.81	36.79
	35	23.5	235	55	5.5	101.60	1.229	3556.01	43.01
	32	24	240	60	6	108.32	1.601	3466.10	51.24
	26	24.5	245	65	6.5	115.32	2.042	2998.38	53.10
	20	25	250	70	7	122.63	2.558	2452.54	51.17
	15	25.5	255	75	7.5	130.24	3.155	1953.54	47.33
	12	26	260	80	8	138.16	3.839	1657.87	46.07
	8	26.5	265	85	8.5	146.39	4.616	1171.13	36.93
	0	27	270	90	9	154.95	5.492	0.00	0.00
	2	27.5	275	95	9.5	163.84	6.473	327.68	12.95
Total Catch	377				Summed Biomass at Length			35674.04	443.91
					Reported Catch Weight			40466	40466

Table 4.2.3.5: Example of the type systematic error that could occur in records invoving pelagic species measured to the ½ cm below that would give rise to sort of large discrepancies in reported catch weight on summed biomass at length plots indicated by the red data in Figure 4.2.3.4. See text for details.

However, if the data provider erroneously enters the first length in cm as 20 cm, entering the data stream,

20,19,22,27,35,42,39,40,35,32,26,20,15,12,8,0,2 , the DATRAS system assumes this to be 20 mm, so the ensuing length categories assigned to subsequent abundance values are 25 mm, 30 mm, and so on, as shown in Table 4.2.3.5 Column 4. When constructing the data product these erroneous mm length categories are converted to the equally erroneous cm length categories 2 cm, 2.5 cm, 3 cm, 3.5 cm, etc., as shown in Table 4.2.3.5 Column 5. Thus we see these unusually, and almost unbelievable, small herring in the sample. Applying the herring weight (*W*) at length (*L*) relationship ($W=0.0069L^{3.04}$) to the correct cm length categories (Column 2 Table 4.2.3.5) and to the erroneous cm length categories (Column 5 Table 4.2.3.5) gives the correct and erroneous estimates of invidual fish weight in each length category shown in Columns 6 and 7 (Table 4.2.3.5) respectively. Then multiplying these numbers by the number of fish caught and measured in each length category (Column 1 Table 4.2.3.5) gives both the correct (Column 8 Table 4.2.3.5) and incorrect (Column 9 Table 4.2.3.5) estimates of sampled biomass in each length category.

Summing these two sets of biomass at length across all length categories gives two very different estimates of summed biomass at length; the erroneous sum being little more than just 1% of the correct sum. In this example, comparison with the reported total catch weight shows close agreement with the correct sum, but wide divergence with the erroneous sum. In both cases though, the number of fish involved is the same, so this discrepancy would only be apparent in a plot similar to that shown in Figure 4.2.3.6a, and the discrepancy large enough to explain the extent of the deviation shown by the red data in this plot. In all cases where the sort of systematic error shown by the red data in Figure 4.2.3.6 was detected, referral back to the data providers confirmed that the process illustrated in Table 4.2.3.5, and described above, provided the explanation. Since the route by which the error had occurred was understood, appropriate corrections could be applied. In all cases where data outliers of the sort illustrated in Figure 4.2.3.6 were referred back to the data providers, either the length parameter or the recorded abundance at length was found to be erroneous and could be corrected at source.

A final check of the abundance at length data was the simple check to ensure that the sum of all actual raw catch totals-at-length matched (within the error range associated with possible rounding errors) the total catch reported for the species in question in the DATRAS database.

4.2.4. HL Records with Genus, Family or Order Identification Codes

As previously stated, if in any given genus or family, only one species was ever recorded, then all the coarser level ID codes were simply substituted by the single species-level identification code. The issue becomes more complicated if there is more than one possible species-level option for any particular coarser taxonomic resolution ID code. Here a 'balance of probabilities' approach to finding a solution was adopted through application of a k-nearest neighbours (k-NN) classification algorithm. This non-parametric classification method essentially uses a 'majority vote' of a number, k, of neighbours of known classification to estimate the classification of an 'item' where this is not known, and where each neighbour's vote is weighted according to distance (d); each neighbour receiving a weight of 1/d. The parameters used for the nearest neighbours comparison are ID Code, length frequency data, abundance, distance between sample locations, and time period between sampling events (in quarter years). These parameters were first normalized to reduce any bias in distance weighting. The normalization routine used the formula

$\sum \frac{x - \min x}{(\max x - \min x)}$ where x is the variable of interest, in this case, 'Year', 'Quarter',

'length', 'abundance at length' and 'location' variables, which were all normalised. The k-NN classification algorithm is a simple machine learning algorithm, where the parameters are determined using a subset of the full data set (e.g. 90% of the available data) as a training data set and the precision of model predictions can then be assessed with reference to the remaining 10% of the data. Thus, for example, the WoRMS Aphia ID code 125930 is commonly found in many of the survey data sets examined. This is a genus-level code for the genus Callionymus, which contains three potential species options,126792 for *Callionymus lyra*, 126793 for *Callionymus maculatus* and 126795 for *Callionymus reticulatus*. In each case the species-level identifications are checked with reference to length-frequency and abundance to ensure their accuracy (see Section 4.2.3). The training data is then fed into the algorithm and used to determine parameter values to be used in the model. The target data is then used to test model prediction accuracy. In the Callionymus example, model prediction precision was found to be 100% accurate. The model is then applied to the full sample data set to estimate the most likely species-level WoRMs Aphia ID code in each instance where a coarser taxonomic resolution ID Codes occurs. Figure 4.2.4.1 shows a simplified representation of this classification process where the item in the dark grey box is unknown. In this instance, the k-NN classification algorithm would predict the item to be species 1 (a circle), as all of the nearest neighbours are circles. Table 4.2.4.1 provides a list of the genus and coarser taxonomic resolution identification codes needing to be resolved to their potential species-level outcomes, and indicates the methods by which this was achieved. Moriarty (2017c) provides the R script required to implement the k-NN procedure.

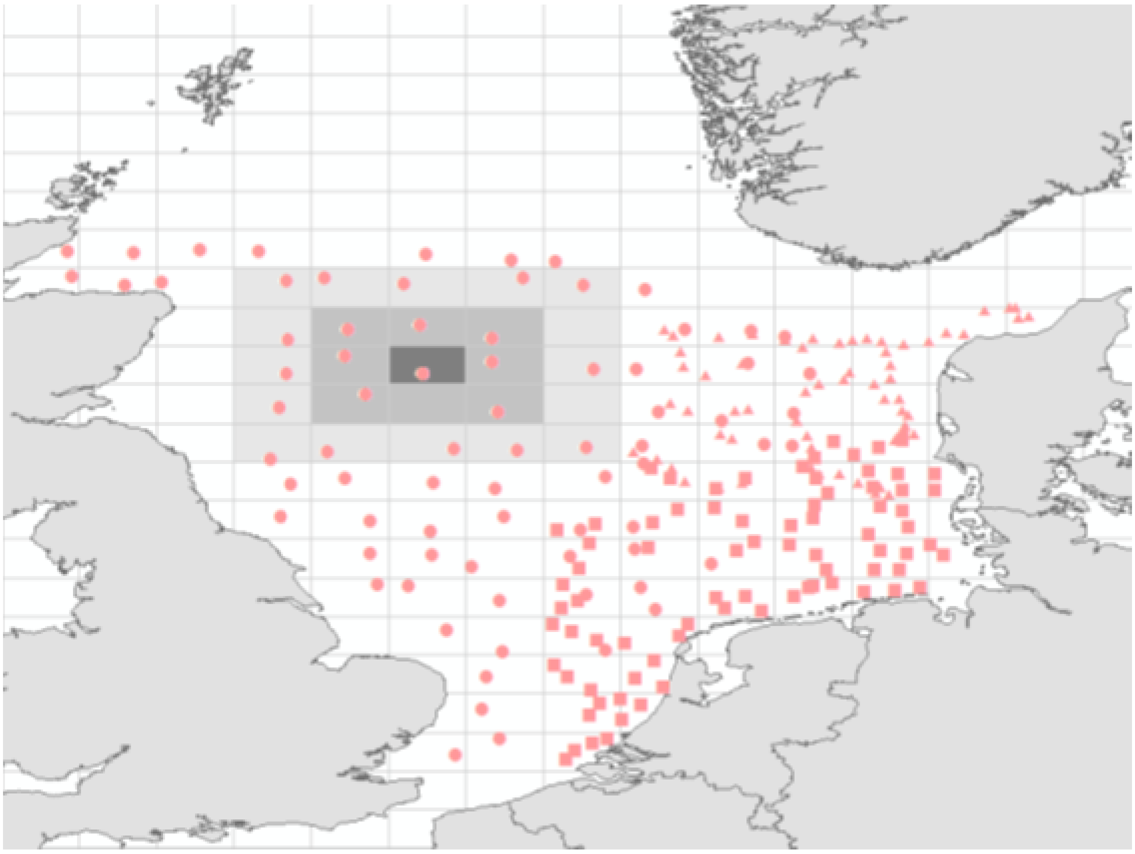

Figure 4.2.4.1: Illustration of the k-NN classification protocol. The dark grey box contains the unknown item, while items the lighter grey boxes are known. Here items in the lightest grey box will have lower weight than items in the medium grey box. Circles are species one, squares are species two and triangles are species three.

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Rank	Scientific Name	Comments
Family	Clupeidae	Use k-NN to estimate likely species
Genus	Alosa	Use k-NN to estimate likely species
Species	*Alosa agone*	
Species	*Alosa alosa*	inconsistencies among countries
Species	*Alosa fallax*	Flagged Lmax
Species	*Clupea harengus*	
Species	*Sardina pilchardus*	
Species	*Spratelloides lewisi*	Unlikely, incorrect distribution
Species	*Sprattus sprattus*	Flagged Lmax
Family	Gadidae	
Genus	Gadiculus	Use k-NN to estimate likely species Valid taxon interpretation is Gadiculus thori Genus with 2 species recorded (check surveys individually)
Species	*Gadiculus argenteus*	Flagged Lmax
Species	*Gadiculus thori*	Valid taxon interpretation of Gadiculus (North Sea Surveys)
Species	*Trisopterus minutus*	Flagged LMax
Family	Lotidae	
Species	*Brosme brosme*	See section 3.4 geo dist ICES, 2007a
Species	*Ciliata mustela*	
Species	*Ciliata septentrionalis*	
Species	*Enchelyopus cimbrius*	
Genus	Gaidropsarus	Use k-NN to estimate likely species
Species	*Gaidropsarus argentatus*	identification error ?
Species	*Gaidropsarus biscayensis*	
Species	*Gaidropsarus macrophthalmus*	identification? (Syn: Antonogadus m.)
Species	*Gaidropsarus mediterraneus*	Flagged Lmax
Species	*Gaidropsarus vulgaris*	See section 3.5.1.1 of ICES, 2007a
Species	*Molva dypterygia*	unlikely species in North Sea
Species	*Nezumia bairdii*	Unlikely, incorrect distribution
Family	Merlucciidae	Vaild taxon is Merluccius merluccius
Species	*Merluccius merluccius*	
Species	*Spinachia spinachia*	inconsistencies (>Lmax) - DEN
Family	Gobiesocidae	Use k-NN to estimate likely species
Species	*Apletodon dentatus*	Problematic taxa
Species	*Diplecogaster bimaculata bimaculata*	Previously Diplecogaster bimaculata
Genus	Lepadogaster	Use k-NN to estimate likely species identification error (>Lmax) - FRA
Species	*Lepadogaster lepadogaster*	
Family	Lophiidae	Use k-NN to estimate likely species
Genus	Lophius	Use k-NN to estimate likely species
Species	*Lophius budegassa*	
Species	*Lophius piscatorius*	
Family	Argentinidae	family with 1 genus

Genus	Argentina	Use k-NN to estimate likely species. Distinctive geographical distribution
Species	*Argentina silus*	Flagged Lmax
Species	*Argentina sphyraena*	
Family	Osmeridae	
Species	*Osmerus eperlanus*	The smelt (Osmerus eperlanus) is a coastal species of brackish and even freshwater habitats. Therefore, it would seem unlikely that a specimen would have been caught on the slope of the Norwegian Trench. In contrast, the lesser argentine (*Argentina sphyraena*) is a typical slope species that would not be expected in the southern North Sea.
Family	Anarhichadidae	
Species	*Anarrhichthys ocellatus*	Unlikely, incorrect distribution
Family	Blenniidae	Use k-NN to estimate likely species
Genus	Blennius	Use k-NN to estimate likely species
Species	*Blennius ocellaris*	
Species	*Coryphoblennius galerita*	
Species	*Parablennius gattorugine*	
Family	Callionymidae	Use k-NN to estimate likely species
Genus	Callionymus	Use k-NN to estimate likely species
Species	*Callionymus lyra*	
Species	*Callionymus maculatus*	inconsistencies (>Lmax)
Species	*Callionymus reticulatus*	inconsistencies (>Lmax)
Species	*Synchiropus phaeton*	
Family	Labridae	Use k-NN to estimate likely species Family with problematic taxa
Species	*Acantholabrus palloni*	
Species	*Centrolabrus exoletus*	
Species	*Ctenolabrus rupestris*	
Species	*Labrus bergylta*	
Species	*Labrus mixtus*	
Genus	Symphodus	Use k-NN to estimate likely species
Species	*Symphodus bailloni*	
Species	*Symphodus melops*	
Species	*Symphodus roissali*	
Family	Moronidae	
Genus	Dicentrarchus	In NS and SWC: genus with 1 species: Dicentrarchus labrax
Species	*Dicentrarchus labrax*	
Species	*Dicentrarchus punctatus*	
Family	Mugilidae	Use k-NN to estimate likely species?
Species	*Chelon labrosus*	
Species	*Liza aurata*	
Species	*Liza ramada*	
Species	*Mugil cephalus*	
Family	Mullidae	Use k-NN to estimate likely species
Genus	Mullus	Use k-NN to estimate likely species
Species	*Mullus barbatus barbatus*	Previously mullus barbatus… identification? rare

Species	*Mullus surmuletus*	
Family	Pholidae	
Species	*Pholis gunnellus*	Flagged Lmax
Species	*Scomber japonicus*	Unlikely, incorrect distribution
Family	Sparidae	Use k-NN to estimate likely species. Problematic taxa
Species	*Boops boops*	
Species	*Dentex dentex*	
Species	*Dentex maroccanus*	
Species	*Diplodus annularis*	
Species	*Diplodus bellottii*	
Species	*Diplodus cervinus cervinus*	
Species	*Diplodus puntazzo*	
Species	*Diplodus sargus sargus*	
Species	*Diplodus vulgaris*	
Species	*Lithognathus mormyrus*	
Genus	Pagellus	Use k-NN to estimate likely species
Species	*Pagellus acarne*	
Species	*Pagellus bogaraveo*	
Species	*Pagellus erythrinus*	
Species	*Pagrus auriga*	
Species	*Pagrus pagrus*	
Species	*Sarpa salpa*	
Species	*Sparus aurata*	
Species	*Spondyliosoma cantharus*	
Family	Stichaeidae	Use k-NN to estimate likely species. Problematic taxa
Species	*Chirolophis ascanii*	
Species	*Leptoclinus maculatus*	id. errors >Lmax - Lumpenus? Den, Eng, Nor, Sco
Species	*Lumpenus lampretaeformis*	
Family	Trachinidae	
Genus	Echiichthys	
Species	*Echiichthys vipera*	Flagged Lmax
Species	*Trachinus draco*	inconsistencies in distribution and LFD
Family	Trichiuridae	
Species	*Benthodesmus elongatus*	Unlikely, incorrect distribution
Species	*Lepidopus caudatus*	
Species	*Trichiurus lepturus*	
Family	Zoarcidae	Use k-NN to estimate likely species
Species	*Lycenchelys sarsii*	
Species	*Lycodes gracilis*	
Species	*Lycodes vahlii*	Unlikely, incorrect distribution
Species	*Zoarces viviparus*	
Family	Bothidae	Use k-NN to estimate likely species
Genus	Arnoglossus	Use k-NN to estimate likely species
Species	*Arnoglossus imperialis*	identification?
Species	*Arnoglossus laterna*	
Species	*Arnoglossus rueppelii*	
Species	*Arnoglossus thori*	identification?

Species	*Limanda limanda*	Flagged Lmax NED 1984
Genus	Zeugopterus	Problematic Taxa
Species	*Zeugopterus punctatus*	identification? inconsistencies among countries Rare! Flagged Lmax
Species	*Zeugopterus regius*	identification? –SCO rare - SCO
Family	Soleidae	Use k-NN to estimate likely species
Species	*Bathysolea profundicola*	
Genus	Buglossidium	Valid taxon Buglossidium luteum
Species	*Buglossidium luteum*	Flagged Lmax
Species	*Dicologlossa cuneata*	
Genus	Microchirus	Genus with 1 species recorded in NS/SWC Valid taxon SWC/NS Microchirus variegatus
Species	*Microchirus azevia*	
Species	*Microchirus boscanion*	
Species	*Microchirus ocellatus*	
Species	*Microchirus variegatus*	
Species	*Monochirus hispidus*	
Genus	Solea	Solea solea only found in NS/SWC
Species	*Solea senegalensis*	
Species	*Solea solea*	Previously Solea vulgaris
Family	Salmonidae	
Genus	Salmo	Use k-NN to estimate likely species
Species	*Salmo salar*	
Species	*Salmo trutta trutta*	Previously Salmo trutta
Family	Agonidae	
Species	*Agonus cataphractus*	
Species	*Leptagonus decagonus*	identification ?
Family	Cottidae	flagged as problematic taxa
Species	*Artediellus atlanticus*	identification?
Species	*Micrenophrys lilljeborgii*	
Genus	Myoxocephalus	NS/SWC: genus with 1 species - Net 1991
Species	*Myoxocephalus quadricornis*	
Species	*Myoxocephalus scorpioides*	not in NS fauna – FRA identification error - FRA
Species	*Myoxocephalus scorpius*	
Species	*Taurulus bubalis*	inconsistencies (>Lmax) – DEN, ENG, FRA, SCO
Species	*Triglops murrayi*	Trachyrhynchus murrayi identification error: (Triglops murrayi??) – SCO
Species	*Triglops pingelii*	
Family	Cyclopteridae	Use k-NN to estimate likely species
Species	*Cyclopterus lumpus*	
Family	Liparidae	
Species	*Careproctus reinhardti*	
Genus	Liparis	?
Species	*Liparis liparis liparis*	Previously Liparis liparis: inconsistencies (>Lmax) - NED
Species	*Liparis montagui*	inconsistencies (>Lmax)
Family	Peristediidae	
Species	*Peristedion cataphractum*	

Family	Psychrolutidae	
Species	*Cottunculus microps*	
Family	Scorpaenidae	Use k-NN to estimate likely species
Species	*Pontinus kuhlii*	
Genus	Scorpaena	Use k-NN to estimate likely species. Flagged as problematic taxa
Species	*Scorpaena loppei*	
Species	*Scorpaena notata*	
Species	*Scorpaena porcus*	
Species	*Scorpaena scrofa*	
Species	*Helicolenus dactylopterus*	
Genus	Sebastes	Flagged as problematic taxa
Species	*Sebastes mentella*	
Species	*Sebastes norvegicus*	
Species	*Sebastes viviparus*	Lmax flagged
Species	*Trachyscorpia cristulata cristulata*	
Family	Triglidae	Use k-NN to estimate likely species
Genus	Chelidonichthys	Use k-NN to estimate likely species
Species	*Chelidonichthys cuculus*	
Species	*Chelidonichthys lucerna*	
Species	*Chelidonichthys obscurus*	
Genus	Eutrigla	Genus with 1 species recorded in surveys
Species	*Eutrigla gurnardus*	
Genus	Lepidotrigla	
Genus	Trigla	Genus with 1 species recorded in surveys
Species	*Trigla lyra*	?? Trigla lucerna - inconsistencies among countries ?
Genus	Trigloporus	Genus with 1 species recorded in surveys
Species	*Trigloporus lastoviza*	
Species	*Maurolicus muelleri*	Flagged Lmax
Family	Stomiidae	
Genus	Stomias	Genus with 1 species recorded in surveys
Species	*Stomias boa boa*	
Family	Centriscidae	
Genus	Macroramphosus	Genus with 1 species recorded in surveys
Species	*Macroramphosus scolopax*	
Family	Syngnathidae	Use k-NN to estimate likely species
Species	*Entelurus aequoreus*	
Species	*Hippocampus guttulatus*	
Species	*Hippocampus hippocampus*	
Species	*Nerophis lumbriciformis*	
Species	*Nerophis ophidion*	identification error (>Lmax) – FRA, NOR
Genus	Syngnathus	?
Species	*Syngnathus acus*	inconsistencies among countries
Species	*Syngnathus rostellatus*	inconsistencies among countries WKTQD: flagged lmax
Species	*Syngnathus typhle*	inconsistencies among countries
Family	Zeidae	Use k-NN to estimate likely species

Species	*Zenopsis conchifer*	
Species	*Zeus faber*	
Class	Cephalaspidomorphi	
Family	Petromyzontidae	Use k-NN to estimate likely species
Genus	Lampetra	Valid taxon L. fluviatilis
Species	*Lampetra fluviatilis*	
Genus	Petromyzon	Valid taxon Petromyzon marinus
Species	*Petromyzon marinus*	
Genus	Mustelus	Irregularities may also occur from taxonomic confusion. A good example is the genus Mustelus, for which two species are generally accepted to occur in the North Sea, M. mustelus and M. asterias, the distinction being generally made on the basis of the absence or presence of white spots, respectively. However, there is growing evidence that this criterion is insufficient to separate the two species because of very gradual differences in both number and size of these white spots, which are often barely visible. For all practical purposes, we suggest to bring all the historically collected information on the two species under the taxon Mustelus, without trying to distinguish species. New information by species should only be accepted if supported by good taxonomic evidence that the two species have been properly identified
Species	*Mustelus asterias*	uncertain identification criteria
Species	*Mustelus mustelus*	uncertain identification criteria Denmark has reported 96 unrealistically small Mustelus mustelus of 3-13 cm, whereas the reported minimum size at birth is about 35cm!
Family	Chimaeridae	
Species	*Chimaera monstrosa*	Not measured to TL need to be converted
Family	Arhynchobatidae	
Species	*Bathyraja brachyurops*	Unlikely – incorrect distribution
Family	Rajidae	Use k-NN to estimate likely species Note: Although this problem can be easily resolved by incorporation a suitable check upon entry in DATRAS, care must be taken that these checks are made area-specific. Also, changes in the taxonomy can easily distort the information existing in the database. For instance, originally unspecified Raja was a valid genus, indicating that it could have been one of the many ray species occurring in the North Sea. At a particular point in time, ICES has adopted the new nomenclature, where the genus Raja has been reserved for a small subset, whereas the other rays have been brought under several other genus. In this case, the unique interpretation of the 12 | ICES WKTQD Report 2007 genus Raja changed at a particular point in time and therefore a suitable correction is required: all Raja sp reported before that time have to be changed to Rajidae! Therefore, changes to the nomenclature used in DATRAS must be supervised by a small group of taxonomists before implementation to ensure consistency in interpretation over the entire period.
Species	Amblyraja radiata	Previously Raja radiata
Genus	Dipturus	
Species	*Dipturus batis*	inconsistencies in distribution- DEN
Species	*Dipturus linteus*	*Dipturus lintea*- unlikely NS Spp (FRA)

Species	*Dipturus oxyrinchus*	
Species	*Leucoraja circularis*	
Species	*Leucoraja fullonica*	
Species	*Leucoraja lentiginosa*	Unlikely, incorrect distribution not in CLOFNAM
Species	*Leucoraja naevus*	inconsistencies (>Lmax) - SCO
Genus	Raja	Valid Taxon “Rajidae”
Species	*Raja brachyura*	
Species	*Raja clavata*	
Species	*Raja microocellata*	
Species	*Raja miraletus*	
Species	*Raja montagui*	
Species	*Raja undulata*	Previously “Leucoraja undulata” Note: only very small specimens reported
Family	Squalidae	Deep water sharks can be a problematic taxa
Species	*Squalus acanthias*	
Species	*Squalus blainville*	
Family	Torpedinidae	
Species	*Tetronarce nobiliana*	
Species	*Torpedo marmorata*	NS: input error: *Raja clavata* – North Sea Netherlands
Species	*Torpedo nobiliana*	
Species	*Torpedo torpedo*	

Table 4.2.4.1: Shows the list of genus and family taxonomic resolution level identifications that were resolved to the species taxonomic resolution level using the k-NN classification algorithm.

4.2.5. Use of the k-NN Procedure to Estimate Missing Length Category Data

In some cases the fish sampled were not measured; and only total counts, and or catch weights of the species in question were available. In the Baseline product, the missing lengths are not estimated and the count, or a count estimated form the weight assuming an average individual fish weight, are recorded against a zero length value. This conserves the database structure. Figure 4.2.5.1 presents an example of density at length data (count only data is assigned a zero length in the baseline product) for *Callionymus lyra* in the GNSFraOT4 survey. Here a mixture of count only and count/weight data was available. To assign length frequency distributions to known species we again use a k-NN classification algorithm, previously described in Section 4.2.4. In Section 4.2.4 we interrogated the known data to provide an estimation of the species identity based on the normalised spatial (Latitude and Longitude), Temporal (Year/Quarter), Abundance (Numbers per km^2) and Length (cm) variables. Here we use a similar approach to estimate the most likely length classes of a species, where count only data are available. The parameters used in the k-NN procedure are again are normalized to reduce any bias in the distance weighting.

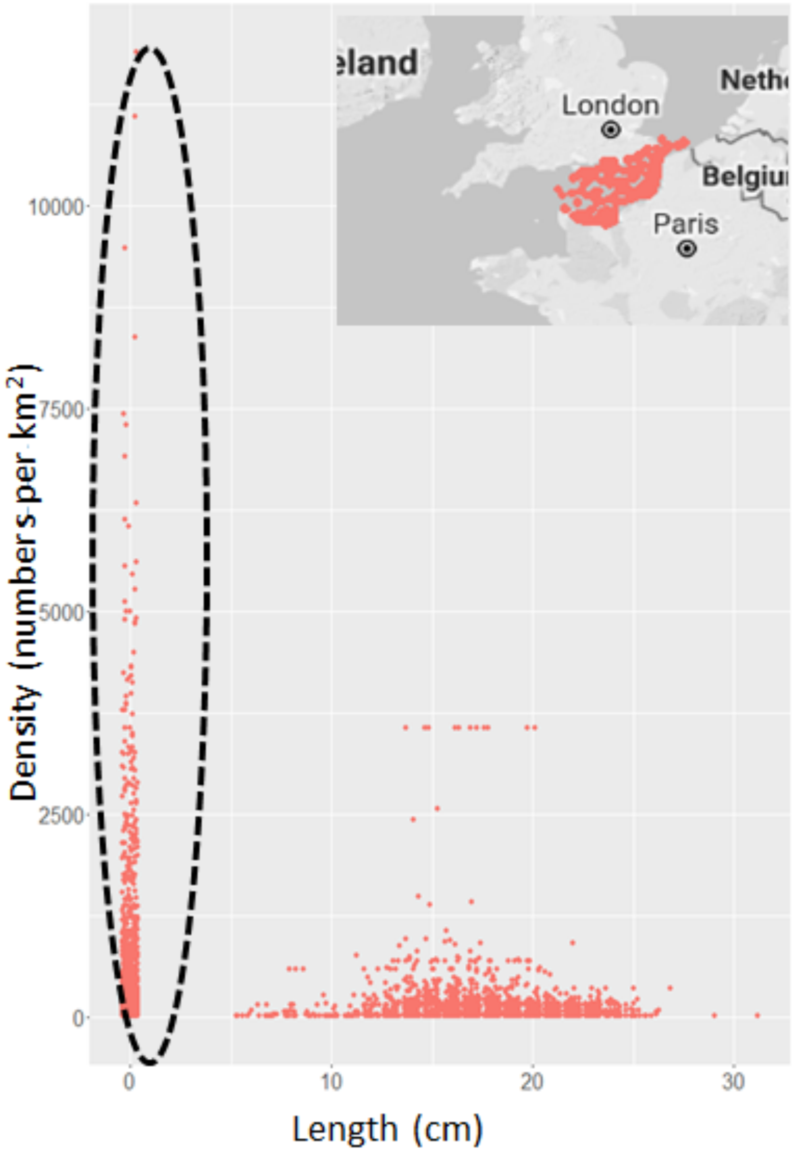

Figure 4.2.5.1: Density at length data for *Callionymus lyra* in the GNSFraOT4 from "BiologicalInfo_GNSFraOT4_FullSMP_Baseline" dataset. The black dashed circle highlights the count only data, where length frequency distributions must be estimated based on surrounding data points within the known data at length which ranges from 5 cm to 32 cm. the map in the top right hand corner provides a spatial reference for the samples.

In Section 4.2.4, we treated each unknown record as one species at length and assigned it to the most likely species at that length. In this case length is unknown, so here we must assign each unknown length of a given species to an estimated length. Using the normalised spatial (Latitude and Longitude), Temporal (Year), Abundance (Numbers per km^2) and Length (cm) variables for known species, the unknown sample is expanded based on the count of fish, e.g. if five fish were counted the k-NN is run five times, searching in different directions through the data. This non-parametric classification method uses a 'majority vote' of a number, k, of neighbours of known classification to estimate the classification of an ‘item’ where this is not known, and where each neighbour’s vote is weighted according to distance (d); each neighbour receiving a weight of 1/d. The parameters used for the nearest neighbours comparison for assigning length frequency distribution are abundance (Numbers per km^2), distance between sample locations (Latitude and Longitude), and time period between sampling events (in quarter years). Because it searches in different directions on each iteration it is really effective at estimating count data. Figure 4.2.5.2 shows the estimated length frequency distribution for the count data within the black circle in Figure 4.x. As previously mentioned the k-NN is a majority rules classifier, this is reflected in the results shown below, in that the “extreme” ranges shown in the recorded data’s length are not present in the estimated data below.

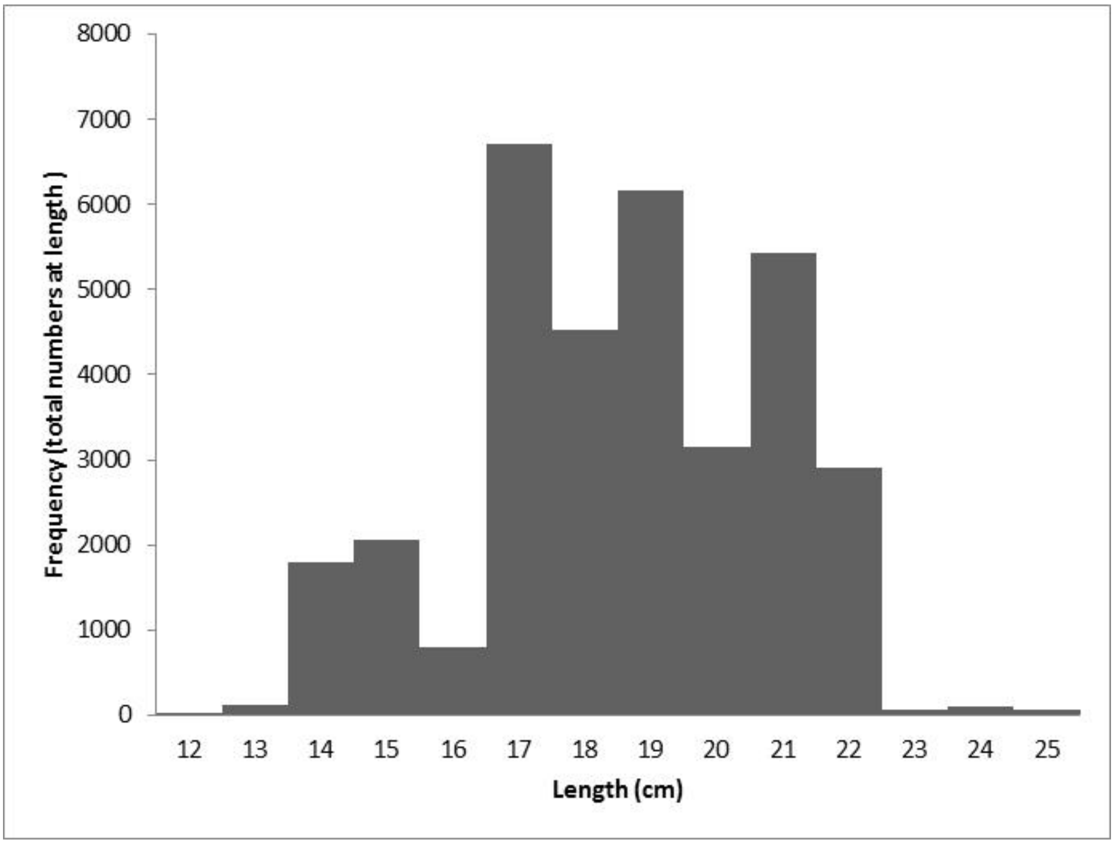

Figure 4.2.5.2: Estimated Density at length data for unknown length classes of *Callionymus lyra* in the GNSFraOT4 using the k-NN classification algorithm.

The k-NN procedure was validated using weight data where this was available. The assigned length frequency distribution was used to calculate an estimated catch weight using the “a” and “b” length weight relationship parameters. For example in GNSFraOT4 haul number 58 in 1988, there was a count of 196 *Callionymus lyra* which had a catch weight of 6400 g. The k-NN assigned these fish within a length range of 14-20 cm based on the nearest neighbour information. The estimated catch weight of the assigned length frequency distribution was 6256 g. This is remarkably close (2.25% difference) given the uncertainty surrounding the "a" and "b" length weight relationship parameters. Moriarty (2017c) provides the R script required to implement the k-NN procedure.

5. Data Product Structure

The groundfish survey monitoring and assessment data product consists of two primary data tables for each survey derived using the data stored on the ICES DATRAS data portal, or from national data bases: a sampling information data table and a biological information data table. The sampling information for all surveys will be combined into a single file but because of their size, the biological information files will be kept separate, a file for each survey. Here the structure of these files is decribed and the content of each file in the date set explained.

5.1. Sampling Information

Field		Unit	Description
HaulID	A27		Unique haul identifier (SurveyAcronym/Ship/Year/HaulNo)[1] (*H*)
Survey-Acronym	A13		Unique survey identifier (SubregionCountryGearTypeQuarter: e.g. GNSNedBT3)
Ship	A4		Unique vessel identifier (e.g. SCO3: *Scotia* III)
GearType	A4		Unique gear type code (BT = Beam Trawl, OT = Otter Trawl)
Gear	A6		Unique gear code (e.g. GOV = Grande Oerverture Verticale)
YearShot	S		Year that gear was shot[2]
MonthShot	S		Month that gear was shot[2]
DayShot	S		Day that gear was shot[2]
TimeShot	S	GMT	Time that gear was shot (in format HHMM)[3]
HaulDur(min)	S	min	Duration of fishing operation[4]
ShootLat(decdeg)	N	Deg.	Latitude in decimal degrees of the haul shoot position[5]
ShootLong(decdeg)	N	Deg.	Longitude in decimal degrees of the haul shoot position[5]
ICESStSq	A12		ICES statistical rectangle where gear was shot
SurvStratum	A12		Stratum tag for stratified surveys[6]
Depth(m)	N	m	Depth tag assigned to the haul[7]
Distance(km)	N	km	Tow distance[8] ($d_{H,TOW}$)
WingSpread(m)	N	m	Mean distance between the wings during fishing operation[9,12] ($d_{H,WING}$)
DoorSpread(m)	N	m	Mean distance between the doors during fishing operation[10,13] ($d_{H,DOOR}$)
NetOpen(m)	N	m	Mean head-line height above seabed during fishing operation[11,14] ($d_{H,HEIGHT}$)
WingSwptArea(sqkm)	N	km^2	Area of seabed swept by the net[15] ($A_{H,WING} = d_{H,TOW} \times d_{H,WING}$)
WingSwptVol_CorF	N		Multiplier ($1 / d_{H,HEIGHT}$): converts to 'density by wing-swept volume'[16]
DoorSwptArea_CorF	N		Multiplier ($d_{H,WING} / d_{H,DOOR}$): converts to 'density by door-swept area'[17]
DoorSwptVol_CorF	N		Multiplier ($d_{H,WING} / (d_{H,DOOR} \times d_{H,HEIGHT})$): converts to 'density by door-swept volume'[18]

5.1.1. Notes for Sampling Information

1. This is a unique tag assigned to each haul. Using the survey acronym avoids conflict where the same haul number is used by more than one survey participant. Using ‘Ship’ avoids conflict where more than one vessel used in the survey by the same country. ‘Haul No’ is the same haul number used in the original national data set so hauls can still be related to original data.
2. All date components kept separate so that queries can be run on any individual component.
3. Time of day in GMT that gear was shot (format HHMM).
4. Time of hauling can be established by adding haul duration to time (“HourShot” & “MinShot”) of shooting.
5. This is the latitudinal and longitudinal position in decimal degrees (e.g. 56.4333°N -01.7895°W) where the haul was shot. Ideally a mid-trawl position would be given, but haul positions were frequently missing. Only the shoot position was supplied for all hauls, although in some instances, this is an arbitrary position as it coincides with the central point of the nominal ICES statistical rectangle.
6. This will be the same as the ICES statistical rectangle (identical to “ICESStSq”) where ICES statistical rectangles constitute the survey strata (e.g. the North Sea IBTS).
7. Each haul will have a depth assignation. In most cases this is real data, either an average depth during the fishing operation, or a depth at the shoot position. But where depth data were absent in the original data, this will have been estimated. See Section 4.1.2 for further details.
8. This is the distance along the seabed that the trawl was towed. The values in this field will have been derived through several different procedures. See Section 4.1.6 for further details.
9. This is the mean distance between the wings of the net while the gear was towed between the shoot and haul positions. The values in this field will have been derived through several different procedures. See Section 4.1.7.1 for further details.
10. This is the mean distance between the trawl doors while the gear was towed between the shoot and haul positions. The values in this field will have been derived through several different procedures. See Section 4.1.7.2 for further details.
11. This is the mean height of the net headline above the seabed while the gear was towed between the shoot and haul positions. The values in this field will

have been derived through several different procedures. See Section 4.1.7.3 for further details.

12. For a beam trawl survey, the value in this field will be the width of the beam trawl.
13. For a beam trawl survey, this field is not strictly applicable. The value in this field will again be the width of the beam trawl, and so identical to the value in the “WingSpread(m)” field.
14. For a beam trawl survey, the value in this field will be the height of the beam trawl.
15. The ‘standard’ density values provided in the Biological Information are based on the area of seabed swept by the net, as this is deemed most appropriate for the majority of species sampled (Fraser et al., 2007). If for any reason these standard density data are considered inappropriate, then these ‘standard’ density estimates can be adjusted by multiplying them by an appropriate correction factor. Likely correction factors required are given in next three fields.
16. For pelagic fish species, or even perhaps some bentho-pelagic species, densities based on the volume of water filtered by the net could be deemed to be more appropriate for some indicators. Multiplying the ‘standard’ density estimates in the Biological Information database by this correction factor will provide the required adjustment.
17. For the majority of demersal fish species, the area swept by the net is the appropriate swept area to use to estimate density. Only for haddock and whiting is there evidence of substantial herding by the trawl doors, such that wing swept densities infer an apparent catchability in the trawl of >1. Density estimates for species deemed likely to be herded by the trawl doors could be considered more appropriate; if so then multiplying the ‘standard’ density estimates in the Biological Information database by this correction factor will provide the required adjustment.
18. Pelagic species might also be considered likely to be herded by the trawls doors, and as stated above, volume-filtered density estimates could be deemed more appropriate. Where both considerations are deemed pertinent, multiplying the ‘standard’ density estimates in the Biological Information database by this correction factor will provide the required adjustment.

5.2. Biological Information

There are four Biological Information data products, ‘BaseLine’ and ‘KNN’. In ‘Baseline’ the k-NN procedure has not been applied, so densities-at-length of species complexes (e.g. genus, family or order taxonomic resolution level identifications codes) have not been resolved to the complexes' constituent species, densities of a species where length data are not provided have not been resolved to their constituent length categories, and destinies of species complexes have not been resolved to their constituent species and length categories. In 'KNN' the k-NN procedure has been applied to address these three types of problem. Consequently the 'KNN' data product will have more records that the 'Baseline' data product and some fields are not relevant to the 'Baseline' data product. The 'KNN' data product will have the following structure.

The two types of product are provided for what we define as the "full standard monitoring programme", which excludes samples collected using non-standard gears (for the survey in question), and samples that are of extreme duration (<13min or >66min), but which includes all hauls meeting these criteria, including samples collected in ICES statistical rectangles that were only infrequently sampled in the survey in question's time series. The two products are also provided for what we have termed the "standard monitoring area covered by the full standard monitoring programme". These are subsets, i.e. BaseLine and k-NN, of the two "full standard monitoring programme" products and only include samples collected from ICES statistical rectangles that meet criteria to be included as part of the "standard survey area".

Field	Unit	Description
HaulID		Unique haul identifier (SurveyAcronym/Ship/Year/HaulNo)[1] (H)
SpeciesSciName		Unique species name for each species sampled across the NE Atlantic[2] (S)
FishLength(cm)	cm	Integer numbers indicating fish length to the 'cm below'[3] (L)
IndivFishWght(g)	g	Estimated weight of individual fish of specified species and length[4] ($W_{S,L}$)
Number		Total number of fish of specified species and length in the catch[5] ($N_{S,L,H}$)
DensAbund(N_sqkm)	km^{-2}	Abundance density estimate[6,8] ($D_{nos,S,L,H} = N_{S,L,H} / A_{H,WING}$)
DensBiom(kg_Sqkm)	kg km^{-2}	Biomass density estimate[7,8] ($D_{biom,S,L,H} = (N_{S,L,H} \times W_{S,L}) / A_{H,WING}$)

5.2.1. Notes for Biological Information

1. This is a unique tag assigned to each haul. This field is identical to the field with the same name in the Sampling Information data table. This is the relational field linking these two tables.
2. Species names are the accepted scientific name as defined in the World Register of Marine Species (WoRMS). This is a relational field linking this table to the Species Information and Species-at-Length Information tables.

3. All lengths in the data base are “to the cm below”: all fish of 11.0 to 11.9 cm, therefore, assigned a length of 11 cm. Effectively, therefore, this is an integer field. This is a relational field linking this table to the Species-at-Length Information table.
4. This is the mean weight of an individual fish of specified species and length derived from a weight at length relationship of the form $W_{S,L} = \alpha_S L^{\beta_S}$. The two species-specific parameters, α_S and β_S, are provided in the supporting ancillary Species Information table and actual mean individual weights for each 1 cm length class of each species ($W_{S,L}$) are given in the supporting ancillary Species-at-Length Information table. Since all recorded lengths are to “the cm below”, the individual mean weights for each length class of each species are calculated for the half-centimetre; e.g. specified weight for a fish of recorded length 11 cm is the weight calculated for a fish of 11.5 cm from the weight at length relationship, this being the probable mean length of all fish between 11.0 and 11.9 cm.
5. This is the number of fish of specified species and length obtained in the trawl sample. This either and actual count or an estimate derived from the raising of a known sub-sample.
6. This is the local point abundance density estimate, the number of fish of species (S) and length (L) per square kilometre estimated at the spatial location of trawl sample (H). This is obtained by dividing the species total catch number at length ($N_{S,L,H}$) by the area swept by the net ($A_{H,WING}$).
7. This is the local point biomass density estimate, the biomass of fish of species (S) and length (L) per square kilometre estimated at the spatial location of trawl sample (H). This is obtained by dividing the species total catch weight at length ($N_{S,L,H}$ x $W_{S,L,H}$) by the area swept by the net ($A_{H,WING}$).
8. As detailed above, if other density estimates are required (e.g. density as number/biomass per cubic metre of water filtered by the net, density as number/biomass per square metre of seabed swept by the gear, density as number/biomass per cubic metre of water filtered by the gear), then these density estimates need to be multiplied by one of the three correction factors given in the Sampling Information table for the haul in question.

The ‘BaseLine’ product will not include the fields IndivFishWght(g) and DensBiom(kg_Sqkm), and the field SpeciesSciName will simply be called SciName. The two fields are excluded because with uncertain species identities it would not be possible to consistently include data for the field IndivFishWght(g), and in addition with uncertainty regarding length category, estimation of appropriate reliable values for the field DensBiom(kg_Sqkm) would also not always be possible. The ‘BaseLine’ data product was included because of feedback from data providers and potential data users, who stated that they would prefer having access the “real” dat, rather than rely on estimated values to fill in where information was missing.

6. Acknowledgements

We could not have undertaken this project without the huge help and support of the numerous data providers who submit groundfish survey data to the ICES DATRAS data portal. We are particularly indebted to Finlay Burns (Marine Scotland Science, Scotland), Gary Burt and Jim Ellis (CEFAS, England), Mathieu Lundy (Agri-Food and Biosciences Institute, Northern Ireland), David Stokes (Marine Institute, Ireland), Barbara Bland (Swedish University of Agricultural Sciences), Matthias Kloppmann and Anne Sell (Thünen Institute of Sea Fisheries, Germany), Jenifer Devine and Trine Haugen (Institute of Marine Research, Norway), Yves Vérin, Michele Salaun, Franck Coppin and Morgane Travers (Ifremer, France), Kai Ulrich Wieland (DTU Aqua, Denmark), Ingeborg de Boois and Ralf van Hal (Wageningen Marine Research, The Netherlands), Francisco Velasco (Instituto Español de Oceanografía, Spain), Corina Chaves (Instituto Portugues do Mar e da Atmosfera, Portugal) for their unlimited patience and unswerving support and assistance with all out numerous queries. We would also like to thank members of the ICES working groups WGIBTS, WGBEAM, and WGMSFDemo for their feedback and other contibutions to this project. We are also grateful to members of the ICES Secretariate, particularly Mark Dickey-Collas, Neil Holdsworth, Vaishav Soni, for their willingness to acknowledge the need for this work and their assistance with seeing it through. We thank Rob Fryer for all his help and statistical advice, and we are also very grateful to colleagues at Marine Scotland Science, particularly Bill Turrell, Matt Gubbins and Colin Moffatt, for the support provided when the going got tough! Finally, we are grateful to all our colleagues involved in the OSPAR IA2017 process for their patience in waiting for the groundfish survey monitoring and assessment data products to be delivered.

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