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Interim Report of the Working Group on Spatial Fisheries Data (WGSFD)

17–20 May 2016

Brest, France

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Executive summary

The Working Group on Spatial Fisheries Data (WGSFD) met in Ifremer, Brest, France, 17–20 May 2016. ICES had issued a data call for aggregated VMS and logbook data for the years 2009–2015, and all participants signed the ICES Conditions for VMS data use. This year an R-script and a guidelines document had been developed to standardize the national data processing, and the data quality checks show that the quality of the submitted data had improved.

The ICES datacentre worked on the data processing, adopting the method to calculate fishing intensity (swept area ratios) developed in WGSFD 2015. This meant that this year WGSFD could focus on outputs requested by OSPAR, ICES WKFBI, ICES WKSand and ICES WGDEC. The methodology and code was reviewed by members in the group that was not involved in the data processing. A list of caveats related to the data outputs was produced.

Outputs for DCF indicators 5, 6 and 7 were created. The group was informed about an inshore VMS programme (iVMS) in Ireland, a VMS management system developed using R, Shiny and PostGIS and updated on the work on the OSPAR BH-3 indicator.

Ideas for improving analysis on spatial fisheries data were discussed, and it was agreed that a subgroup will intersessionally look more into methods for quantifying fishing effort for passive gears and small-scale fishery.

Like previous years, WGSFD produced outputs for an advisory request for from OSPAR to ICES. The proportions of total fisheries represented by the VMS data was assessed using information from logbook data and an output from WGCATCH 2015 based on questionnaires. The proportion of VMS coverage was mapped based on the logbook data, and the fishing intensity (surface and subsurface swept ratios) was plotted for the OSPAR region by year and gear group, as well as maps describing the significant trends in fishing intensity during the period 2012–2015.

As part of the request from OSPAR, WGSFD was also asked to provide advice on the development of alternative smaller grids than the 0.05 degrees that is currently used for exchange of the VMS data. Potential data and methodological improvements including pros and cons were listed. The VMS data was compared with AIS data collected by JRC. Although there were some differences due to different methodologies used to obtain the gear used, the two data sources showed similar patterns.

For the ICES sandeel benchmark (WKSand), WGSFD was requested to provide maps and data for the sandeel fishery in the North Sea.

WGSFD was also asked to provide input for an ICES workshop on Fisheries Benthic Impact (WKFBI). In collaboration with the ICES BEWG, WGDEC and WGMHM groups the fishing pressure data was combined with habitat sensitivity data. For the WKFBI report, WGSFD produced two chapters on “Fishing pressure – methods and results” and “Impact assessment – methods and results”.

As input for the ICES advice on VME’s, WGSFD was requested to analyse VMS data provided to ICES for the NEAFC Convention Area. Fisheries in and in the vicinity of

VME habitats were mapped and described looking at 2004–2014 and at 2015 data separately.

WGSFD 2016 elected Niels Hintzen (the Netherlands) and Christian von Dorrien (Germany) as co-chairs for the term 2017/2018.

1 Administrative details

Working Group name

Working Group on Spatial Fisheries Data (WGSFD)

Year of Appointment

2016

Reporting year within current cycle (1, 2 or 3)

1

Chair(s)

Josefine Egekvist, Denmark

Meeting venue

Ifremer, Brest, France

Meeting dates

17–20 May 2016

2 Terms of Reference a) – z)

a) Develop robust methods to calculate DCF environmental indicators 5, 6 and 7.
b) Work on standardized methods to produce spatial fishery distribution products.
c) Review ongoing work for analyzing spatial fisheries data.
d) Initiate innovative methods to analyze spatial fisheries data.
e) 2016/1: Further development of fishing intensity/ pressure mapping. Following on from the format of the previous OSPAR requests; OSPAR requests ICES, using the latest versions of the indicator description/summaries of the 'Extent of Physical damage indicator' (BH3), to:
   i. Collect relevant national VMS and logbook data for 2014. The data request should follow same format as last's year and include any amendments following the WG SFD meeting in June 2015;
   ii. Estimate the proportions of total fisheries represented by the data;
   iii. Using methods developed in previous advice, where possible, collect other non-VMS data for 2014 to cover other types of fisheries (e.g. fishing boats < 12 m length)
   iv. Prepare maps for the OSPAR maritime area (including ABNJ) on the spatial and temporal intensity of fishing using mobile bottom contacting gears;
   v. Provide advice on the development and application of alternative smaller grids (smaller resolution than 0.05°) to improve the analysis of fishing abrasion data:

- What data and methods can be used for regional assessments, including pros and cons on data accessibility, and costings, if possible;
- Explore any alternative approaches such as the "Nested grid approach", to ascertain if it can be used to provide supporting data to refine and calibrate the abrasion fishing layers. This can be done using a case study or pilot area.

vi. Provide advice on the applicability and use of AIS data, in particular to:

- Ascertain if it can be used as supporting information for the spatial analysis of fisheries data;
- Indicate if it can be used as an alternative source of data to VMS;
- Indicate potential costing for the collation and management of AIS data;
- Advice can be based on a case study or pilot area.

f) Produce spatial fishery distribution product on a specific fishery - (Advisory request). WGSFD will use the sandeel fishery in the North Sea as a case study, analyzing the spatial and temporal fishery distribution (2009–2015) (by month and at a resolution of 0.05x0.05 degrees). The results will be provided to WKSand, the sandeel benchmark that is proposed to meet immediately after WGSFD to evaluate data and work to incorporate these results into the sandeel assessments.

g) Produce impact maps by combining and evaluating benthic information on sensitivity (from WGDEC, BEWG, WGMHM) together with fishing pressure maps (fishing abrasion, weight and value of landed catch), taking into account differences in benthic impact of the various fishing gears /metiers.

ICES has been asked by the EU (DGENV) to provide guidance in the interpretation of fishing pressure maps in relation to impacts on benthic habitats and the related indicators.

- WGDEC and BEWG will provide recommendations for scoring the sensitivity of habitats; these recommendations should preferably be compatible with each other.
- WGMHM will incorporate information on sensitivity of the benthic community of the various seafloor habitats, and will produce habitat sensitivity maps for at least one demonstration area of NW European waters (MSFD region/subregion).
- WGFSD will produce impact maps by combining and evaluating the benthic information on sensitivity and fishing pressure maps (fishing abrasion, weight and value of landed catch), taking into account differences in benthic impact of the various fishing gears / metiers.
- Following this, an ICES Workshop on guidance on how pressure maps of fishing intensity contribute to an assessment of the state of seabed habitats (WKFBI) on 31 May-1 June 2016 will develop indicator principles and good practices for use regionally when assessing the impact of fishing on the seafloor. The workshop outputs will then be used in the ICES advisory process.

h) Using NEAFC VMS and catch data, describe "fisheries activities in and in the vicinity of such (VME) habitats" (areas defined by WGDEC) within the NEAFC Convention Area in

2015. If possible, descriptions should be made of each area near such habitats, and separate each bottom contact gear type (e.g. static or mobile gears).

Provide a technical document that can be used to discuss a revision of the NEAFC VMS agreement with ICES, and ANNEX VII (4) of the NEAFC Scheme of Control and Enforcement (Jan–Jun 2015).

3 Summary of Work plan

In addition to the WGSFD ToRs a, b, c and d, WGSFD had received ToRs to provide input for advice for OSPAR, ICES WKSand for the Sandeel benchmark, input for an ICES WKFBI workshop and provide input for WGDEC on NEAFC VMS data.

ICES had issued a data call for aggregated Logbook and VMS data on 15 January with the deadline of 15 March. An R-script based on VMStools and guidelines had been developed by WGSFD and were provided to standardize the methods used for answering the data call. Data reports and an overview data quality table were produced before the meeting. The group was informed about the ICES policy on Conditions for VMS data use and all participants signed the document. The group was also informed about the reviews of the 2015 report for the OSPAR request and the DCF indicators 5, 6 and 7, and about the resulting ICES Advice.

In 2015 WGSFD processed the VMS data to produce outputs on fishing intensity (swept area ratios), but it was time consuming to do during the meeting. Therefore in 2016 this data processing had been done by the ICES datacentre prior to the meeting. As a result of including average vessel lengths and average kW of the vessels, the method for calculating the fishing intensity could be improved using relationships between vessel lengths/kW and gear widths developed by the EU FP-7 BENTHIS project (Eigaard *et al.* 2015).

Presentations were given on new developments in the area of spatial fisheries data:

- Update on OSPAR BH3 indicator – Extent of physical damage, by Cristina Vina-Herbon
- Inshore VMS programme (iVMS) in Ireland, by Yves Reecht
- VMS management using R, Shiny and PostGIS, by Roi Martinez

The WGSFD participants split into the following subgroups to deal with specific issues associated with answering the ToRs:

- ToR a: DCF indicators
- ToR b: Methods
- ToR e ii: Using logbook data make tables of VMS/non-VMS effort from OSPAR region
- ToR e iii: Maps with VMS/non-VMS effort by ICES rectangle
- ToR e iv: Maps of surface and subsurface abrasion for the OSPAR region
- ToR e v: Advice on smaller resolution data
- ToR e vi: AIS data
- ToR f: Request on sandeel fishery for WKSand

- ToR h: Request from WGDEC
- ToR d: Suggestions for further development
- ToR g: Outputs for the WKFBI workshop

At the meeting there were discussions about which data products that could be made publicly available. Currently it is only possible to publish data as part of ICES advice.

Niels Hintzen (the Netherlands) and Christian von Dorrien (Germany) were elected as co-chairs for the term 2017/2018.

4 List of Outcomes and Achievements of the WG in this delivery period

- R-script and guidelines for answering the ICES data call on Logbook/VMS data;
- Quality reports and summary tables for data submissions;
- Assisting the ICES datacentre in implementing the workflow for calculating fishing abrasion;
- Calculation of DCF indicators 5, 6 and 7;
- Review of the method implemented for calculating fishing abrasion;
- A list of suggestions for project that could bring further development in the subject of spatial fisheries data;
- The proportions of the fisheries represented by the VMS data were listed using logbook data for the OSPAR region, to answer the request from OSPAR;
- The ratio of fishing effort covered by VMS data were mapped for the OSPAR region, to answer the request from OSPAR;
- Maps of fishing intensity by mobile bottom contacting gears were produced for the OSPAR region for the years 2009–2015, by year and gear group;
- Significant trends in the fishing intensity during the period 2012–2015 were mapped;
- Advice on development and application of alternative smaller grids was produced, and pros and cons for different solutions were listed, to answer the request from OSPAR;
- Outputs based on AIS data collected by JRC were compared with the VMS data, to answer the request from OSPAR;
- Maps and outputs describing the sandeel fishery from 2009–2015 were produced for WKSand;
- Input for two chapters for the ICES WKFBI report: "Fishing Pressure – methods and results" and "Impact assessment – methods and results";
- NEAFC VMS data were processed and mapped with the VME's to answer a request from WGDEC.

5 Progress report on ToRs and workplan

The work of WGSFD 2016 is outlined in this section. Please see Annex 2 for a list of abbreviations.

5.1 Data

5.1.1 Data submission

ICES issued a data call for VMS and logbook data 15 January 2016 for fishing activities in the North East Atlantic and Baltic Sea for the years 2009–2015, with a deadline for data submissions by 15 March 2016. An R-script and a document with guidelines were produced by WGSFD and information sent to the National Correspondents. The exchange format of the data call was based on recommendations made by WGSFD in 2015. The data call asked for two datasets:

Annex 1 : Coupled VMS and logbook data providing information on country, year, month, c-square, vessel length category (<12, 12–15, >=15), gear code, DCF metier level 6, average fishing speed, fishing hours, average vessel length, average kW, kW*fishing hours, total weight of the landed species and total value of the landings in euro.

Annex 2: Based solely on logbook data information providing information on: country, year month, ICES statistical rectangle, gear code, DCF metier level 6, vessel length category, VMS enabled (Yes/No), fishing days, kW*fishing days, total weight of the landed species and value of the landings in euro.

Data were submitted by Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Sweden and UK. Faroe Islands submitted logbook data with information on haul positions, but it was not possible to distinguish between demersal and pelagic trawls, and could therefore not be used for the analysis made by WGSFD. Greenland did not submit data. Iceland submitted data, but with the condition that it could only be used for maps for the OSPAR request, not for other purposes and not as a data product, which is a key delivery to the OSPAR request. It was therefore decided that under these conditions, Iceland did not answer the data call, and the data were not used. Russia and Spain did not submit data. In addition VMS data from the NEAFC area were available through the MoU between ICES and NEAFC, and were used to answer ToR h for WGDEC.

The VMS data are considered to be sensitive, and therefore precautions need to be taken when sharing these data. All participants were informed about the ICES policy on Conditions for VMS data use (http://ices.dk/marine-data/Documents/VMS_DataAccess_ICES.pdf) and signed an agreement to adhere to these terms. The data received from the data call is only to be used for the purpose of answering the ToRs and have to be deleted after the work has finished. At the meeting there were some discussions on whether the WGSFD group can decide to publish a data product, but as it is now, data products can only be published in relation to ICES advice.

For the years 2009–2011 VMS was mandatory for fishing vessels larger than 15 m, and during the years 2012/2013 this changed to 12 m. Logbook data were requested to provide information on fishing activity from vessels that are not VMS enabled. Reporting of logbook data is mandatory for vessels larger than 10 m / 8 m in the Baltic Sea. Some member states may have partial logbook coverage of vessels under 10m.

5.1.2 Caveats

In 2015 WGSFD made a list of caveats applying to all VMS maps and indices presented in the report. As the data have changed for 2016, this list is updated below. It is important that they are considered when interpreting the results.

- The outputs can only reflect the data submitted. Spain, Iceland, Greenland, Faroe Islands and Russia did not submit data; therefore the maps are incomplete for any areas where vessels from these countries operate.
- The data for 2012–2015 is not directly comparable to the data of previous years in the data call (2009–2011) due to the gradual increase in VMS-enabled vessels in the 12 to 15 m range. This is likely to be most relevant when examining trends in effort for inshore areas.
- Many countries have substantial fleets of smaller vessels that are not equipped with VMS (< 15 m prior to 2012, < 12 m thereafter); logbook data is at the spatial resolution of ICES rectangles
- The methods for identifying fishing activity from the VMS data varied between countries; therefore there may be some country-specific biases. In one member state for example, vessel landings for an entire 24hr period were attributed to a single ICES rectangle, irrespective of the number of rectangles in which the vessel may have been active over the period. As some countries may have restricted their data submission to only include VMS pings from those rectangles for which there are associated landings values, it is likely that effort and intensity will be underestimated in certain areas. Due to the lack of a standardized audit of pre-submission extraction routines, the extent of this issue was difficult to determine. Additionally, activities other than active towing of gear may have been incorrectly identified as fishing activity. This would have the effect of increasing the apparent fishing intensity around ports and in areas used for passage.
- For calculating fishing intensities, as well as surface and subsurface abrasion, fishing hours, gear widths and fishing speeds are used as input. Where possible, gear widths are an estimate based on BENTHIS project relationships between gear widths and vessel lengths or engine power. Using average vessel length and kW in relationships to estimate gear widths. Estimates of fishing speed were based on average fishing speed values of requested in the exchange format. However, if not available WGSFD used available information on the same or similar gears to fill any gaps.
- Inconsistencies in the gear coding. Examples include dredges coded as HMD (Mechanized Dredges) instead of DRB (Boat Dredges) and OTT (Otter Trawl Twin) coded as OTB (Otter Trawl Bottom).

5.2 ToR a: Develop robust methods to calculate DCF environmental indicators 5, 6 and 7

5.2.1 Request

The Memorandum of Understanding (MoU) between the European Union and ICES requests ICES to "Provide time series for environmental indicators…, as designed in Appendix XIII of the multiannual Community programme related to the DCF to measure the effects of fisheries on the marine ecosystems for each eco-region".

The table below is extracted from Appendix XIII, the 'Definition of environmental indicators to measure the effects of fisheries on the marine ecosystem' (EU, 2008).

Indicator	Definition
5. Distribution of fishing activities	Indicator of the spatial extent of fishing activity. It would be reported in conjunction with the indicator for 'Aggregation of fishing activity'.
6. Aggregation of fishing activities	Indicator of the extent to which fishing activity is aggregated. It would be reported in conjunction with the indicator for 'Distribution of fishing activity'.
7. Areas not impacted by mobile bottom gears.	Indicator of the area of seabed that has not been impacted by mobile bottom fishing gears in the last year. It responds to changes in the distribution of bottom fishing activity resulting from catch controls, effort controls or technical measures (including MPA established in support of conservation legislation) and to the development of any other human activities that displace fishing activity (e.g. wind farms).

5.2.2 Methods

5.2.2.1 Distribution of fishing activities (DCF indicator 5)

In 2013, DCF indicator 5 was understood as the area A_j occupied by n rectangles a_i of size 0.05*0.05 degrees by métier j (DCF métier level 6) for which effort E_j was greater than 0.

$$I_{DCF5,j} = A_j = \sum_n a_{i,j||E_{i,j}>0}$$

The indicator was based on annual values. The indicator was both mapped with binary values (0/1) and calculated as index for each. Computation was performed for some national case study, as there was no VMS data call issued by ICES that year.

In 2014, the definition of DCF indicator 5 remained unchanged. For the first time, the indicator was computed as VMS data were received following an ICES data call. Computation were done by gear groups (bottom trawls, gillnets, longlines, midwater trawls, and all mobile bottom contacting gears), rather than by métiers. Computation was performed for each ICES divisions, and reported according to its belonging to the HELCOM or the OSPAR regions.

In 2015, the definition of the DCF indicator 5 has been modified. To prevent bias introduced for c-squares where swept area was lower than the c-square area, the group agreed to produce a new indicator that consists of summing the areas corresponding to the swept area of a c-square, when the swept area was lower than the c-square area, and to the area of a c-square, when the swept area was greater than the c-square area. The new indicator was reported in absolute and in relative terms, i.e. in proportion to the total area of an ICES ecoregion. The new indicator was computed per years and per ICES ecoregions for all mobile bottom contacting gears only.

In 2016, the definition of the DCF indicator 5 was unchanged. The indicator was computed per years and per ICES ecoregions for all mobile bottom contacting gears and other gear groups as Otter, Beam, Dredge, Seine. However, results from 2015 and 2016 for all mobile bottom contacting gears were not comparable as an error was found and corrected in the estimation of the swept area.

5.2.2.2 Aggregation of fishing activities (DCF indicator 6)

Over the years 2013–2016, two approaches were discussed by the group to best illustrate the aggregation of fishing activity.

The first approach is inspired from the work of Jennings *et al*. (2012). It consisted of reporting the proportion of the impacted area containing the top x% of the fishing intensity of a given mobile bottom contacting gear or a group of those gears. Such index can be conveniently represented on a curve relating the proportion of the fished area to the proportion of the fishing intensity ordered in the decreasing manner (Figure 5.2.2.2.1A). For instance, in 2012, for the Greater North Sea ICES ecoregion, this index can be computed for an arbitrary threshold of fishing intensity for all the mobile bottom contacting gear. One can state that 46% of the fished area contained the top 90% of the fishing intensity. These proportions of the fished area correspond to 230,000 km^2 of the Greater North Sea ICES ecoregion (Figure 5.2.2.2.1B).

The drawback of such an approach is that one must consider many arbitrary thresholds to characterize the aggregation curve shown in figure 5.2.2.2.1A. Hereafter, 3 thresholds (70%, 80% and 90%) were considered and reported for this approach in the result section. For the Greater North Sea example, one can state that 22%, 31% and 46% of the fished area contained the top 70%, 80%, and 90% of the fishing intensity in 2012 for all the mobile bottom contacting gear. These proportions of the swept area correspond respectively to 107,000 km^2, 155,000 km^2 and 230,000 km^2 of the Greater North Sea ICES ecoregion. However considering several thresholds cannot fully characterize the aggregation of any fishing activity. Actually, many different aggregation curves can be drawn knowing only few points (i.e. the 3 chosen threshold points and the 2 known extreme points). Consequently, an alternative approach was considered and reported for representing the DCF indicator 6.

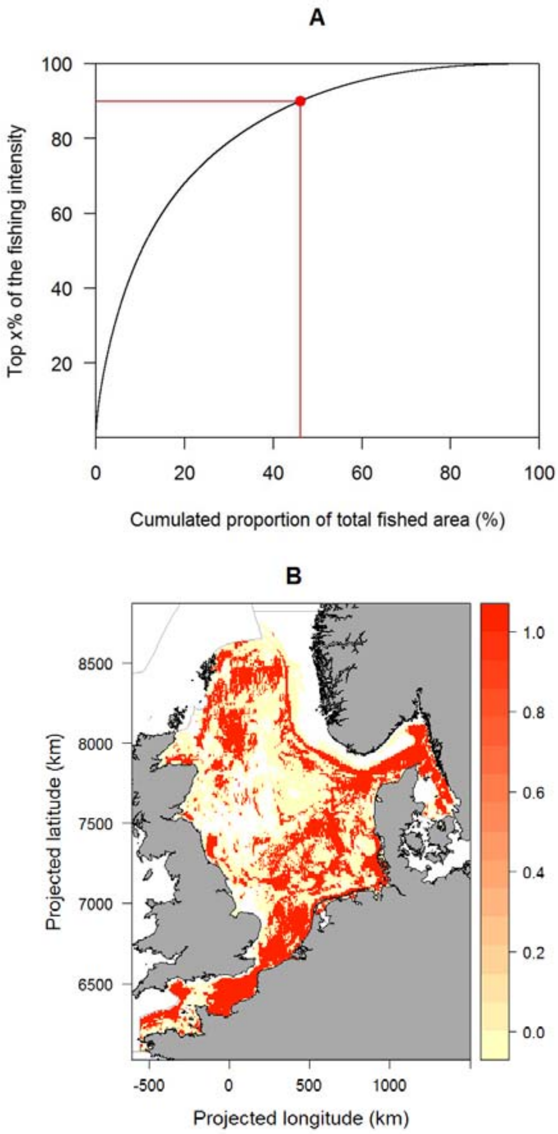


Figure 5.2.2.2.1. A) Aggregation of fishing activity representing the DCF indicator 6 calculated as the top 90% percentile cut-off in cdf histograms of the fishing intensity for all mobile bottom contacting gears in the Greater North Sea ICES ecoregion in 2012. B) The fishing grounds are represented by a core area (here the red area corresponding to the top 90% of the fishing intensity) and a margin (the yellow area corresponding to the remaining 10%). The core area represents 46% of the fished area of the Greater North Sea ICES ecoregion, i.e. 230 000 km^2.

The alternative approach is inspired from the work of Woillez *et al*. (2007). It is a measure of area relative to the overall variation in fishing intensity. It is tightly linked to the aggregation curve previously depicted in Figure 5.2.2.2.1A. Practically, let A be the cumulative area occupied by all fishing intensity values, for instance, still for all the mobile bottom contacting gear in the Greater North Sea ICES ecoregion in 2012, ranked in decreasing order; I(A) is the corresponding cumulative fishing intensity; and I is the overall fishing intensity. The indicator of the second approach, called the spreading area (expressed in squared kilometres), is then simply defined as twice the area below the curve expressing (I–I(A))/I as a function of A (figure 5.2.2.2.2):

$$SA = 2\int \frac{I - I(A)}{I} dA$$

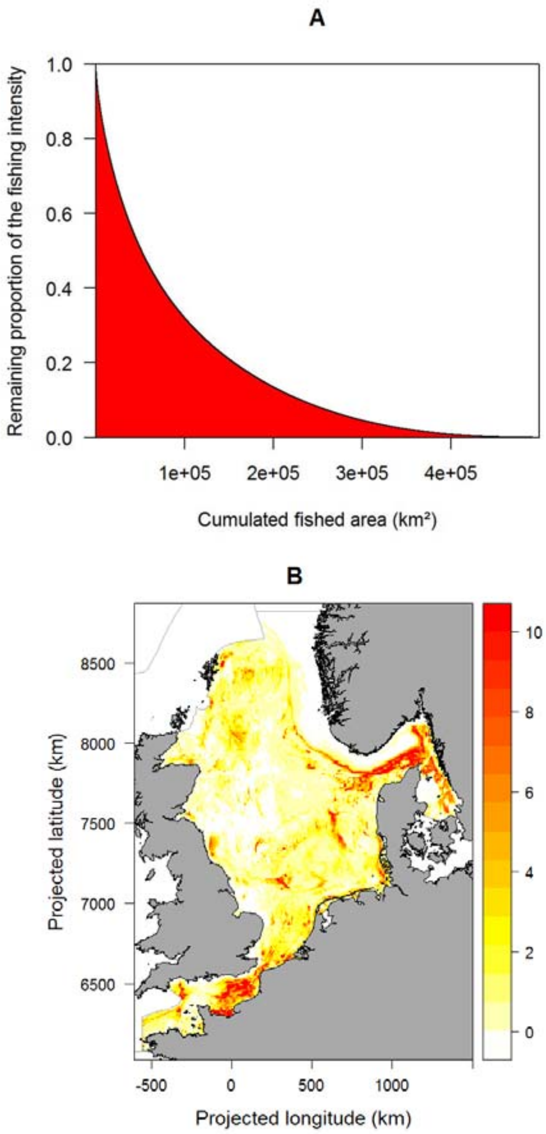


Figure 5.2.2.2.2. A) Aggregation of fishing activity representing the DCF indicator 6 calculated as the spreading area equals twice the red shaded area below the curve relating the remaining top proportion of the fishing intensity and the corresponding cumulated fished area. The spreading area for all the mobile bottom contacting gear is here 171 000 km² representing 25.2% of the Greater North Sea ICES ecoregion. B) The fishing ground are represented continuously according to the fishing intensity. For representation purpose, the color scale has been threshold at a fishing intensity of 10. The maximum fishing intensity value is 84.2.

By contrast with the first approach, the spreading area has the advantage of taking into account the overall variation across the entire distribution of fishing intensity values for a given fishing activity. In addition, zero values make no contribution to the spreading area, contrary to various indices that characterize aggregation (Gini index: Myers and Cadigan, 1995; spatial selectivity index: Petitgas, 1998). As example, the Figure 5.2.2.2.3 illustrates that the Gini index would have different values (i.e. the 2 green area) depending if the zero fishing intensity values are taken into account or not. In addition, as (I–I(A))/I decreases from 1 to 0, and is convex, the SA is less than the positive area (PA), the total area where fishing occurs. It is equal to the PA when the fishing intensity is evenly spread. When normalizing the SA by the PA, we have the simple relation:

$$\frac{SA}{PA} + G_0 = 1,$$

where G_0 is the Gini index computed only from the positive fishing intensity values.

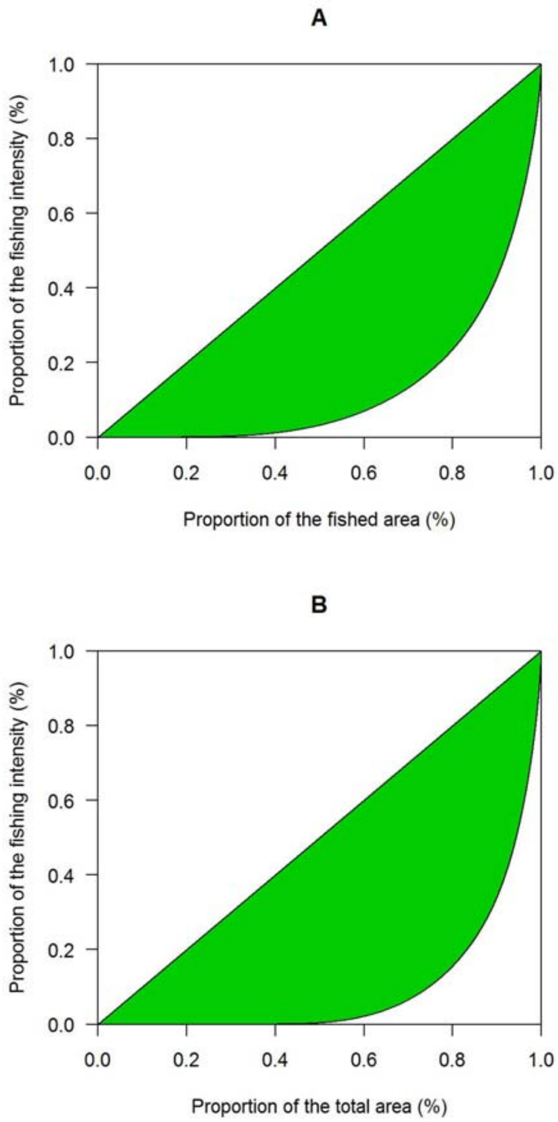


Figure 5.2.2.2.3. A) Aggregation of fishing activity for all the mobile bottom contacting gear in the Greater North Sea in 2012 calculated as the Gini index of the positive fishing intensity values equal twice the green shaded area comprised between the curve relating the proportion of the fishing intensity and the corresponding proportion of the fished area, and the equality line. B) Aggregation of fishing activity for all the mobile bottom contacting gear in the Greater North Sea in 2012 calculated as the Gini index of all values (i.e. with the zero fishing intensity values included) equals twice the green shaded area comprised between the curve relating the proportion of the fishing intensity and the corresponding proportion of the total area, and the equality line.

The group decided to report both indicators, as they were judged to be complementary. The spreading area of fishing intensity was reported in absolute and relative terms, i.e. in proportion of the total area of an ICES ecoregion. Both indicators were computed per year and per ICES ecoregion for mobile bottom contacting gears and other gear groups (Otter, Beam, Dredge, Seine).

5.2.2.3 Areas not impacted by mobile bottom contacting gears (DCF indicator 7)

DCF indicator 7 is closely connected to DCF indicator 5. Consequently it has followed the same methodological improvement over years as DCF indicator 5.

In 2013, all métiers with mobile bottom contacting gears *b* were included in the analysis. Mid-water gears with potential bottom contact were excluded. DCF indicator 7 was both mapped and calculated as index value:

$$I_{DCF7} = A_{SA} - A_b = A_{SA} - \sum_m a_{i,b|E_{i,b}>0},$$

where E_b is the effort by all bottom contacting gears in area unit a_i , m is the number of rectangles where $E_b>0$ and A_{SA} is the space of the respective ICES area.

Instead of relating the figure for DCF indicator 7 to ICES areas it appears more reasonable to relate DCF indicator 7 to habitat areas (Fock *et al*. 2011). This would require habitat maps digitized and resolved to 0.05*0.05° c-squares, which were not available. It is recommendable to prepare such maps for all ICES areas. Habitats smaller than 0.05*0.05° can still be assigned to c-squares and be weighted by a multiplier indicating the portion of c-square inhabited by this habitat type (method applied in Fock *et al*. 2011). This statement was still valid for years 2013-2016.

In 2014, the DCF indicator 7 was computed for the first time, as VMS data were received following an ICES data call. It is the complement to the total area fished for all mobile bottom contacting gears. It is obtained simply by subtracting the fished area of DCF indicator 5 from the total area. WGSFD stated that such an indicator is only relevant when all mobile bottom contacting gears are aggregated together; however, index values of the non-impacted area were also reported when the analysis was run per gear groups. This indicator was reported in absolute and in relative terms, i.e. in proportion of the total area (that of an ICES area).

In 2015, the DCF indicator 7 was now based on the swept area estimates, as the DCF indicator 5. It is the complement to the total area swept by all mobile bottom contacting gears. It is obtained simply by subtracting the total area swept of DCF indicator 5 from the total area for each respective ICES ecoregion for a given year. WGSFD stated that such an indicator is only relevant when all mobile bottom contacting gears are aggregated together. This indicator was reported in absolute and in relative terms, i.e. in proportion of the total area of an ICES ecoregion. DCF indicator 7 was computed per year and per ICES ecoregion.

In 2016, no change was made in the methodology, except an error in the estimation of the swept area that was corrected making results 2015 and 2016 not comparable.

5.2.3 Results

The result below are output tables compiling the various values of the DCF indicators 5, 6 and 7 for the different ICES ecoregions, years and gear groups (mobile bottom contacting gears, Otter, Beam, Dredge and Seine gears).

Maps were also produced for the last year of the time series (2015) to illustrate the DCF indicators 5, 6 and 7. They can be found in the Annex 3.

5.2.3.1 Distribution of fishing activities (DCF indicator 5)

5.2.3.1.1 All mobile bottom contacting gears

Table 5.2.3.1.1.1. Total swept area (km²) for all mobile bottom contacting gears.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	37632	42000	42923	47313	45684	47721	44663
Barents Sea	12041	11938	9151	12240	14148	14031	14948
Bay of Biscay and the Iberian Coast	71439	67268	63962	83558	88786	89892	88688
Celtic Seas	272273	272601	243295	263483	264235	261292	254802
Faroes	5265	5642	238	345	382	1373	2563
Greater North Sea	340468	333410	291194	317809	318433	304995	316865
Greenland Sea	3010	2853	4076	4624	3900	4269	0
Iceland Sea	249	15	41	35	584	933	0
Norwegian Sea	1119	1486	1988	1696	1794	55	4247
Oceanic Northeast Atlantic	1175	2085	1440	945	1069	1224	1199

Table 5.2.3.1.1.2. Percentage of ICES ecoregion area that was swept for all mobile bottom contacting gears

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	8.9	9.9	10.2	11.2	10.8	11.3	10.6
Barents Sea	0.5	0.5	0.4	0.6	0.6	0.6	0.7
Bay of Biscay and the Iberian Coast	9.5	8.9	8.5	11.1	11.8	11.9	11.8
Celtic Seas	29.6	29.6	26.5	28.7	28.7	28.4	27.7
Faroes	2.0	2.1	0.1	0.1	0.1	0.5	1.0
Greater North Sea	50.0	48.9	42.7	46.6	46.7	44.7	46.5
Greenland Sea	0.3	0.3	0.4	0.4	0.4	0.4	0.0
Iceland Sea	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Norwegian Sea	0.1	0.1	0.2	0.1	0.1	0.0	0.4
Oceanic Northeast Atlantic	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5.2.3.1.2 The Otter gear

Table 5.2.3.1.2.1. Total swept area (km²) for the Otter gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	35987	40187	41741	45914	44542	46640	43457
Barents Sea	12041	11938	9151	12240	14148	14031	14948
Bay of Biscay and the Iberian Coast	68772	62951	59324	78535	84576	86610	85445
Celtic Seas	258490	256929	228038	248032	247891	243141	236879
Faroes	5265	5642	238	345	382	1373	2526
Greater North Sea	237953	228064	190365	216440	218150	207588	218575
Greenland Sea	3010	2853	4076	4624	3900	4269	0
Iceland Sea	249	15	41	35	584	933	0
Norwegian Sea	1119	1486	1988	1696	1794	55	4247
Oceanic Northeast Atlantic	1175	2085	1440	945	1069	1224	1195

Table 5.2.3.1.2.2. Percentage of ICES ecoregion area that was swept for the Otter gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	8.5	9.5	9.9	10.9	10.5	11.0	10.3
Barents Sea	0.5	0.5	0.4	0.6	0.6	0.6	0.7
Bay of Biscay and the Iberian Coast	9.1	8.4	7.9	10.4	11.2	11.5	11.3
Celtic Seas	28.1	27.9	24.8	27.0	27.0	26.4	25.8
Faroes	2.0	2.1	0.1	0.1	0.1	0.5	0.9
Greater North Sea	34.9	33.5	27.9	31.8	32.0	30.5	32.1
Greenland Sea	0.3	0.3	0.4	0.4	0.4	0.4	0.0
Iceland Sea	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Norwegian Sea	0.1	0.1	0.2	0.1	0.1	0.0	0.4
Oceanic Northeast Atlantic	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5.2.3.1.3 The Beam gear

Table 5.2.3.1.3.1. Total swept area (km²) for Beam gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Bay of Biscay and the Iberian Coast	3917	3173	2916	2336	2970	3154	2052
Celtic Seas	21202	22034	17741	22529	23033	19551	19893
Greater North Sea	96812	100868	94169	96118	94677	88705	90611

Table 5.2.3.1.3.2. Percentage of ICES ecoregion area that was swept for Beam gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Bay of Biscay and the Iberian Coast	0.5	0.4	0.4	0.3	0.4	0.4	0.3
Celtic Seas	2.3	2.4	1.9	2.4	2.5	2.1	2.2
Greater North Sea	14.2	14.8	13.8	14.1	13.9	13.0	13.3

5.2.3.1.4 The Dredge gear

Table 5.2.3.1.4.1. Total swept area (km²) for Dredge gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	43	51	48	85	99	116	111
Bay of Biscay and the Iberian Coast	0	2	1	3	11	11	15
Celtic Seas	7764	6926	4872	7271	7792	9826	8604
Greater North Sea	9672	10009	8684	12513	12123	14025	12633

Table 5.2.3.1.4.2. Percentage of ICES ecoregion area that was swept for Dredge gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bay of Biscay and the Iberian Coast	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Celtic Seas	0.8	0.8	0.5	0.8	0.8	1.1	0.9
Greater North Sea	1.4	1.5	1.3	1.8	1.8	2.1	1.9

5.2.3.1.5 The Seine gear

Table 5.2.3.1.5.1. Total swept area (km²) for Seine gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	3344	3095	2851	3021	1674	1689	1410
Bay of Biscay and the Iberian Coast	3520	9488	12295	12692	15270	13885	12332
Celtic Seas	17077	20140	23850	20814	23182	24513	23211
Faroes	0	0	0	0	0	0	37
Greater North Sea	76694	71348	64303	66956	68130	66629	69243
Oceanic Northeast Atlantic	0	0	0	0	0	0	9

Table 5.2.3.1.5.2. Percentage of ICES ecoregion area that was swept for Seine gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	0.8	0.7	0.7	0.7	0.4	0.4	0.3
Bay of Biscay and the Iberian Coast	0.5	1.3	1.6	1.7	2.0	1.8	1.6
Celtic Seas	1.9	2.2	2.6	2.3	2.5	2.7	2.5
Faroes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Greater North Sea	11.3	10.5	9.4	9.8	10.0	9.8	10.2
Oceanic Northeast Atlantic	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5.2.3.2 Aggregation of fishing activities (DCF indicator 6)

5.2.3.2.1 All mobile bottom contacting gears

Table 5.2.3.2.1.1. Spreading area of fishing intensity (km^2) for mobile bottom contacting gears.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	23464	25496	26210	25939	25425	26383	24705
Barents Sea	12678	11972	11100	14879	17391	18122	18559
Bay of Biscay and the Iberian Coast	43336	40240	36929	45922	47701	48631	48293
Celtic Seas	158644	156462	139939	147630	151429	145329	143502
Faroes	4507	5684	171	216	221	2025	1273
Greater North Sea	190206	183002	159720	171591	172345	159279	171512
Greenland Sea	1200	1179	1671	2245	1912	2228	0
Iceland Sea	1239	60	149	76	686	797	0
Norwegian Sea	1601	2114	2283	2421	1655	116	3363
Oceanic Northeast Atlantic	1608	2501	1594	995	1124	1850	1054

Table 5.2.3.2.1.2. Spreading area of fishing intensity relative to the ICES ecoregion area for mobile bottom contacting gears (in %).

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	5.6	6.0	6.2	6.1	6.0	6.2	5.8
Barents Sea	0.6	0.5	0.5	0.7	0.8	0.8	0.8
Bay of Biscay and the Iberian Coast	5.8	5.3	4.9	6.1	6.3	6.5	6.4
Celtic Seas	17.3	17.0	15.2	16.1	16.5	15.8	15.6
Faroes	1.7	2.1	0.1	0.1	0.1	0.8	0.5
Greater North Sea	27.9	26.8	23.4	25.2	25.3	23.4	25.2
Greenland Sea	0.1	0.1	0.2	0.2	0.2	0.2	0.0
Iceland Sea	0.1	0.0	0.0	0.0	0.1	0.1	0.0
Norwegian Sea	0.1	0.2	0.2	0.2	0.1	0.0	0.3
Oceanic Northeast Atlantic	0.0	0.1	0.0	0.0	0.0	0.0	0.0

Table 5.2.3.2.1.3. Percentage of the fished area containing the top 70%, 80% and 90% of the fishing intensity for all mobile bottom contacting gears.

ICES ecoregions	2009			2010			2011			2012		
	70%	80%	90%	70%	80%	90%	70%	80%	90%	70%	80%	90%
Baltic Sea	20	27	39	22	30	42	22	29	41	21	29	40
Barents Sea	35	47	63	32	43	58	26	37	54	26	37	54
Bay of Biscay and the Iberian Coast	29	38	52	27	35	48	26	34	46	25	34	47
Celtic Seas	24	32	45	24	32	46	24	32	45	24	33	46
Faroes	16	23	37	18	27	43	20	30	44	25	33	47
Greater North Sea	24	34	48	24	33	47	21	30	45	22	31	46
Greenland Sea	9	13	23	13	19	29	12	17	29	18	26	39
Iceland Sea	57	69	82	57	69	85	54	65	79	36	52	71
Norwegian Sea	39	51	66	37	51	68	35	50	67	32	45	67
Oceanic Northeast Atlantic	23	32	50	20	28	42	26	36	51	21	28	44

ICES ecoregions	2013			2014			2015		
	70%	80%	90%	70%	80%	90%	70%	80%	90%
Baltic Sea	21	28	40	20	27	39	19	27	40
Barents Sea	24	35	52	24	34	50	22	31	47
Bay of Biscay and the Iberian Coast	26	35	49	26	36	50	26	35	49
Celtic Seas	25	34	47	23	32	45	24	32	45
Faroes	29	39	54	16	26	45	5	10	19
Greater North Sea	22	31	46	20	29	44	21	31	46
Greenland Sea	13	20	34	14	23	39	0	0	0
Iceland Sea	25	36	60	27	40	58	0	0	0
Norwegian Sea	25	35	51	15	27	47	21	31	48
Oceanic Northeast Atlantic	26	35	49	35	46	61	17	26	40

5.2.3.2.2 The Otter gear

Table 5.2.3.2.2.1. Spreading area of fishing intensity (km²) for Otter gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	24056	25293	25899	25278	24980	25994	24336
Barents Sea	12678	11972	11100	14879	17391	18122	18559
Bay of Biscay and the Iberian Coast	41750	37790	35445	43454	45799	47675	47732
Celtic Seas	153675	151850	137745	143842	147840	138550	136066
Faroes	4507	5684	171	216	221	2025	1235
Greater North Sea	140545	135320	116005	129926	131409	121492	135183
Greenland Sea	1200	1179	1671	2245	1912	2228	0
Iceland Sea	1239	60	149	76	686	797	0
Norwegian Sea	1601	2114	2283	2421	1655	116	3363
Oceanic Northeast Atlantic	1608	2501	1594	995	1124	1850	1050

Table 5.2.3.2.2.2. Spreading area of fishing intensity relative to the ICES ecoregion area for Otter gear (in %).

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	5.7	6.0	6.1	6.0	5.9	6.2	5.8
Barents Sea	0.6	0.5	0.5	0.7	0.8	0.8	0.8
Bay of Biscay and the Iberian Coast	5.5	5.0	4.7	5.8	6.1	6.3	6.3
Celtic Seas	16.7	16.5	15.0	15.6	16.1	15.1	14.8
Faroes	1.7	2.1	0.1	0.1	0.1	0.8	0.5
Greater North Sea	20.6	19.9	17.0	19.1	19.3	17.8	19.8
Greenland Sea	0.1	0.1	0.2	0.2	0.2	0.2	0.0
Iceland Sea	0.1	0.0	0.0	0.0	0.1	0.1	0.0
Norwegian Sea	0.1	0.2	0.2	0.2	0.1	0.0	0.3
Oceanic Northeast Atlantic	0.0	0.1	0.0	0.0	0.0	0.0	0.0

Table 5.2.3.2.2.3. Percentage of the fished area containing the top 70%, 80% and 90% of the fishing intensity for the Otter gear.

ICES ecoregions	2009			2010			2011			2012		
	70%	80%	90%	70%	80%	90%	70%	80%	90%	70%	80%	90%
Baltic Sea	20	28	40	22	30	42	22	29	41	21	28	40
Barents Sea	35	47	63	32	43	58	26	37	54	26	37	54
Bay of Biscay and the Iberian Coast	28	37	50	25	33	46	25	33	46	24	32	45
Celtic Seas	25	33	46	25	33	47	25	33	46	25	34	48
Faroes	16	23	37	18	27	43	20	30	44	25	33	47
Greater North Sea	21	29	43	21	29	42	18	26	41	20	29	43
Greenland Sea	9	13	23	13	19	29	12	17	29	18	26	39
Iceland Sea	57	69	82	57	69	85	54	65	79	36	52	71
Norwegian Sea	39	51	66	37	51	68	35	50	67	32	45	67
Oceanic Northeast Atlantic	23	32	50	20	28	42	26	36	51	21	28	44

ICES ecoregions	2013			2014			2015		
	70%	80%	90%	70%	80%	90%	70%	80%	90%
Baltic Sea	21	28	40	20	27	39	19	27	40
Barents Sea	24	35	52	24	34	50	22	31	47
Bay of Biscay and the Iberian Coast	25	34	48	26	36	50	26	35	50
Celtic Seas	26	35	49	24	32	46	24	33	46
Faroes	29	39	54	16	26	45	5	10	19
Greater North Sea	20	29	43	19	27	42	20	29	44
Greenland Sea	13	20	34	14	23	39	0	0	0
Iceland Sea	25	36	60	27	40	58	0	0	0
Norwegian Sea	25	35	51	15	27	47	21	31	48
Oceanic Northeast Atlantic	26	35	49	35	46	61	17	26	40

5.2.3.2.3 The Beam gear

Table 5.2.3.2.3.1. Spreading area of fishing intensity (km²) for Beam gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Bay of Biscay and the Iberian Coast	6209	4754	5059	4494	4939	5524	4150
Celtic Seas	32293	32681	27781	27985	30892	30065	29489
Greater North Sea	72318	75570	76288	75252	73522	68705	73111

Table 5.2.3.2.3.2. Spreading area of fishing intensity relative to the ICES ecoregion area for Beam gear (in %).

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Bay of Biscay and the Iberian Coast	0.8	0.6	0.7	0.6	0.7	0.7	0.6
Celtic Seas	3.5	3.6	3.0	3.0	3.4	3.3	3.2
Greater North Sea	10.6	11.1	11.2	11.0	10.8	10.1	10.7

Table 5.2.3.2.3.3. Percentage of the fished area containing the top 70%, 80% and 90% of the fishing intensity for the Beam gear.

ICES ecoregions	2009			2010			2011			2012		
	70%	80%	90%	70%	80%	90%	70%	80%	90%	70%	80%	90%
Bay of Biscay and the Iberian Coast	34	44	57	32	42	55	32	42	57	31	40	55
Celtic Seas	24	33	47	25	34	48	22	31	45	24	32	46
Greater North Sea	24	32	44	25	33	45	26	34	47	25	34	47

ICES ecoregions	2013			2014			2015		
	70%	80%	90%	70%	80%	90%	70%	80%	90%
Bay of Biscay and the Iberian Coast	32	41	54	33	42	56	31	40	55
Celtic Seas	26	34	47	25	34	48	25	34	49
Greater North Sea	25	34	47	23	32	44	25	34	47

5.2.3.2.4 The Dredge gear

Table 5.2.3.2.4.1. Spreading area of fishing intensity (km²) for Dredge gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	102	152	96	306	327	249	245
Bay of Biscay and the Iberian Coast	0	134	235	281	537	136	191
Celtic Seas	14316	12243	9403	12287	15268	16829	14781
Greater North Sea	15164	13012	11295	14402	16629	17747	18302

Table 5.2.3.2.4.2. Spreading area of fishing intensity relative to the ICES ecoregion area for Dredge gear (in %).

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Bay of Biscay and the Iberian Coast	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Celtic Seas	1.6	1.3	1.0	1.3	1.7	1.8	1.6
Greater North Sea	2.2	1.9	1.7	2.1	2.4	2.6	2.7

Table 5.2.3.2.4.3. Percentage of the fished area containing the top 70%, 80% and 90% of the fishing intensity for the Dredge gear.

ICES ecoregions	2009			2010			2011			2012		
	70%	80%	90%	70%	80%	90%	70%	80%	90%	70%	80%	90%
Baltic Sea	24	32	41	23	30	40	21	29	41	20	27	41
Bay of Biscay and the Iberian Coast	0	0	0	27	36	51	42	55	69	30	38	52
Celtic Seas	21	29	43	19	26	39	18	25	38	19	26	39
Greater North Sea	20	27	38	18	25	36	18	24	35	19	26	37

ICES ecoregions	2013			2014			2015		
	70%	80%	90%	70%	80%	90%	70%	80%	90%
Baltic Sea	20	28	38	20	27	41	17	23	32
Bay of Biscay and the Iberian Coast	23	31	45	12	20	31	14	19	35
Celtic Seas	22	30	43	19	27	39	20	27	40
Greater North Sea	20	27	38	20	27	38	20	28	40

5.2.3.2.5 The Seine gear

Table 5.2.3.2.5.1. Spreading area of fishing intensity (km²) for Seine gear.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	1644	1614	1738	1494	798	863	659
Bay of Biscay and the Iberian Coast	3841	6065	6814	6924	8063	7615	6493
Celtic Seas	9515	10762	12431	10452	11639	13855	13294
Faroes	0	0	0	0	0	0	175
Greater North Sea	43657	37980	33485	33877	34707	32166	34329
Oceanic Northeast Atlantic	0	0	0	0	0	0	61

Table 5.2.3.2.5.2. Spreading area of fishing intensity relative to the ICES ecoregion area for Seine gear (in %).

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	0.4	0.4	0.4	0.4	0.2	0.2	0.2
Bay of Biscay and the Iberian Coast	0.5	0.8	0.9	0.9	1.1	1.0	0.9
Celtic Seas	1.0	1.2	1.4	1.1	1.3	1.5	1.4
Faroes	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Greater North Sea	6.4	5.6	4.9	5.0	5.1	4.7	5.0
Oceanic Northeast Atlantic	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.2.3.2.5.3. Percentage of the fished area containing the top 70%, 80% and 90% of the fishing intensity for the Seine gear.

ICES ecoregions	2009			2010			2011			2012		
	70%	80%	90%	70%	80%	90%	70%	80%	90%	70%	80%	90%
Baltic Sea	18	25	38	13	20	34	19	29	48	15	23	38
Bay of Biscay and the Iberian Coast	22	33	49	19	25	36	20	27	38	19	26	37
Celtic Seas	18	27	44	16	24	40	19	27	42	18	26	40
Faroes	0	0	0	0	0	0	0	0	0	0	0	0
Greater North Sea	21	32	50	19	29	47	18	28	45	19	28	45
Oceanic Northeast Atlantic	0	0	0	0	0	0	0	0	0	0	0	0

ICES ecoregions	2013			2014			2015		
	70%	80%	90%	70%	80%	90%	70%	80%	90%
Baltic Sea	21	29	43	21	28	40	19	27	41
Bay of Biscay and the Iberian Coast	16	22	33	17	23	33	19	25	35
Celtic Seas	16	24	39	18	26	42	20	29	46
Faroes	0	0	0	0	0	0	50	66	81
Greater North Sea	18	27	45	16	25	41	17	26	43
Oceanic Northeast Atlantic	0	0	0	0	0	0	61	70	83

5.2.3.3 Areas not impacted by mobile bottom contacting gears (DCF indicator 7)

Table 5.2.3.3.1. Total area (km²) not impacted by mobile bottom contacting gears.

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	384862	380494	379571	375181	376810	374773	377831
Barents Sea	2191342	2191445	2194232	2191143	2189235	2189352	2188435
Bay of Biscay and the Iberian Coast	681765	685936	689242	669646	664418	663312	664516
Celtic Seas	647283	646955	676261	656073	655321	658264	664754
Faroes	261340	260963	266367	266260	266223	265232	264042
Greater North Sea	341119	348177	390393	363778	363154	376592	364722
Greenland Sea	1054808	1054965	1053742	1053194	1053918	1053549	1057818
Iceland Sea	851962	852196	852170	852176	851627	851278	852211
Norwegian Sea	1200132	1199765	1199263	1199555	1199457	1201196	1197004
Oceanic Northeast Atlantic	4795206	4794296	4794941	4795436	4795312	4795157	4795182

Table 5.2.3.3.2. Total area not impacted by mobile bottom contacting gears relative to the ICES ecoregion area (in %).

ICES ecoregions	2009	2010	2011	2012	2013	2014	2015
Baltic Sea	91.1	90.1	89.8	88.8	89.2	88.7	89.4
Barents Sea	99.5	99.5	99.6	99.4	99.4	99.4	99.3
Bay of Biscay and the Iberian Coast	90.5	91.1	91.5	88.9	88.2	88.1	88.2
Celtic Seas	70.4	70.4	73.5	71.3	71.3	71.6	72.3
Faroes	98.0	97.9	99.9	99.9	99.9	99.5	99.0
Greater North Sea	50.0	51.1	57.3	53.4	53.3	55.3	53.5
Greenland Sea	99.7	99.7	99.6	99.6	99.6	99.6	100.0
Iceland Sea	100.0	100.0	100.0	100.0	99.9	99.9	100.0
Norwegian Sea	99.9	99.9	99.8	99.9	99.9	100.0	99.6
Oceanic Northeast Atlantic	100.0	100.0	100.0	100.0	100.0	100.0	100.0

5.3 ToR b: Work on standardized methods to produce spatial fishery distribution products

In section 5.8.1 a thorough description of the workflow and method used to process the data in 2016 is found.

The quality of the work produced by WGSFD is highly dependent on the data provided by the member states. Due to the complexity of the data and the different setups individual countries have for holding and extracting VMS /Logbook data, trying to standardize workflows and/or final products can be a challenging task. To address these issues, WGSFD in 2015 proposed developing a best practices guide and workflows in R to help states stream line data extraction, cleaning, aggregating and submission processes. The R-script was sent out to national data-submitters to be used for the combination and aggregation of fisheries data on national levels. Although not all countries used the R-script, the quality of submitted data improved over the last years.

Quality reports for the data submitted by each country were created and returned to the data submitter. In case of serious errors or issues, those where highlighted and a resubmission of data was asked for. However, as the overview about the overall quality of the data shows (tables 5.3.1. and 5.3.2), not all issues could be resolved. In the case of missing data for average vessel speed, this was estimated by calculating the average vessel speed from all available data, separated for each metier (level 4).

Whereas the data call revealed effort data for all métiers, calculations of swept area ratios covered data for mobile bottom contacting gears only, according to the requested advice for the effects of fishing on the sea bottom. Of all records that include mobile contacting gear (according to métier information), more than 99.8% were included in further analysis. There are only a few métiers (level 4), for example sum wing or electric 'pulse' trawls, that were not included in the analyses.

The method developed by WGSFD in 2015, including a workflow and an R-script, to calculate fishing intensity from the data available through the data call was implemented by the ICES data centre in advance of the 2016 meeting. In estimating intensity, values of both gear width and the proportion of the gear that contacts with the sea floor (surface and sub-surface) are required. As this information is not readily available from the logbook, values were derived from the EU funded BENTHIS project. Thus, as an initial step in estimating fishing intensity, some preliminary work was required to assign DCF level 6 métiers to the BENTHIS metiers. Measures of both the average vessel power (kW) and average vessel length (m) for each métier per c-square were included in submitted data, to estimate bottom contact values for individual gears based on the relationship between gear size and vessel power/length as published by Eigaard *et al.* (2015).

The code to aggregate the data submitted, allocate them to Benthis metiers, and calculate gear width and swept areas was checked by members of WGSFD not involved in the data analysis. No inconsistencies or logical errors were found.

Table 5.3.1. Quality of VMS data submitted, by category with reported data.

	Years	Vessel length categories	No of gear codes	No of DCF metiers	Average fishing speed	Average vessel length	Average kW	Comment
Belgium	2009-2015	>15 12-15	8	20	Yes	Yes	Yes	
Denmark	2009-2015	>=15 12-15 <12	24	97	Yes	Yes	Yes	
Estonia	2009-2015	?15 10-15 12-15 15<	4	NULL	Yes	NA	Yes	
Faroe Islands								Logbook data with haul positions sent, but not possible to distinguish between demersal and pelagic
Finland	2009-2015	>15 12-15	5	11	Yes	Yes	Yes	
France	2009-2015	<12 12-15 >=15	21	288	NA	Yes	Yes	
Germany	2009-2015	>15 12-15	19	80	Yes	Yes	Yes	
Greenland								No data submitted
Iceland								Data submitted, but only to be used for maps for OSPAR request, not as a data product
Ireland	2009-2015	>=15 12-15	14	119	Yes	Yes	Yes	
Latvia	2009-2015	>=15	3	5	Yes	Yes	Yes	
Lithuania	2009-2015	>=15 >15	7	20	Yes	Yes	Yes	
Netherlands	2009-2015	<12 12-15 >15	26	100	Yes	Yes	Yes	
Norway	2011-2015	[11 - 14, (12 - 14, [15 - 20, [21 - 27, [28 +]	32	89	Yes	Yes	Yes	Data for 2009-2010 are missing. Overlapping vessel length categories No information on total value of landings
Poland	2009-2015	<12 12-15 >=15	10	32	Yes	Yes	Yes	

Portugal	2009- 2015	<12 12-15 >=15	5	17	Yes	Yes	Yes	
Russia								No data submitted
Spain								No data submitted
Sweden	2009- 2015	>=15 12-15	15	98	Yes	Yes	Yes	
UK	2009- 2015	>=15	21	137	Yes			

Table 5.3.2. Quality of logbook data submitted, by category with reported data.

	Years	Vessel length categories	No of gear codes	No of DCF metiers	VMS enabled	Fishing days	kW*fishing days	Tot weight	Tot value	Comment
Belgium	2009-2015	<12 12-15 >15	10	23	Yes/No	Yes	Yes	Yes	Yes	
Denmark	2009-2015	<12 12-15 >=15	29	114	Yes/No	Yes	Yes	Yes	Yes	
Estonia	1899,1933, 2009-2015	?15 >10 10-15 12-15 15<	7	16	Yes/No	Yes	Yes	Yes	NA	
Faroe Islands										Logbook data with haul positions sent, but not possible to distinguish between demersal and pelagic
Finland	2009-2016	<12 12-15 >15	11	21	Yes/No	Yes	Yes	Yes	Yes	
France	2009-2015	<12 12-15 >=15	28	416	Yes/No	Yes	Yes	Yes	Yes	
Germany	2009-2015	<12 12-15 >15	26	110	Yes/No	Yes	Yes	Yes	Yes	
Greenland										No data submitted
Iceland										Data submitted, but only to be used for maps for OSPAR request, not as a data product

Ireland	2009-2015	<10 10-12 12-15 >=15	18	168	1/0	NA	Yes	Yes	Yes	
Latvia	2009-2015	<12 >15	14	19	Yes/No	Yes	Yes	Yes	NA	
Lithuania	2009-2015	<12 12-15 >15	7	24	Y/N	Yes	Yes	Yes	Yes	
Netherlands	2009-2015	<12 12-15 >15	32	136	Yes/No	Yes	Yes	Yes	Yes	
Norway	2011-2015	[11 - 14, (12 - 14, [15 - 20, [21 - 27, [28 +]	45	118	Yes/No	Yes	Yes	Yes	NA	
Poland	2009-2015	<12 12-15 >15	22	54	Yes/No	Yes	Yes	Yes	Yes	
Portugal	2009-2015	<12 12-15 >=15	5	18	S/N	Yes	Yes	Yes	NA	
Russia										No data submitted
Spain										Some correspondence, but not data submitted
Sweden	2009-2015	<12 12-15 >=16	20	157	VMS/noVMS	Yes	Yes	Yes	Yes	
UK	2009-2015	<12 12-15 >=15	47	198	Yes/No	Yes	Yes	Yes	Yes	

Following discussions at the WGSFD meeting it is suggested to change ToR b) to following:

Work on standardized methods to analyse, and produce products that describe, the fishery in space and time	Products on spatial fishery distribution have been requested by OSPAR, HELCOM and by ICES expert groups as input fisheries impact assessments. WGSFD wants to continue to work on standardized methods and data products.	3 years	Method to be implemented by the ICES datacentre Maps and data products to be used by ICES expert groups

5.4 ToR c: Review ongoing work for analyzing spatial fisheries data

5.4.1 Inshore VMS programme (iVMS) in Ireland, by Yves Reecht, Marine Institute, Ireland

A VMS programme for inshore vessels under twelve meters length overall was started in 2014 to improve data provision and enforcement tools for shellfish fisheries in Ireland. The aims of the programme are in relation to: *(i)* enforcement of fishery regulations (e.g. compliance with closed areas to protect sensitive habitats), *(ii)* food safety and traceability (tracking origin regarding classified production areas for bivalve molluscs) and *(iii)* fishing effort monitoring. In its first phase, the system has become mandatory for all vessels fishing razor-clams (*Ensis siliqua* and *Ensis arcuatus*) along the coast of the Republic of Ireland from July 2015.

The VMS device sends information (GPS coordinates, speed, course,…) every 5 minutes when the vessel is in motion and every hour – in order to limit data volume and storage issues – when it has been stopped for more than 30 minutes. The main difference between iVMS devices and standard VMS is the communication mode: in the case of iVMS information is sent through the terrestrial GPRS network (versus satellite transmission for VMS) and has therefore to be stored in an internal memory when the unit is out of range. The data, provided by the contracted companies who are managing and maintaining the pool of devices, are ultimately hosted by the Marine Institute. An interface to the devices allows vessel positions to be viewed in real time and retrospective reports and data downloads generated.

The programme is now in its operational phase with more than 90 vessels equipped. Intended future developments include *(i)* the combination of these high frequency VMS data with catch and landing data from various sources such as sales notes, shellfish gatherer documents (so called consignment data) or data from a Sentinel Vessel Programme (SVP, participating vessels under 12m in length provide logbook-like data and biological and economic data on a voluntary basis) to produce razor-clam abundance indices or absolute abundance (catchability of the fishing gear is very high) at a high spatial resolution, *(ii)* the use of high resolution effort maps together with habitat maps for the purpose of habitat pressure and impact assessment and *(iii)* expansion of the programme to other dredging fleets.

5.4.2 VMS management using R, Shiny and PostGIS, by Roi Martinez, Cefas, UK

A spatial data infrastructure (SDI) distribution in a local computer was used to perform a flexible and high speed VMS analysis. The tool uses Shiny R server as a user interface, using R code in the background. The R code performs some statistical and spatial analysis and sends the queries to PostGIS, converting the SQL query output in an R object (spatial or tabular) to be used in the code.

The PostGIS geo database server allows storage of a large amount of data that can be used for the analysis, e.g. the last ten years VMS points are stored in the relational database, and can be queried by the user. In addition, the UK waters sediment distribution (JNCC sediment map), is stored in a raster format in the database.

The R spatial analysis summarizes the effort derived from VMS point data by area and time as selected by the user, and aggregates the points within a user specified grid. The sediment percentages within the grid cells are extracted using the database spatial functions.

The tool using the SDI allows the user to query and store the analysis outputs and intermediate steps. The intermediate step outputs are used within the next tool analysis stage, although they can be opened in a desktop GIS application like QGIS for visualization or other analysis purposes.

R Customized main functions:

- PostGIS communication functions. Data exchange database – R, solving problem RGDAL has no direct communication with PostGIS databases using "sp" as proxy. Request data from PostGIS with the spatial column in EWKT format;
- Spatial grid creation, aggregation and swept area ratio calculation: Function with three grid formats, rectangular, hexagonal and nested grid cells (Gerritsen *et al.*);
- Calculation of nearest neighbour analyses per cell as indicator of point density and distribution within the cell. (Not implemented yet).

PostGIS Customized main functions:

- VMS data queries to get data in a specific time and spatial extension;
- Spatial transformation of VMS location into points;
- Calculation of sediment raster pixel percentage within each grid cell.

5.5 ToR d: Initiate innovative methods to analyze spatial fisheries data

This ToR was added to the WGSFD list of ToRs as a result of discussions in 2015, to have a stronger focus on science in the working group, so that the group can also make use of the expertise in the WGSFD group to develop methods/analysis on spatial fisheries data of value for the ICES community. This could be a manuscript submitted to a peer-reviewed scientific journal, initiate project ideas or to propose a theme session for the ICES ASC. Because a most of the time at the WGSFD meeting 2016 was spent answering requests for advice, the time spent on this ToR was relatively limited.

Below is a list of ideas for research projects:

- Study the use of AIS data in lieu of VMS data (proponent: Maurizio)
- Analyze VMS data by use of modelling (and a number of covariates) rather than interpolating. Predicting fishing behaviour/effort (proponent: Niels)
- Investigate the influence of the temporal resolution on the estimates of fishing effort (how decreasing polling frequency degrades the estimates of fishing effort, as well as the detection of fishing activity); (proponent: Yves). Some work has already been done. Would be connected with the idea about modelling fishing behaviour. R package VMSbase (Russo *et al.*, 2014) does something related (predicting metier from the geometry of the track), but this has only been tested in the Mediterranean so far.

- Estimate zones of influence of ports (for inshore fisheries). Regionalize the inshore areas using boundaries derived from these zones of influence. Compare with the use of ICES rectangles to report landings. (proponent: Dan)
- Analyze spatial conflicts with others human uses, how new uses (e.g. wind farms, MPAs) will affect the distribution of fishing effort, revenue from fisheries, etc. (proponent: Torsten). A better way of saying the same thing: Analyse the international cumulative loss of fishing grounds in terms of effort and catch according to future spatial activities excluding fishing activities.
- Study the use of catch data (e.g. CPUE) to quantify the spatial/temporal dynamics of species (only possible for those metiers that are very species-specific, e.g. the *Crangon crangon* fishery, sandeel fishery). (Proponent: Torsten).
- For the static gear fisheries: Can we find a model to predict soaking time? (proponent: Dan)
- CPUE data based on VMS could be used by assessment working groups, looking at metiers.

Additionally a need was identified to look into methods for quantifying fishing effort for passive gears and small-scale fishery. This can be done as a focus-point under ToR c, with presentations of work on these issues. A subgroup of WGSFD members (Patrik, Rabea, Mathieu, Christian, Dan, Yves, Niels, Neil and Maurizio) volunteered to have intersessional discussions. Results of discussions and on-going projects will be presented at the WGSFD meeting in 2017. Mathieu Woillez will initiate the discussions.

5.6 ToR e: OSPAR request

As in 2014 and 2015, WGSFD received an additional ToR to answer a request from OSPAR. WGSFD was requested to:

i) Collect relevant national VMS and logbook data for 2014. The data request should follow same format as last’s year and include any amendments following the WG SFD meeting in June 2015;

ii) Estimate the proportions of total fisheries represented by the data;

iii) Using methods developed in previous advice, where possible, collect other non-VMS data for 2014 to cover other types of fisheries (e.g. fishing boats < 12m length);

iv) Prepare maps for the OSPAR maritime area (including ABNJ) on the spatial and temporal intensity of fishing using mobile bottom contacting gears;

v) Provide advice on the development and application of alternative smaller grids (smaller resolution than 0.05°) to improve the analysis of fishing abrasion data:

- What data and methods can be used for regional assessments, including pros and cons on data accessibility, and costings, if possible;
- Explore any alternative approaches such as the “Nested grid approach", to ascertain if it can be used to provide supporting data to refine and calibrate the abrasion fishing layers. This can be done using a case study or pilot area.

vi) Provide advice on the applicability and use of AIS data, in particular to:

- Ascertain if it can be used as supporting information for the spatial analysis of fisheries data;
- Indicate if it can be used as an alternative source of data to VMS;
- Indicate potential costing for the collation and management of AIS data;
- Advice can be based on a case study or pilot area.

Point i. is covered by the data call issued by the ICES secretariat asking for VMS and logbook data for the period 2009–2015. Work on the other points are described in the sections below.

5.6.1 Estimate the proportions of total fisheries represented by the data

This year's data call asked for logbook data for all vessel size categories and fishing activities, and a field was added with information whether the logbook information was represented in the VMS data. The proportion of total fisheries represented by vessels equipped with VMS was estimated using landings weights submitted with the logbook data. The percentage of fishing days and total landings weight for the VMS equipped fleet is derived from logbooks and compared to the total weight derived from logbooks of all vessels operating in the OSPAR region. The proportions of total fisheries represented by VMS data for the OSPAR region are given in the table 5.6.1.1 and figures 5.6.1.1a and 5.6.1.1b below. In general when looking at table 5.6.1.1 it can be seen that the percentage of total weight with VMS is higher than the percentage of fishing days VMS because the larger vessels with VMS tend to have bigger landings.

The figures shows that in the time period 2009–2015 there is a trend of increasing percentages of VMS landings compared to total landings.

During the WGSFD meeting some data issues were identified, of which some could be solved: data not in proper format, data not in correct columns, gear codes are different from metiers (for example: GNS_DEF_110-156_0_0 - OTB), due to national data corrections. Next year before the meeting, data should undergo a strict quality checks for the LE data set. There was problem with the data processing of logbook data from Norway for 2014, which is solved in the tables below. The Wider Atlantic percentages have a high variation but low fishing activity.

Table 5.6.1.1. Fishing days and landed weight represented by the VMS data by gear group and the OSPAR regions for the years 2009 to 2015. Note that for 2009–2011 VMS was mandatory for vessels larger than 15 meters; in 2012–2015 VMS was mandatory for vessels larger than 12 meters. No data were submitted from Spain, Iceland, Greenland, Faroe Islands and Russia.

Year	OSPAR region	Gear group	Fishing days without VMS	Fishing days with VMS	Percentage of fishing days with VMS	Total weight without VMS	Total weight with VMS	Percentage of total weight with VMS
2009	Arctic Waters	Dredge	32		0.0	20,814		0.0
		Midwater	7	305	97.8	1,963,233	75,999,077	97.5
		Otter		1,684	100.0		21,740,130	100.0
		Static	195	148	43.2	10,220	13,793	57.4

		Other/NA	25	1	3.8	3,895	1,050,266	99.6
	Bay of Biscay and Iberian Coast	Beam	75	916	92.5	9,802	536,440	98.2
		Dredge	10,787	21	0.2	5,431,873	38,597	0.7
		Midwater	3,348	6,470	65.9	8,415,027	45,704,563	84.5
		Otter	41,716	42,481	50.5	17,982,840	35,220,256	66.2
		Seine	4	169	97.7	2,057	169,952	98.8
		Static	102,291	26,273	20.4	20,932,920	17,149,149	45.0
		Other/NA	10,091	41	0.4	3,638,507	389,697	9.7
	Celtic Seas	Beam	296	7,740	96.3	33,735	4,650,331	99.3
		Dredge	3,862	8,314	68.3	542,698	3,313,157	85.9
		Midwater	266	2,864	91.5	17,183,579	204,981,213	92.3
		Otter	26,247	65,432	71.4	2,468,505	56,718,772	95.8
		Seine	15	1,061	98.6	2	2,388,040	100.0
		Static	58,257	9,346	13.8	5,643,404	7,520,836	57.1
		Other/NA	3,076	752	19.7	26,074,778	5,121,983	16.4
	Greater North Sea	Beam	10,685	74,476	87.5	3,794,291	74,360,749	95.1
		Dredge	36,372	16,063	30.6	39,949,060	22,568,516	36.1
		Midwater	3,058	6,377	67.6	19,930,740	289,156,894	93.6
		Otter	63,755	104,843	62.2	24,509,193	803,319,446	97.0
		Seine	1,329	8,222	86.1	1,637,569	11,096,897	87.1
		Static	179,928	14,197	7.3	29,362,928	9,843,078	25.1
		Other/NA	4,009	567	12.4	2,962,376	9,176,761	75.6
	Wider Atlantic	Beam		30	100.0		41	100.0
		Dredge	48	2	4.0	39,973	2,958	6.9
		Midwater	19	1,440	98.7	3,222,407	98,984,735	96.8
		Otter	128	4,369	97.2	191,340	5,465,932	96.6
		Seine		2	100.0		13	100.0
		Static	252	3,866	93.9	48,751	4,371,158	98.9
		Other/NA	32	222	87.4	379,865	1,021,924	72.9
2010	Arctic Waters	Beam		1	100.0		235	100.0
		Dredge	19		0.0	20,589		0.0
		Midwater	28	365	93.0	5,922,156	72,532,352	92.5
		Otter		2,578	100.0		28,678,260	100.0
		Seine		7	100.0		166	100.0
		Static	144	524	78.4	26,080	680,407	96.3
		Other/NA	16	108	87.1	500	102,095	99.5
	Bay of Biscay and Iberian Coast	Beam	24	871	97.4	827	643,163	99.9
		Dredge	9,355	6	0.1	5,350,463	5,223	0.1
		Midwater	2,631	6,810	72.1	3,848,043	55,602,761	93.5
		Otter	43,072	39,580	47.9	18,507,292	32,158,503	63.5
		Seine	9	798	98.9	43	1,068,959	100.0
		Static	116,833	27,025	18.8	18,813,573	20,373,757	52.0
		Other/NA	13,742	41	0.3	20,739,556	1,967,170	8.7

	Celtic Seas	Beam	486	7,812	94.1	1,296	5,468,269	100.0
		Dredge	4,152	8,855	68.1	849,660	4,254,294	83.4
		Midwater	258	3,810	93.7	19,844,917	321,973,710	94.2
		Otter	23,518	63,913	73.1	2,887,565	56,751,399	95.2
		Seine	2	1,304	99.8	3	2,888,142	100.0
		Static	61,856	9,515	13.3	7,318,788	8,639,890	54.1
		Other/NA	1,324	1,000	43.0	1,391,216	7,428,424	84.2
	Greater North Sea	Beam	12,782	87,678	87.3	5,806,919	94,400,442	94.2
		Dredge	34,951	17,915	33.9	34,172,344	23,731,377	41.0
		Midwater	2,443	6,690	73.3	14,249,324	340,133,734	96.0
		Otter	63,085	100,657	61.5	29,840,614	812,070,772	96.5
		Seine	1,428	8,257	85.3	2,225,756	14,439,607	86.6
		Static	193,158	13,436	6.5	28,025,360	11,050,925	28.3
		Other/NA	4,495	371	7.6	13,050,423	11,259,688	46.3
	Wider Atlantic	Beam		2	100.0		4,275	100.0
		Dredge	33	1	2.9	20,382	2,025	9.0
		Midwater	9	1,058	99.2	1,885,000	72,917,797	97.5
		Otter	89	4,426	98.0	93,623	4,769,595	98.1
		Seine		1	100.0		477	100.0
		Static	493	3,594	87.9	96,695	4,055,057	97.7
		Other/NA	33	149	81.9	303,426	140,943	31.7
2011	Arctic Waters	Dredge	16		0.0	14,325		0.0
		Midwater	3,682	8,214	69.0	281,590,126	709,420,372	71.6
		Otter	4,687	76,241	94.2	21,709,095	269,910,221	92.6
		Seine	5,968	19,526	76.6	17,820,583	54,340,193	75.3
		Static	8,078	62,583	88.6	16,753,491	119,604,089	87.7
		Other/NA	11	137	92.6	51,621	11,423,305	99.6
	Bay of Biscay and Iberian Coast	Beam	68	703	91.2	41,412	539,593	92.9
		Dredge	8,562	23	0.3	8,980,752	26,690	0.3
		Midwater	2,212	6,481	74.6	2,914,782	49,526,754	94.4
		Otter	43,456	40,380	48.2	19,822,140	35,467,363	64.1
		Seine	15	1,520	99.0	1,317	1,849,225	99.9
		Static	116,227	24,811	17.6	19,299,191	22,798,412	54.2
		Other/NA	21,667	37	0.2	22,645,623	874,568	3.7
	Celtic Seas	Beam	327	8,042	96.1	54,293	6,500,027	99.2
		Dredge	4,587	10,359	69.3	929,875	3,023,211	76.5
		Midwater	376	3,664	90.7	14,780,876	185,526,129	92.6
		Otter	20,780	61,420	74.7	2,876,399	58,739,762	95.3
		Seine	14	1,752	99.2	3,783	4,470,965	99.9
		Static	56,366	9,643	14.6	6,937,119	11,186,622	61.7
		Other/NA	1,292	938	42.1	529,597	8,965,546	94.4
	Greater North Sea	Beam	8,815	72,818	89.2	5,887,714	91,429,461	93.9
		Dredge	31,407	26,078	45.4	39,611,685	44,928,472	53.1

		Midwater	2,646	11,044	80.7	95,588,465	529,948,984	84.7
		Otter	56,520	145,916	72.1	26,247,556	862,550,798	97.0
		Seine	962	8,429	89.8	1,810,108	17,766,975	90.8
		Static	203,310	24,193	10.6	31,448,237	25,901,033	45.2
		Other/NA	5,790	326	5.3	14,153,548	5,040,073	26.3
	Wider Atlantic	Dredge	27	2	6.9	7,162	1,982	21.7
		Midwater	11	1,042	99.0	1,444,099	36,008,535	96.1
		Otter	45	4,190	98.9	57,255	4,153,386	98.6
		Seine	1		0.0	3,690		0.0
		Static	228	4,085	94.7	60,016	5,528,026	98.9
		Other/NA	19	252	93.0	80,429	375,825	82.4
2012	Arctic Waters	Beam		5	100.0		3,737	100.0
		Dredge	1	2	63.6	426	10	2.3
		Midwater	3,212	8,574	72.8	201,288,610	729,378,465	78.4
		Otter	5,131	83,904	94.2	24,700,439	269,698,591	91.6
		Seine	6,319	24,180	79.3	18,823,898	64,014,990	77.3
		Static	8,860	62,002	87.5	18,504,927	122,452,718	86.9
		Other/NA	4	6	63.2	97	711,902	100.0
	Bay of Biscay and Iberian Coast	Beam	15	564	97.4	510	615,576	99.9
		Dredge	10,969	34	0.3	9,569,129	11,101	0.1
		Midwater	1,170	7,726	86.9	2,235,730	56,019,731	96.2
		Otter	44,816	66,373	59.7	17,537,276	39,032,691	69.0
		Seine	9	1,517	99.4	147	2,037,907	100.0
		Static	110,435	22,070	16.7	19,366,706	21,101,312	52.1
		Other/NA	16,623	19	0.1	27,984,056	313,729	1.1
	Celtic Seas	Beam	392	7,397	95.0	124,565	7,236,354	98.3
		Dredge	4,608	11,267	71.0	1,022,782	1,702,461	62.5
		Midwater	677	2,951	81.3	16,836,834	227,541,260	93.1
		Otter	22,272	58,975	72.6	3,567,599	66,269,263	94.9
		Seine	72	1,445	95.3	9,555	4,664,553	99.8
		Static	55,656	9,430	14.5	6,675,723	9,569,295	58.9
		Other/NA	1,899	740	28.0	579,440	4,439,829	88.5
	Greater North Sea	Beam	8,670	85,582	90.8	4,528,512	93,425,349	95.4
		Dredge	23,748	29,536	55.4	25,776,696	49,134,347	65.6
		Midwater	2,093	10,785	83.8	63,449,388	564,016,464	89.9
		Otter	45,393	142,957	75.9	7,864,954	346,325,491	97.8
		Seine	527	10,134	95.1	785,464	20,438,458	96.3
		Static	199,386	28,680	12.6	26,627,414	27,910,591	51.2
		Other/NA	5,328	645	10.8	16,795,948	3,029,144	15.3
	Wider Atlantic	Beam	0	3	100.0	1	2,180	100.0
		Dredge	5		0.0	3,466		0.0
		Midwater	12	921	98.7	1,820,001	93,406,897	98.1
		Otter	27	2,514	99.0	27,433	7,594,411	99.6

		Seine		1	100.0		828	100.0
		Static	345	3,494	91.0	423,011	5,473,218	92.8
		Other/NA	2	78	97.5	171	318,808	99.9
2013	Arctic Waters	Beam		1	100.0		3,068	100.0
		Dredge	9		0.0	973,000		0.0
		Midwater	1,798	5,123	74.0	123,219,757	447,747,550	78.4
		Otter	3,352	77,245	95.8	17,740,853	284,346,888	94.1
		Seine	6,974	28,832	80.5	19,544,172	81,675,611	80.7
		Static	11,139	51,454	82.2	28,487,919	120,926,791	80.9
		Other/NA	118	397	77.1	155,850	1,274,534	89.1
	Bay of Biscay and Iberian Coast	Beam	65	669	91.1	2,906	581,964	99.5
		Dredge	11,281	59	0.5	19,025,219	32,915	0.2
		Midwater	1,399	7,169	83.7	2,429,609	58,814,356	96.0
		Otter	43,155	66,787	60.7	18,490,143	40,874,457	68.9
		Seine	5	1,817	99.7	28	2,080,753	100.0
		Static	102,601	27,070	20.9	17,011,487	23,669,862	58.2
		Other/NA	10,396	18	0.2	19,903,313	23,592	0.1
	Celtic Seas	Beam	400	8,340	95.4	33,615	7,444,654	99.6
		Dredge	4,572	11,995	72.4	1,053,587	2,470,493	70.1
		Midwater	639	3,545	84.7	20,970,819	290,476,052	93.3
		Otter	16,936	62,168	78.6	2,020,900	68,367,456	97.1
		Seine	51	2,183	97.7	47,205	6,079,839	99.2
		Static	53,049	9,562	15.3	6,150,895	12,612,075	67.2
		Other/NA	1,759	861	32.9	1,351,976	2,486,502	64.8
	Greater North Sea	Beam	6,624	84,608	92.7	3,036,126	99,460,211	97.0
		Dredge	20,431	29,704	59.2	24,386,762	50,893,226	67.6
		Midwater	1,838	10,598	85.2	77,559,872	673,385,146	89.7
		Otter	36,748	166,752	81.9	7,484,326	699,893,572	98.9
		Seine	1,368	10,373	88.4	1,046,760	19,994,820	95.0
		Static	186,821	28,556	13.3	27,618,632	26,691,316	49.1
		Other/NA	5,631	1,385	19.7	15,327,517	9,393,380	38.0
	Wider Atlantic	Beam	28	10	26.3	10,281	2,197	17.6
		Dredge	1		0.0	250		0.0
		Midwater	28	1,396	98.0	6,220,450	185,304,157	96.8
		Otter	21	3,862	99.5	471,492	26,601,839	98.3
		Seine		4	100.0		3,668	100.0
		Static	105	3,823	97.3	85,490	6,584,054	98.7
		Other/NA		130	100.0		176,317	100.0
2014	Arctic Waters	Beam	1	7	87.5	255	11,663	97.9
		Dredge	1,132		0.0	103,380,081		0.0
		Midwater	1,621	5,045	75.7	114,369,453	471,526,057	80.5
		Otter	2,192	75,909	97.2	12,587,644	274,232,814	95.6
		Seine	7,403	33,733	82.0	18,859,787	95,286,065	83.5

		Static	9,607	45,491	82.6	22,181,658	105,786,212	82.7
		Other/NA	157	762	82.9	313,369	25,784,369	98.8
	Bay of Biscay and Iberian Coast	Beam	22	683	96.9	1,087	562,886	99.8
		Dredge	8,815	102	1.1	12,750,069	81,492	0.6
		Midwater	1,418	8,267	85.4	2,223,904	64,575,095	96.7
		Otter	42,006	62,408	59.8	19,365,948	41,578,296	68.2
		Seine	14	1,718	99.2	70	2,144,462	100.0
		Static	97,193	26,995	21.7	16,005,675	24,597,695	60.6
		Other/NA	8,076	59	0.7	19,269,801	2,877,405	13.0
	Celtic Seas	Beam	305	7,503	96.1	6,404	5,949,080	99.9
		Dredge	4,534	13,741	75.2	919,520	2,378,797	72.1
		Midwater	438	2,861	86.7	21,459,709	333,377,200	94.0
		Otter	10,450	65,377	86.2	755,238	70,062,864	98.9
		Seine	6	2,001	99.7	12	4,687,026	100.0
		Static	50,025	12,830	20.4	4,428,804	19,845,328	81.8
		Other/NA	1,756	1,032	37.0	1,392,073	4,830,318	77.6
	Greater North Sea	Beam	6,219	83,798	93.1	3,660,713	96,632,347	96.3
		Dredge	16,175	33,795	67.6	46,012,864	48,690,729	51.4
		Midwater	1,587	10,858	87.2	68,804,729	758,566,010	91.7
		Otter	35,401	172,972	83.0	21,280,665	628,512,437	96.7
		Seine	860	10,203	92.2	463,089	24,578,898	98.2
		Static	189,662	32,376	14.6	24,839,770	26,564,567	51.7
		Other/NA	4,375	1,392	24.1	7,889,502	2,810,189	26.3
	Wider Atlantic	Beam		6	100.0		6,360	100.0
		Midwater	49	2,378	98.0	14,555,550	300,914,406	95.4
		Otter	20	4,503	99.6	479,998	14,314,412	96.8
		Seine		2	100.0		4,970	100.0
		Static	1,849	3,128	62.9	633,826	5,427,761	89.5
		Other/NA		174	100.0		8,061,605	100.0
2015	Arctic Waters	Beam	1	2	69.7	1,003	2,482	71.2
		Dredge	1,234		0.0	109,699,701		0.0
		Midwater	1,468	7,332	83.3	101,496,145	563,900,280	84.7
		Otter	2,508	76,007	96.8	9,511,324	267,228,334	96.6
		Seine	6,850	34,868	83.6	17,139,017	89,577,785	83.9
		Static	12,162	41,367	77.3	26,772,181	95,928,072	78.2
		Other/NA	211	926	81.4	446,765	16,462,565	97.4
	Bay of Biscay and Iberian Coast	Beam	1	490	99.9	1	492,448	100.0
		Dredge	7,173	144	2.0	2,432,234	52,450	2.1
		Midwater	1,161	8,437	87.9	1,580,699	51,175,863	97.0
		Otter	38,602	63,855	62.3	17,928,791	45,256,846	71.6
		Seine		1,802	100.0		2,551,653	100.0
		Static	76,315	30,114	28.3	14,101,634	25,899,063	64.7
		Other/NA	12,422	56	0.5	12,225,021	1,282,833	9.5

	Celtic Seas	Beam	155	7,390	97.9	70,678	6,160,896	98.9
		Dredge	3,872	13,705	78.0	711,268	1,898,167	72.7
		Midwater	356	2,775	88.6	18,672,440	266,741,213	93.5
		Otter	8,411	61,958	88.0	601,480	59,937,163	99.0
		Seine	31	1,637	98.2	17	4,318,989	100.0
		Static	46,639	13,088	21.9	4,274,126	20,340,181	82.6
		Other/NA	1,533	1,308	46.0	21,725	3,187,604	99.3
	Greater North Sea	Beam	6,519	81,738	92.6	7,370,731	90,881,848	92.5
		Dredge	15,718	32,755	67.6	33,298,583	51,104,148	60.5
		Midwater	1,560	13,025	89.3	53,638,693	884,699,985	94.3
		Otter	29,334	163,660	84.8	13,242,339	991,451,157	98.7
		Seine	351	9,672	96.5	491,733	26,420,589	98.2
		Static	145,210	44,210	23.3	19,552,253	29,520,819	60.2
		Other/NA	4,519	1,163	20.5	2,684,049	4,026,528	60.0
	Wider Atlantic	Beam	1	14	93.3	779	11,968	93.9
		Midwater	51	1,701	97.1	18,580,001	347,677,860	94.9
		Otter	12	4,991	99.8	1,951,296	6,132,814	75.9
		Seine		7	100.0		16,086	100.0
		Static	110	3,322	96.8	62,997	5,589,221	98.9
		Other/NA	2	259	99.2	10,127	27,491,627	100.0

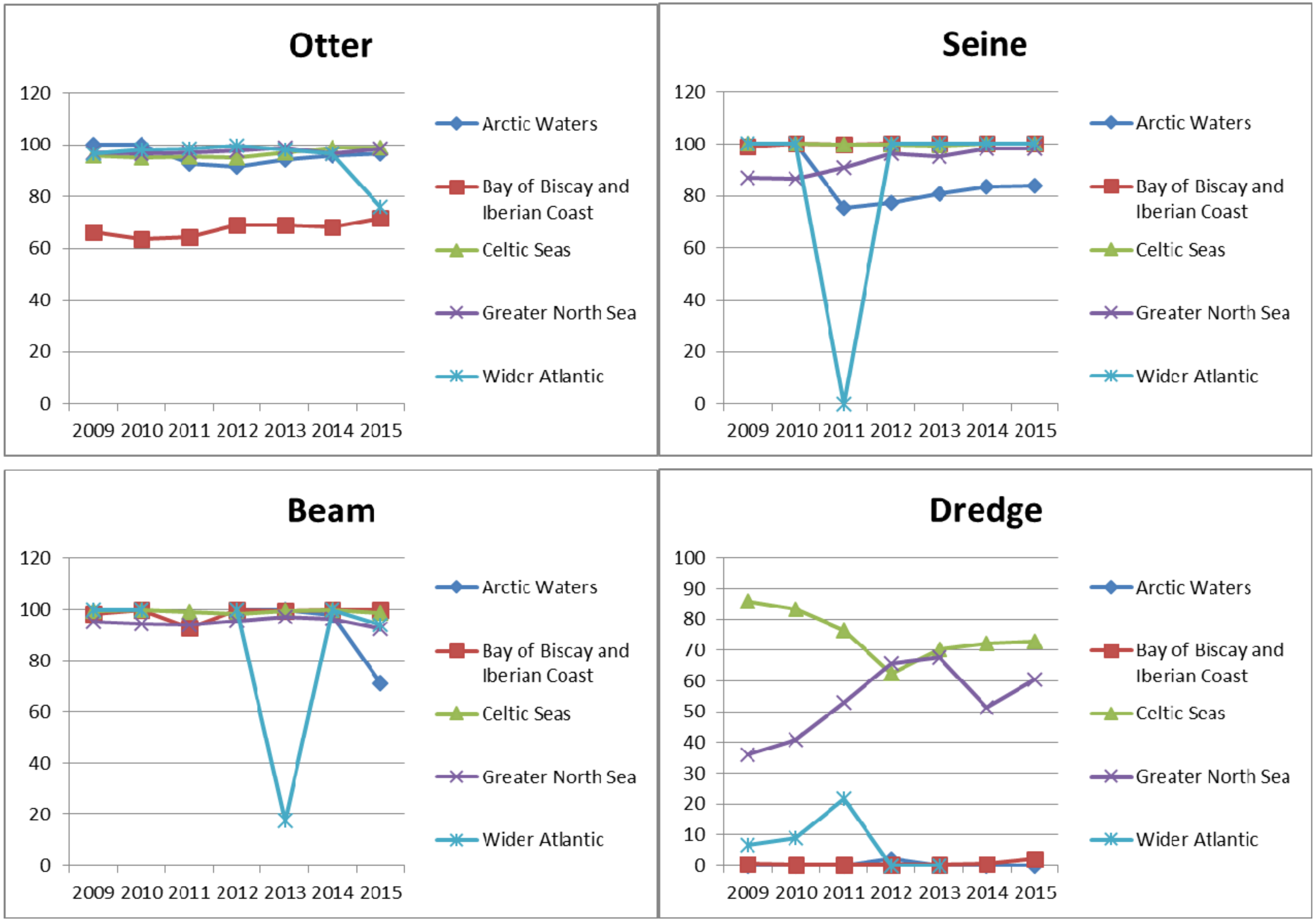


Figure 5.6.1.1a. Percentage of landed weight represented by the VMS data by bottom contact fishing categories and the OSPAR regions for the years 2009 to 2015.

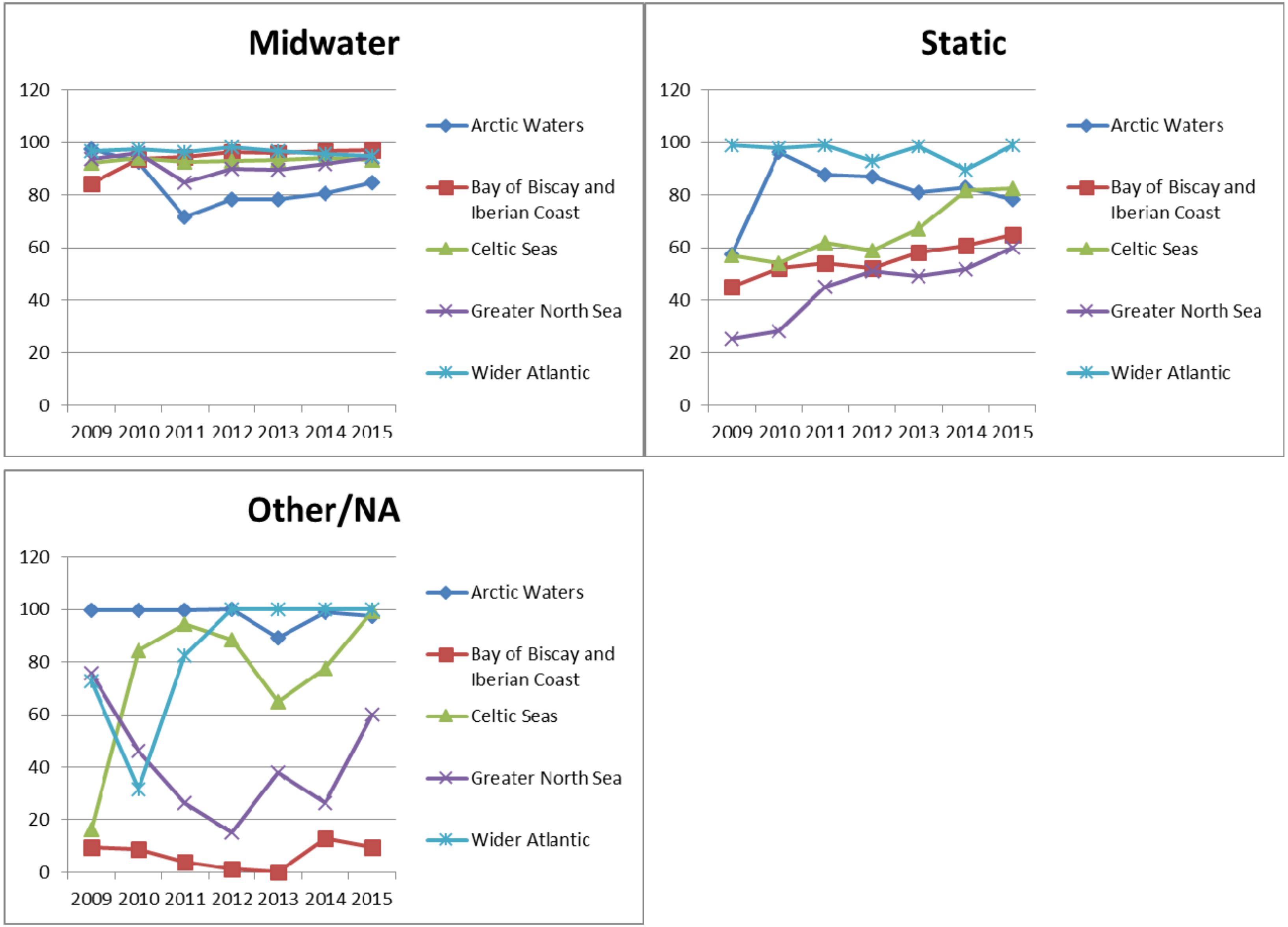


Figure 5.6.1.1b. Percentage of landed weight represented by the VMS data by non-bottom contact fishing categories and the OSPAR regions for the years 2009 to 2015.

5.6.2 Using methods developed in previous advice, where possible, collect other non-VMS data for 2014 to cover other types of fisheries (e.g. fishing boats < 12 m length)

5.6.2.1 Proportion of VMS coverage from logbook data

The 2016 data call included requests for vessel logbook data for all vessels in annex 2 of the data call. This was the only non VMS data available for use in this analysis. Effort (kW Fishing days) from logbooks which could be linked to VMS activity data was compared to that which could not be linked to VMS data (table 5.6.2.1), and the ratio of landings not covered by VMS were plotted by ICES rectangle for each gear type. An example is given in figure 5.6.2.1 and more maps in two zoom scales are found in Annex 4.

Future analysis should seek to include effort data for those of fisheries that are not included in logbook data (<10m vessels). Data published by STECF may be a source for this, but work would need to be undertaken in advance to ensure comparable data.

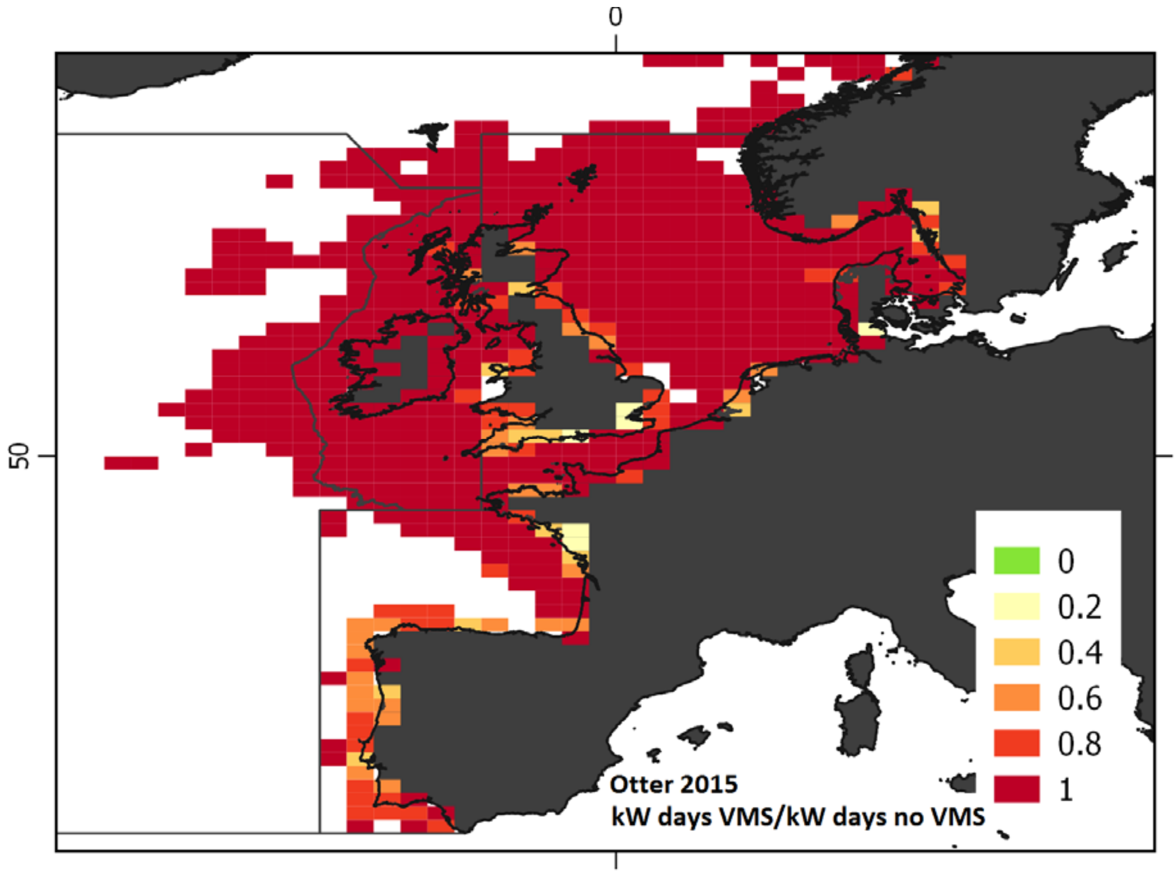


Figure 5.6.2.1. Proportion of VMS coverage for otter trawls based on logbook data. kW fishing days with VMS/kW fishing days without VMS.

Table 5.6.2.1. Effort in kW Fishing Days within the OSPAR region. No data were submitted from Spain, Iceland, Greenland, Faroe Islands and Russia.

Gear group	Year	Non VMS enabled	VMS enabled	total kW fishing days	Percentage of total kW fishing days represented by VMS
Beam	2009	2,298,357	51,715,154	54,013,510	96
	2010	2,768,045	53,744,062	56,512,107	95
	2011	2,183,867	48,029,857	50,213,724	96
	2012	2,038,371	47,606,742	49,645,113	96
	2013	1,536,630	48,037,979	49,574,610	97
	2014	1,620,656	46,065,749	47,686,404	97
	2015	2,791,550	45,254,911	48,046,461	94
Dredge	2009	6,663,646	8,685,702	15,349,348	57
	2010	6,434,397	9,342,598	15,776,995	59
	2011	5,492,734	11,154,556	16,647,291	67
	2012	4,598,046	11,716,219	16,314,264	72
	2013	4,181,529	11,604,869	15,786,398	74
	2014	3,128,621	12,969,912	16,098,533	81
	2015	2,818,008	12,460,841	15,278,850	82
Otter	2009	22,646,793	101,450,635	124,097,428	82
	2010	21,898,891	97,496,716	119,395,607	82
	2011	40,974,980	452,205,436	493,180,416	92
	2012	45,515,171	489,734,422	535,249,593	91
	2013	34,830,361	506,386,771	541,217,132	94
	2014	27,778,761	535,648,733	563,427,495	95
	2015	27,622,403	516,911,788	544,534,191	95
Seine	2009	190,708	4,345,937	4,536,644	96
	2010	283,299	4,974,061	5,257,360	95
	2011	4,657,148	20,328,622	24,985,770	81
	2012	5,247,878	26,590,782	31,838,661	84
	2013	6,221,621	31,889,503	38,111,124	84
	2014	7,076,507	38,835,565	45,912,072	85
	2015	6,149,092	39,933,458	46,082,549	87

5.6.2.2 Figures by country and vessel lengths from WGCATCH 2015 including small-scale fishery (vessels smaller than 10 m)

In the ICES WGCATCH report 2015 (ICES, 2016), figures were produced showing number of vessels, effort, landings and value of landings by country and by vessel length categories (<10, 10–12, >=12) for the year 2012. The values were given for a questionnaire for WGCATCH 2015. Figures 5.6.2.2–5.6.2.7 are included below as they give a valuable overview of the importance of the small-scale fishery in relation to the various parameters: fleet, effort and landings by country. They also give an indication of the importance of the small-scale fishery not obliged to fill in logbooks. It can be concluded from these figures is that the small-scale fishery <10 m is very important when looking at the fleets and effort, but less important when looking at landings and value of landings.

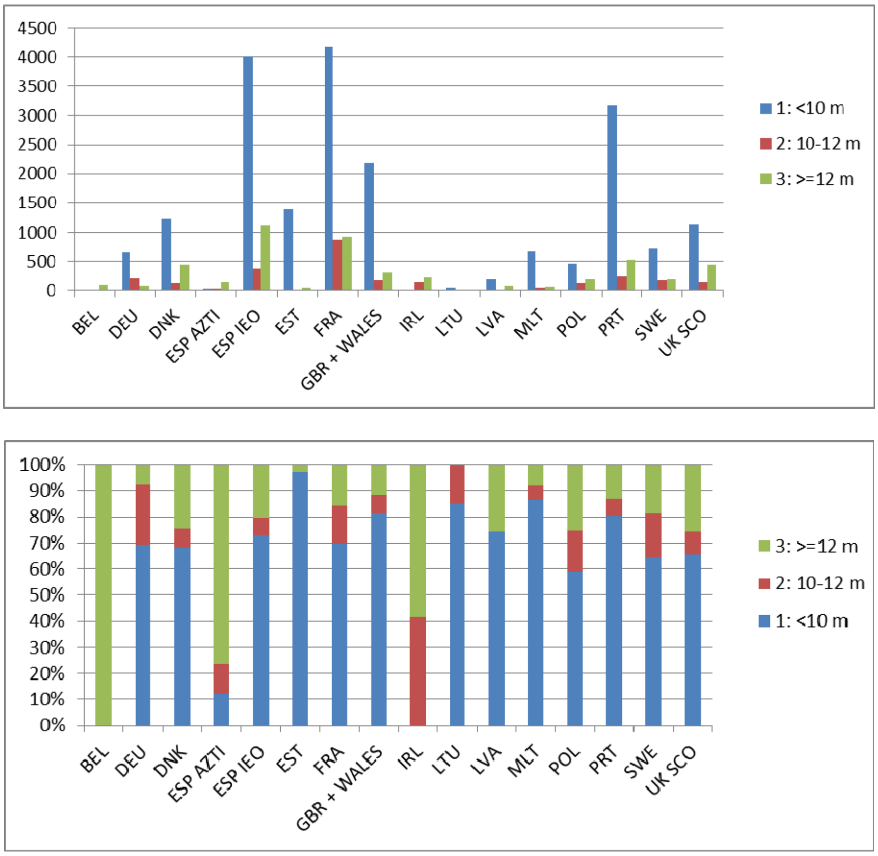
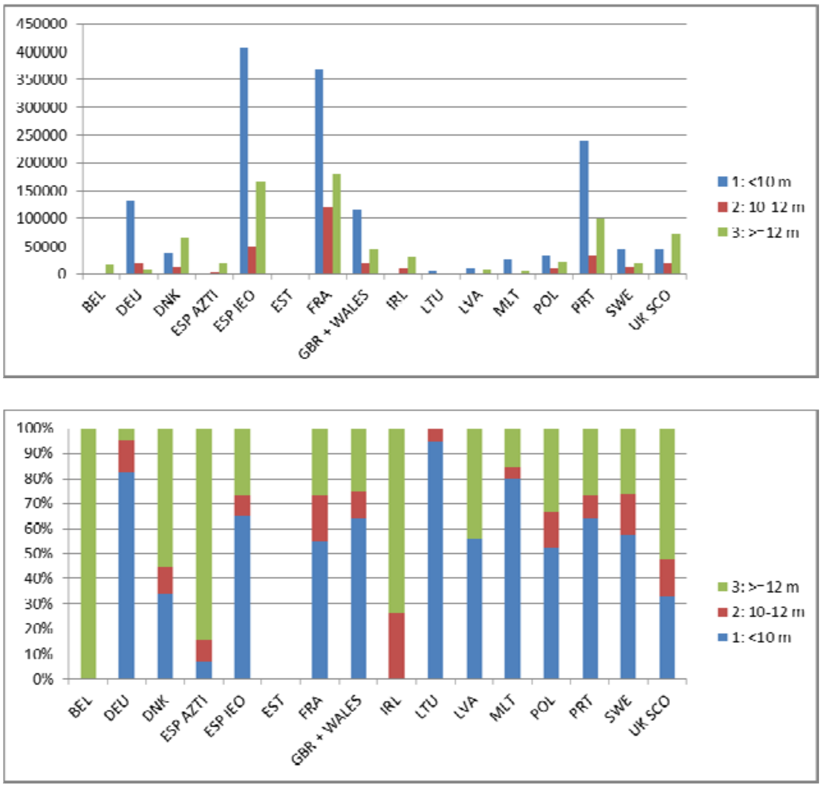


Figure 5.6.2.2. Number of active vessels per country and vessel length group in number (upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016).



Figures 5.6.2.3. Number of days at sea per country and vessel length group in days (upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016).

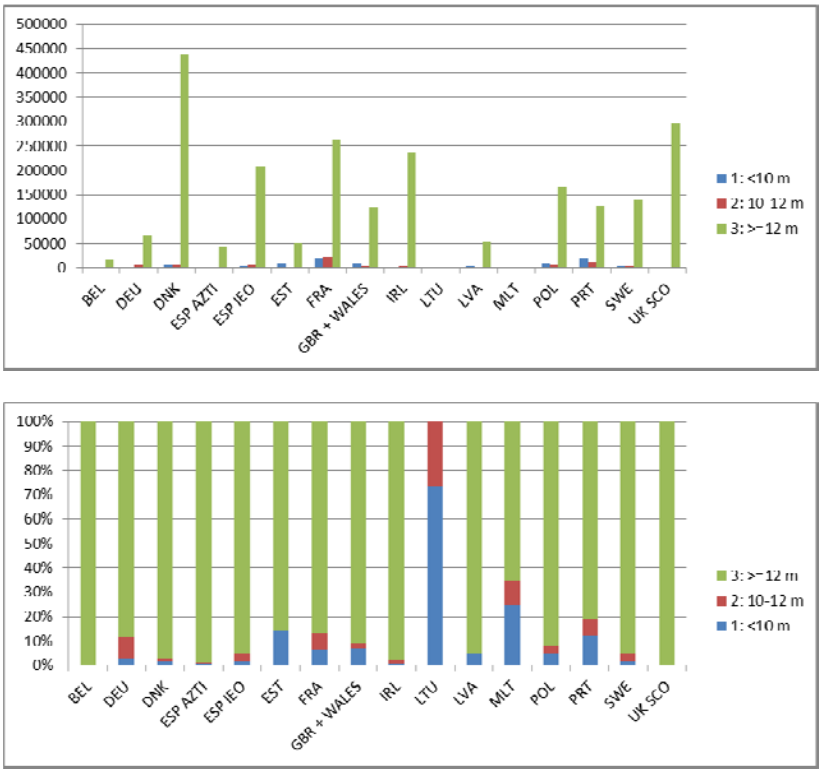


Figure 5.6.2.4. Total fish landings per country and vessel length group in tons (upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016).

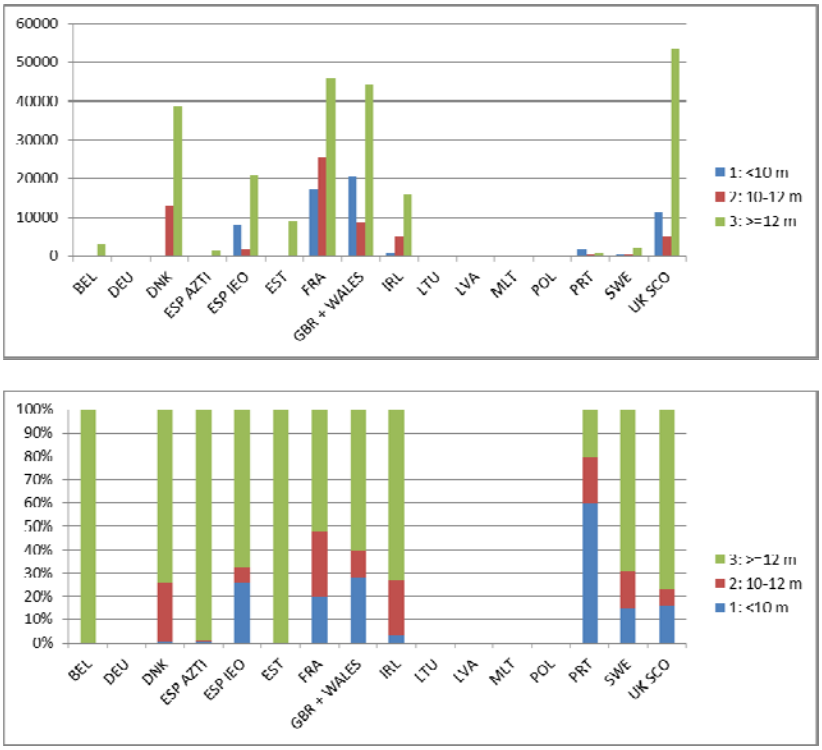


Figure 5.6.2.5. Total shellfish landings per country and vessel length group in tons (upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016).

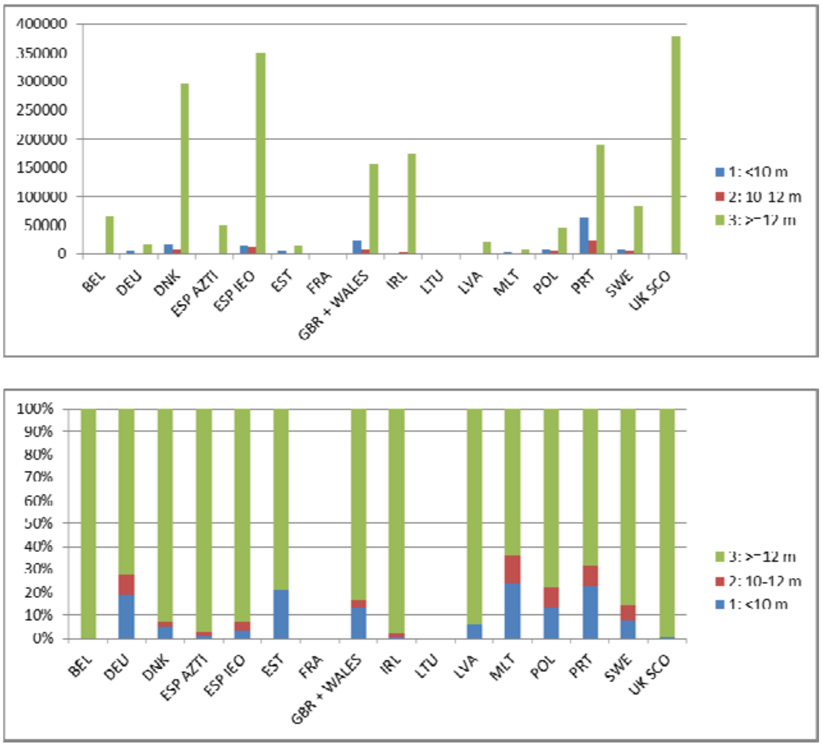


Figure 5.6.2.6. Total fish landings per country and vessel length group in value (euros*1000, upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016).

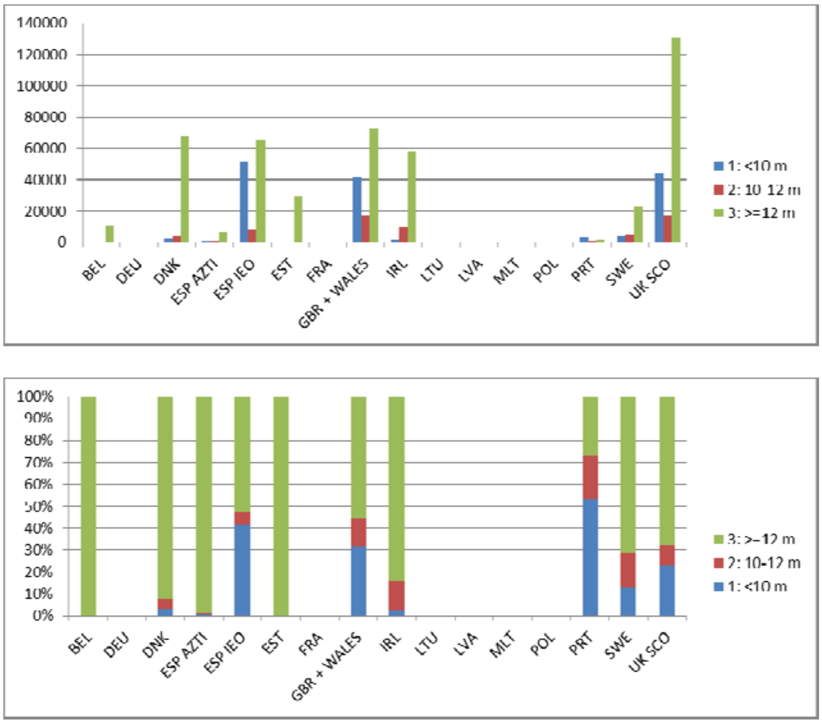


Figure 5.6.2.7. Total shellfish landings per country and vessel length group in value (euros*1000, upper graph) and percentage (lower graph) 2012. Source: ICES WGCATCH 2015 (ICES, 2016).

5.6.3 Prepare maps for the OSPAR maritime area (including ABNJ) on the spatial and temporal intensity of fishing using mobile bottom contacting gears

In WGSFD 2015, a workflow was developed for mapping fishing intensity for mobile bottom contacting gears expressed as swept area ratio. The method is described in detail in section 5.8.1 of this report, and reviewed in section 5.3. The swept area is calculated as a function of hours fished, vessel speed and gear width. The hours fished and average vessel speeds are given by the data call. The gear width need to be estimated and the method has been improved in 2016 to use relationships between vessel length/kW and gear widths developed by the EU-FP7 BENTHIS project (Eigaard *et al.*, 2016). These relationships are given by "Benthis métiers" and to use them, a table relating the DCF level 6 metiers to the Benthis métiers has been made. For each Benthis métier is given the proportion of the surface swept area that have a sub-surface impact. By dividing the surface and sub-surface swept area with the area of the c-squre, the surface- and subsurface swept area ratio's are found.

The fishing intensity expressed as swept area ratio (number of times the c-square has been swept) for mobile bottom contact gears have been mapped using R. Two sets of maps have been created: one covering most of the OSPAR region and another covering the area around the North Sea, as this is the area with most data.

The sum of surface and subsurface abrasion for each fishing category (Beam, Dredge, Otter and Seine) per year was calculated for each c-square and transformed to raster layers for mapping. Furthermore, the mean of all years from 2009–2015 per fishing category was calculated and mapped, as were the sum of all fishing categories.

The abrasion values in each raster layer were generally close to 0 for most c-squares (see figure 5.6.3.1), but in relatively few highly fished areas the abrasion values were high. To be able to distinct between abrasion values in the maps, a threshold was set for each raster layer. Both the minimum value (<0), maximum value and threshold are depicted in the scale bar (see Figures 5.6.3.2–5.6.3.5)

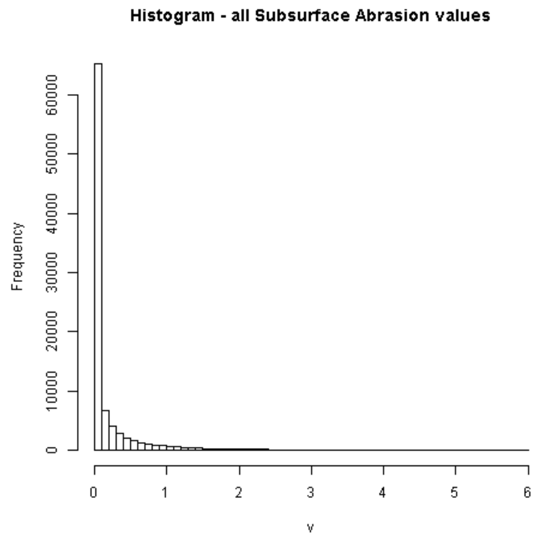


Figure 5.6.3.1. Histogram showing the frequency of all subsurface abrasion values.

The maps of total surface and subsurface swept area ratios are shown in figures 5.6.3.2, 5.6.3.3, 5.6.3.4 and 5.6.5.5 in two different zoom scales, one covering the OSPAR regions II, III and IV and one covering most of the OSPAR region (where there is data). The maps by gear group are available in Annex 5. In the headings of the maps "Sur" mean surface swept area ratio and "Sub" mean subsurface swept area ratio. Shapefiles with surface and subsurface swept area ratios by year, c_square and gear category is part of the ICES advice to OSPAR.

To map the trend during the time period 2012–2015 (where vessels >=12 m were obliged to have VMS onboard), the raster layers were used to generate a linear model (lm) for each c-square. The p-values from the model were used to sort where slopes would be displayed, so that only the c-squares with p-values above 0.95 would display slopes, and those below 0.95 would be blank. The trend-map of surface and subsurface swept area ratios is found as figures 5.6.3.6 and 5.6.3.7. Table 5.6.3.1 gives the percentage of c-squares with significant changes by OSPAR region and gear group.

Table 5.6.3.1. Percentage of c-squares with significant changes by OSPAR region and gear group.

OSPAR regions	Total surface	Total sub-surface	Beam sub-surface	Beam surface	Dredge sub-surface	Dredge surface	Otter sub-surface	Otter surface	Seine sub-surface	Seine surface
Arctic Waters	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Bay of Biscay and Iberian Coast	0.72	0.72	0.04	0.03	0.00	0.00	0.76	0.74	0.09	0.09
Celtic Seas	2.96	2.92	0.67	0.67	0.21	0.21	2.70	2.64	0.17	0.15
Greater North Sea	2.28	2.17	0.75	0.75	0.19	0.19	1.80	1.73	0.31	0.29
Wider Atlantic	0.10	0.10	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00

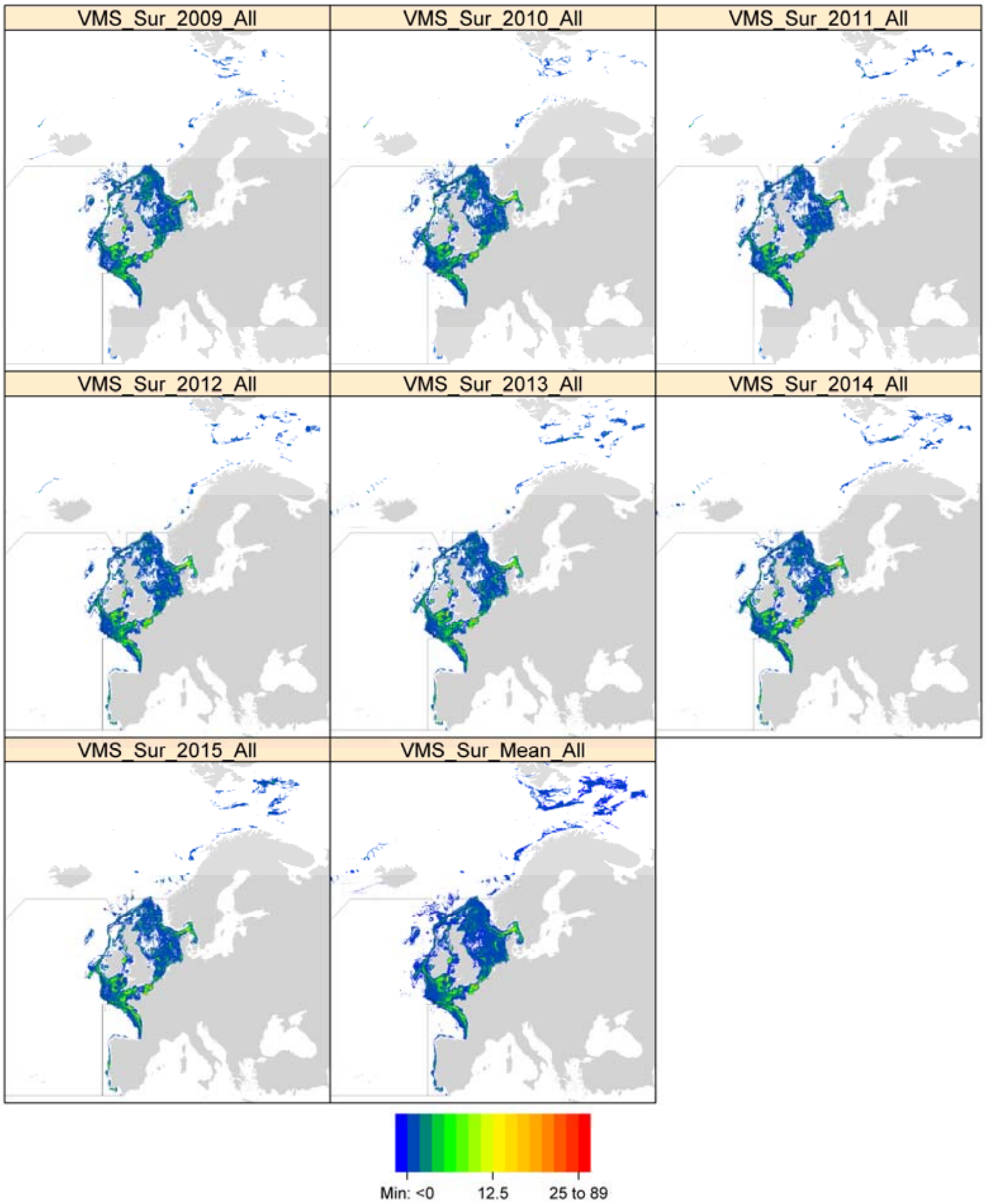


Figure 5.6.3.2. Total surface swept area ratio for each year 2009–2015 and the average of the time period. Zoom to most of the OSPAR region. No data were submitted from Spain, Iceland, Greenland, Faroe Islands and Russia. Note caveats listed in section 5.1.2.

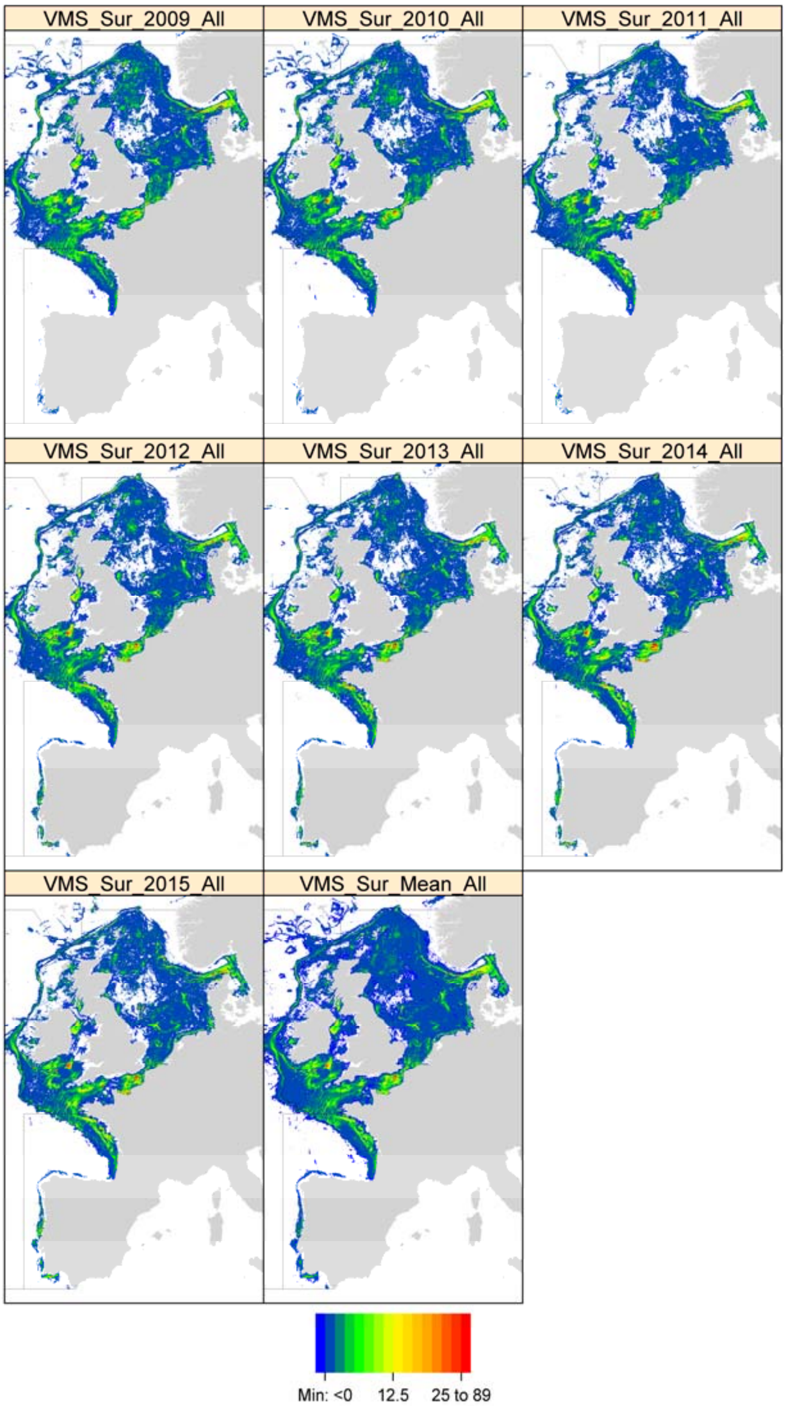


Figure 5.6.3.3. Total surface swept area ratio for each year 2009–2015 and the average of the time period. Zoom to the area around the North Sea. No data were submitted from Spain, Iceland, Greenland, Faroe Islands and Russia. Note caveats listed in section 5.1.2.

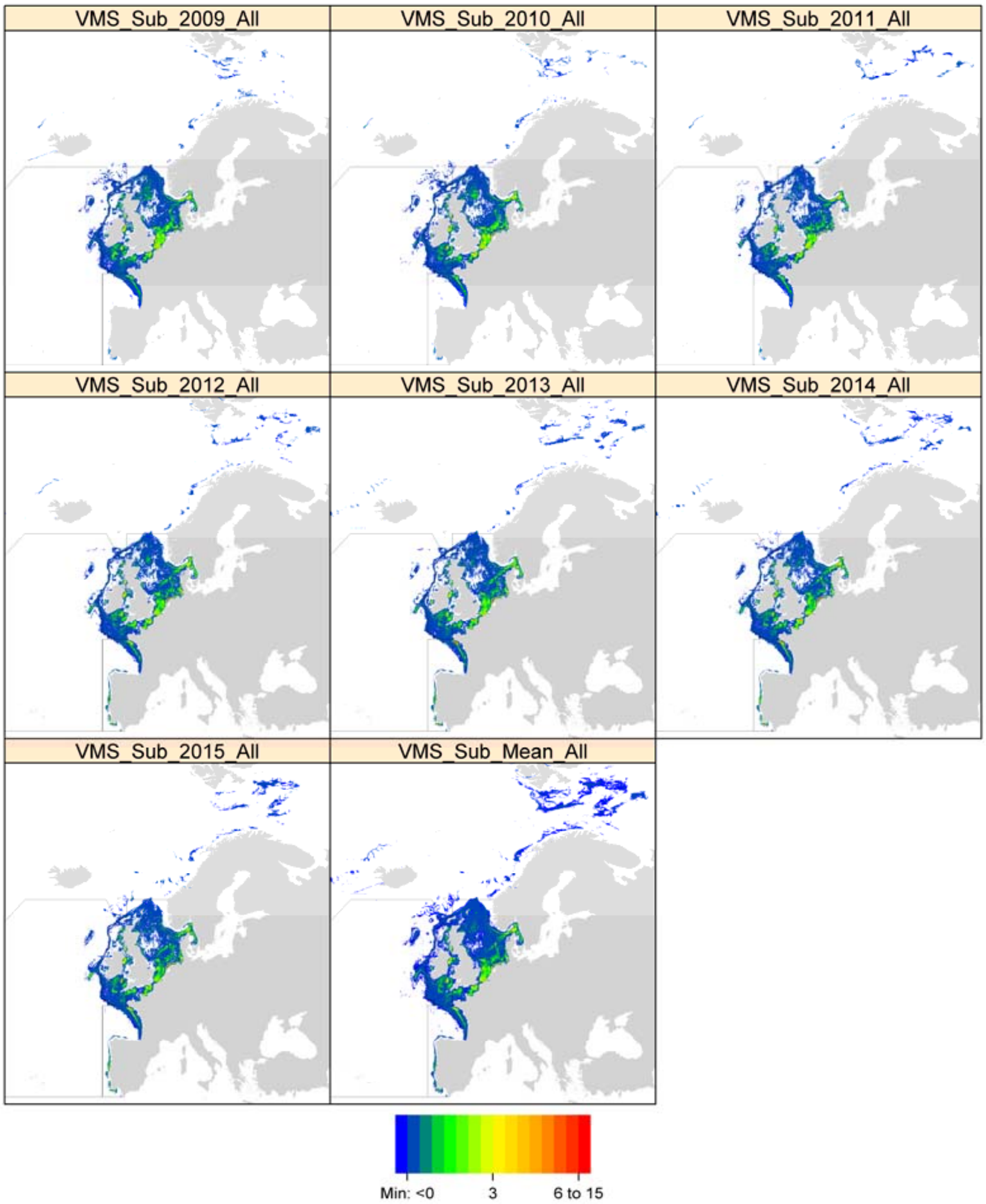


Figure 5.6.3.4. Total subsurface swept area ratio for each year 2009–2015 and the average of the time period. Zoom to most of the OSPAR region. No data were submitted from Spain, Iceland, Greenland, Faroe Islands and Russia. Note caveats listed in section 5.1.2.

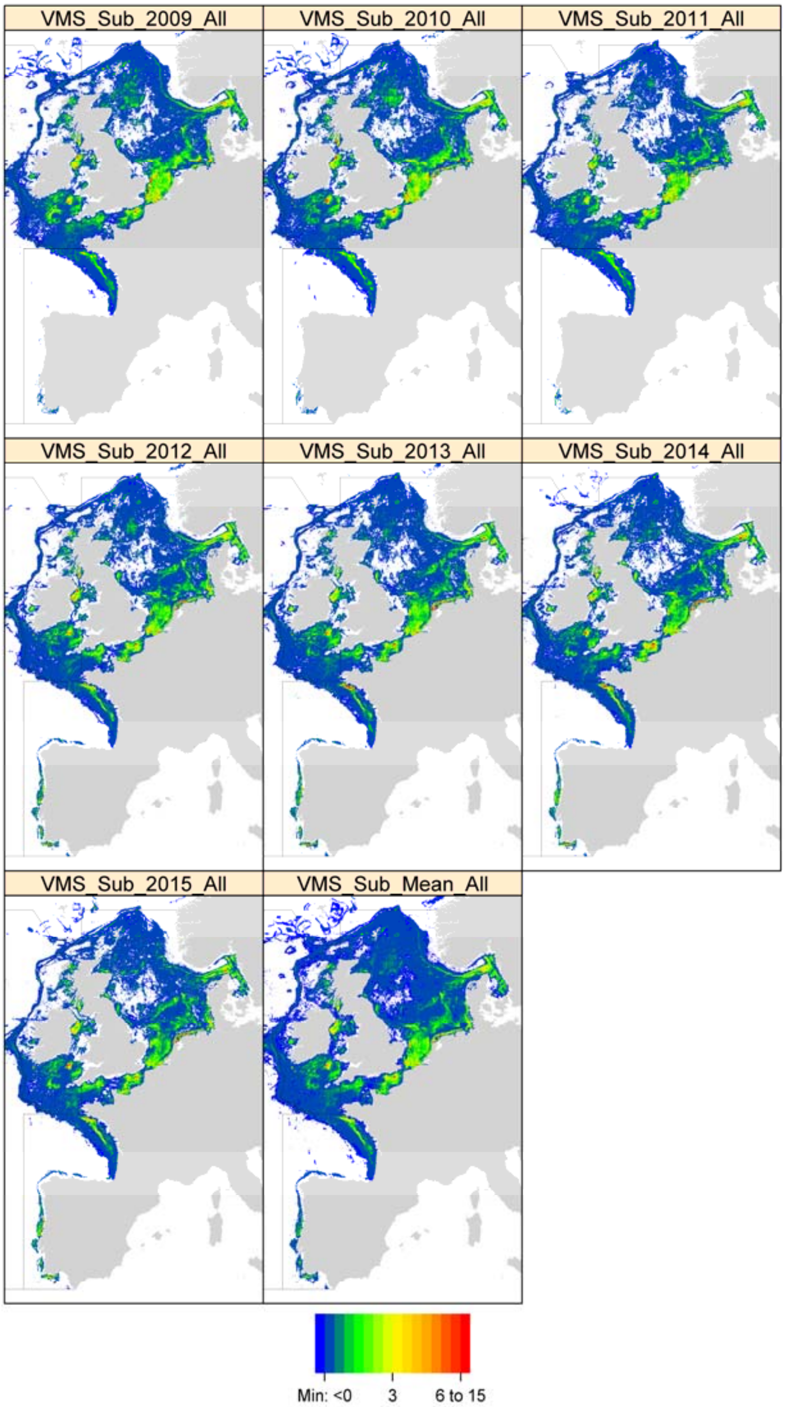


Figure 5.6.3.5. Total subsurface swept area ratio for each year 2009–2015 and the average of the time period. Zoom to the area around the North Sea. No data were submitted from Spain, Iceland, Greenland, Faroe Islands and Russia. Note caveats listed in section 5.1.2.

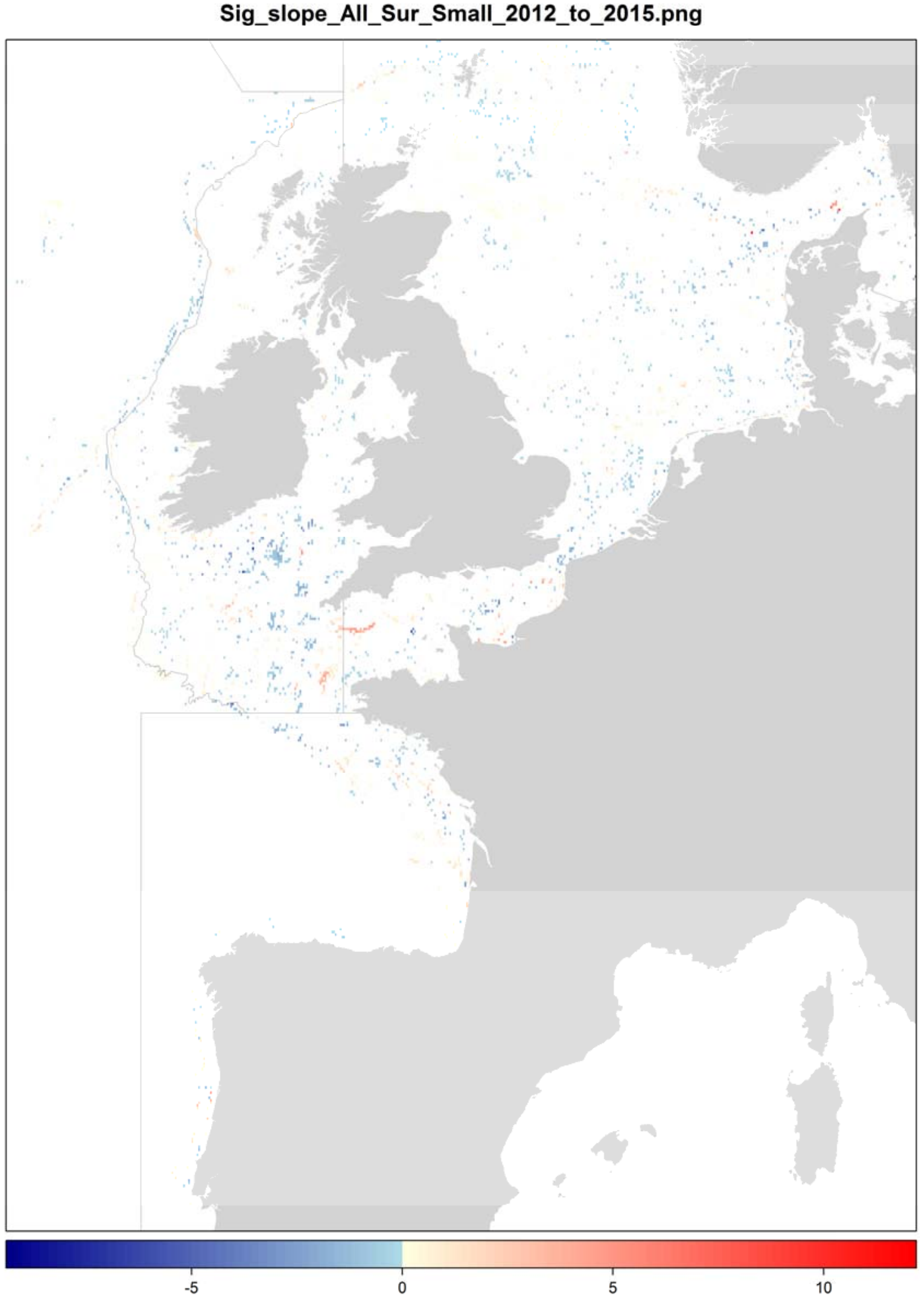


Figure 5.6.3.6. Surface swept area ratio trend map. Plot of the slope of the trend (only significant with a confidence interval of 95%) for the time period 2012–2015.

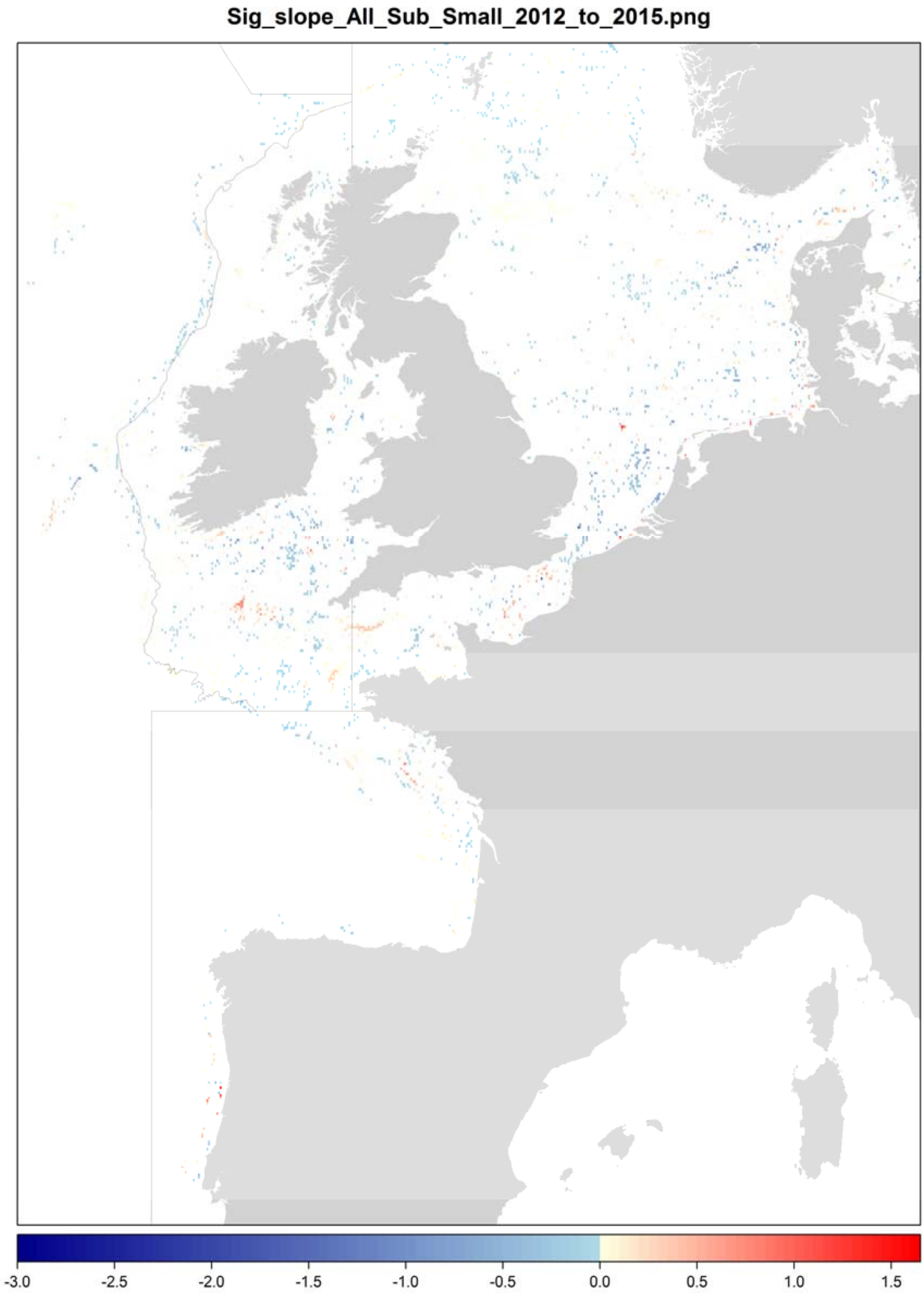


Figure 5.6.3.7. Subsurface swept area ratio trend map. Plot of the slope of the trend (only significant with a confidence interval of 95%) for the time period 2012–2015.

5.6.4 Advice on the development and application of alternative smaller grids (smaller resolution than 0.05) to improve the analysis of fishing abrasion data

Data

To improve the understanding of fishing abrasion at appropriate (smaller) spatial and temporal scales requires an increase in available GPS positions of fishing activity, in the same amount of time. The most practical approach to this is by either increasing the polling frequency of VMS or co-analyse VMS with AIS data that is already routinely collected. Using smaller regular grids is seen as most appropriate to combine and compare these fisheries data. Trade-offs exist between the availability of data and the spatial grid cell size one can appropriately use.

Methods

With increased polling rates, assumptions underlying interpolation can be relaxed and hereby reduce uncertainty on fishing abrasion, and automatically contributes to analysing fishing abrasion at finer spatio-temporal scales. Using existing techniques to interpolate VMS pings to artificially achieve a higher spatio-temporal resolution may also facilitate using smaller grids. Investments in statistical spatial modelling, such as kriging, are needed to 1) improve understanding the drivers of spatio-temporal patterns in fishing abrasion, 2) increase the flexibility in generating outputs for a variety of end-users at different spatio-temporal scale and 3) reduce confidentiality issues associated with GPS activity data from fishing vessels.

Additional improvements in fishing abrasion data quality can most practically be achieved by 1) including start and end position / time of a fishing haul in logbooks, 2) extending the coverage of VMS / AIS to small scale fisheries and 3) including detailed gear characteristics, such as gear width or dimension of passive gears, in the logbook.

Overview of potential data and methodological improvements to be made to improve fishing abrasion estimates

<u>Data</u>

a. AIS and Radar
    i. Pro: high resolution (detection of behavior easier plus better spatial location), no need to interpolate
    ii. Con: high amount of data, accessibility unclear, not available in all countries, can be switched off by fishermen (depends on national legislation), needs receiver stations (FM-signal, coverage; problem at off shore areas), no direct link to log book data, small boats are not obliged to have AIS (same as vms); trade-off between safety and control/research (resentments of fishermen)
    iii. Costs: data storage capacities, processing capacities; maybe reduction/filter of data needed
b. Plotter data from industry
    i. Pro: high resolution (detection of behavior easier plus better spatial location), no need to interpolate

   ii. Con: Industry may not be willing to give this information, verification (completeness and correctness)
   iii. Costs: high effort to collect and format this data

c. E-Logbook (start and end of haul, start and end of gill net lines, position of pots and fyke nets)
   i. Pro: No need to estimate activity from speed, small amount of extra data needs to be stored; reduced need for VMS-data analyses
   ii. Con: no coverage of small vessels; availability limited to flag state of vessel
   iii. Costs: GPS and Computer needed (E-Logbook); some amount of extra data
d. Higher VMS frequency /variable frequency (higher when active/fishing)
   i. Pro: cannot easily be switched off (controlled by national fisheries agencies); Satellite, coverage also off shore;
   ii. Con: higher cost (see below)
   iii. Costs: transmitting, storing and processing data
e. Include activity in VMS signal
   i. Pro: no need to estimate activity
   ii. Con: development of active sensor for all gears
   iii. Costs: extra infrastructure (sensor), extra data
f. Coverage of small vessel by vms
   i. Pro: big increase of information about a lot of very small vessels
   ii. Con: costs might be bigger than revenues; acceptation by fishermen low
   iii. Costs: extra infrastructure
g. Satellite-Fotos (day and night)
   i. Pro: regular interval; might detect illegal fisheries; visual confirmation of activity; might be especially suitable for passive gears from small (non-vms) vessels
   ii. Con: low frequency (once per day); identification of gears/vessels difficult; processing time consuming
   iii. Costs: acquiring fotos; processing
h. Air-Surveys/observations/ Drones (counting flags of set passive gears)
   i. Pro: might detect illegal fisheries; visual confirmation of activity; might be especially suitable for passive gears from small (non-vms) vessels; flexible; suitable in coastal areas and shallow waters, remote locations
   ii. Con: special activity, develop infrastructure, depends on weather conditions
   iii. Costs: development and installation of infrastructure, operation, processing; maybe cheaper than inspection vessels
i. Questionnaires
   i. Pro: expert knowledge from the industry

  - ii. Con: Industry may not be willing to give this information, verification (completeness and correctness); processing might be difficult (statistics)
  - iii. Costs: development of questionnaire; processing of data

<u>Methods</u>

- a. Statistical spatial methods
  - i. Interpolation of tracks (Include further covariates, like topography, sediments, habitats, …)
    1. Pro: fast, covariates easily available, no more fisheries data needed; continuous scale
    2. Con: no explicit behavioral element; needs parameterization for each fishery
    3. Costs: continued development
  - ii. Kriging (covariates, like topography, sediments, habitats, …)
    1. Pro: easy to expand to include covariates (variables); estimate of uncertainty included; continuous scale; covariates easily available, no more fisheries data needed; reduced confidentially issues since single tracks and positions
    2. Con: slow, no explicit behavioral element;
    3. Costs: development, processing
- b. Mechanistic spatial methods
  - i. IBMs (individual based models)
    1. Pro: includes behavioral elements; mechanistic approach improves understanding of processes and fisheries behavior; assumptions and behavior may be test (e.g. against high resolution data)
    2. Con: needs several assumptions; parameterization needed; uncertainties might be unclear
    3. Costs: development, testing
  - ii. ISIS FISH
    1. Pro: includes behavior and interactions between fisheries and population dynamics; can include several species, stocks and métiers; scenario testing (evaluation of management options)
    2. Con: parameterization difficult; processing is slow, especially with high spatial resolution
    3. Costs: development; processing
  - iii. Dynamic state variable models
    1. Pro: strong dependences of choices within a year (e.g. quota use); includes behavior and interactions between fisheries and population dynamics; can include several species, stocks and metiers

2. Con: parameterization difficult; processing is slow, especially with high spatial resolution
3. Costs: development; processing

c. Grids and Polygons

i. Finer grid (finer 0.05°) depends on input data, or data processing (see interpolation))
1. Pro: easily available (concepts are known)
2. Con: depends on data availability;
3. Costs: see interpolation, higher GPS-signal-frequency

ii. Nested grid
1. Pro: easily available already, no development needs
2. Con: different shape/character of grid for each country, year, month, gear, métier may be different; opportunities for comparison are limited; depends on effort/ observations/ input data
3. Costs: see higher GPS-signal-frequency

iii. Hexagons
1. Pro: good neighbor definition (use in IBMs)
2. Con: does not fit in established global straight line systems (lat, lon; ICES rectangles); mismatch with other existing data in rectangular systems (bathymetry)
3. Costs: development of labeling system; transferring existing data to hexagonal data

iv. Pre-Stratified Design
1. Pro: stable grid cells / polygons over years/countries etc.; can fit in established global straight line systems
2. Con: might not fit in established global straight line systems (lat, lon; ICES rectangles); mismatch with other existing data in rectangular systems (bathymetry); changes and trends might not be represented in preselected design
3. Costs: development of stratification

5.6.5 Advice on the applicability and use of AIS data

By Maurizio Gibin, JRC Maps by Lena Szymanek

One of the requests in the terms of reference this year for the WGSFD featured a comparison between AIS and VMS data[1]. Specifically it was asked if:

1) AIS can be used in supporting spatial analysis of fisheries data;

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1 VMS data here refers to the integrated VMS + Logbook dataset, obtained from the ICES data call R script.V MS effort refers to fishing effort calculate on VMS + Logbook data. AIS effort refers to fishing effort calculated using AIS data.

2) AIS can be used as an alternative source of data to VMS;

3) Indicate the costing for the collation and management of AIS data.

5.6.5.1 AIS data information

AIS data used for the comparison were kindly provided to JRC by courtesy of the Volpe Center of the U.S. Department of Transportation, the U.S. Navy, and MarineTraffic. AIS data was collated through terrestrial networks of receivers and contain information on the time, position, direction and speed of individual vessels above 15 meters length. AIS data is formatted as typical GPS data with a rather high time granularity compared to VMS data. The data used in the analysis have been decimated to a five minutes[2] sampling rate and spans a one year period, from 1 October 2014 to 30 September 2015. The AIS dataset was linked to the European Fleet Register (http://ec.europa.eu/fisheries/fleet/) through the call sign name by the vessel identifiers transmitted with AIS (Maritime Mobile Service Identity – MMSI).

The EU fleet register link allowed identification of EU fishing vessels and to obtain information on the primary and secondary gears, vessel length and power, country and port of registration, subsequently used to isolate specific fishing categories such as trawlers, purse seiners, etc. (ISSCFG, 1980). In this comparison we considered fishing activities related to trawlers only, which represent the largest portion of the EU fishing vessels above 15 meters of length. AIS data reliability (Fernandez *et al.* 2014); (Vespe *et al.* 2016); (Natale *et al.* 2016) is affected by strength of the recorded signal and, as a result coverage is better in the proximity of the coasts (Figure 5.6.5.1).

2 In signal processing decimation is the process of the reducing the sampling rate. AIS data has a variable refresh time that depends on the vicinity of another vessel. For ease of analysis the difference in time between two consecutive messages was set to five minute.

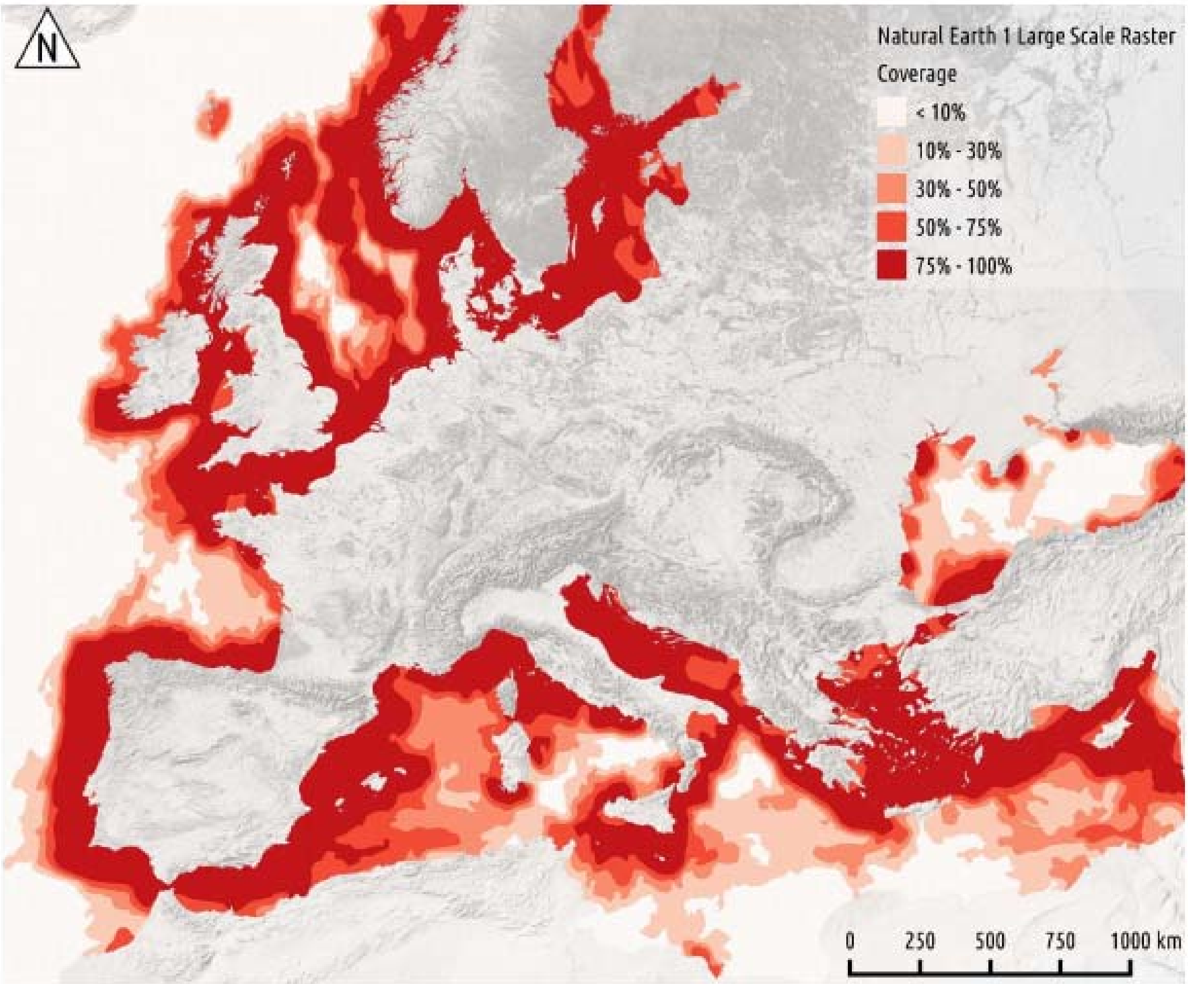

Figure 5.6.5.1. Spatial coverage and reliability of AIS data, image from (Vespe *et al.* 2016).

5.6.5.2 Effort calculation using AIS data

The AIS dataset described in the previous paragraph comprised six trawled gears, at DCF level 4: such information does not contain on the target species or mesh size. The Terms of Reference for the data call requested Member States for DCF level 6 data, including *metier* information.

AIS Effort was calculated using six mobile trawled gears coded using the ISSFG FAO gear definitions: OTB, PTB, OTT and TBB for demersal gears and PTM and OTM for pelagic gears. The methodology used to estimate effort on AIS data uses the same unsupervised machine learning technique (Natale *et al.* 2015 and Vespe *et al.* 2016) used for VMS data: Normal Gaussian Mixtures (GMM) with an Expectation Maximization (EM) algorithm.

However there are some small differences in the effort estimation process that could complicate a direct comparison of effort calculated using the two data sources. In the case of VMS data, effort is calculated on the entire gear group. With AIS data, the fishing speed is calibrated on each fishing vessel. In addition the fishing speed identified with VMS data tends to have a wider interval than the one determined using AIS data[3].

The final effort, estimated from AIS data, was mapped and aggregated using c-square notation with a 0.05 degrees resolution and mapped for the six gears previously mentioned: OTB, PTB, TBB, OTT and PTM and OTM.

5.6.5.3 Comparison of effort obtained from AIS and from VMS data: caveats and findings

Effort obtained from AIS data was calculated and measured (see Annexes 7 and 8 for maps and statistical analysis) as:

1) number of points estimated as fishing per 0.05 x0.05
2) fishing hours
3) Kilo Watt per fishing hours, with a vessel power information obtained from the European Fleet Register.

AIS estimated effort was then compared to the effort calculated using VMS and Logbook data. Effort calculated on VMS data[4] was obtained through the ICES data call. Every effort calculation is subjected to a series of arbitrary choices dictated by common sense or domain expert knowledge. Such arbitrary choices[5] are either taken in the data preparation phase or implemented in the software used in calculate effort and sometimes cannot be highlighted when the data is aggregated.

When comparing AIS and VMS data, effort measured as Fishing hours was the variable chosen to avoid the bias in gear declaration that affects the EU fleet register and consequently the AIS dataset. Vessel power is underreported on the Fleet register, resulting in underestimation of the effort measured as Kilowatt fishing hours[6].

AIS data linked with information from the EU fleet register overestimated the share of Otter Trawl Bottom gears compared to the other five gears and resulted in OTB effort being inflated compared to the effort from VMS data.

It was therefore considered that rather than a comparison on absolute effort values it was more appropriate to transform AIS and VMS effort to a ***Range Normalized***:

$$log(fishing_{hours} + 1 - min(fishing_{hours}))$$

with a range of 1. Using this transformation it was possible to observe the behavior of the single effort distributions and also assess association and similarity of AIS and VMS data

3 While AIS data uses the fishing speed calibrated on each single vessel + or – its standard deviation, for VMS data the confidence interval is the same for every vessel in the gear group and identified as the point of intersection between the second and third component of the GMM.

4 Both AIS data and VMS data pertain to vessels of length more than 15 meters long and for the period 1st October 2014 30th September.

5 Examples of such arbitrary choices are: the filters on minimum and maximum speed allowed for the calibration of fishing speed, the choice of the buffer radius used to include or exclude points in harbor.

6 Fishing hours was preferred to Fishing days. As the allocation of effort to a day is not unique and uniform among the Member States.

in *c-squares* containing effort form both sources. From the statistical analysis available in the appendix, the AIS effort is correlated to the VMS effort but in general AIS effort tends to underestimate VMS effort.

5.6.5.4 Conclusions

The results of the comparison between AIS and VMS data highlighted the need for comparable effort datasets obtained through the same processing work flow, capable of managing the considerable size of AIS data[7] through scalable code and processing power. Despite these limitations and 'caveats', AIS is of support to spatial fisheries as it can improve the spatial resolution of fishing effort, and, when coupled with an assessment of its coverage, AIS data provides a highly disaggregated measure of fishing effort .for fishing vessels of more than 15 meters long. When observing absolute values AIS effort tends to be lower than VMS[8]. For OTB effort, however AIS data maximum values are higher than the VMS one. This is the result of the inflation in AIS data coded as OTB with gear information provided by the EU fleet register. Transformed values show correlation and similarity between AIS data and VMS data. AIS data could be used as an alternative source to VMS for the large fleet, as it is mandatory for vessels > 15m length. However, it is the combination of the two datasets that would allow precise effort estimation: while VMS data contains better vessel's information, AIS data has a better time resolution and would improve the identification of fishing tracks.

The cost of AIS data varies. AIS data can be purchased from commercial vendors or can be assessed through the national coast guards AIS database. Data access can be granted for scientific purposes subject to agreement on confidentiality issues.

5.6.5.5 Acknowledgements

AIS data used for the comparison were kindly provided by courtesy of the Volpe Center of the U.S. Department of Transportation, the U.S. Navy, and MarineTraffic.

5.7 ToR f: Request from WKSand on the sandeel fishery

WGSFD ToR f): Produce spatial fishery distribution product on a specific fishery – (Advisory request). WGSFD will use the sandeel fishery in the North Sea as a case study, analyzing the spatial and temporal fishery distribution (2009–2015) (by month and at a resolution of 0.05x0.05 degrees). The results will be provided to WKSand, the sandeel benchmark that is proposed to meet immediately after WGSFD to evaluate data and work to incorporate these results into the sandeel assessments

Sandeel fishery has been extracted from the ICES data base using EU level 6 - métier 'OTB_DEF_<16_0_0' or fishing activities reporting sandeel landings from Norwegian data set (lacking métier definitions).

Data are aggregated on a geographical grid of 3 minute (0.05 x 0.05 degree) resolution. The grid cells are named following the "C_squares" – procedure. These C-squares were converted to latitude and longitude (grid cell midpoints) and the data set were further

7 More than 100000000 records only for AIS data coded as OTB.

8 Since there is not a standard methodology for the calculation of effort, fishing effort may vary according to the software used.

filtered for fishing activities taking place within the North Sea sandeel management areas (see maps) in the North Sea region.

Shape files and .csv files were produced for further use by WKSand. The files contains total values of; fishing hours, kW*fishing hours and total landings in kg, aggregated by C-square, month, gear (gear code EU level 4) and vessel length classes (12–15 m, > =15 m) and sandeel management area code.

Landings are total weight of *all* species (in kg) from logbook summed by day (and for some country by trip) and distributed evenly on the VMS pings determined as representing fishing activities on the corresponding day (or trip). The VMS coverage is high; typically 96–99 % of the landings in weight are covered by the VMS data (see table 1) slightly less in terms of fishing days. There is a small difference between the total VMS distributed landings and the total logbook landing weights. This might be due to fishing activities (actual or false positive due to the speed filtering method) outside of the sandeel management area during the same fishing trip and/or misreportings of ICES rectangle in the logbook.

Table 5.7.1. Coverage of VMS data in relation to total fishing activity represented as landings (kg) and fishing days from the logbook.

Year	VMS enabled	Total weight (kg) VMS	Total weight (kg) Logbook	Coverage	Fishing days in Loggbook	Coverage
2009	No		5 091 307	2%	174	5%
	Yes	311 445 410	311 443 548	98%	3 234	95%
2010	No		6 271 126	2%	238	8%
	Yes	310 970 865	307 051 757	98%	2 701	92%
2011	No		9 008 982	2%	222	6%
	Yes	388 282 178	388 814 370	98%	3 511	94%
2012	No		500 226	1%	35	2%
	Yes	87 751 516	92 733 031	99%	1 647	98%
2013	No		732 749	0.3%	66	1%
	Yes	239 505 220	239 394 033	99.7%	4 476	99%
2014	No		9 783 412	4%	289	7%
	Yes	220 303 459	227 508 850	96%	3 676	93%
2015	No		3 464 783	1%	76	2%
	Yes	345 796 587	358 158 619	99%	3 988	98%

The shapefiles are point shapefiles, one file for each year 2009 to 2015. The projection is WGS 84. The data contained in the attribute table are the following.

Table 5.7.2: Format for shapefile forwarded to WKSand

Shapefile column name		Shapefile column name	
Year	*Year*	**kW_h_tot**	*Engine power (in kW) * fishing hours*
Csqr	*C- square notation of (0.05x0.05 degree grid cell)*	**h_tot**	*Fishing hours*
Month	*Month*	**SI_LONG**	*Longitude (midpoint of 0.05x0.05 degree grid cell)*
LenthCl	*Vessel length class*	**SI_LATI**	*Latitude (midpoint of 0.05x0.05 degree grid cell)*
gear	*gear code Eu level 4*	**area**	*Sandeel management area number*
kg_tot	*total landings distributed equally on VMS pings by day (for some country by trip)*		

Requested maps

Yearly fishing effort maps are produced. Maps show yearly aggregations of fishing hours (and kW*fishing hours) over, month, gear and length class over the 0.05x0.05 degree grid. Yearly fishing hours are shown below. Further monthly maps of fishing effort are produced for April, May, June and July representing more than 99.6% of the total yearly effort. See Annex 6 for maps.

5.8 ToR g: Input for the WKFBI workshop

The EU (DG ENV) has requested advice from ICES on "guidance on how pressure maps of fishing intensity contribute to an assessment of the state of seabed habitats". In preparation of this advice, a core group with participants from WGDEC Working Group on Deep-water Ecology, BEWG Benthos Ecology Working Group, WGMHM Working Group on Marine Habitat Mapping and WGSFD Working Group on Spatial Fisheries Data, chaired by Adriaan Rijnsdorp (IMARES) was formed. The group worked on this task in order to provide input to an open workshop (WKFBI – Workshop on guidance on how pressure maps of fishing intensity contribute to an assessment of the state of seabed habitats), taking place from 31.05 to 01.06 at ICES headquarters. The role of WGSFD was to produce impact maps by combining and evaluating the benthic information on sensitivity and fishing pressure maps (fishing abrasion, weight and value of landed catch), taking into account differences in benthic impact of the various fishing gears / métiers.

5.8.1 General approach to estimate surface and subsurface abrasion

In accordance with ToR e (chapter 5.6.3) and this year's data call, WGSFD prepared maps on the spatial and temporal intensity of fishing using mobile bottom contacting gears. Fishing intensity was expressed as swept area ratio (SAR), using a workflow developed in 2015. The aggregation of national data from the data call provided estimates of total fishing time per métier within each 0.05°x0.05° c-square for the years 2009–2015. In order to calculate swept area values certain assumptions about the spread of the gear, the extent of bottom contact and the fishing speed of the vessel needed to be made and thus a number of working steps were necessary (Figure 5.8.1.1, for further details, see ICES

WGSFD Report (ICES 2015)). First a full quality assessment of all submitted data was performed (Step 1). Submitted VMS datasets usually contained information on the gear based on standard DCF métiers (from EU logbooks, usually at the resolution of métier level 6) and the gear-specific fishing speed, but not on gear size and geometry. Therefore, vessel size-gear size relationships developed by the EU FP7 project BENTHIS project (Eigaard *et al.*, 2016) or by the Joint Nature Conservation Committee (JNCC) were used to approximate the bottom contact (e.g. gear width). To do this, it was necessary to aggregate métier level 6 to lower and more meaningful gear groups, for which assumptions regarding the extend of bottom contact were robust (Step 2). If possible the so-called "Benthis métiers" were used; otherwise the more general bottom contacting gear groups from JNCC were assigned. Following this, fishing effort (hours) was calculated and aggregated per c-square for each métier and year (Step 3). Fishing speeds were based on average speed values for each métier and grid cell submitted as part of the data call, or, where missing, a generalised estimate of speed was derived (Step 4). Similarly, vessel length or power were submitted through the data call, but where missing average vessel length/power values were assumed from the BENTHIS survey (Eigaard *et al.*, 2016) or were derived based on a review done by JNCC (Step 5). Parameters necessary to fulfil steps 2, 4, and 5 are listed in table 5.8.1.1 for Benthis métiers and table 5.8.1.2 for corresponding JNCC gear groups. The resulting bottom contact values (m) were finally used to calculate swept areas (SA) per gear group, grid cell and year (Step 6).

For towed gears (Otter trawls, beam trawls, dredges): $SA = \sum evw$,

For Danish seines (SDN_DMF):

$$SA = \sum(pt * (w/2pt)^\wedge 2 * (e/2.591234)) ,$$

For Scottish seines (SSC_DMF):

$$SA = \sum(pt * (w/2pt)^\wedge 2 * (e/1.9125) * 1.5),$$

where *SA* is the swept area, *e* is the time fished (h), *w* is the total width (m) of the fishing gear (gear group) causing abrasion, and *v* is the average vessel speed (m/h).

The swept area information was additionally aggregated across métiers for each gear class (Otter trawl, Beam trawl, Dredge, Demersal seine) with two layers, one for surface abrasion and one for subsurface abrasion (as proportion of the total area swept, see table 5.8.1.1 and 5.8.1.2). To account for varying cell sizes of the GCS WGS84 grid, swept area values were additionally divided by the grid cell area:

$$SAR = SA/CA,$$

where *SAR* is the swept area ratio (number of times the cell was theoretically swept), *SA* is the swept area, and *CA* is the cell area.

Finally effort and swept area maps were generated at appropriate scales (Step 7 and 8).

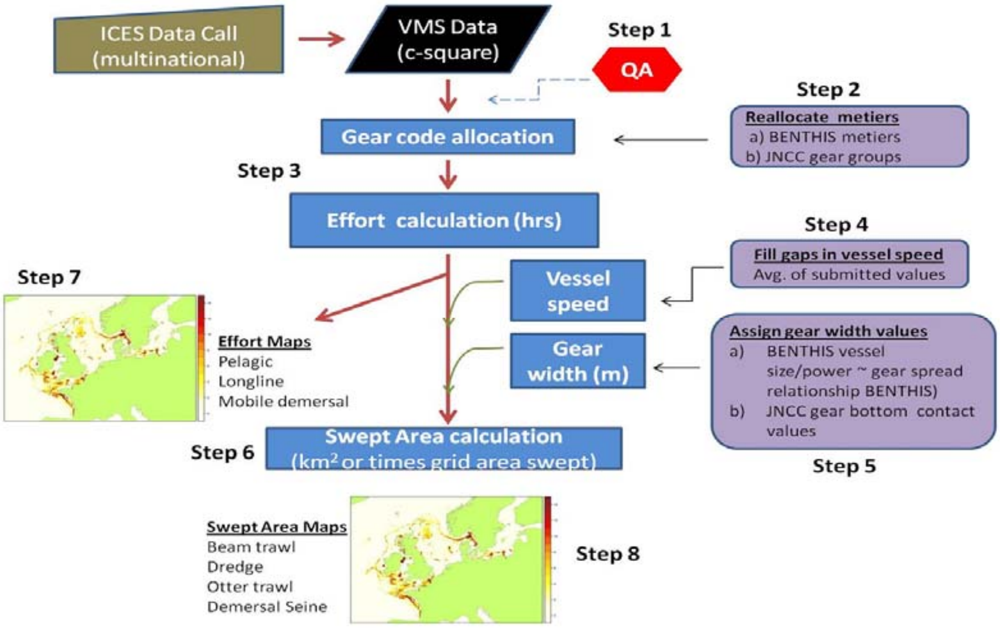

Figure 5.8.1.1. Workflow for production of fishing effort and swept area maps from aggregated VMS data (0.05°x0.05° C-square resolution) (from ICES 2015).

Table 5.8.1.1. Parameter estimates of the relationship between vessel size (as length (m) or power (kW)) and gear width, the average width of fishing gear causing abrasion (surface and subsurface), the corresponding proportion of subsurface abrasion, and the average fishing speed for each BENTHIS métier (derived from (Eigaard *et al.*, 2016) and ICES 2016).

Gear class	Benthis metier	Model	Average gear width (m)	Subsurface proportion (%)	Fishing speed (knots)
Otter trawl	OT_CRU	5.1039*(kW$^{0.4690}$)	78.92	32.1	2.5
	OT_DMF	9.6054*(kW$^{0.4337}$)	105.47	7.8	3.1
	OT_MIX	10.6608*(kW$^{0.2921}$)	61.37	14.7	2.8
	OT_MIX_CRU	37.5272*(kW$^{0.1490}$)	105.12	29.2	3.0
	OT_MIX_DMF_BEN	3.2141*LOA+77.9812	156.31	8.6	2.9
	OT_MIX_DMF_PEL	6.6371*(LOA$^{0.7706}$)	76.21	22	3.4
	OT_MIX_CRU_DMF	3.9273*LOA+35.8254	113.96	22.9	2.6
	OT_SPF	0.9652*LOA+68.3890	101.58	2.8	2.9
Beam trawl	TBB_CRU	1.4812*(kW$^{0.4578}$)	17.15	52.2	3
	TBB_DMF	0.6601*(kW$^{0.5078}$)	20.28	100	5.2
	TBB_MOL	0.9530*(LOA$^{0.7094}$)	4.93	100	2.4
Dredge	DRB_MOL	0.3142*(LOA$^{1.2454}$)	16.97	100	2.5
Demersal seines	SDN_DMF	1948.8347*(kW$^{0.2363}$)	6536.64	5	NA
	SSC_DMF	4461.2700*(LOA$^{0.1176}$)	6454.21	14	NA

Table 5.8.1.2. Estimates of fishing gear width causing abrasion (surface and subsurface) and the corresponding proportion of subsurface abrasion for each JNCC gear group (from ICES 2014, section 5.4.2).

JNCC gear group	Gear width	Subsurface proportion (%)	Fishing speed (knots)
Beam Trawl	18	100	4.5
Nephrops Trawl	60	3.33	3
Otter Trawl	60	5	3
Otter Trawl (Twin)	100	5	3
Otter Trawl (Other)	60	3.33	3
Boat Dredge	12	100	4
Pair Trawl and Seine	250	0.8	3

Swept area ratios (SARs) were calculated as grid cell averages of the seven annual estimates from 2009–2015, and were mapped as surface and subsurface abrasion of the four main bottom-contacting gear groups (beam trawlers, dredges, otter board trawlers and demersal seines) as well as for the sum of all gear group SARs (see Figures 5.6.3.2–5.6.3.5).

5.8.2 Small-scale variability

It is well known that fishing effort is highly clustered in space and even within the applied 0.05°x0.05° grid cell resolution a lot of variability is found. Generally, c-square estimates resulting from a high number of VMS observations will have a high precision, whereas grid cells experiencing low fishing intensity will have a low precision. Further, due to the clustering of VMS points, i.e. the repeated trawling of the same or similar tracks, a SAR estimate of 1 does not mean that 100% of the cell is impacted by the fishing gears. We can rather observe areas that are repeatedly trawled, whereas others are not impacted at all. To illustrate this, we used an example from the North Sea, where the spatial distribution of VMS pings from the Danish fleet is shown in relation to the respective SAR grid cell estimates (Figure 5.8.2.1). Similarly to fishing, benthic habitats can vary on small-spatial scales. Because fishing effort values are aggregated within grid cells, habitats, and by this sensitivities were assigned accordingly. As an approximation we used the habitat/sensitivity found at the midpoint of each grid cell. However, as shown in Figure 5.8.2.2, this does not necessarily represent the prevailing habitat of the grid cell.

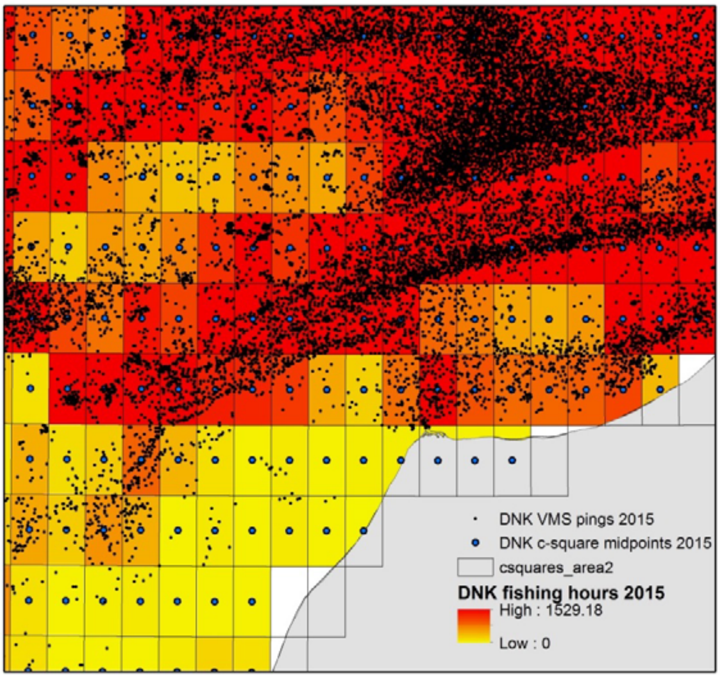

Figure 5.8.2.1. Spatial distribution of VMS pings from the Danish fleet recorded in a small area at the Danish North Sea coast in 2015. Pings are shown in relation to the respective swept area ratio grid cell estimates (0.05°x0.05°) Blue dots represent c-square midpoints.

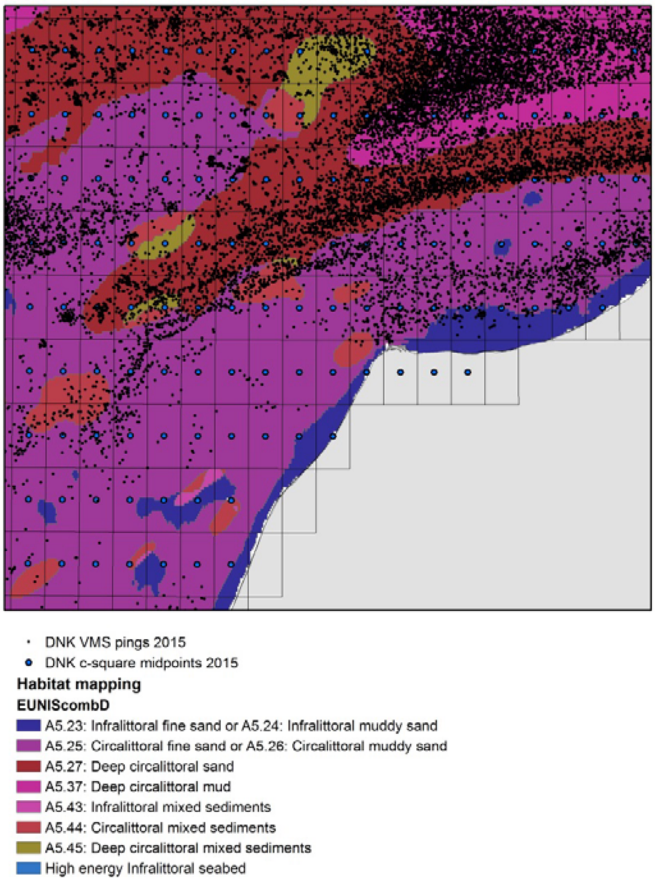

Figure 5.8.2.2. Spatial distribution of VMS pings from the Danish fleet recorded in a small area at the Danish North Sea coast in 2015. Pings are shown in relation to the underlying habitat (EUNIS level 3) and the c-square borderlines (0.05°x0.05°). Blue dots represent c-square midpoints.

5.8.3 Pilot impact assessment: Categorical approach

In order to provide a pilot assessment of the impact of fisheries on benthic communities, a unified habitat map for European Seas was used based on the 2016 interim EMODNET maps. Habitat sensitivity was estimated using a categorical approach developed in the UK (MB0102). Sensitivity depends on the resistance of the receptor (species or habitat feature) and the ability of the receptor to recover (resilience). For each habitat resistance and resilience was estimated of a selection of key and characterizing species based on scientific evidence by experts. The sensitivity scoring for the shelf habitats (0–200m) was carried out by BEWG, the scoring for the deep-sea habitats was done by WGDEC. WGMHM has incorporated this information on habitat sensitivity to existing habitat mapping and has provided this information to WGSFD as a shapefile.

As a tentative approach the habitat/sensitivity map was combined with the abrasion layers by using a combination matrix (categorical attribution of pressure and sensitivity). Because the sensitivity scoring used the MB0102 benchmark of medium physical pressure which is not related to a specific trawling intensity, trawling intensity classes (here for the swept area ratio of the surface and subsurface layer) were arbitrarily set (Table 5.8.3.1, Figure 5.8.3.1). Interval boundaries were based on the range and frequency of SAR values within grid cells of the investigated area, but other classifications may be also possible and potentially lead to different results.

Table 5.8.3.1. Classification of fishing pressure into five different pressure classes from very low to very high defined by intervals of swept area ratios (SAR).

Fishing pressure	SAR interval
1: Very low	[0.05; 0.1] *
2: Low	[0.1; 0.5]
3: Medium	[0.5; 1.0]
4: High	[1.0; 5.0]
5: Very high	>5

* The first interval does not include values smaller than 0.05 SAR because this has a high risk of including grid cells where vessel activity has been misclassified as fishing.

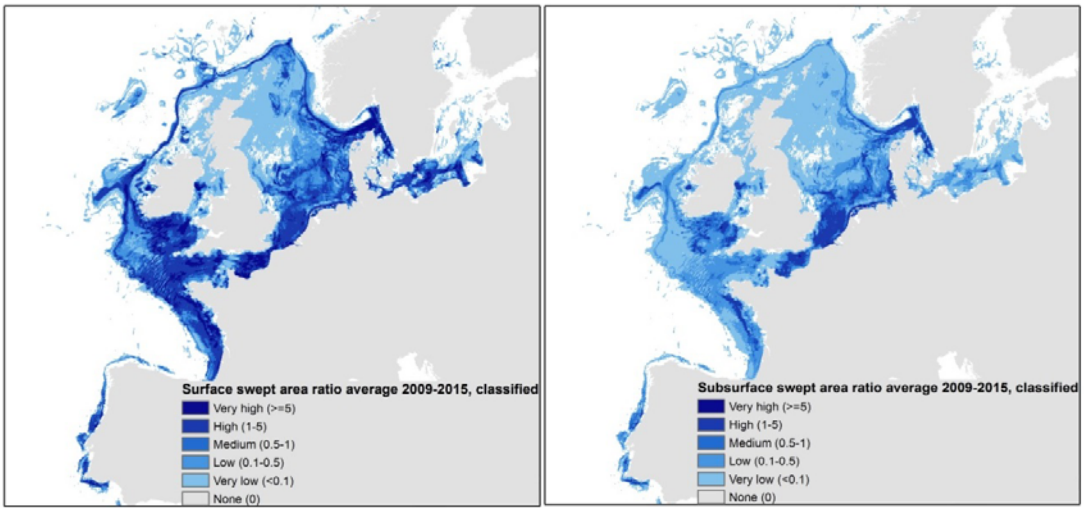

Figure 5.8.3.1. Surface (left) and subsurface (right) abrasion from bottom-contacting fishing gears classified into five categories (from very low to very high) based on swept area ratio estimates.

Because fishing pressure values are available on a 0.05°x0.05° c-square grid, a spatial overlay has been performed assigning the habitat and by this the sensitivity metrics found at the midpoint of each grid cell to the respective fishing pressure category (Figure 5.8.3.2). In order to create the impact map, impact scores had to be assigned to each possible pressure-sensitivity combination. Four sensitivity categories were distinguished in relation to surface abrasion (Figures 5.8.3.3), whereas the sensitivity to shallow abrasion and to penetration had only three categories (Figure 5.8.3.4), both resulting in six impact classes ranging from very low to high.

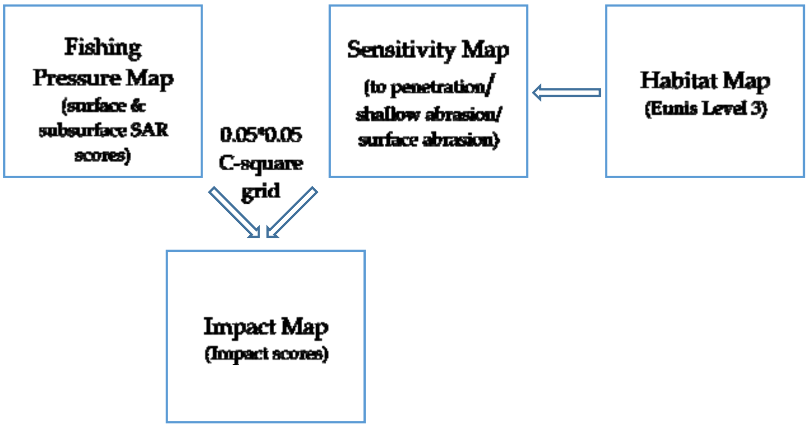

Figure 5.8.3.2. Conceptual diagram describing how categorical impact scores were estimated from the overlay between habitat and the respective sensitivity maps and the fishing pressure maps (expressed as surface or subsurface SAR).

	Sensitivity level to surface abrasion			
Pressure level	**L**	**L-M**	**M**	**H**
None	None	None	None	None
Very low	Very low	Very low	Low	Low-Medium
Low	Very low	Low	Low-Medium	Medium
Medium	Very low	Low-Medium	Medium	Medium-High
High	Very low	Medium	Medium-High	High
Very high	Low	Medium-High	High	High

Figure 5.8.3.3. Impact matrix relating five fishing pressure levels to four sensitivity levels (surface abrasion).

	Sensitivity level to shallow abrasion and penetration		
Pressure level	**L**	**M**	**H**
None	None	None	None
Very low	Very low	Low	Low-Medium
Low	Very low	Low-Medium	Medium
Medium	Very low	Medium	Medium-High
High	Very low	Medium-High	High
Very high	Low	High	High

Figure 5.8.3.4. Impact matrix relating five fishing pressure levels to three sensitivity levels (valid for shallow abrasion and penetration).

Maps of the scores describing the potential impact due to surface abrasion, shallow abrasion and penetration show very distinct patterns (Figure 5.8.3.5). Surface impact scores are mainly driven by the underlying habitat sensitivity scores. Although surface abrasion can be very high, the habitat sensitivity to this pressure is locally low, e.g. in the Wadden Sea, resulting in low to very low impact scores. In contrast to this, deep water habitats are usually highly sensitive resulting in high impact scores, even when the corresponding fishing pressure was comparatively low. Sensitivity scores in relation to shallow abrasion and penetration are usually higher and thus only few areas show a low impact score. Here the impact scores are mainly driven by pressure, i.e. the subsurface abrasion caused by fishing gears. Consequently, highest impacts were estimated in areas where beam-trawling and dredging is taking place, but the main areas for otter trawling, e.g. along the shelf breaks, experience high impact scores as well.

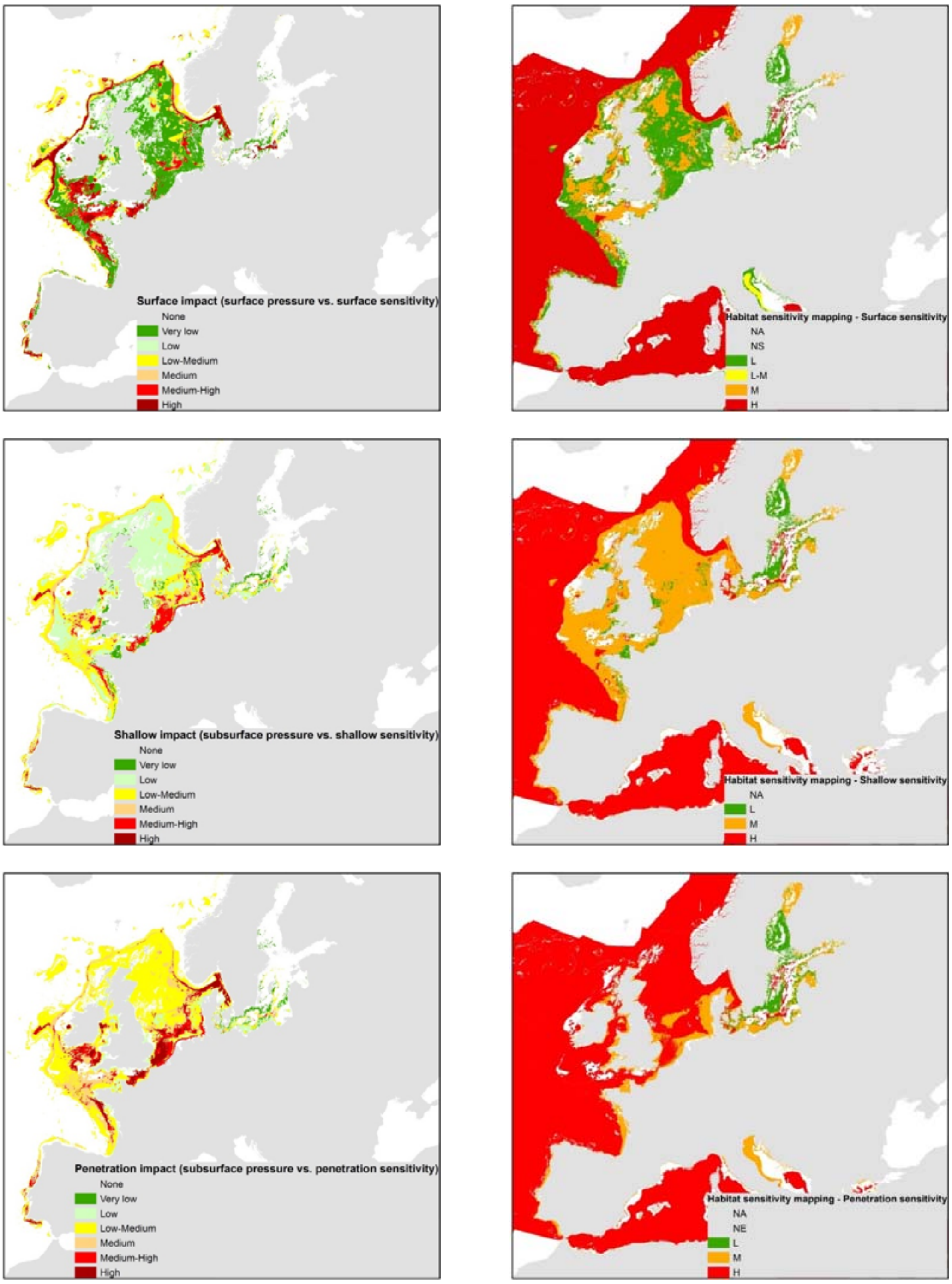

Figure 5.8.3.5. Fishing impact scores (left panels) resulting from the combination of swept area ratio categories (Figure 5.8.3.1) and the habitat sensitivity (right panels) to surface abrasion (upper panels), shallow abrasion (central panels) and penetration (lower panels).

The variability of impact scores over the seven years (Figure 5.8.3.6) was low for most areas but locally a high variability, resulting from variations in fishing effort, was encountered. Surface impact classes hardly changed from one year to the other but for subsurface abrasion highest variability was found in the south-eastern North Sea, mainly driven by changes in beam trawling activities. Before 2012 vessels with a length of 12–15m were not obliged to have VMS on board. Following this legislation change we therefore investigated the variability of impact scores in the three most recent years (2013-2015, Figure 5.8.3.7). The areas with a high variability in impact scores were still detectable, and, according to Figure 5.8.3.7 often showed a slightly decreasing trend. However, because only three years are considered, this only provides a rough indication that the situation might have recently improved.

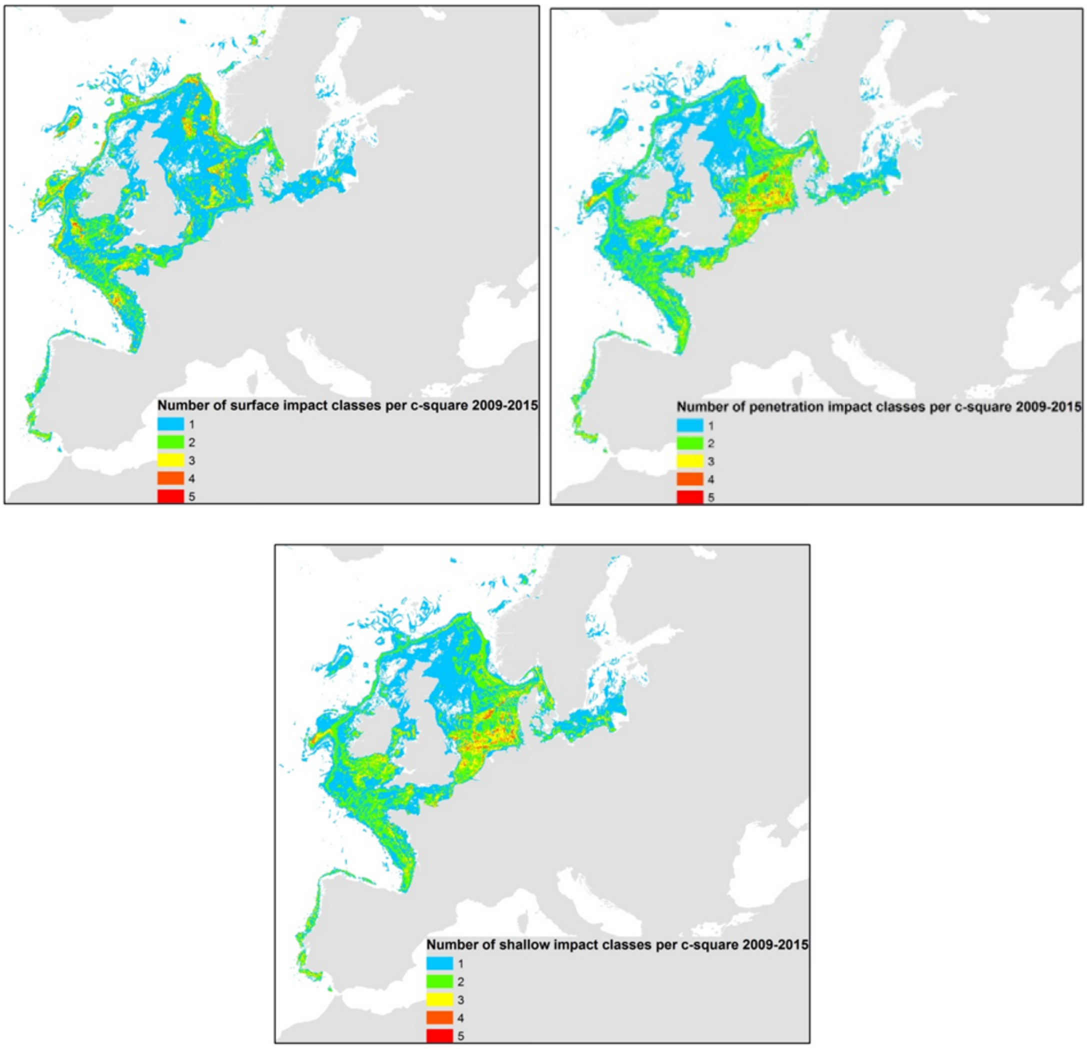

Figure 5.8.3.6. Temporal variability in fishing impact scores caused by surface abrasion (upper left), shallow abrasion (upper right) and penetration (lower left) over the seven year time period (2009–2015). Variability is expressed as the number of different impact classes found within each grid cell. Because habitat is not assumed to change, variability is caused only by variations in fishing pressure.

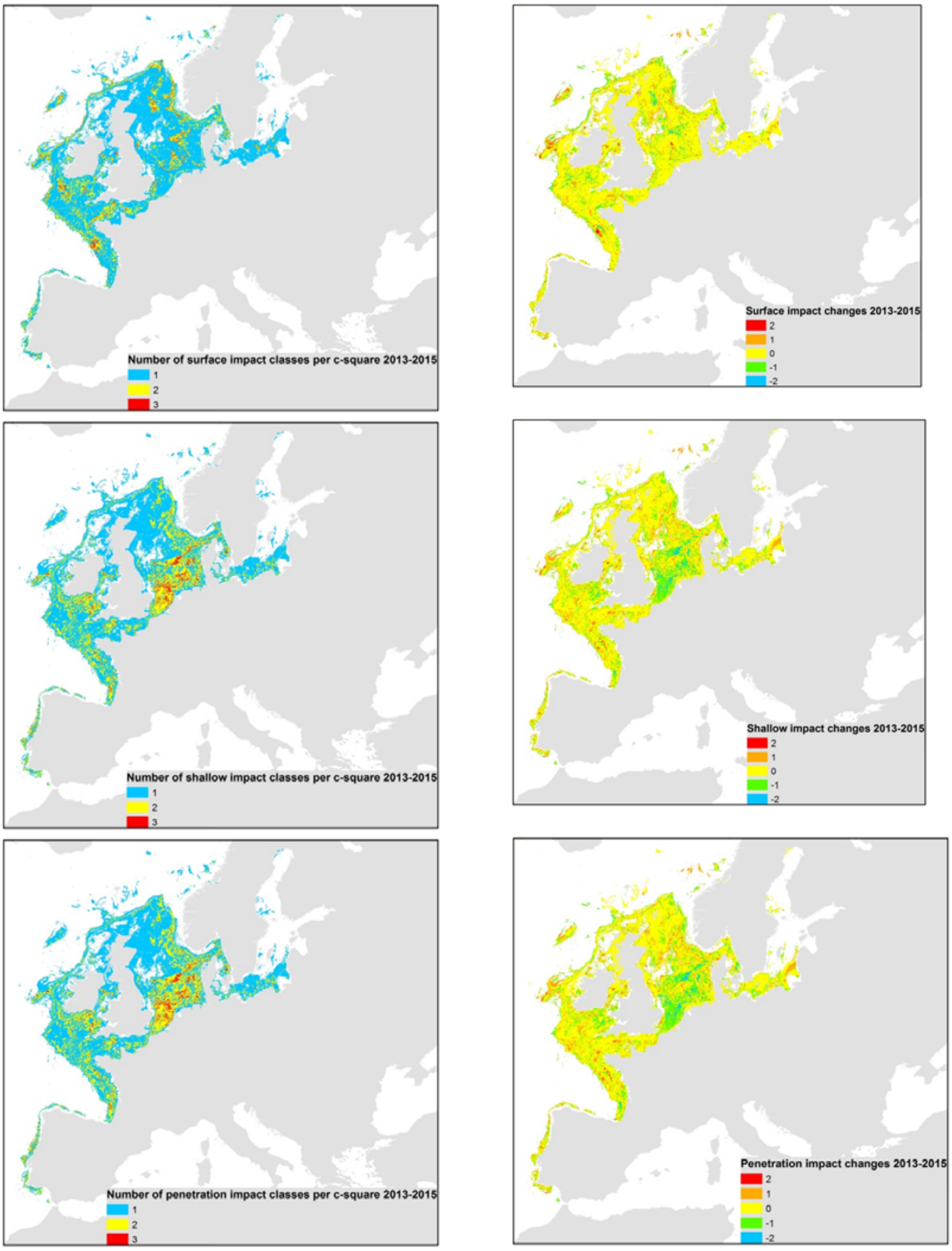

Figure 5.8.3.7. Temporal variability in fishing impact scores caused by surface abrasion (upper panels), shallow abrasion (central panels) and penetration (lower panels) from 2013 to 2015. Variability is expressed as the number of different impact classes found within each grid cell (left panels), as well as the indication of the trend in impact scores, i.e. if it is increasing or decreasing from 2013 to 2015.

In order to investigate the economic importance of areas (grid cells) experiencing a low to high impact score, the catch (in 10^3t) and value of the catch (in Mill. €) was investigated (Figure 5.8.3.8). Most grid cells show a very low to low impact due to surface abrasion and consequently a very high amount of the total catch and value is made within these cells. However, even though fewer grid cells experience a medium-high to high impact the catch and especially the value of the catch from these areas reach similar values. For most of the grid cells, impact scores due to shallow abrasion and penetration were low to low-medium or low-medium to medium, respectively. Highest catches and revenues were made in the few areas experiencing a medium-high impact score in relation to shallow abrasion. Similarly the majority of the catches were made in areas with low-medium to high impact due to penetration. However, the value of the catch from highly impacted areas is very high.

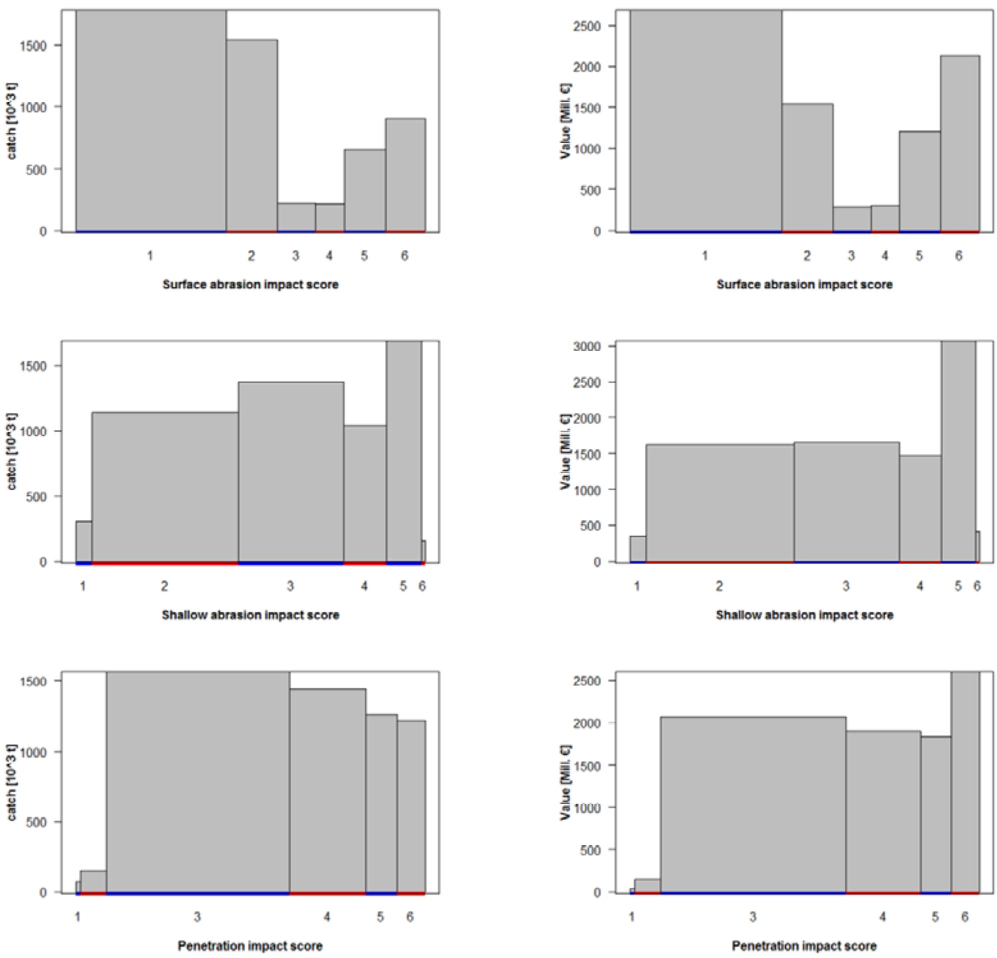

Figure 5.8.3.8. Fisheries catch (in 1000t, left panels) and value (in Mill. €, right panels) from grid cells with the same impact score. Bar width corresponds to the number of grid cells with the respective impact score. Impact Scores correspond to 1 – very low, 2 – low, 3 – low-medium, 4 – medium, 5 – medium-high, 6 – high. Top: Impact scores due to surface abrasion; Centre: Impact scores due to shallow abrasion; Bottom: Impact Scores due to penetration.

5.8.4 Knowledge gaps, caveats and uncertainties

Estimating fisheries impact on benthic habitats involves a number of assumptions. These are partly related to the underlying data of fishing pressure (section 5.8.1) and habitat sensitivity but also depend on the methodology how the information is combined. Generally, the current approach represents a regional assessment, meaning that fine-scale features cannot be resolved.

When using impact scores, categories for habitat sensitivity as well as for fishing pressure are needed. This means that a continuously scaled variable like SAR is converted into an ordinal scale. The underlying uncertainties caused by interval definitions still need to be explored. Further, the definition of the matrix describing the impact scores needs to be assessed by using experimental and field studies in order to improve evidence on the pressure-impact-response relationships.

In the current approach we investigated fisheries impact over the last seven years. However, bottom trawling has been an ongoing activity for more than 100 years and consequently persistent effects on benthic communities need to be expected. This means that sensitive species could have been replaced by opportunistic and less sensitive species over time.

5.8.5 BENTHIS approach

The FP7-project BENTHIS developed two quantitative methods to determine the state of the seafloor depending on trawling pressure and habitat sensitivity: (i) population dynamic approach (Piet *et al.*, in prep); (ii) longevity approach (Rijnsdorp *et al.*, 2016). The methods are fully quantitative and based on empirical information on the effect of bottom trawls on the biomass and composition of the benthic community and avoid the qualitative scaling of habitat sensitivity. Both methods build on the annual swept area ratios at the surface and subsurface layer taking account of the dimensions and rigging of the different bottom trawls following Eigaard *et al.* (2016). BENTHIS used grid cell size of 1 minute x 1 minute grid cells as compared to the 0.05 x 0.05 degree C-squares used by ICES. The methods differ in the way they estimated the sensitivity of the benthic community to the trawling pressure.

5.8.5.1 Population dynamic approach

The state of the seafloor is here assumed to be represented by the benthic community biomass relative to that in an undisturbed situation (B/K). This benthic community biomass can be calculated by solving the logistic population growth model:

Eq. 1 $$\frac{dB}{dt} = rB\left(1 - \frac{B}{K}\right) - dFB$$

for the equilibrium state (i.e. $dB/dt=0$), in which case Eq. 1 has the solution (Pitcher *et al.*, in prep):

Eq. 2 $B/K=1-Fd/r$ (or where $F > r/d$, $B/K=0$)

Since the benthic community is composed of a variety of taxa which differ in their population growth rates, and therefore the effect of trawling is also different for each species, the community biomass is calculated as the sum of the individual species. Here we assume that there are no species interactions and that the r and K values have an exponential distribution, with the sum of K within the community summing to 1, and the mean of r being equal to the r in Table 5.8.5.1. Values of K and r were randomly chosen for 1000 species, and the effect of fishing on the biomass of each species was calculated. The community biomass was then calculated as the sum of the biomass of all individual species. This community biomass can be used as a proxy for the state of the seafloor (Seafloor Integrity SI).

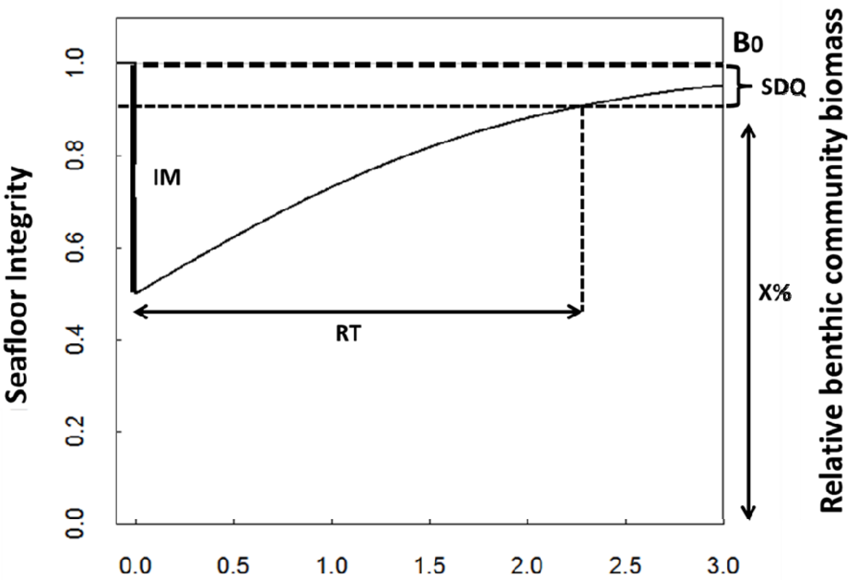

Figure 5.8.5.1 Decrease in benthic biomass following the mortality imposed by a trawling event and the subsequent recovery to the carrying capacity B0. The relative biomass can be used as an indicator of the Seafloor Integrity. IM denotes the proportion at which the biomass is reduced by a trawling event. RT denotes the recovery time to a "significant deterioration of quality" (SDQ) at 90% of the carrying capacity B0 (unimpacted biomass).

Using the mean parameter estimates of d and r from Pitcher *et al.* (in prep.), based on data of Collie *et al.*, 2000 (Table 5.8.5.1), the state of the seafloor was calculated based on the composed benthic community consisting of a variety of taxa (Figure 5.8.5.2). The analysis shows the higher sensitivity of biogenic and gravel habitat. In gravel and biogenic habitats, benthic biomass is already reduced to 90% at relatively low trawling intensities of 0.1 to 0.2. For mud habitats, the trawling intensities which result in a reduction in biomass to 90% is between 0.3 - 0.6. For sand, the trawling intensity is between 0.6 and 0.9. The results also show the consequences of the higher depletion rate of dredge and beam trawling.

Defining GES as a community biomass of 80%, 90% or 95% of its carrying capacity, our quantitative model gives the corresponding trawling frequency thresholds (Table 5.8.5.1). In the most common habitat in the North sea, i.e. Sublittoral sand covering almost 60% of the area, a 90% threshold would allow a patch to be fished with a beam trawl less than once every year (Sustainable trawling frequency < 0.87 y^{-1}). In contrast, in case of the application of an otter trawl (OT) in a gravel habitat, this same 90% deterioration in quality threshold would determine any fishing intensity <0.14 yr^{-1} compatible with GES.

When this method is applied to average trawling frequencies in the Greater North Sea over the years 2009–2015, the following map was obtained. The map shows the equilibrium biomass given the average annual bottom trawling intensity by all European fishing nations at a scale of 0.05 degrees longitude and latitude. Although different gears can be active within the same area, all bottom fisheries were classified as otter trawling. Habitat characteristics were obtained from a shapefile compiled within the BENTHIS project that provided a EUNIS habitat for each grid cell used in the calculation. These EUNIS habitats were thereafter converted to categories: gravel, sand, mud and biogenic to link with the parameters in Table 5.8.5.1. A lookup table, representing equilibrium community biomass at different fishing intensities, was used to show final SIs on a geographical map.

Table 5.8.5.1. Mortality (d) and Recovery rate (r) values for the different gear habitat combinations and corresponding trawling frequencies that result is four levels of "significant deterioration of quality" (SDQ); (Piet *et al.*, in prep).

Habitat	Gear	d	r (y^{-1})	Trawling frequency at which the benthic biomass is reduced to a specific level relative to the carrying capacity			
				80%	90%	95%	99%
Biogenic	OT	0.39	3.03	0.44	0.17	0.06	0.01
Gravel	OT	0.48	3.03	0.36	0.14	0.05	<0.01
Sand	OT	0.37	15.59	2.28	0.93	0.39	0.06
Mud	OT	0.27	6.39	1.59	0.64	0.26	0.03
Biogenic	BT	0.45	3.03	0.46	0.19	0.09	0.01
Gravel	BT	0.53	3.03	0.36	0.14	0.06	0.01
Sand	BT	0.43	15.59	2.17	0.87	0.40	0.06
Mud	BT	0.33	6.39	1.18	0.43	0.17	0.02
Biogenic	TD	0.67	3.03	0.28	0.11	0.04	<0.01
Gravel	TD	0.72	3.03	0.24	0.09	0.04	<0.01
Sand	TD	0.66	15.59	1.55	0.60	0.25	0.04
Mud	TD	0.61	6.39	0.62	0.25	0.10	0.02

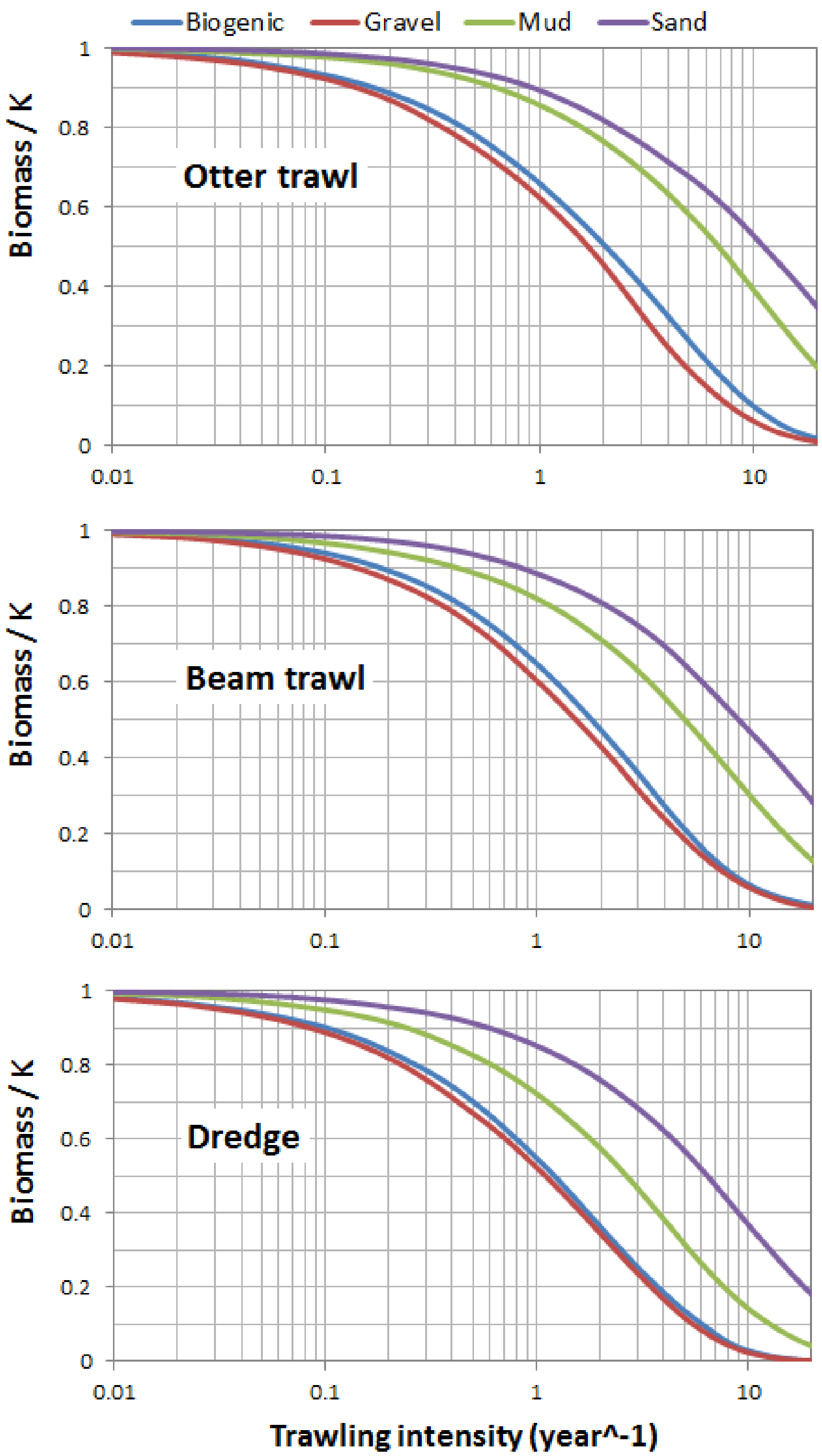

Figure 5.8.5.2. State of the seafloor, i.e. Seafloor Integrity (Biomass /K), at different trawling intensities for three trawling gears (Otter trawl, Beam trawl and Dredge) and four habitats.

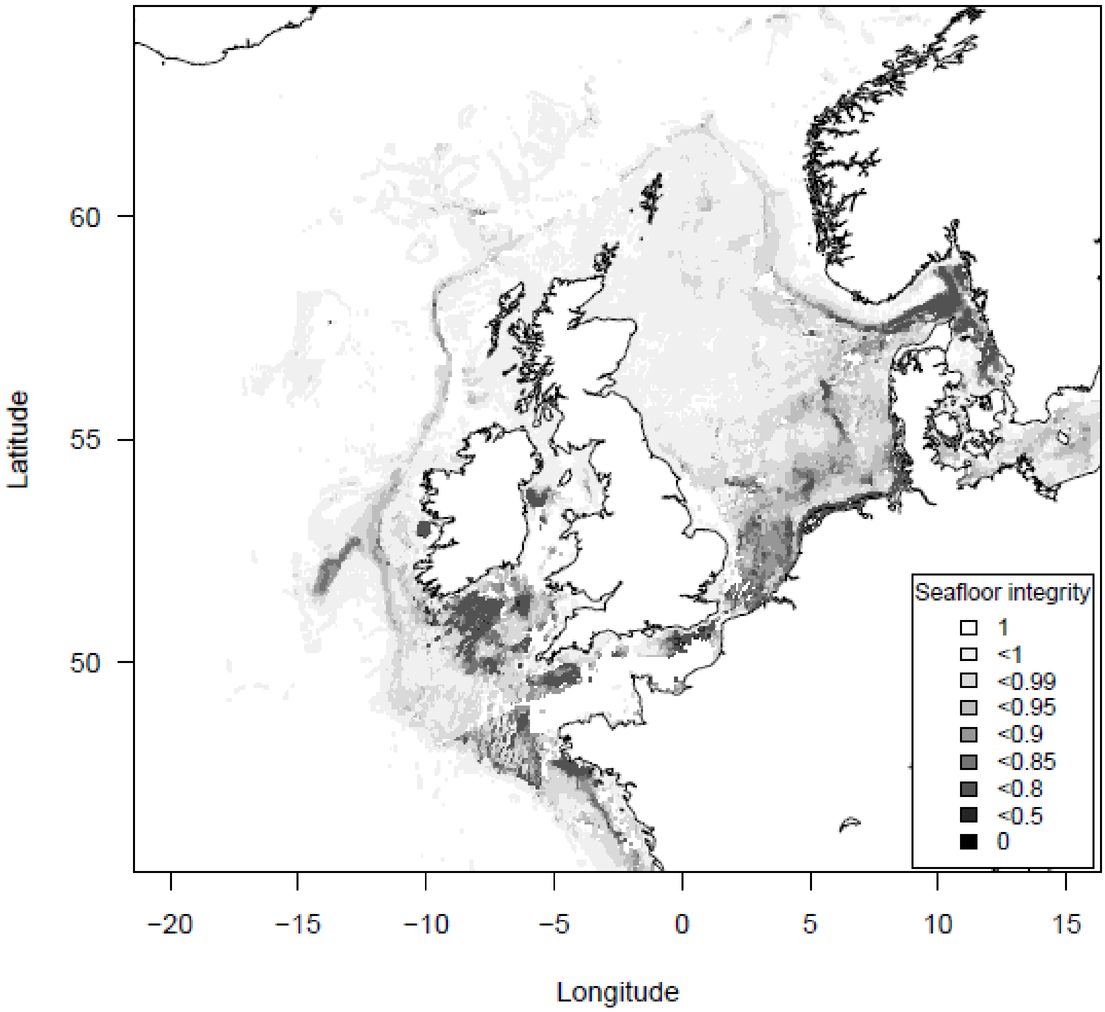

Figure 5.8.5.3. Equilibrium biomass (B/K) remaining in the Greater North Sea given the mean annual subsurface bottom trawling intensities observed between 2009–2015.

5.8.5.2 Approach based on longevity

In this approach, the sensitivity of the sea floor is estimated from the longevity distribution of the benthic community that is typical for a sea floor habitat (Rijnsdorp *et al.*, 2016). The impact of bottom trawling on sea floor was estimated by combining trawling intensity with the longevity distribution of the benthic community. If the reciprocal of the trawling intensity, which reflects the average time interval between two successive trawling events, is less than the life span of an organism, the integrity of the sea floor habitat to allow the species to complete its full life cycle will be compromised (Thrush *et al.*, 2005).

Because the longevity equals the reciprocal of the trawling intensity $(\frac{1}{t})$, seafloor integrity can be estimated as the cumulative biomass proportion of the benthic community where the reciprocal of the trawling intensity $(\frac{1}{t})$ is larger than the longevity of the taxa:

Eq(2) $SI = \exp(\alpha + \beta\left(\ln\frac{1}{t}\right)/(1 + \exp(\alpha + \beta\left(\ln\frac{1}{t}\right))$

α and β are the coefficients of the logistic regression of the cumulative biomass against the $\log_e$ of the life span of the taxa.

The sea bed integrity of a habitat or management area can be obtained by adding up the sea bed integrity indices over the grid cells and dividing by the surface area of the habitat or management area.

Longevity distribution of benthos in untrawled habitats

Differences in the longevity composition of the benthic community across seafloor habitats were estimated using benthic samples collected in the North Sea and Channel. One data set comprise of infaunal samples taken at 304 stations in the waters of England (Bolam *et al.*, 2014). The second data set comprise of infaunal samples taken annually on about 100 stations on the Dutch continental shelf (van Denderen *et al.*, 2015, van Denderen *et al.*, 2014). For each sampling station, the EUNIS-3 habitat was determined based on the depth and sediment characteristics. The trawling intensity for each station was estimated by the swept area ratio of the corresponding 1x1 minute grid cell of four bottom trawl metiers (dredge, otter trawl, seine, beam trawl) in the period 2010–2012 (Eigaard *et al.*, submitted). We assumed that the trawling gradient observed in this period reflected the differences in trawling intensity of the stations sampled in other years. The longevity composition was estimated by assigning the longevity (<1, 2–3, 5–10, >10 years) by taxon as compiled by Bolam *et al.* (2014).

To estimate the biomass in relation to longevity a logistic regression was fitted through the cumulative biomass (B) in relation to $\log_e$ transformed longevity (L) and taking account of the EUNIS_3 habitat (H) and the $\log_e$ trawling intensity (F) using the following random mixed effect model:

Eq(3) $B \sim a + b_1 L + H + b_2 L^*H + b_3 F + b_4 F^*H + \varepsilon_1 +$

$\text{random(station intercept and slope)} + \varepsilon_2$

We used a mixed effect model to take account on the dependency of the cumulative biomass estimates for each station. The ε_1 represents a binomial error. $\varepsilon 2$ represents the normally distributed error of the random effect on the intercept and slope by station. For stations with zero trawling, a trawling intensity of 10^{-3} was assumed, corresponding to the lowest observed trawling intensity. The random mixed effect model was estimated using library lme4 in R version 3.02.

The analysis showed a significant difference across habitats in both the intercept and slope of the cumulative biomass in relation to the longevity of the taxa (Table 5.8.5.2). The benthos community of the coarse sediment habitat A5.1 showed a larger proportion of long-lived species. A5.3 showed the lowest proportion of long-lived species. Habitats A5.2 and A5.4 were intermediate (Figure 5.8.5.4). Trawling intensity showed a significant negative effect on the proportion of long-lived species as illustrated with the dashed relationships.

Table 5.8.5.2. Parameter estimates of the effect of EUNIS_3 habitat and $\log_e$ trawling intensity on the logistic relationship between the cumulative biomass of the infauna community and the $\log_e$ transformed longevity of the contributing taxa. Parameters were estimated using a mixed effect model with sampling stations and the slope of the relationship as random effects.

	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-4.43714	0.36551	-12.140	< 2e-16 ***
$\log_e$ longevity (ll)	2.81834	0.21608	13.043	< 2e-16 ***
as.factor(Eunis_3)A5.2	-1.37804	0.45147	-3.052	0.002270 **
as.factor(Eunis_3)A5.3	-0.99355	0.61474	-1.616	0.106046
as.factor(Eunis_3)A5.4	0.48277	1.01179	0.477	0.633260
lfreq	0.10936	0.03719	2.941	0.003273 **
ll:as.factor(Eunis_3)A5.2	0.99395	0.26780	3.712	0.000206 ***
ll:as.factor(Eunis_3)A5.3	1.10568	0.42025	2.631	0.008514 **
ll:as.factor(Eunis_3)A5.4	0.04438	0.61888	0.072	0.942827

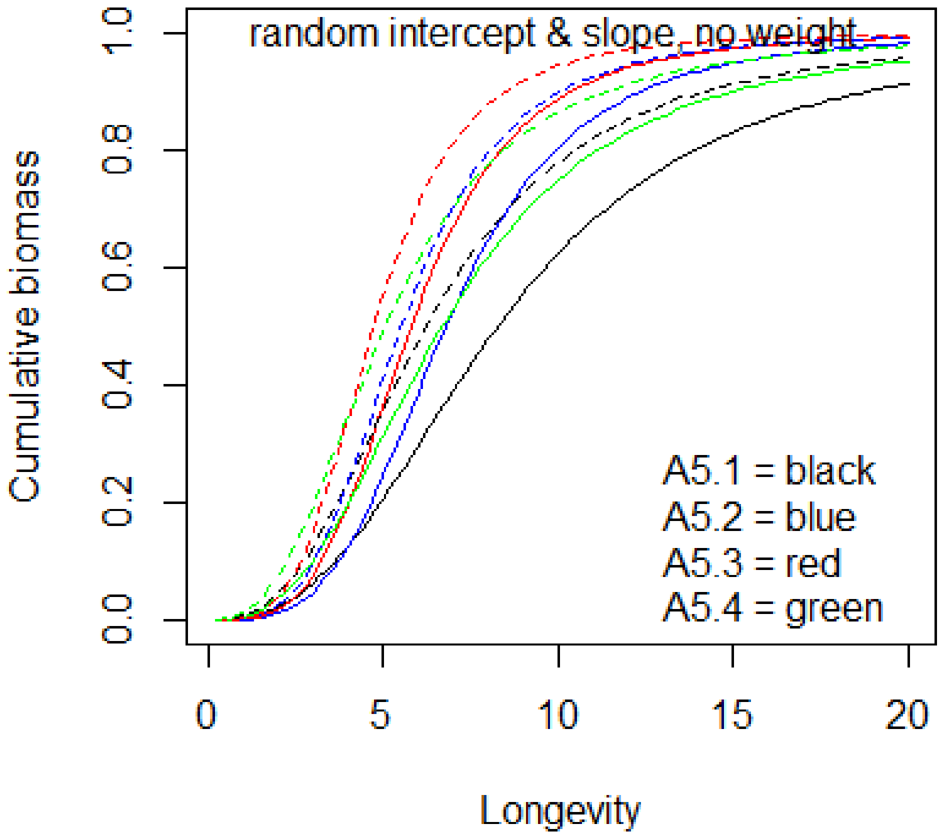

Figure 5.8.5.4. Cumulative biomass in relation to the longevity of the taxa for four EUNIS-3 habitats: sublittoral coarse sediment (A5.1); sublittoral sand (A5.2); sublittoral mud (A5.3); sublittoral mixed sediments (A5.4) for two levels of trawling pressure (full line - un-fished, dashed line - trawled 1x per year). Data: Bolam *et al.* 2014; van Denderen *et al.* 2015. Preliminary result from the BENTHIS project.

With the parameter estimates of the longevity distributions given in Table 5.8.5.2, the seafloor integrity of each grid cell in the North Sea was estimated given the observed annual trawling frequency and its habitat classification over the past 7 years provided that all nations adjacent to the North Sea provided information on swept area by gear. Habitat characteristics were obtained from a shapefile compiled within the BENTHIS project that provided a EUNIS habitat for each grid cell used in the calculation. These EUNIS habitats were thereafter converted to categories: EUNIS A5.1, 5.2, 5.3 and 5.4. All EUNIS habitats lower than 5.1 were classified as 5.1 and all EUNIS habitats higher than 5.4 were classified as 5.3.

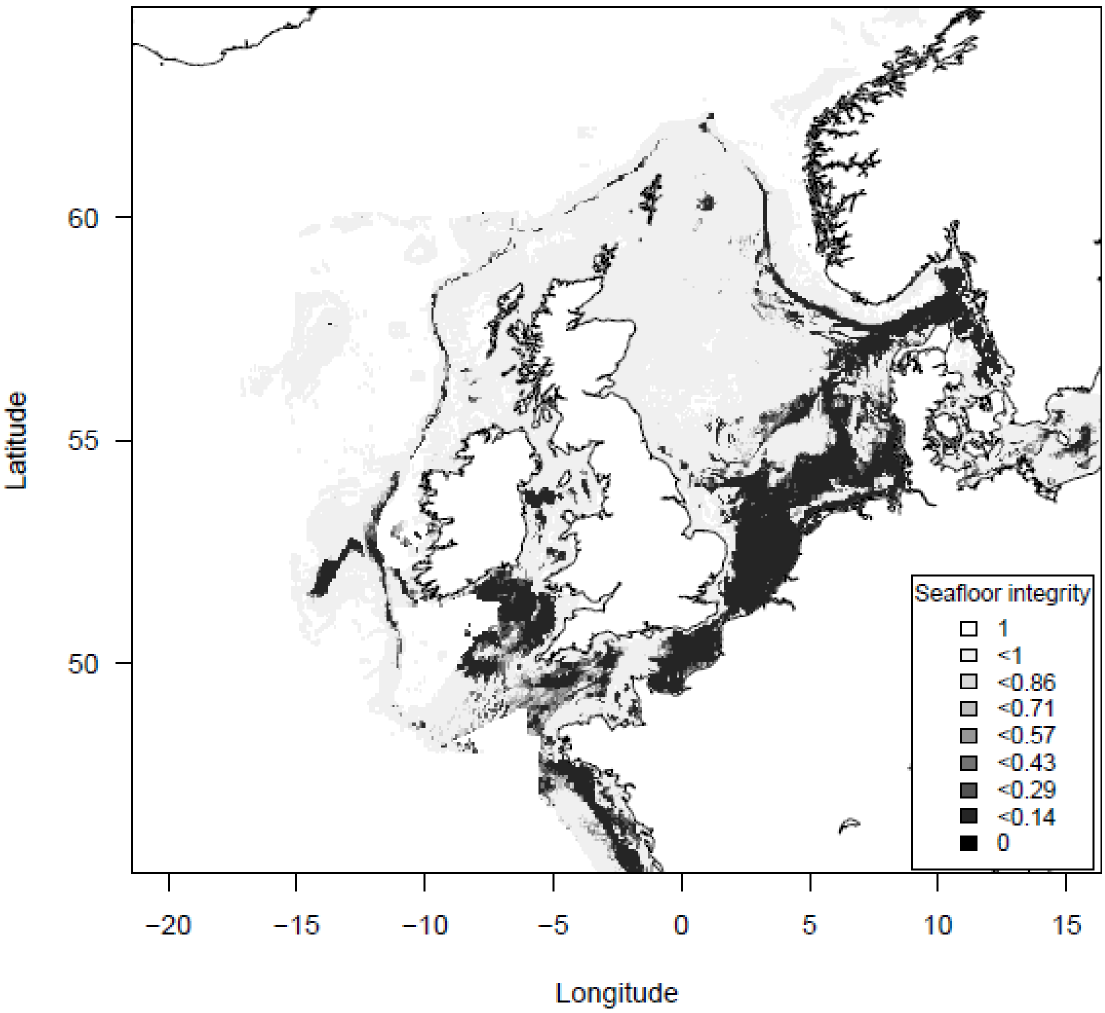

Figure 5.8.5.5. Seafloor integrity in the Greater North Sea estimated using the longevity distribution by habitat and the mean annual subsurface bottom trawling intensities observed between 2009–2015.

5.8.5.3 Discussion

The two approaches developed in BENTHIS allow us to estimate Seafloor Integrity on a continuous scale without the need to classify fishing pressure and habitat sensitivity.

The longevity approach is a rather simple quantitative approach which necessarily makes a number of rather strong assumptions. The key assumption is that the sensitivity of the benthic community can be estimated from its longevity distribution. It is well established that bottom trawling reduce species composition of the community towards short-lived species. Indeed, the analysis of the grab and boxcore samples collected in the North Sea and Channel, showed a significant effect of trawling intensity on the longevity distribution of the community. A second assumption is that the cumulative longevity distribution can be modelled as a log-linear logistic relationship. We are unaware of an established theoretical model of the longevity distribution of communities. Although the choice for a log-linear logistic relationship is an arbitrary choice, the fitted relationship showed a good fit to the data and is considered a useful step to convert the factorial longevity classes into a continuous scale. We are aware of the fact that the longevity of individual taxa is rather poorly known. Nevertheless, because of the wide variation in longevity, the uncertainty in the longevity estimation on the level of the taxa will not affect the estimated longevity distribution of the community.

The method applied here is a first attempt that can be refined. If sufficient data are available on the benthic community, the longevity distribution could be estimated for only those taxa that come into contact with the fishing gear. The longevity distribution of the habitats was estimated based on grab and boxcore samples representing the infaunal community. Whether this also represents the longevity distribution of the epibenthos remains to be studied. Further investigations of the differences in the longevity distribution between the epifaunal, shallow infaunal and deeper infaunal communities of various seafloor habitats will allow a more refined estimate of the seafloor integrity which can be coupled to surface, shallow and deep penetration trawling intensities.

The seafloor integrity estimate based on the longevity distribution of the untrawled habitat assumes that the taxa with a longevity exceeding the interval between two trawling events will already be impacted by bottom trawling. Because taxa with a longevity of 10 years or more comprise around 10% of the benthic biomass, a trawling intensity of >0.1 will reduce the seafloor integrity to values below 0.9.

A seafloor integrity estimated with the longevity approach does not imply that habitats with a low seafloor value of less than 0.9, however, does not imply that the seafloor habitat will be devoid of long lived taxa. Only if the trawling interval between two trawling events will approach the time required till the first reproduction, taxa may no longer be able to survive. With trawling intensities that corresponds to a trawling interval between the age at maturation and the maximum life span, we may expect taxa to survive although at a reduced population size. The longevity based seafloor integrity thus can be considered to be a worst case indicator. An alternative indicator of seafloor integrity can be estimated using the same rationale but replacing the longevity distribution of the community by the distribution of the age at maturation. BENTHIS currently explores further improvements of this methodology.

The seafloor integrity estimated using the population dynamic approach quantitatively takes account of the mortality induced by trawling and the recovery during the time interval between two successive trawling events. It can be considered to be a more realistic representation of how bottom trawling affect the benthic community. The sensitivity of the habitat is a result of the available empirical data on the mortality induced by bottom trawling and the recovery rate of the taxa. An update on the meta-analysis of Collie *et al.*

(2000) and Kaiser *et al.* (2006) is currently being conducted which is expected to provide improved estimates of these parameters.

The results presented here are a preliminary illustration of the potential application of the population dynamic approach to provide a quantitative and generic underpinning of the seafloor integrity. Further research is required to study the sensitivity of the results for the various assumptions made. Nevertheless, the potential of the method is illustrated by the estimated trawling intensities which will reduce the biomass to a certain threshold level. These results provide a quantitative basis for the thresholds of fishing pressure and benthos sensitivity as required in the sensitivity matrix approach.

5.9 ToR h: Request from WGDEC on fishing activities at VME habitats

WGSFD ToR h): Using NEAFC VMS and catch data, describe "fisheries activities in and in the vicinity of such (VME) habitats" (areas defined by WGDEC) within the NEAFC Convention Area in 2015. If possible, descriptions should be made of each area near such habitats, and separate each bottom contact gear type (e.g. static or mobile gears)

The response to this ToR will be used to answer part of the NEAFC request "NEAFC requests ICES to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fishing activities in and in the vicinity of such habitats, and provide advice….". WGDEC has supplied a list of areas where such habitats occur.

This aims to improve quality/resolution of raw VMS and linked catch data with the purpose to better facilitate future analysis of fisheries activities in and in the vicinity of such (VME) habitats within the NEAFC Convention Area.

Also, provide a technical document that can be used to discuss a revision of the NEAFC VMS agreement with ICES, and ANNEX VII (4) of the NEAFC Scheme of Control and Enforcement (Jan–Jun 2015)

Data processing

Only VMS data transmitted from within the NEAFC Convention Area was used, including both entry and exit positions, as well as the regular polls. VMS data was linked to vessel, gear and catch information using unique identifiers which were assigned to vessels for a six-month period. Where possible VMS data was linked with information on each vessel's gear type and separated into static gears, active bottom gears and mid-water gears. Where it was not possible to establish this link, due to mismatching records, VMS data was excluded from further analysis. For the active gears a speed filter was applied; from those records, only data where the reported vessel speed was between 1 knot and 6 knots were used as a proxy for fishing activity in the calculations below.

Point data on occurrence of VME indicator species was provided to the group, however, without expert knowledge, the relative significance of this information was difficult to interpret. Results were compared to the NEAFC VME and bottom fishing areas, downloaded from the FAO VME Database (http://www.fao.org/in-action/vulnerable-marine-ecosystems/vme-database/en/).

Exploration of data revealed static gears were only used in NEAFC Reporting Areas 2 and 3 ("Banana Hole" and "Loop hole"). There are no VME areas defined in these reporting areas therefore static gears were not further considered.

Fishing with mid-water gears (midwater trawl - OTM, and purse seine - PS and PS1) was carried out extensively in NEAFC Regulatory Area 1 during 2004–2014, and was associated with catches of redfish, blue whiting, mackerel and herring (figure 5.9.1).

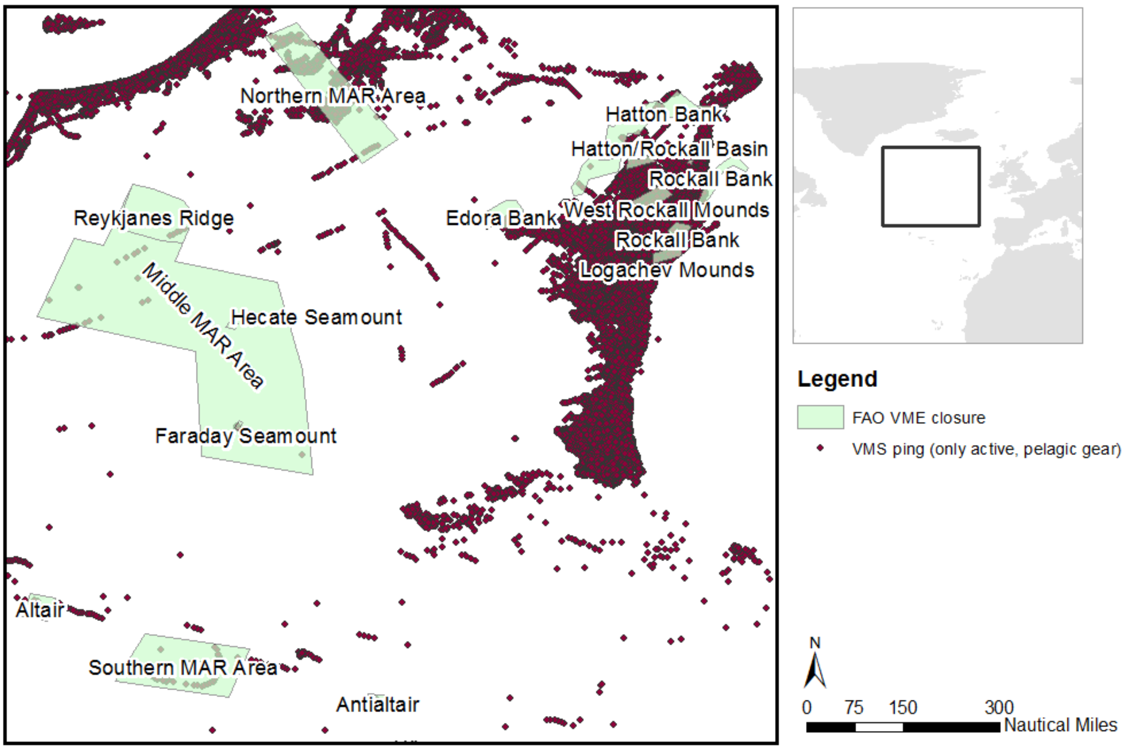

Figure 5.9.1. Distribution of positions of vessels with active, pelagic gear registered in and around the VME (Vulnerable Marine Ecosystem) closures, in the NEAFC area, from VMS data.

The distribution of fishing activity with midwater gear appears to bear no spatial relationship with the VME closures. Mid-water gears are not designed to contact the seafloor in the normal course of fishing operations, therefore are not subject to the prohibition of fishing activities in VME areas laid out in NEAFC Recommendation 19-2014.

Data for active, bottom-contacting gears from the 2004–2014 data was processed further. Firstly, tows were interpolated between consecutive VMS pings at fishing speeds, as straight lines (Figure 5.9.2). Subsequently, tow density was calculated in GIS as the total number of tows per unit area using a search radius of 2000 m. This was necessary because plotting of all individual VMS pings as points resulted in a cluttered data visualization which obscured small scale patterns of variation (Figure 5.9.3).

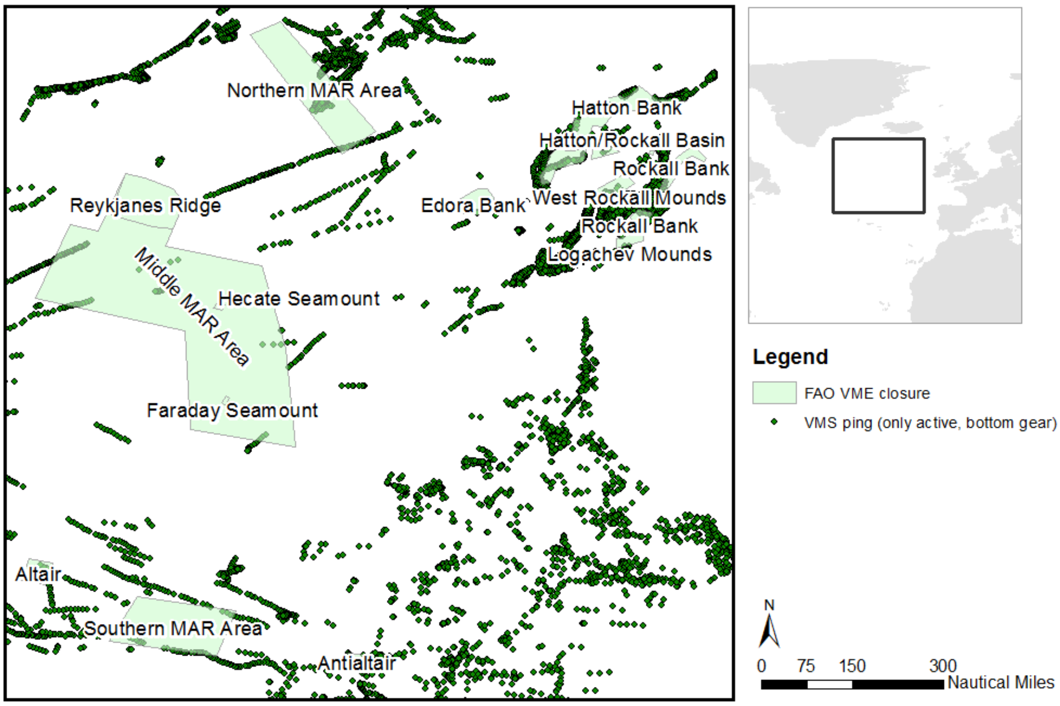

Figure 5.9.2. Distribution of positions of vessels with active, bottom-contacting (demersal) gears registered in and around the VME (Vulnerable Marine Ecosystem) closures, in the NEAFC area, from VMS data (for speeds between 1 and 6 knots).

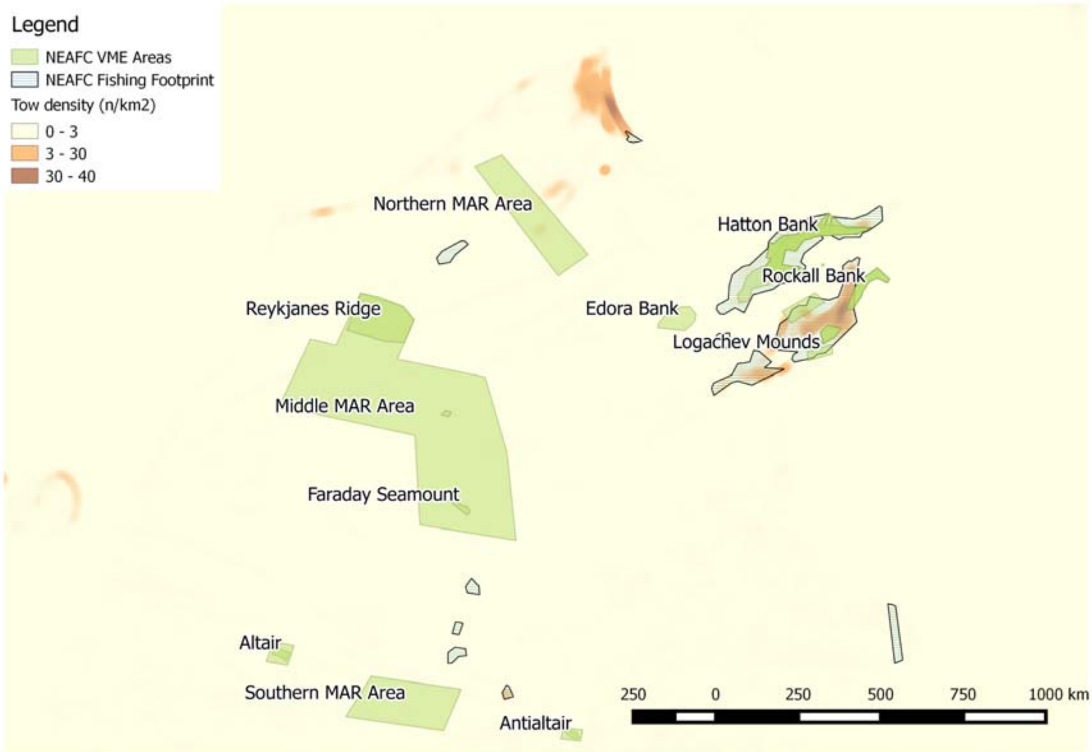

Figure 5.9.3. Distribution of tow density in relation to the NEAFC VME and fishing footprint areas.

Examination of the data reveals the vast majority of bottom fishing has taken place within the NEAFC fishing footprint, but outside the VME areas. An area of high fishing activity is found to the southwest of the Icelandic EEZ, on the western side of the Mid-Atlantic Ridge. Examination of associated catches showed this fishery to report catches of redfish, and given the depth of water in this region (1500–2500m) and the direction of trawling with respect to the bathymetry, it is suspected that these vessels were fishing with pelagic gears for beaked redfish (*Sebastes mentella*) and have been mis-coded in the database.

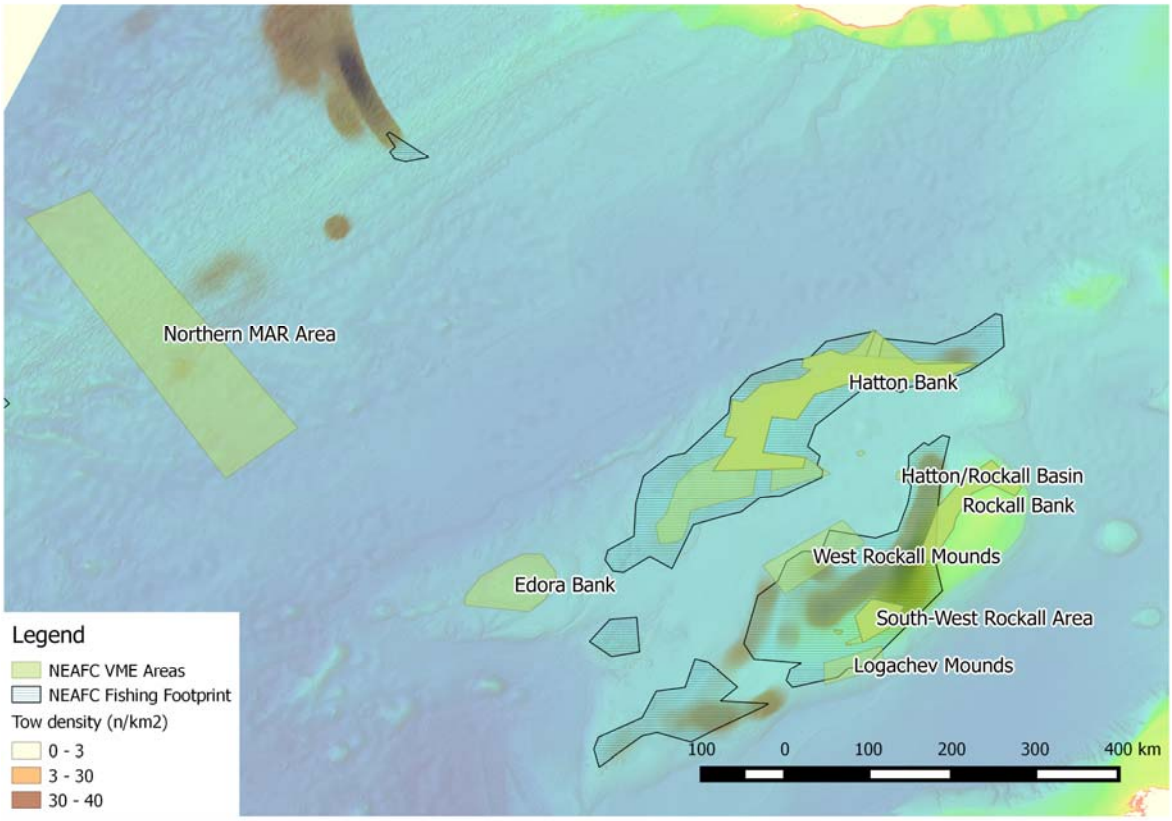

Figure 5.9.4. Distribution of tow density in relation to the NEAFC VME and fishing footprint areas overlaid over the bathymetry, for the Northern MAR area, and Hatton and Rockall banks.

Some fishing by active bottom gears was recorded inside the Northern MAR area (four vessels, although one never reported any catches). These vessels were fishing for *Sebastes mentella*. All intrusions took place in May 2009, shortly after the introduction of the closure.

When examining the data for 2015, it was noted that approximately 25% of pings reported a speed of zero. Having considered the spatial distribution of these points, this was felt to be unlikely to represent a real phenomenon and more likely to be a technical problem with the data. As a consequence, a “derived speed” was calculated for each VMS position, based on the great circle distance between consecutive points, and the elapsed time between them. Data was filtered to exclude vessels using static or pelagic gears, and a raster of fishing effort (time between consecutive pings at speeds of 1–5 knots) prepared, with a cell size of 0.05° (Figure 5.9.5a). Fishing appears to be concentrated on the southern and western slopes of Rockall Bank, and to the north of Hatton Bank (figure 5.9.5b). In the mid-Atlantic area, a fishery for redfish around the limits of the Icelandic EEZ takes place, however as previously stated, the water depth in this area, and the catch being composed entirely of redfish, leads to the conclusion that this is midwater trawling which has been miscoded. A further fishery takes place to the east of the ridge, in waters around 1500–1700m deep, catching a mixture of redfish, grenadiers and black scabbardfish. This may represent a bottom fishery. There was no evidence of fisheries around the other seamounts of the NEAFC regulatory area in 2015.To validate this approach and to visualise the general direction of fishing activity, consecutive pings at fishing speeds were aggregated into putative tows and plotted (Figure 5.9.6a).

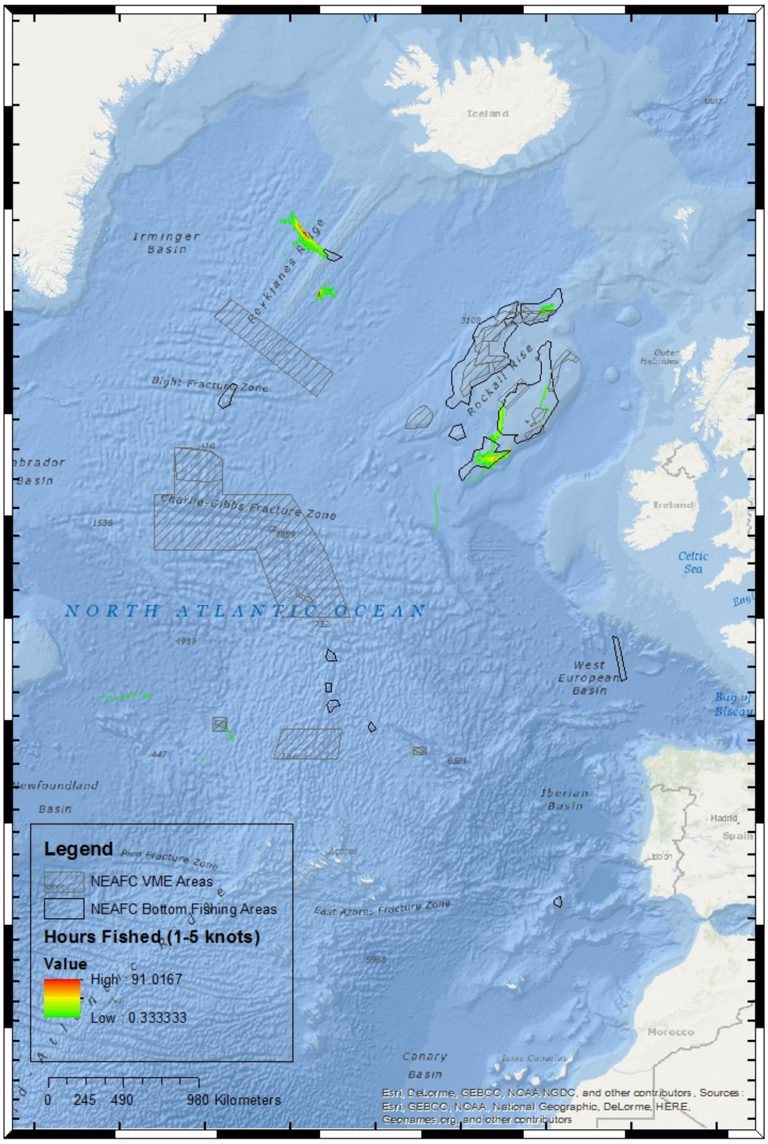

Figure 5.9.5a. Distribution of bottom fishing activity in the NEAFC regulatory area during 2015.

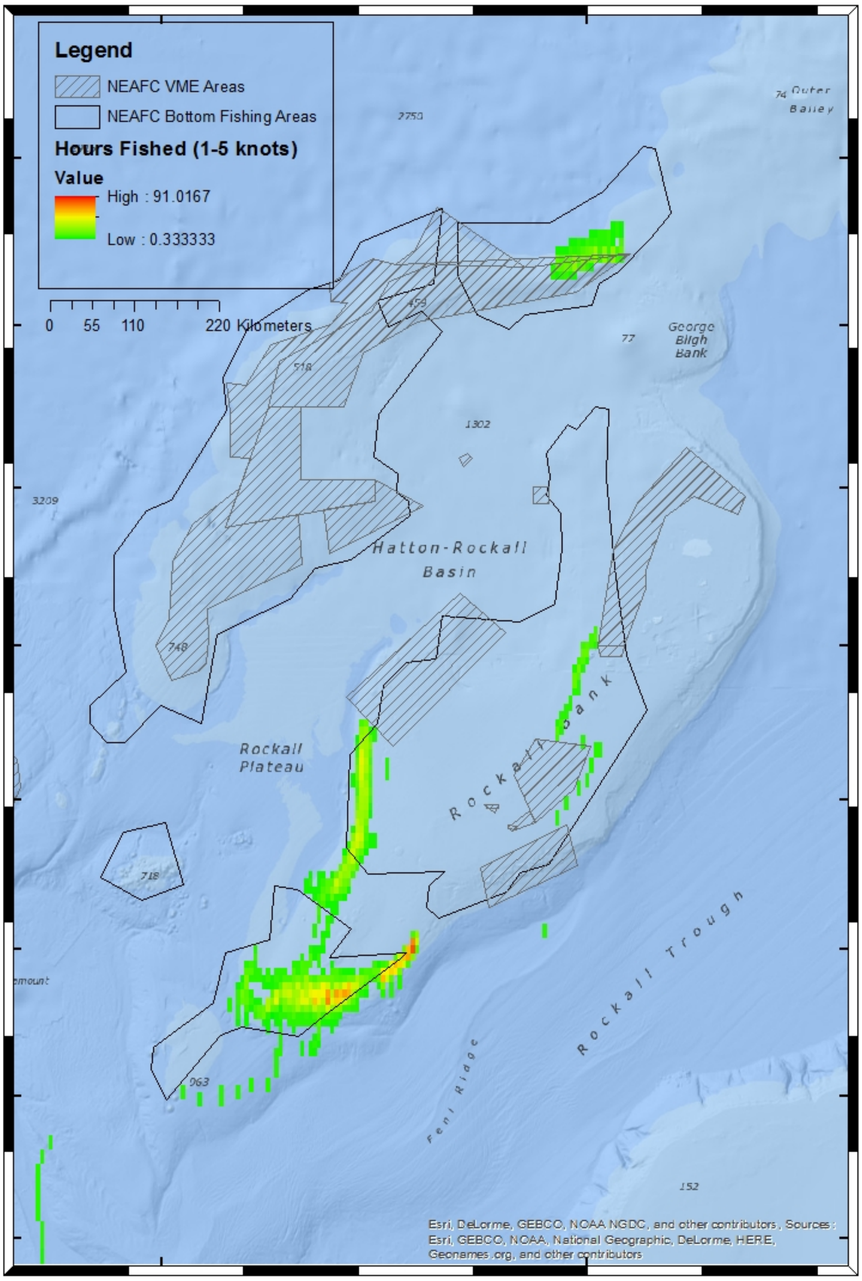

Figure 5.9.5b. Bottom fishing activity at Rockall and Hatton Bank during 2015.

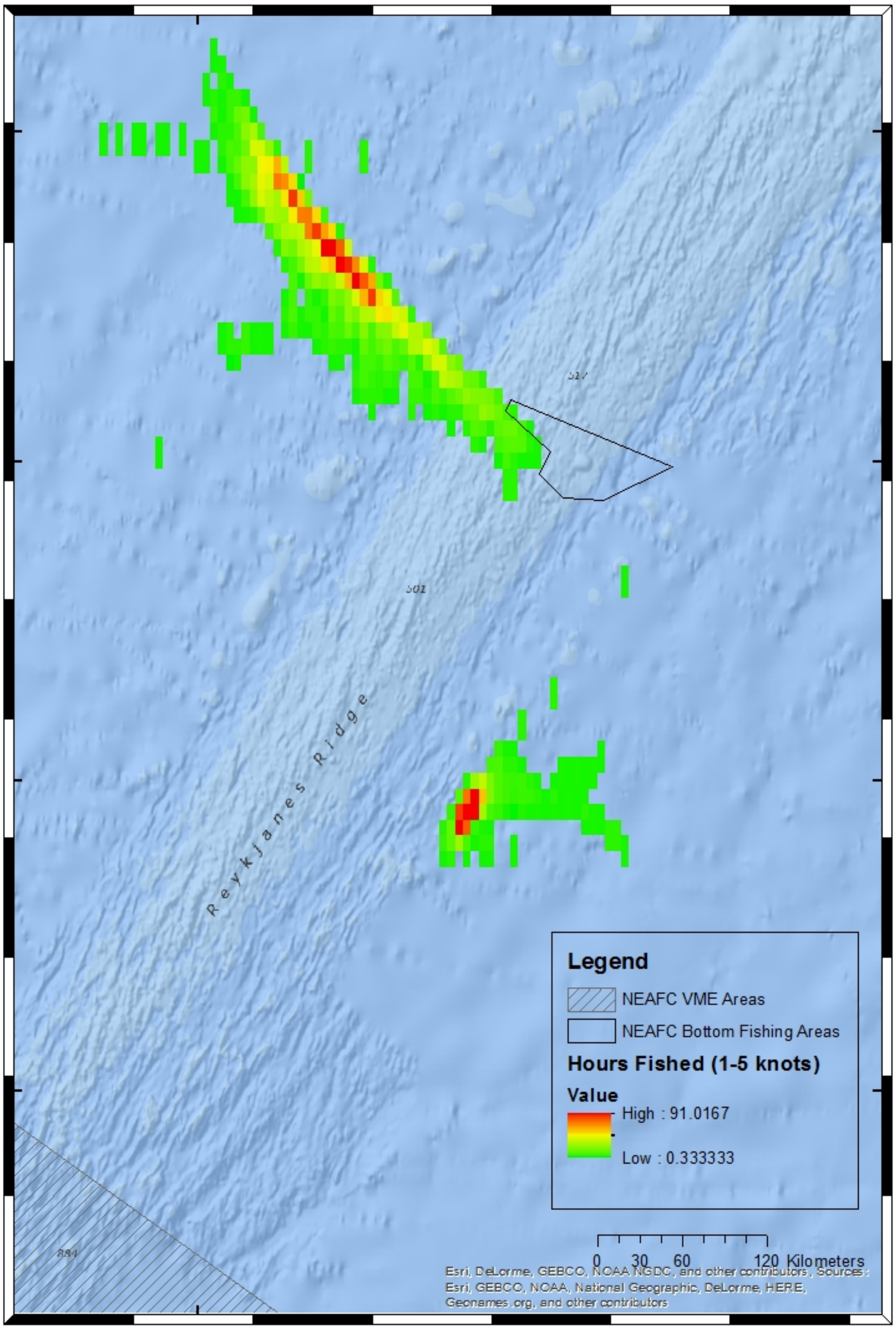

Figure 5.9.5c. Bottom fishing activity at Rockall and Hatton Bank during 2015.

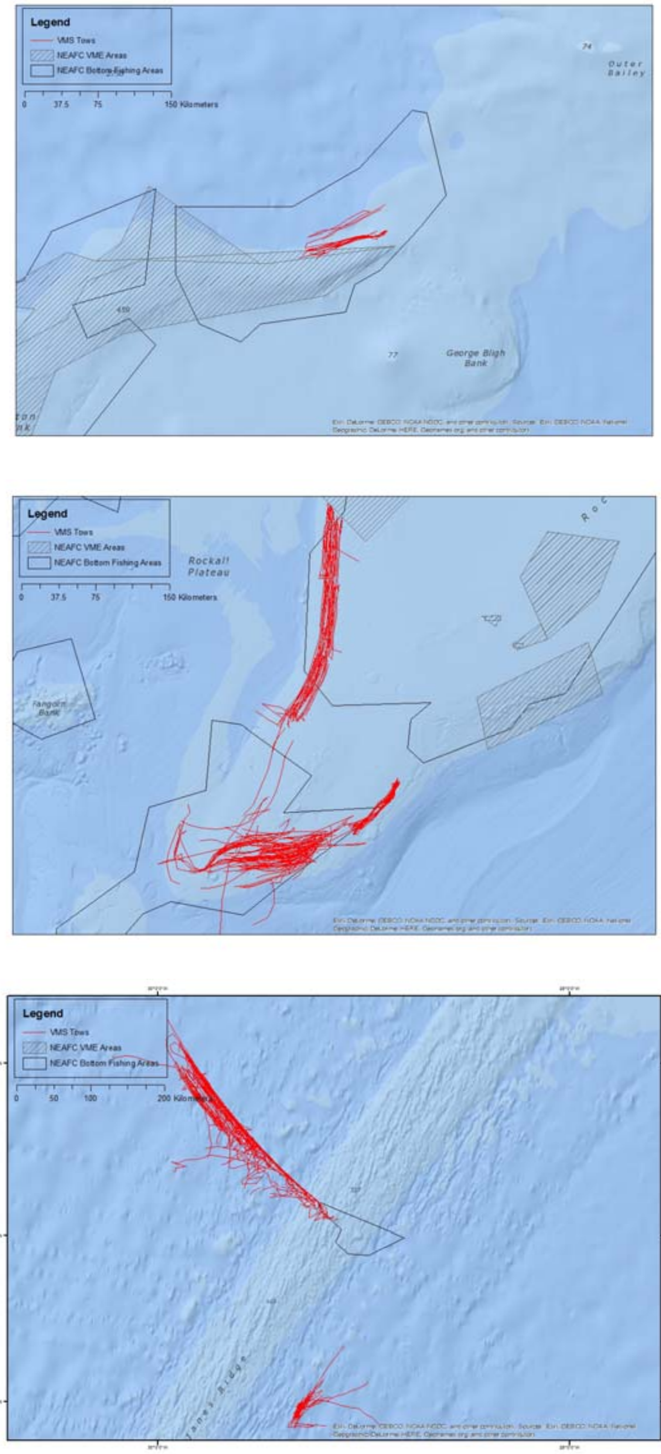

Figure 5.9.6. Direction of tows on Hatton Bank (top), Rockall (Centre) and around the mid-Atlantic ridge (bottom).

In order to inform the discussion of any potential revision of the NEAFC VMS agreement with ICES, and ANNEX VII (4) of the NEAFC Scheme of Control and Enforcement (Jan–Jun 2015), the group detailed the issues it found with the data which prevented a more thorough analysis.

Firstly, it was noted that data quality has increased markedly as time has progressed, in terms of polling frequency and coverage. There remains, however, scope for improvement. The current approach to anonymising the data involves vessels being assigned a random ID (RID) for a six month period, which is used to link VMS and catch data. The percentage of vessels which have no gear code associated with their RID has decreased from 40% to 20% over the ten years of the data set (Table 5.9.1). The RID table had not been updated for the 2015 trips, therefore it was not possible to complete this table.

Table 5.9.1. Provision of gear information in the NEAFC data set which can be linked to vessel ID (RID) over time.

Year	Total RIDs	RIDs Lacking Gear Code (%)
2005	1244	496 (39.9%)
2006	1086	408 (37.6%)
2007	1015	281 (27.7%)
2008	994	265 (26.7%)
2009	999	293 (29.3%)
2010	929	296 (31.9%)
2011	867	255 (29.4%)
2012	726	154 (21.2%)
2013	605	133 (22.0%)
2014	704	142 (20.2%)

Catches have increasingly been reported on a per day basis but there is still a significant proportion where reports cover multiple fishing days. 58% of catch reports cover 1 fishing day, the remainder range between 2 and 100 fishing days. Multiple records of catches are provided without associated temporal information under a single RID value, meaning those catches could have come at any point in the six months when that value is assigned to a vessel. This prevents the linking of catches and VMS data at a sufficiently granular level to accurately plot distribution of catches. There remain 316 catch records without a corresponding entry in the RID table, completely preventing their linkage to vessel and positional information.

In future, the scope of analysis which can be performed on the NEAFC VMS data could be improved by:

- the inclusion of temporal information on catches at a sufficiently fine scale of aggregation to allow interpretation of linked VMS data and catches
- the inclusion of gear information for all vessels
- the provision of information on vessel length and power

6 Revisions to the work plan and justification

Following discussions at the WGSFD meeting it is suggested to change ToR b to following:

Work on standardized methods to analyse, and produce products that describe, the fishery in space and time	Products on spatial fishery distribution have been requested by OSPAR, HELCOM and by ICES expert groups as input fisheries impact assessments. WGSFD wants to continue to work on standardized methods and data products.	3 years	Method to be implemented by the ICES datacentre Maps and data products to be used by ICES expert groups

Suggestions for changes in the procedure for next year:

- Include quality checks in R-script
- Update relation table between DCF level 6 metiers, Benthis metiers, JNCC metiers and gear groups with both VMS and logbook data from newest datacall before the meeting
- Outputs ready and quality checked before the meeting
- Documenting the method implemented by the ICES datacentre in pseudocode, so that it possible to follow.

7 Next meetings

The 2017 meeting will take place on 29 May, 13:00 – 2 June, 13:00 in Hamburg, Germany. Chaired by Niels Hintzen (the Netherlands) and Christian von Dorrien (Germany).

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Annex 2: Abbreviations list

ABNJ	Areas Beyond National Jurisdiction
ACOM	ICES Advisory Committee
AIS	Automatic Identification System
BENTHIS	Studies the impacts of fishing on benthic ecosystems (bottom systems) and will provide the science base to assess the impact of current fishing practices
BH1	OSPAR Indicator - Condition of Typical Species
BH2	OSPAR Indicator - Condition of Habitat Community Indicator
BH3	OSPAR Indicator - Physical Damage Indicator
CPUE	Catch Per Unit Effort
DCF	Data Collection Framework
DGENV	EU Environment Directorate-General
HELCOM	Helsinki Commission
ICES ASC	Ices Annual Science Conference
JNCC	Joint Nature Conservation Committee
JRC	Joint Research Centre. The European Commission's science and knowledge service
MoU	Memorandum of Understanding
MPA	Marine Protected Area
NEAFC	North East Atlantic Fisheries Commission
OSPAR	Oslo and Paris Convention on the protection of the NE Atlantic OSPAR region: North-East Atlantic
STECF	Scientific, Technical and Economic Committee for Fisheries
ToR	Terms of Reference
VME	Vulnerable Marine Ecosystem
VMS	Vessel Monitoring System
VMStools	VMStools R package to analyse VMS and Logbook data

Working Groups

BEWG	Benthos Ecology Working Group

WGDEC	Working Group on Deep-water Ecology
WGCATCH	Working Group on Commercial Catches
WGMHM	Working Group on Marine Habitat Mapping
WKFBI	Workshop on Fisheries Benthic Impact
WKSand	Benchmark Workshop on Sandeel

Annex 3: Maps prepared to illustrate DCF environmental indicators 5, 6 and 7

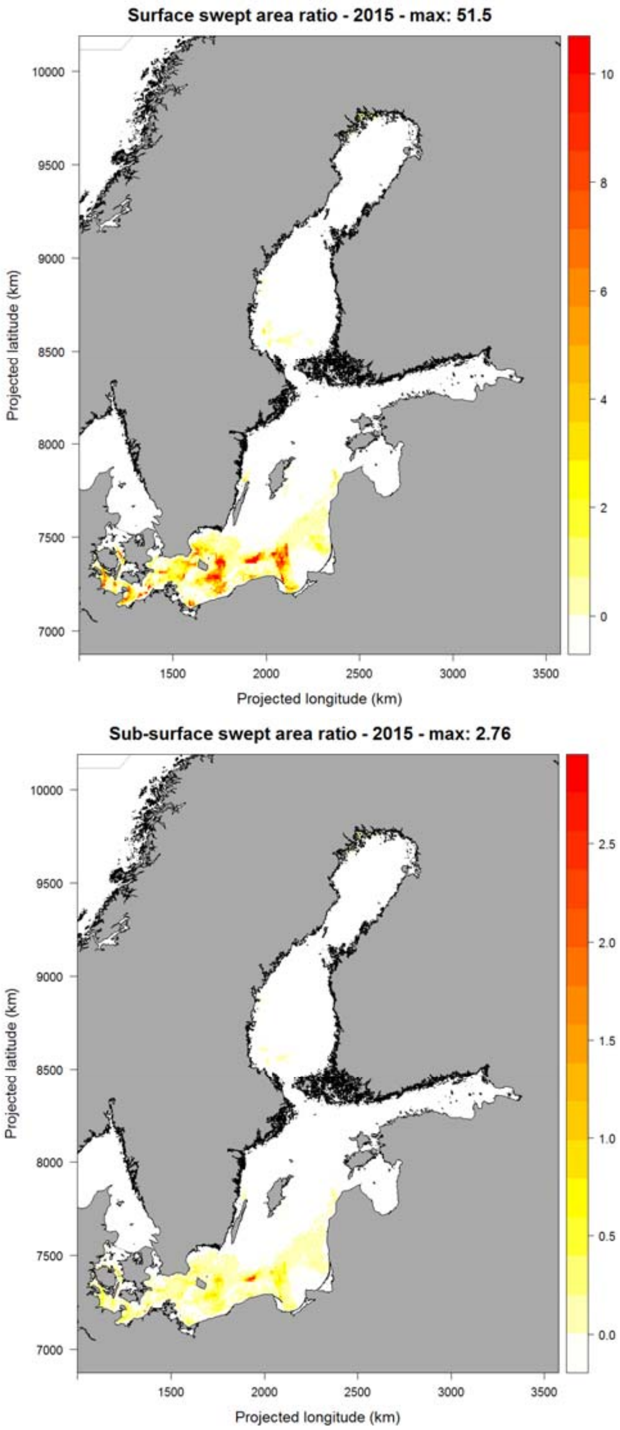


Figure: Surface (top) and sub-surface swept area ratio for the mobile bottom contacting gear in 2015 (the Baltic Sea ICES ecoregion).

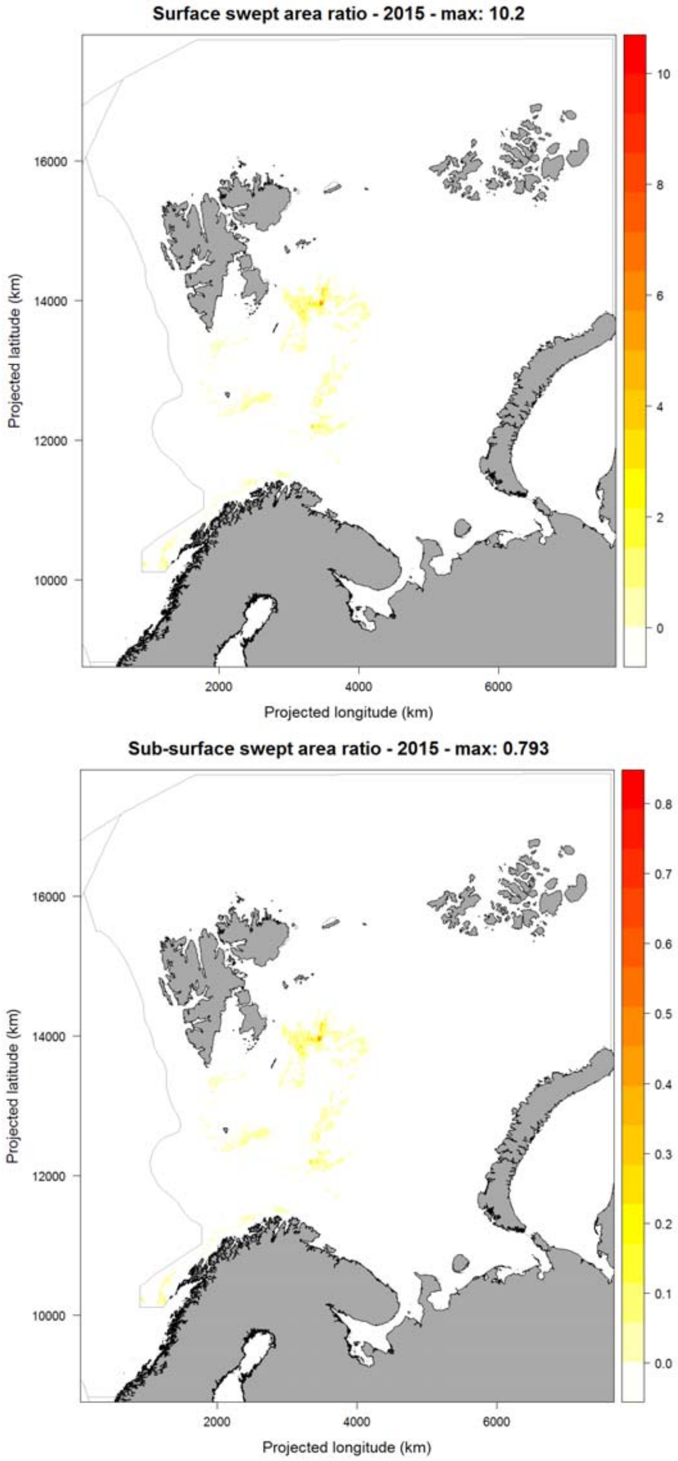


Figure: Surface (top) and sub-surface swept area ratio for the mobile bottom contacting gear in 2015 (the Barents Sea ICES ecoregion).

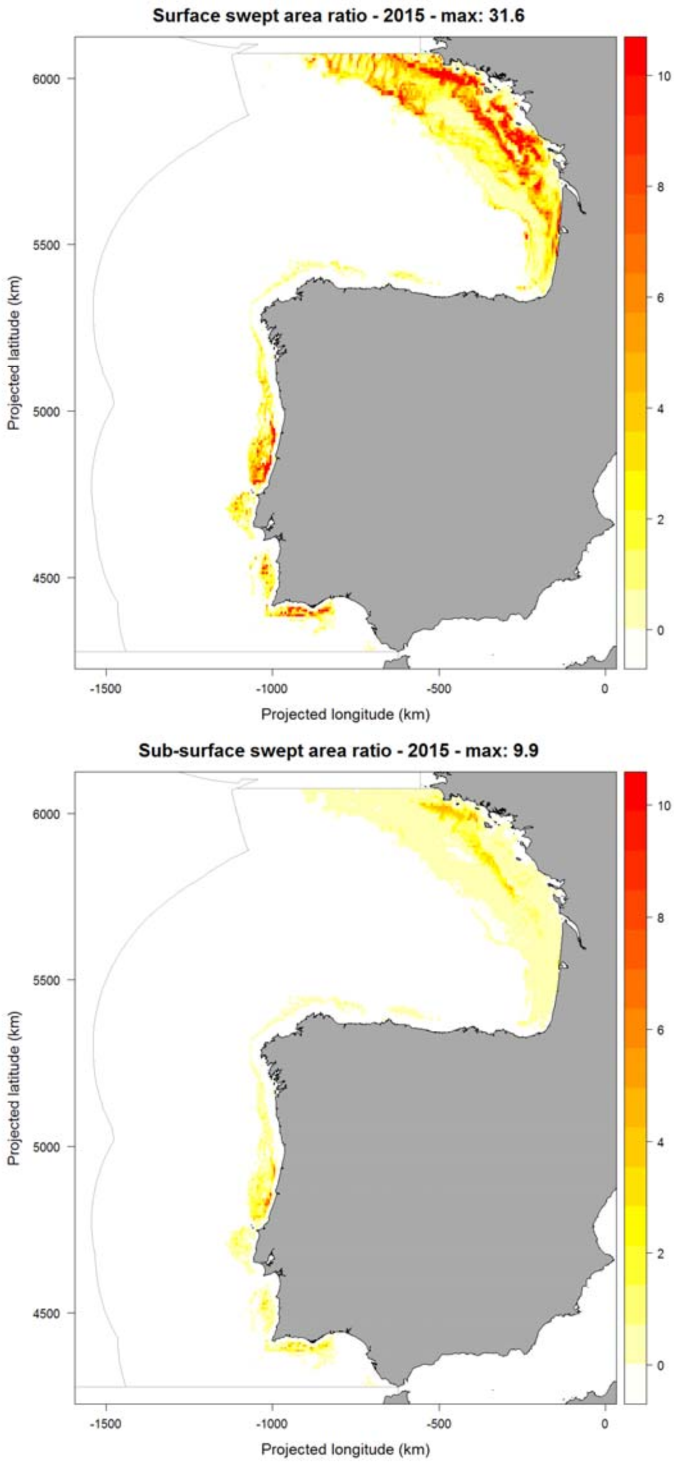


Figure: Surface (top) and sub-surface swept area ratio for the mobile bottom contacting gear in 2015 (the Bay of Biscay and the Iberian Coast ICES ecoregion).

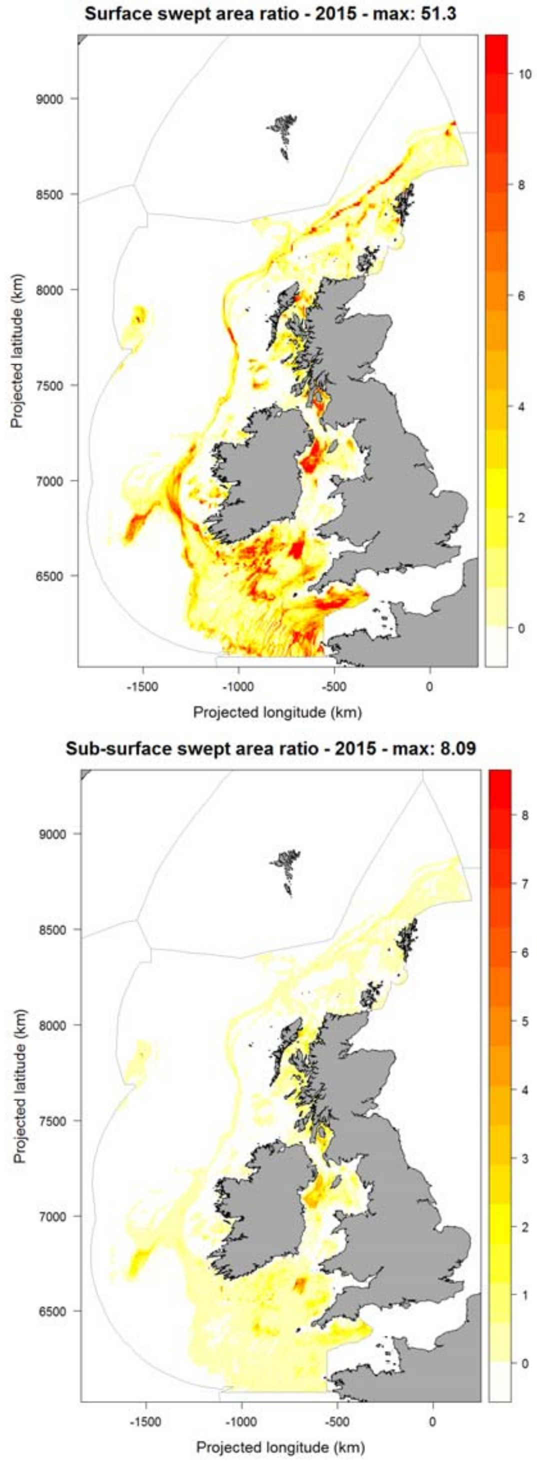


Figure: Surface (top) and sub-surface swept area ratio for the mobile bottom contacting gear in 2015 (the Celtic Seas ICES ecoregion).

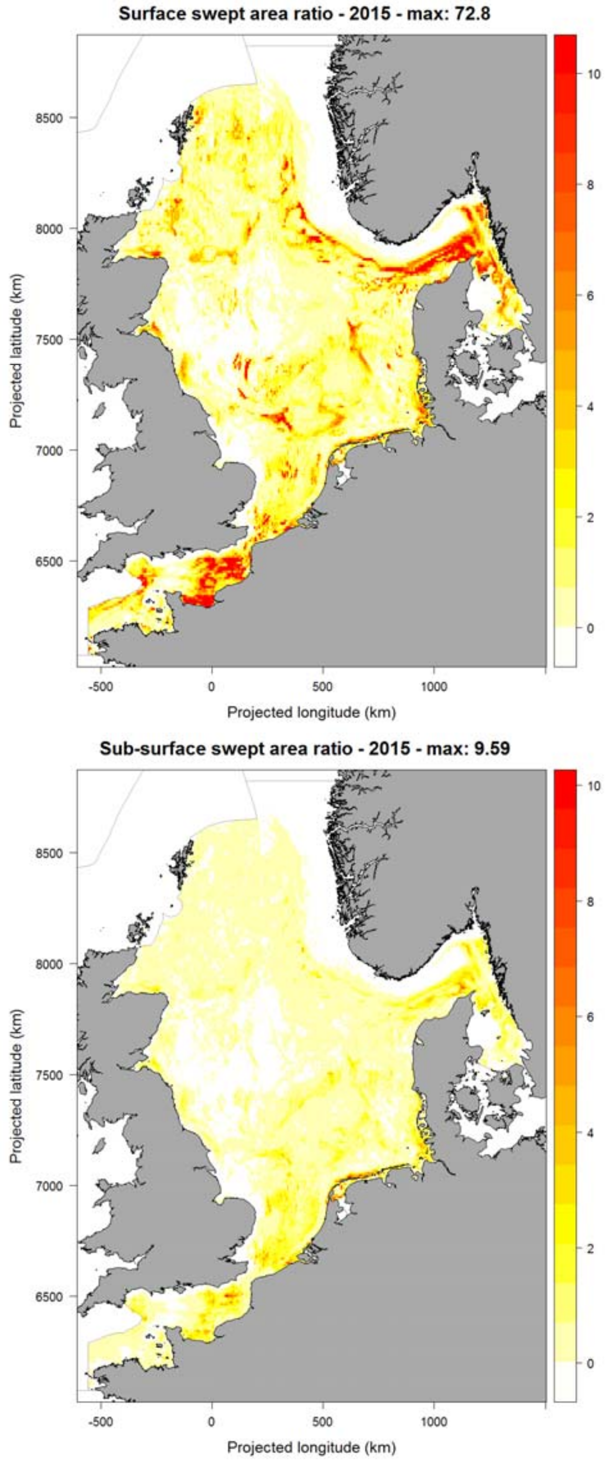


Figure: Surface (top) and sub-surface swept area ratio for the mobile bottom contacting gear in 2015 (the Greater North Sea ICES ecoregion).

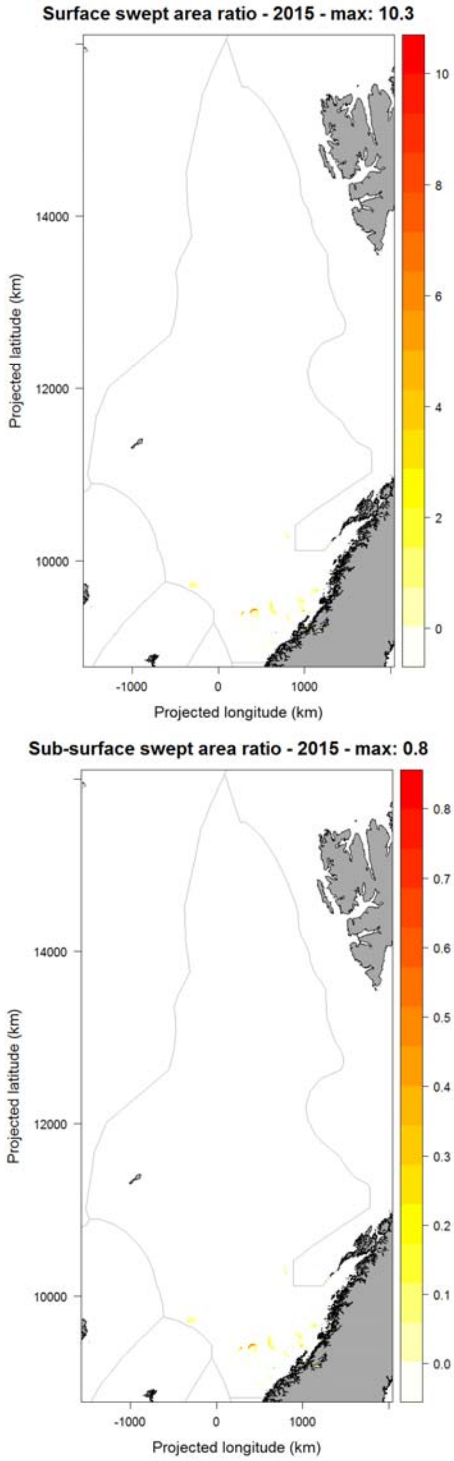


Figure: Surface (top) and sub-surface swept area ratio for the mobile bottom contacting gear in 2015 (the Norwegian Sea ICES ecoregion).

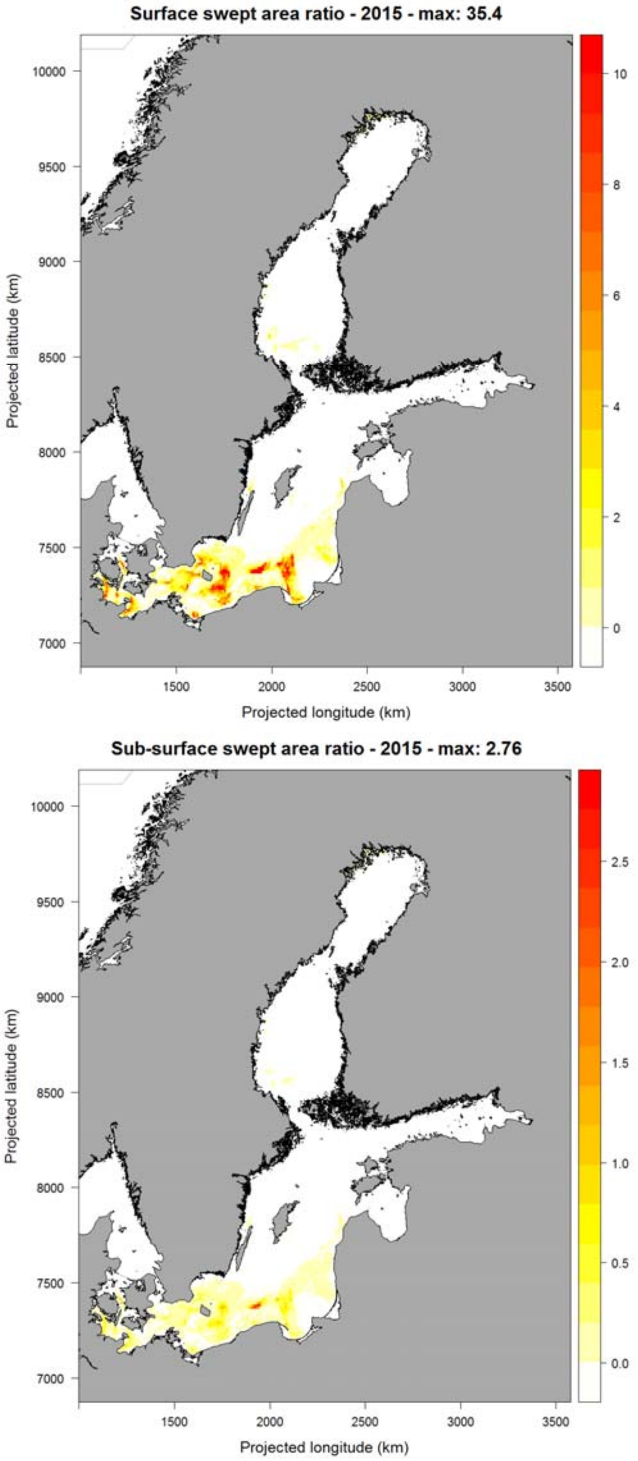


Figure: Surface (top) and sub-surface swept area ratio for the Otter gear in 2015 (the Baltic Sea ICES ecoregion).

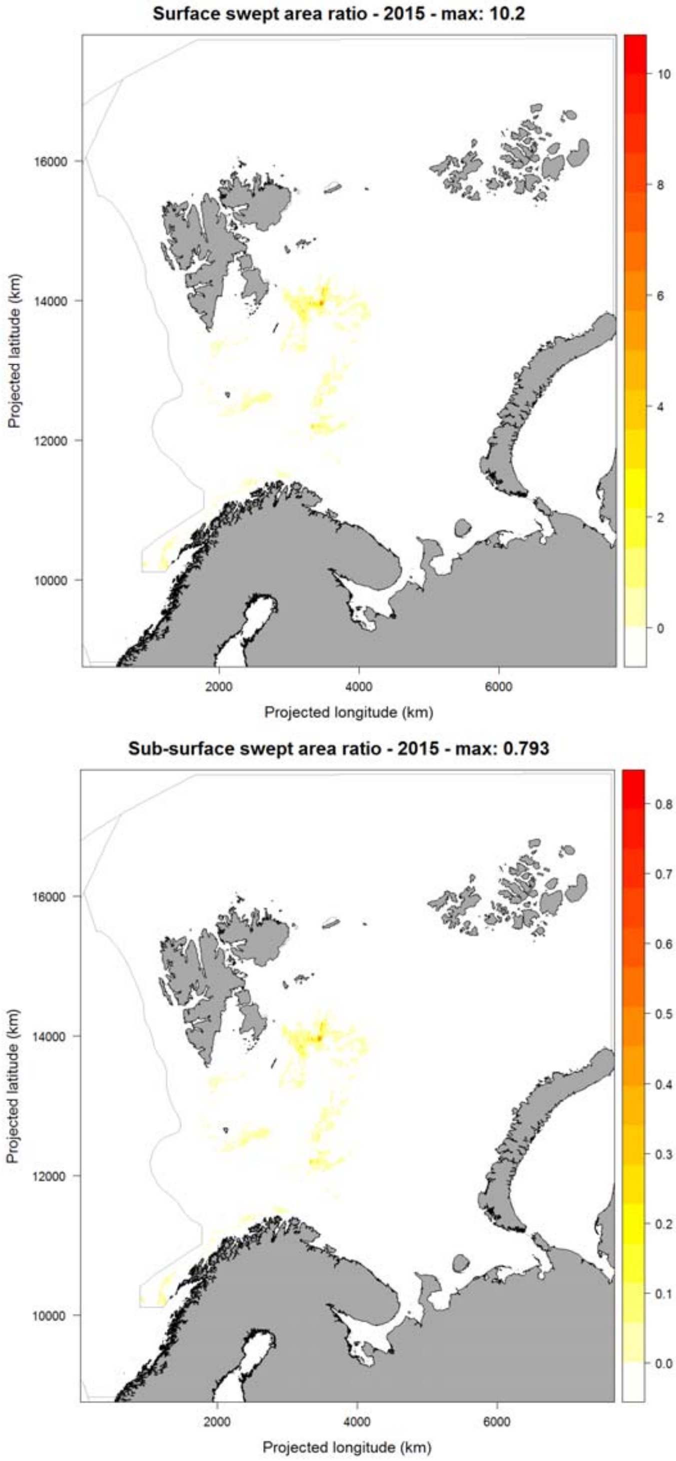


Figure: Surface (top) and sub-surface swept area ratio for the Otter gear in 2015 (the Barents Sea ICES ecoregion).

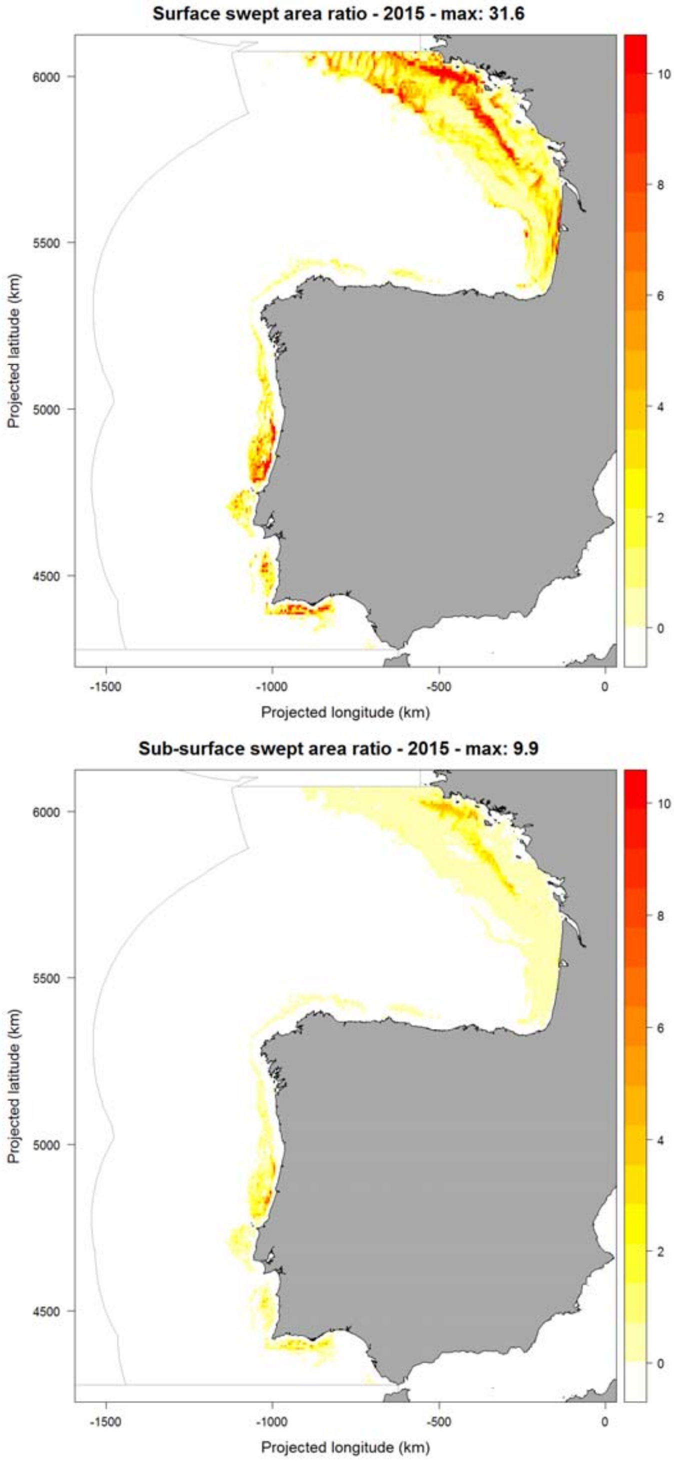


Figure: Surface (top) and sub-surface swept area ratio for the Otter gear in 2015 (the Bay of Biscay and the Iberian Coast ICES ecoregion).

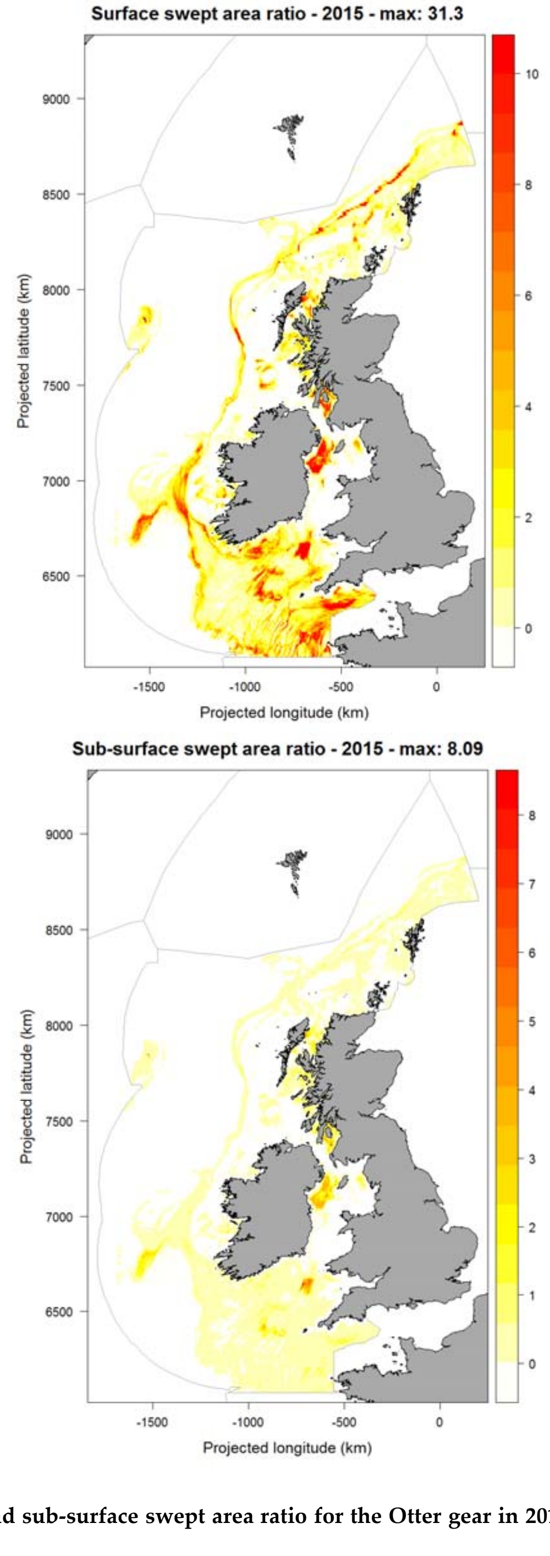


Figure: Surface (top) and sub-surface swept area ratio for the Otter gear in 2015 (the Celtic Seas ICES ecoregion).

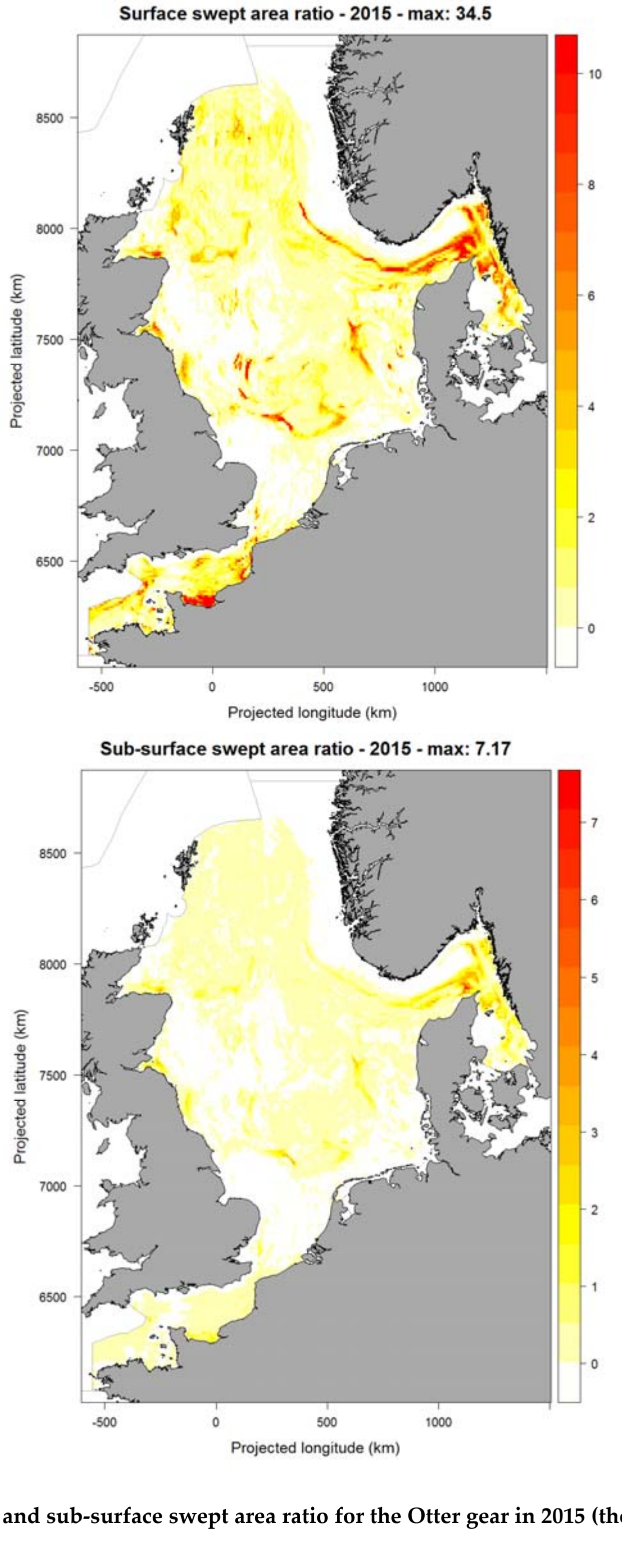


Figure: Surface (top) and sub-surface swept area ratio for the Otter gear in 2015 (the Greater North Sea ICES ecoregion).

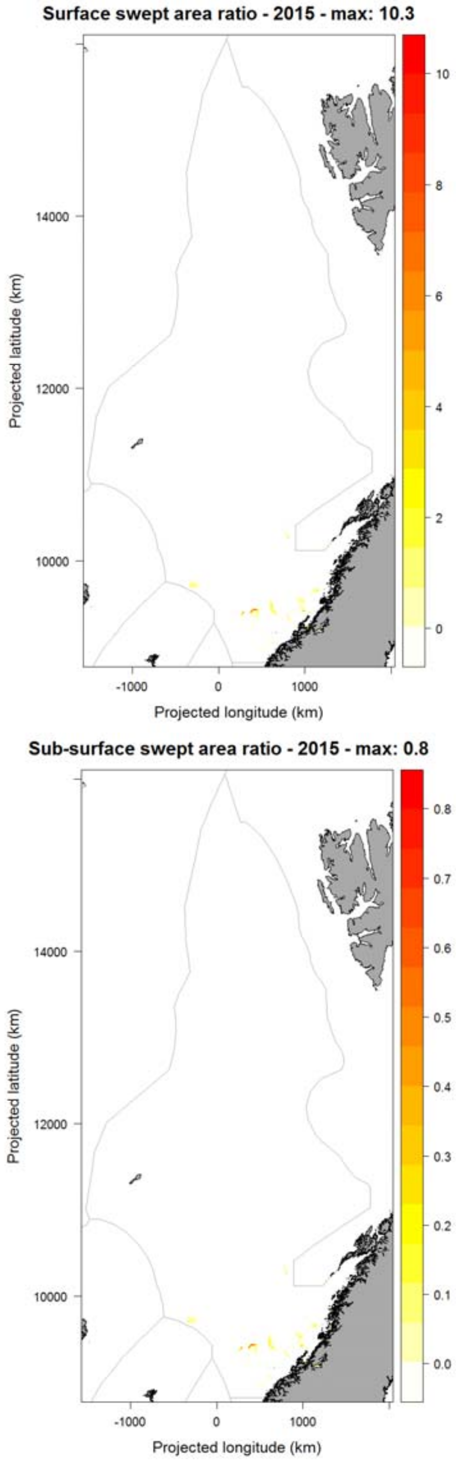


Figure: Surface (top) and sub-surface swept area ratio for the Otter gear in 2015 (the Norwegian Sea ICES ecoregion).

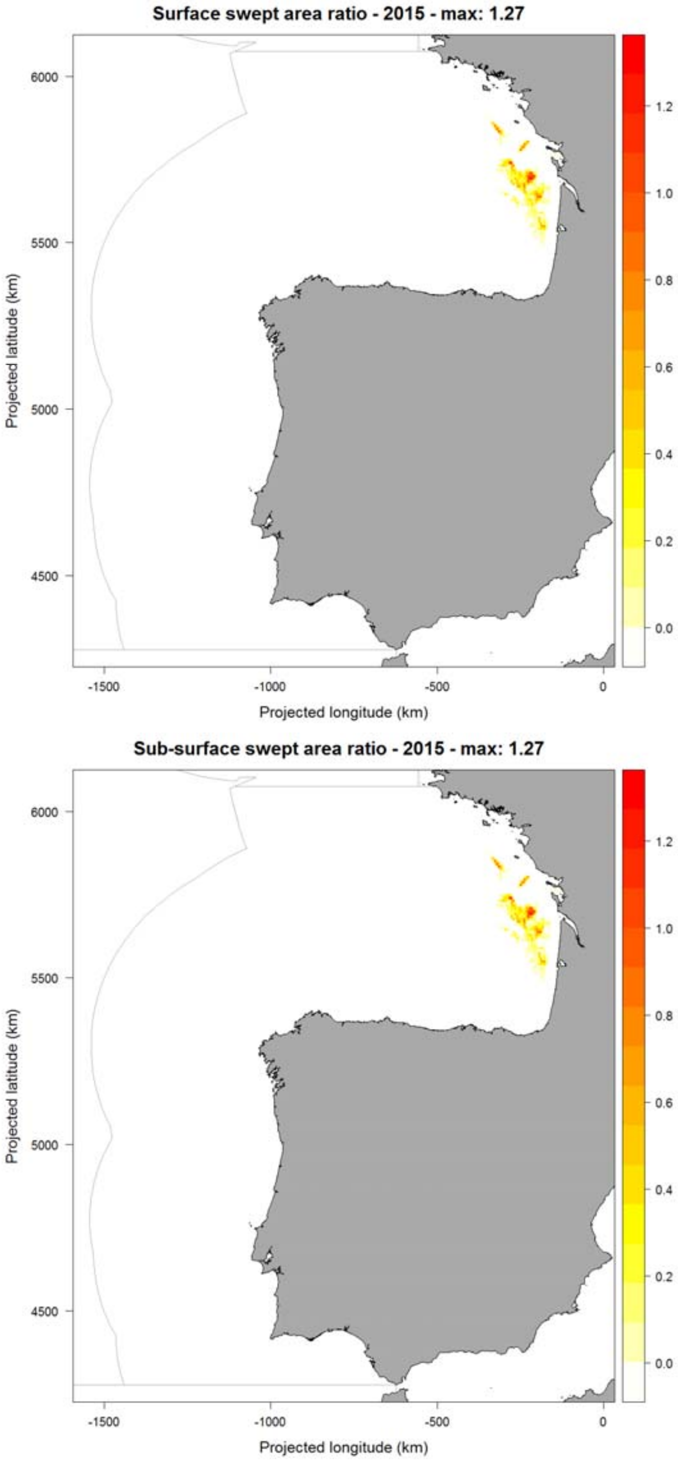
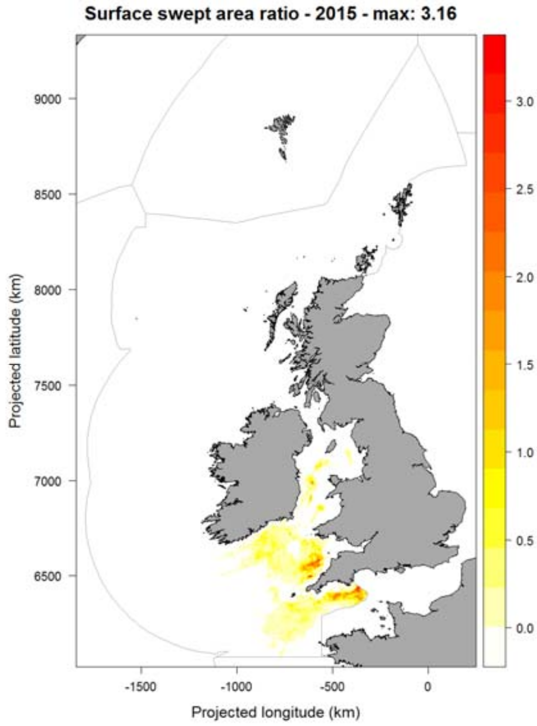


Figure: Surface (top) and sub-surface swept area ratio for the Beam gear in 2015 (the Bay of Biscay and the Iberian Coast ICES ecoregion).



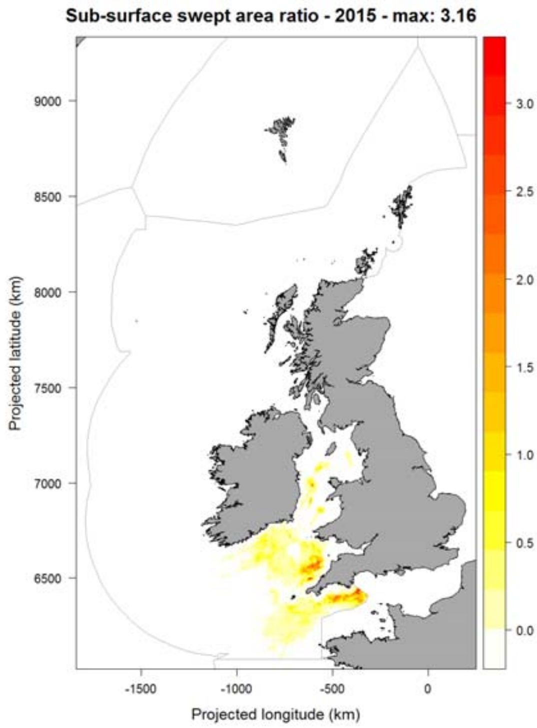


Figure: Surface (top) and sub-surface swept area ratio for the Beam gear in 2015 (the Celtic Seas ICES ecoregion).

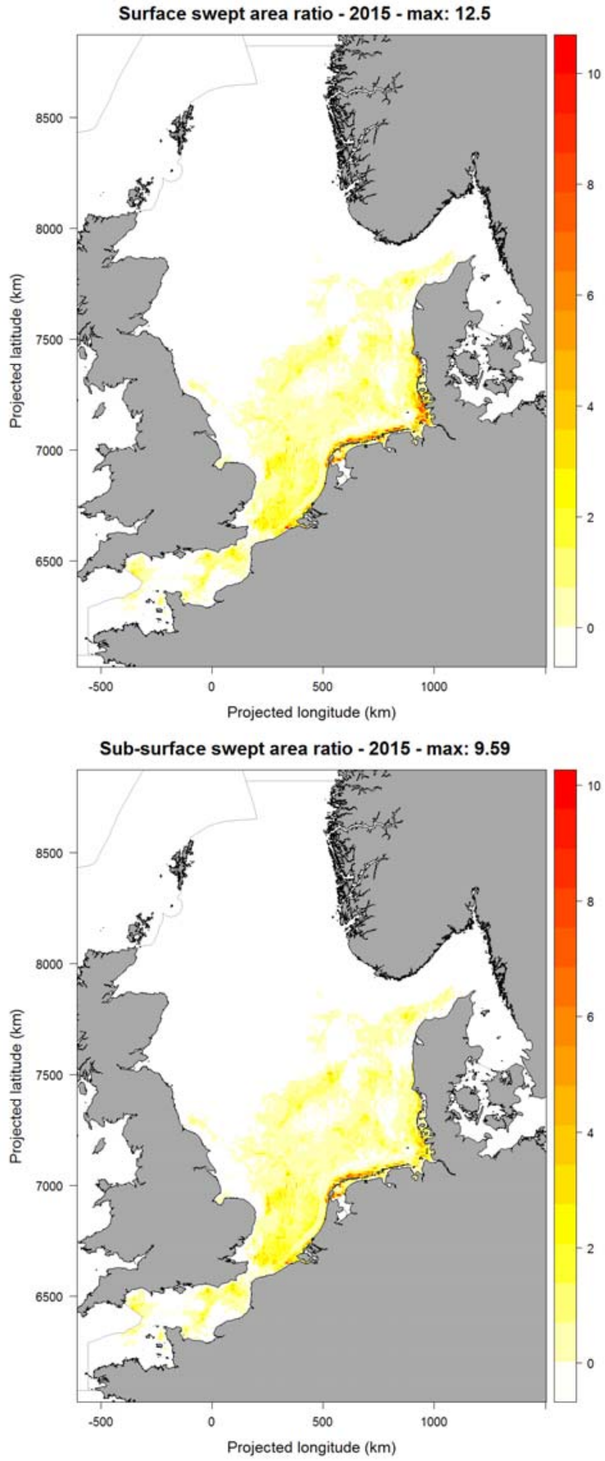


Figure: Surface (top) and sub-surface swept area ratio for the Beam gear in 2015 (the Greater North Sea ICES ecoregion).

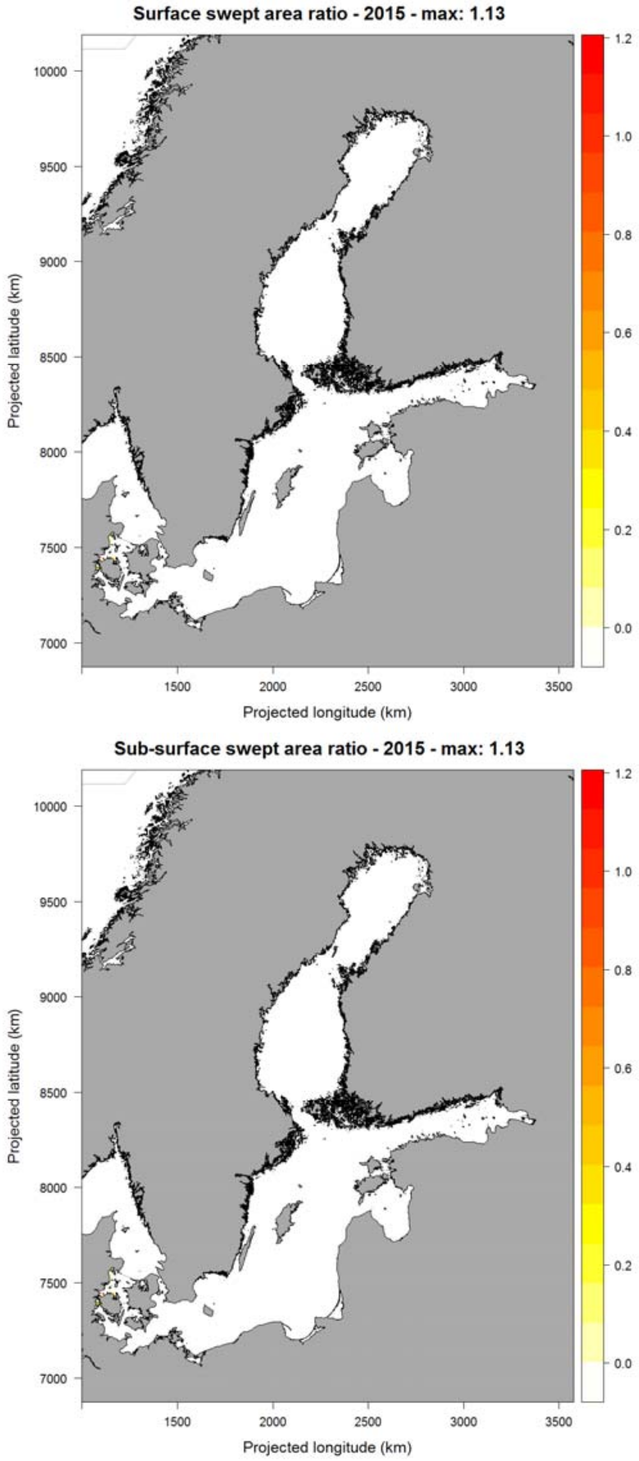


Figure: Surface (top) and sub-surface swept area ratio for the Dredge gear in 2015 (the Baltic Sea ICES ecoregion).

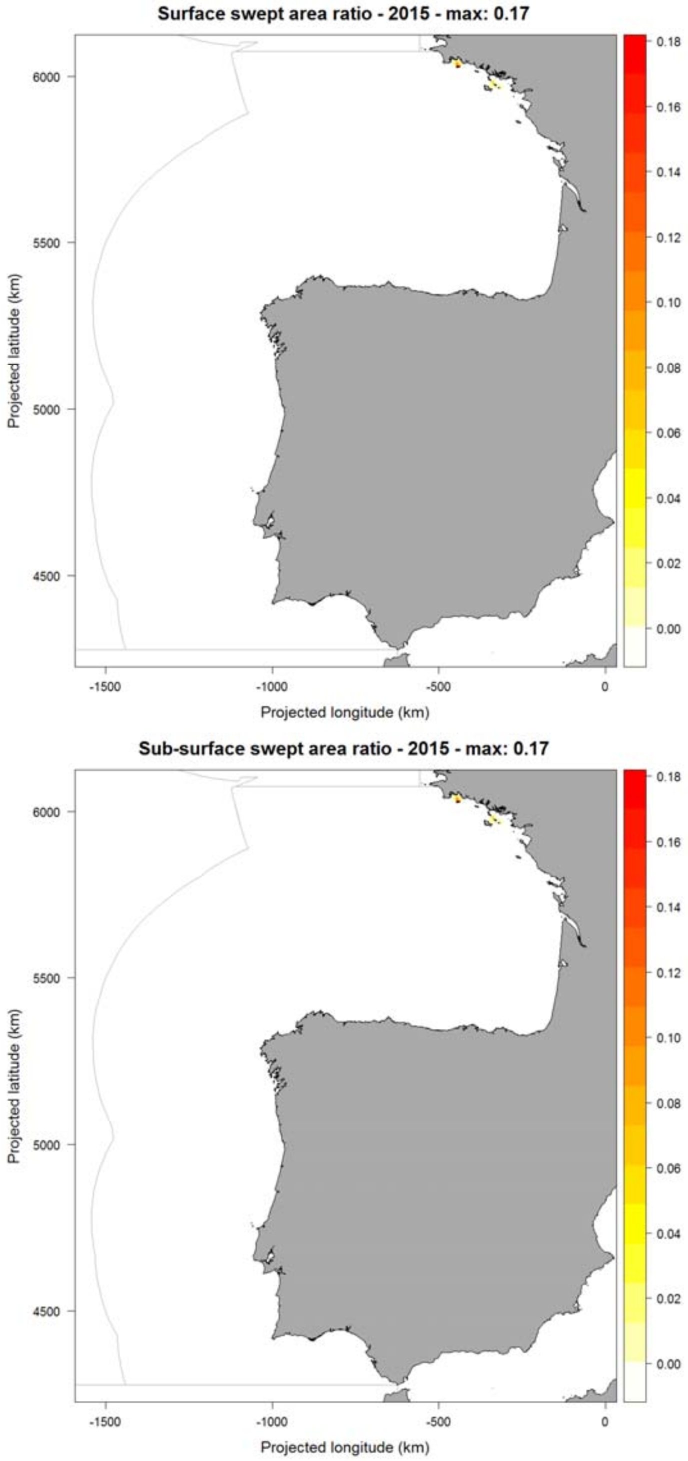


Figure: Surface (top) and sub-surface swept area ratio for the Dredge gear in 2015 (the Bay of Biscay and the Iberian Coast ICES ecoregion).

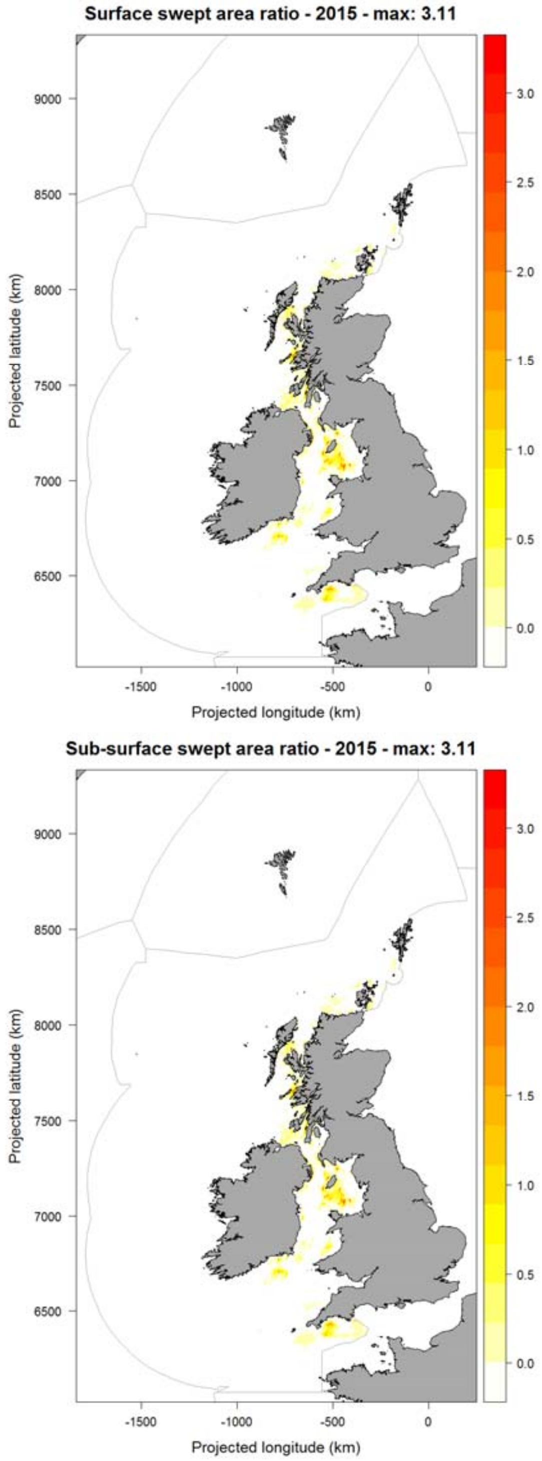


Figure: Surface (top) and sub-surface swept area ratio for the Dredge gear in 2015 (the Celtic Seas ICES ecoregion).

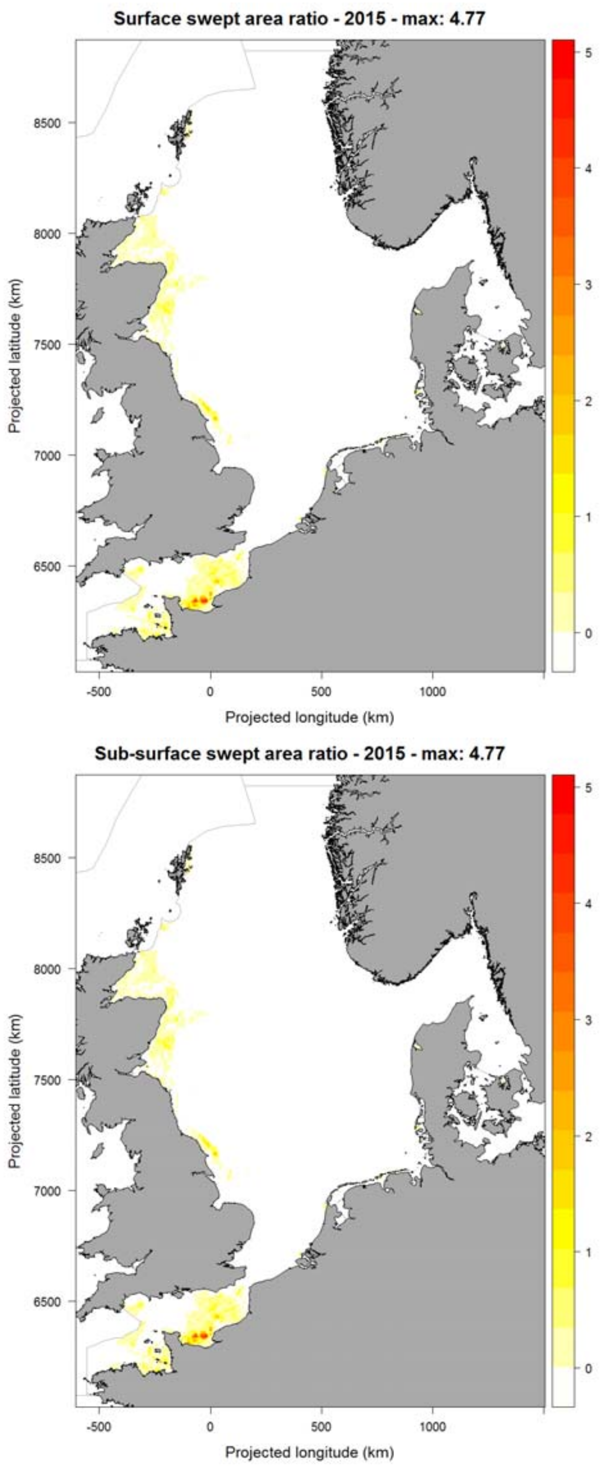


Figure: Surface (top) and sub-surface swept area ratio for the Dredge gear in 2015 (the Greater North Sea ICES ecoregion).

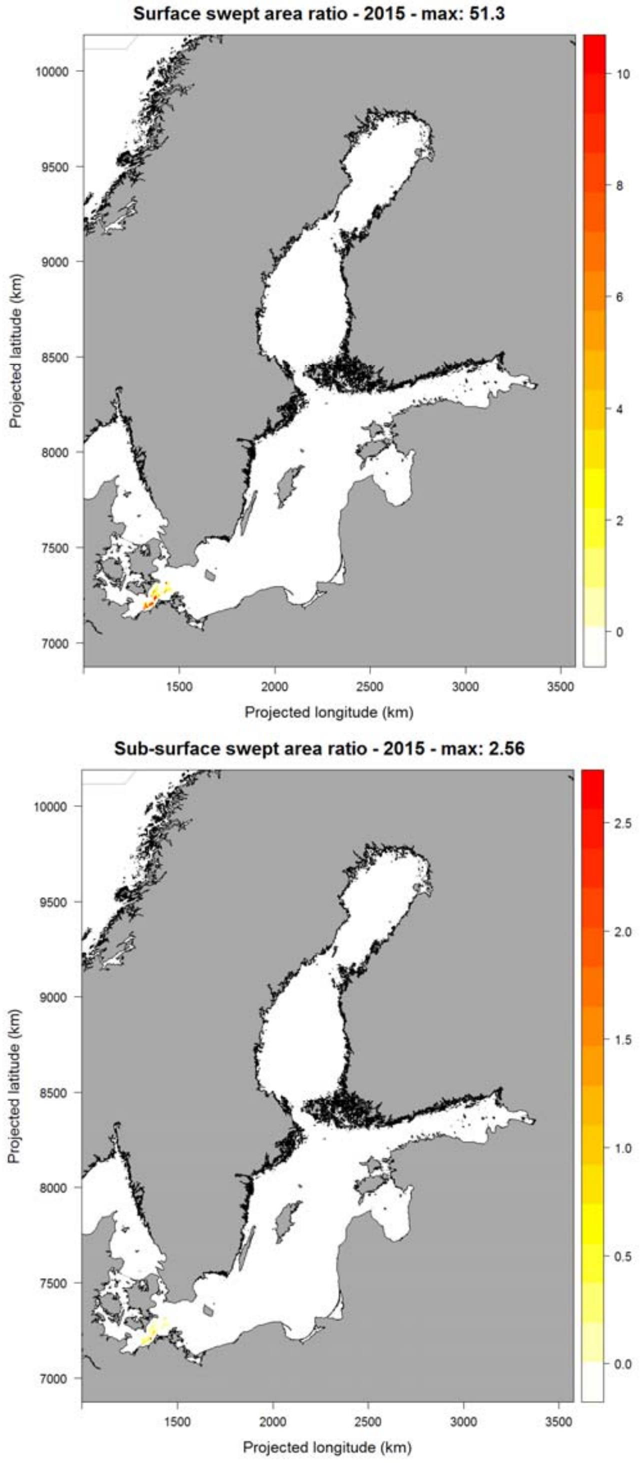


Figure: Surface (top) and sub-surface swept area ratio for the Seine gear in 2015 (the Baltic Sea ICES ecoregion).

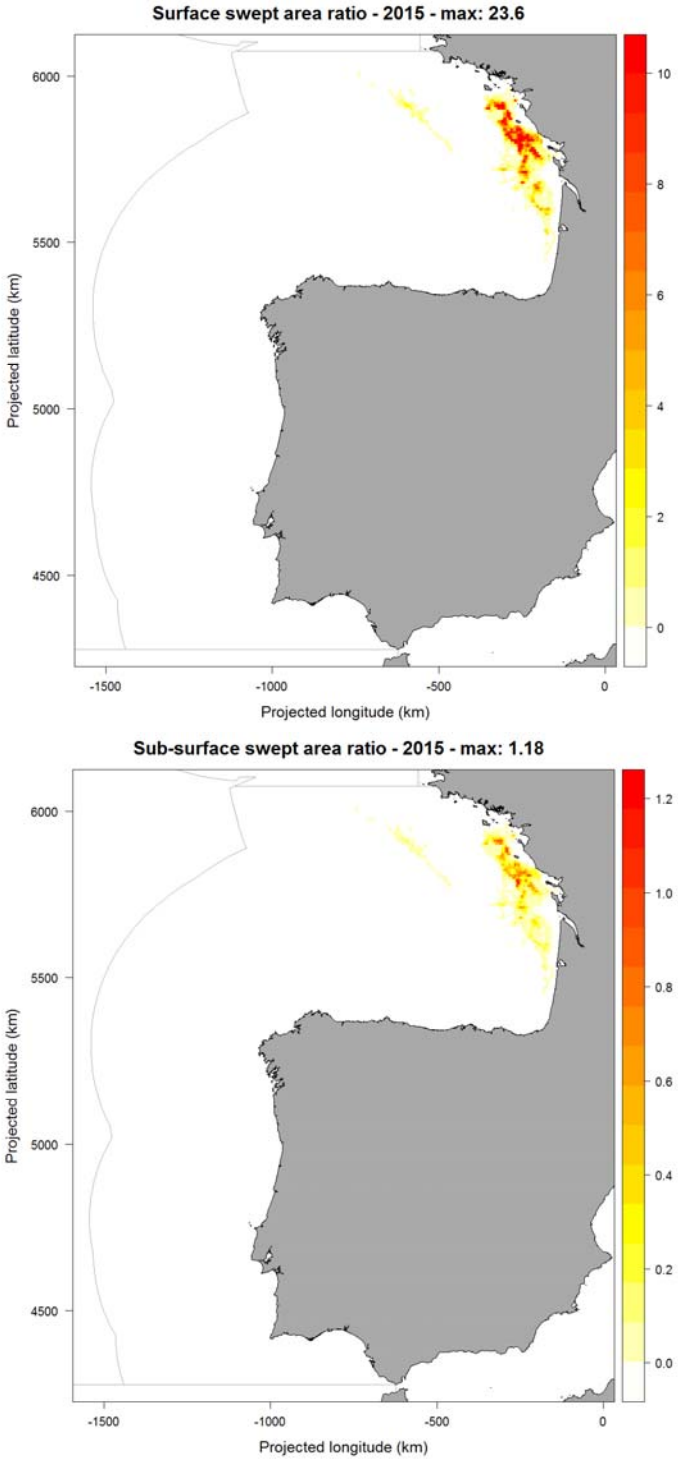


Figure: Surface (top) and sub-surface swept area ratio for the Seine gear in 2015 (the Bay of Biscay and the Iberian Coast ICES ecoregion).

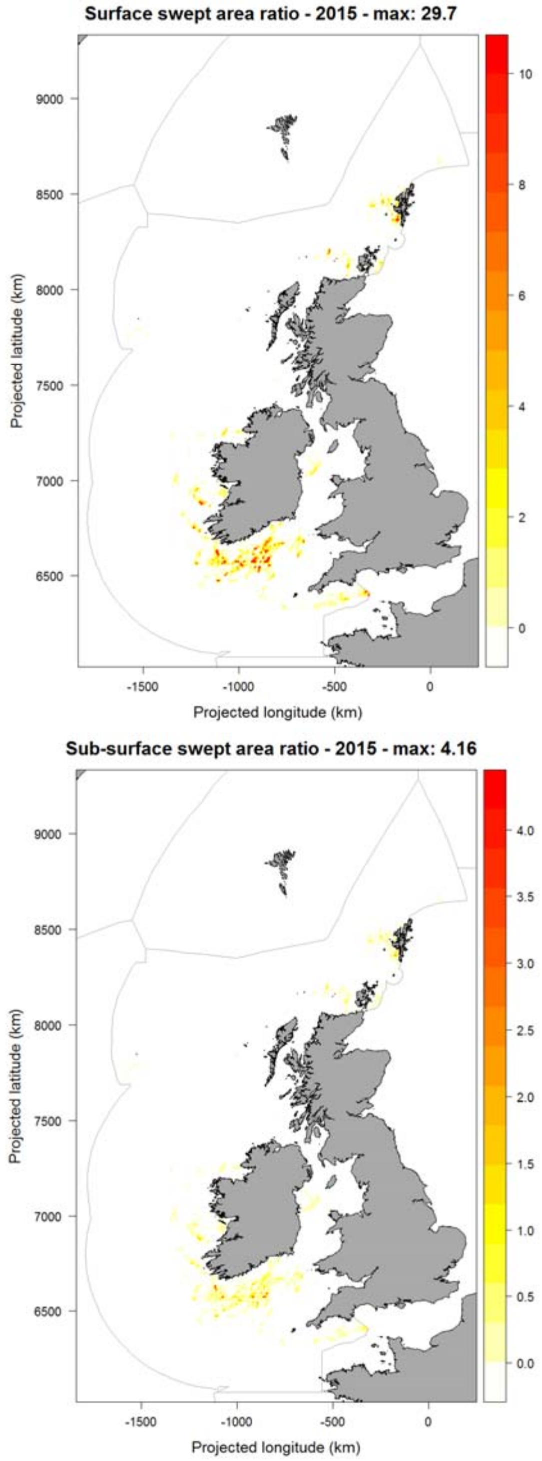


Figure: Surface (top) and sub-surface swept area ratio for the Seine gear in 2015 (the Celtic Seas ICES ecoregion).

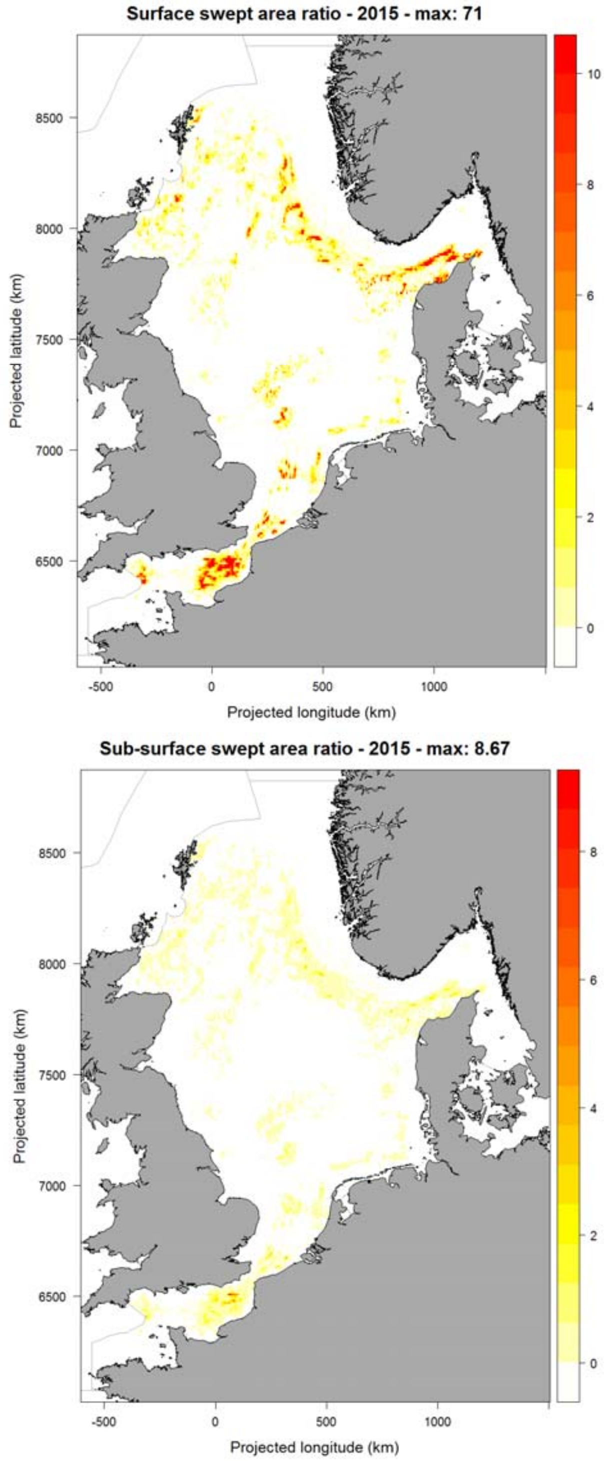
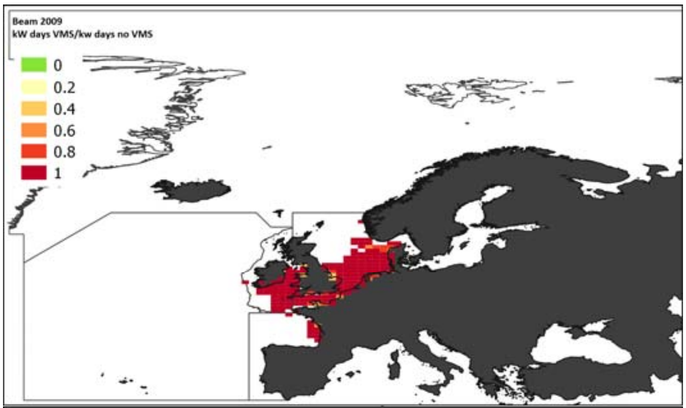
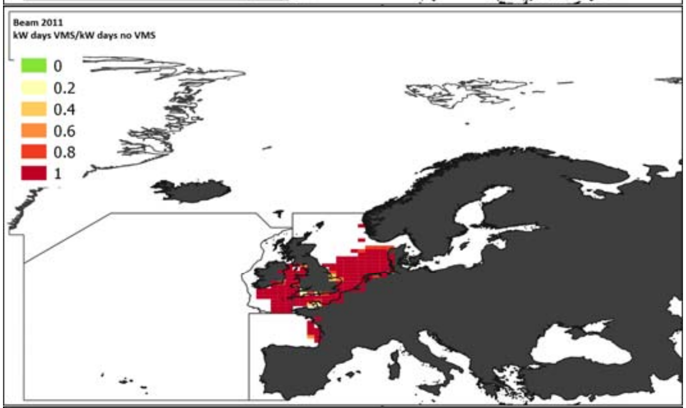
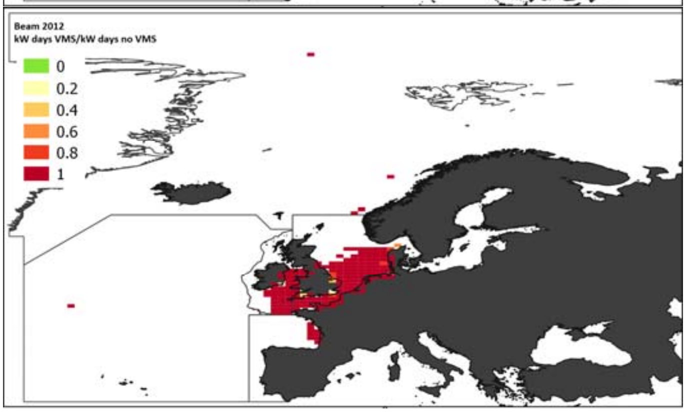


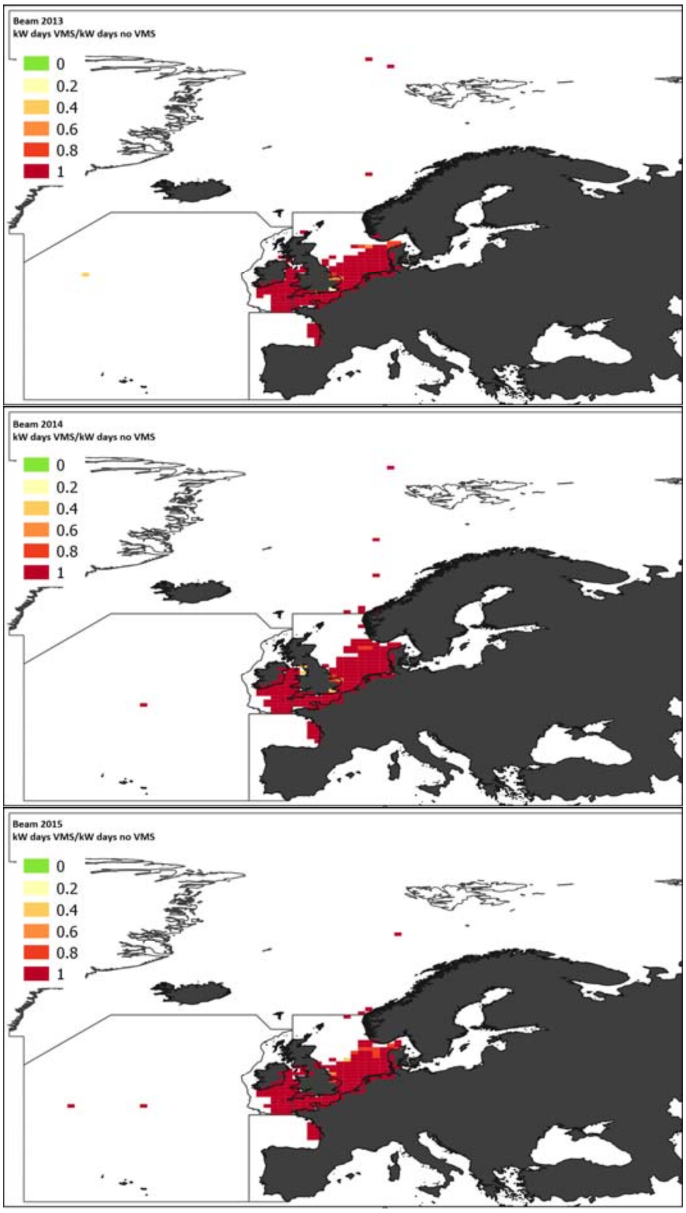
Figure: Surface (top) and sub-surface swept area ratio for the Seine gear in 2015 (the Greater North Sea ICES ecoregion).

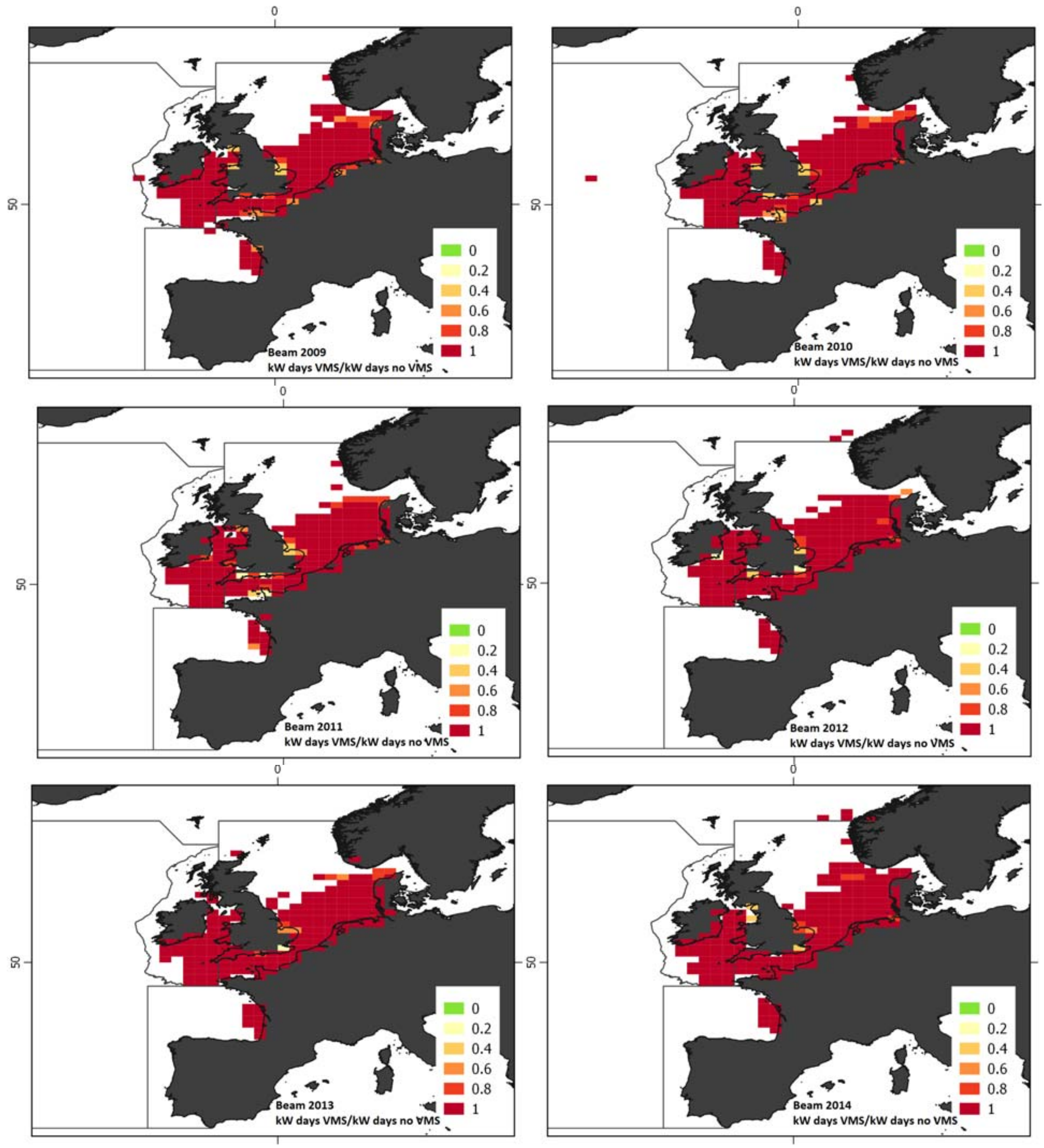
Annex 4: Maps showing VMS coverage

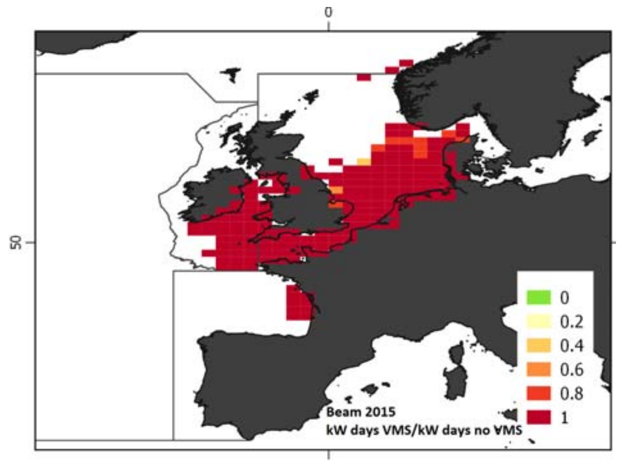


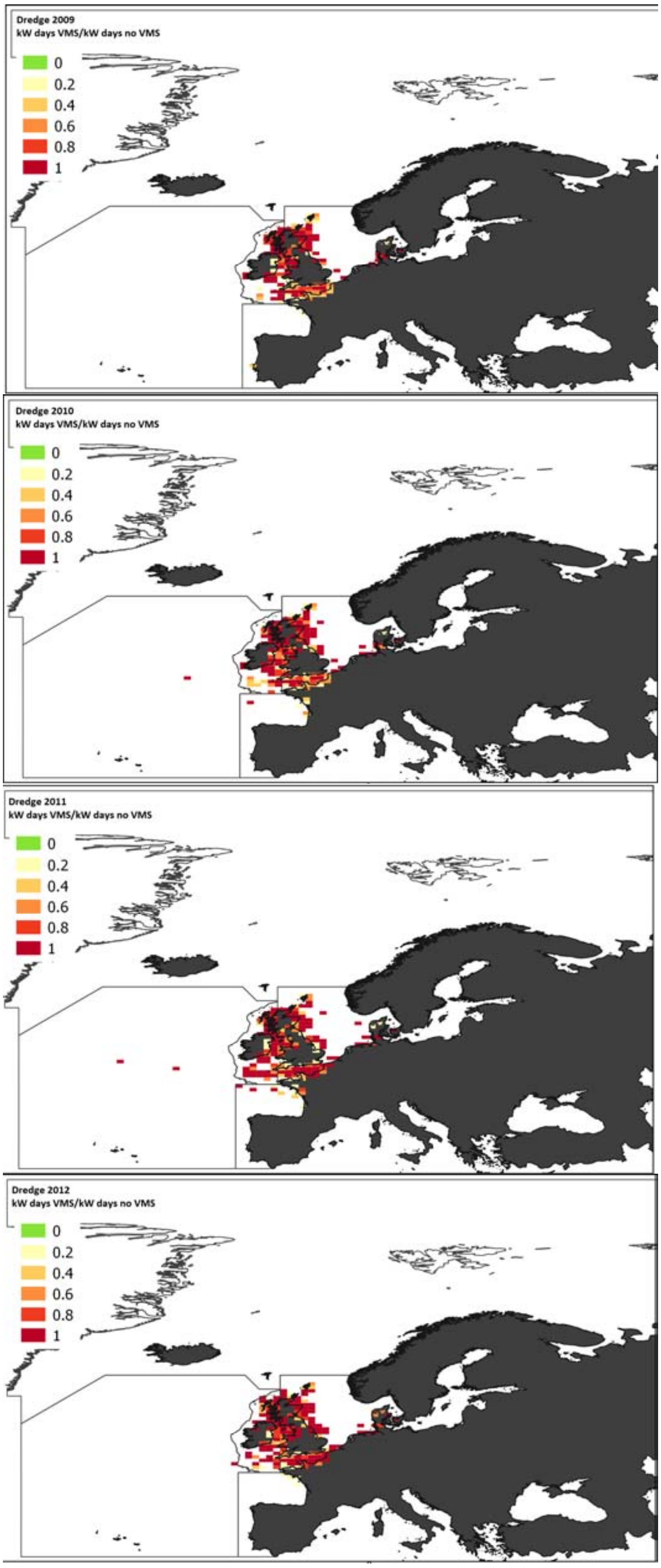


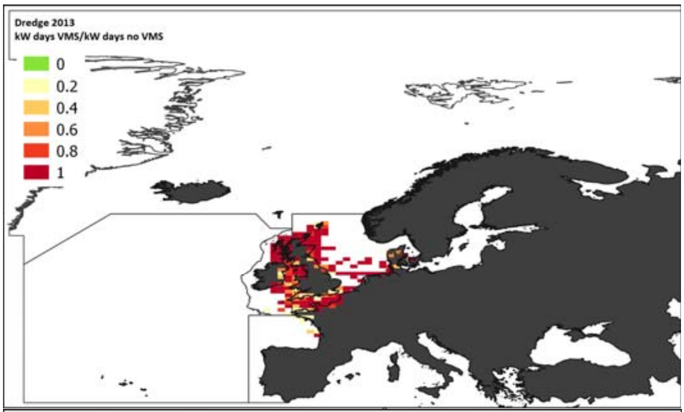


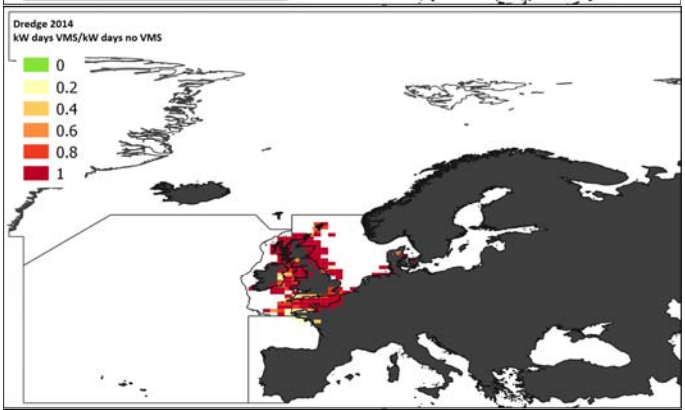

Beam 2013
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
Beam 2014
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
Beam 2015
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1

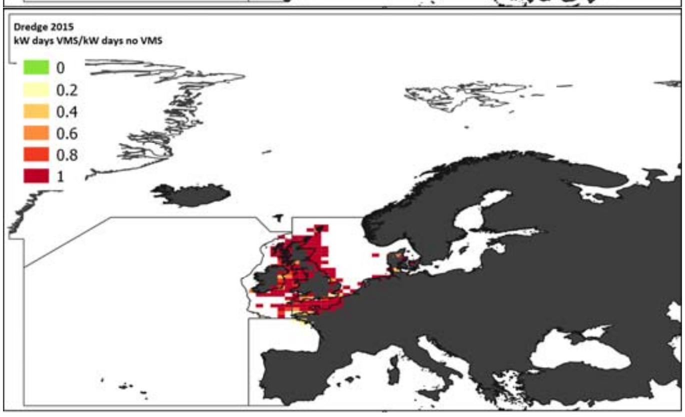

Beam 2009
kW days VMS/kW days no VMS
Beam 2010
kW days VMS/kW days no VMS
Beam 2011
kW days VMS/kW days no VMS
Beam 2012
kW days VMS/kW days no VMS
Beam 2013
kW days VMS/kW days no VMS
Beam 2014
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
50
0

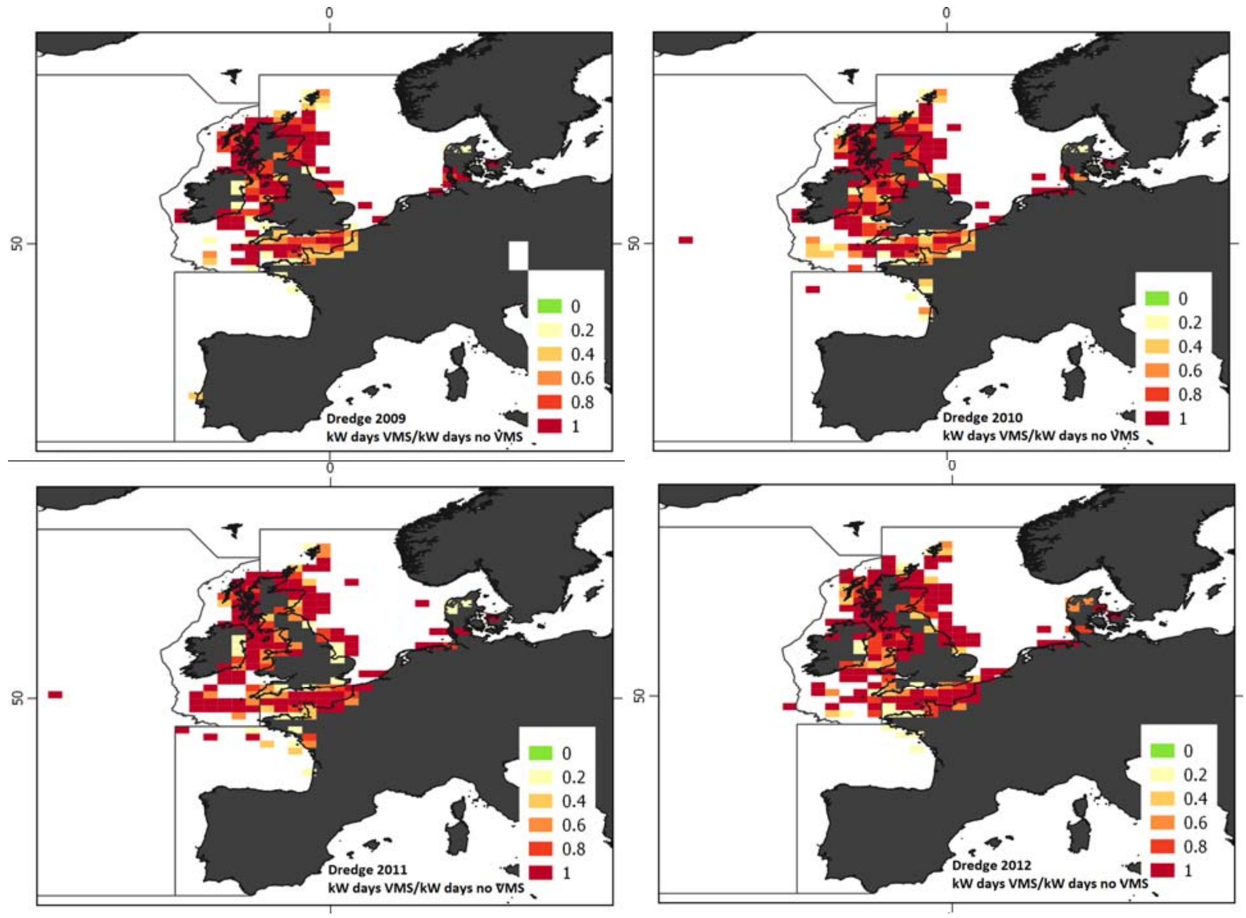

0
50
0
0.2
0.4
0.6
0.8
1
Beam 2015
kW days VMS/kW days no VMS

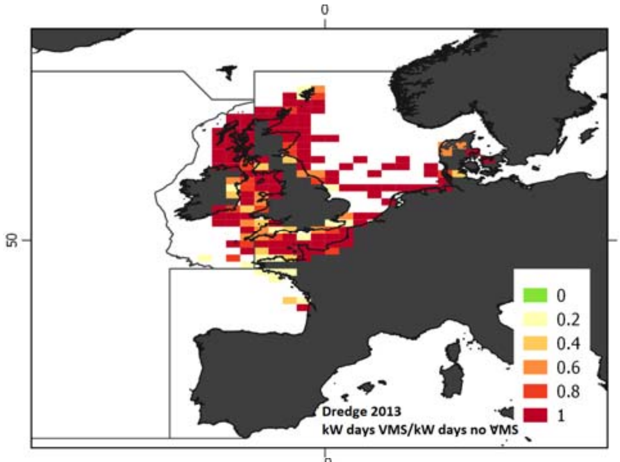

Dredge 2009
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
Dredge 2010
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
Dredge 2011
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
Dredge 2012
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1


Dredge 2013
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1


Dredge 2014
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1


Dredge 2015
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1


Dredge 2009
kW days VMS/kW days no VMS
Dredge 2010
kW days VMS/kW days no VMS
Dredge 2011
kW days VMS/kW days no VMS
Dredge 2012
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
50
0


0
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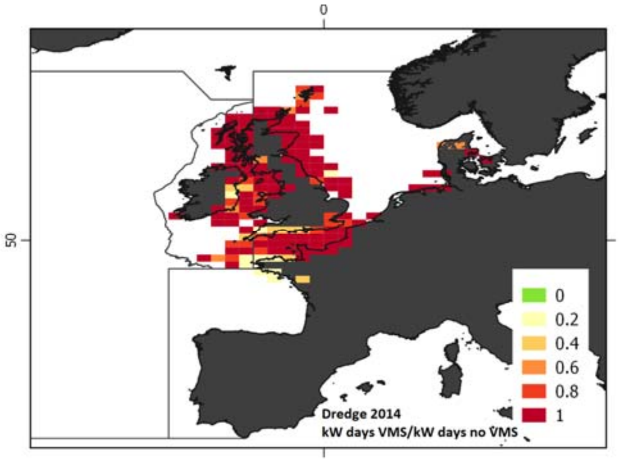
0.2
0.4
0.6
0.8
1
Dredge 2013
kW days VMS/kW days no VMS


0
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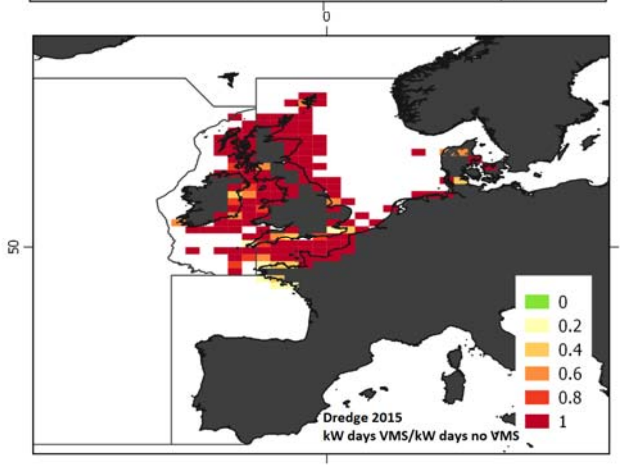
0
0.2
0.4
0.6
0.8
1
Dredge 2014
kW days VMS/kW days no VMS


0
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0.2
0.4
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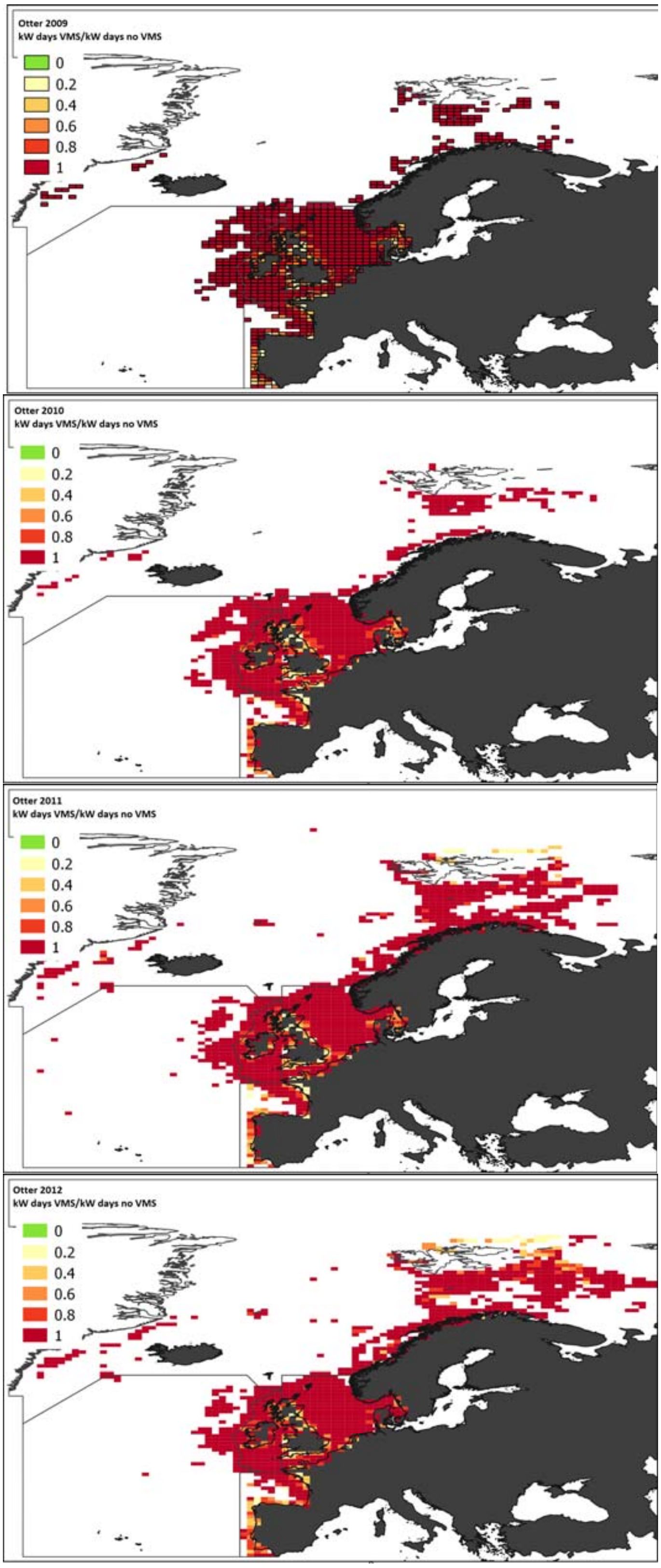
0.8
1
Dredge 2015
kW days VMS/kW days no VMS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kW days VMS/kW days no VMS
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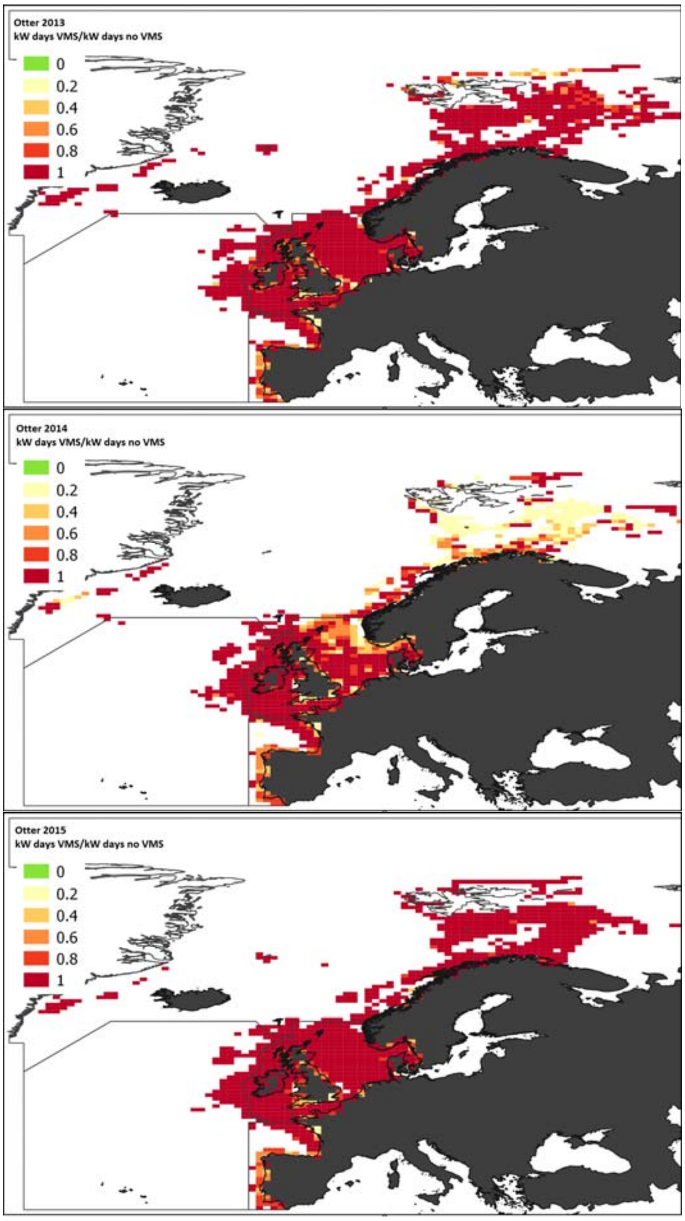
0.2
0.4
0.6
0.8
1
Otter 2010
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
Otter 2011
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
Otter 2012
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1


Otter 2013
kW days VMS/kW days no VMS
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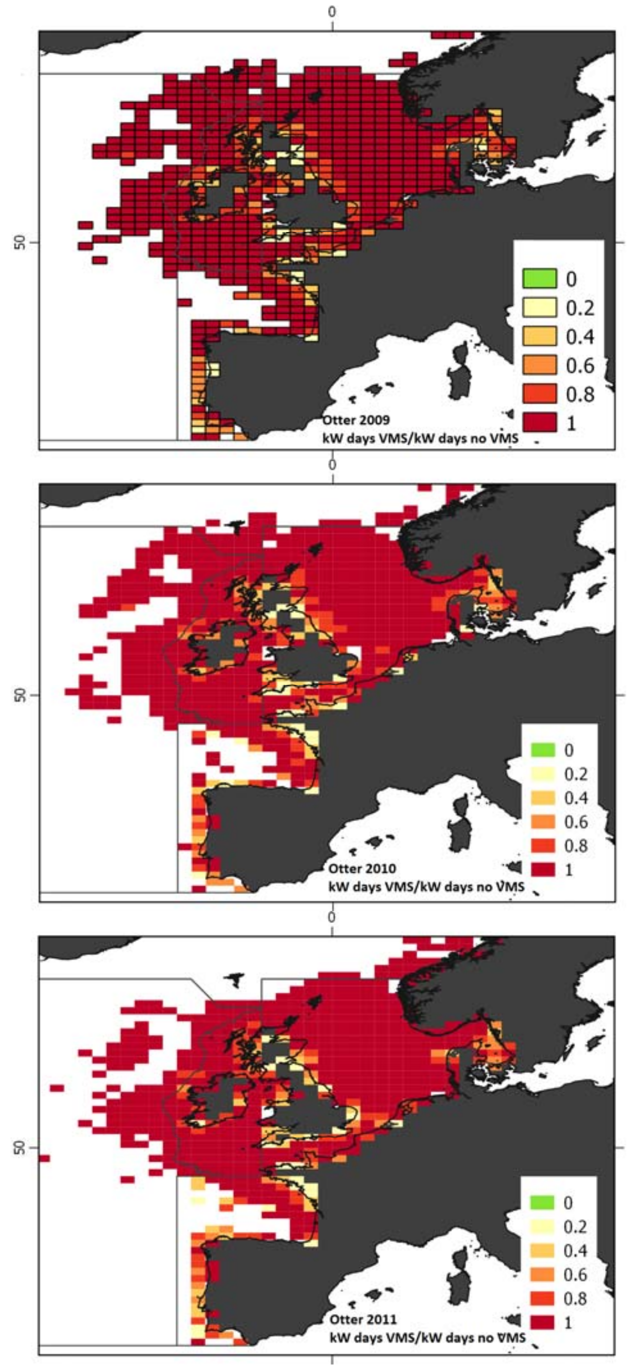
0.6
0.8
1
Otter 2014
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
Otter 2015
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1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Otter 2009
kW days VMS/kW days no VMS
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0.8
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Otter 2010
kW days VMS/kW days no VMS
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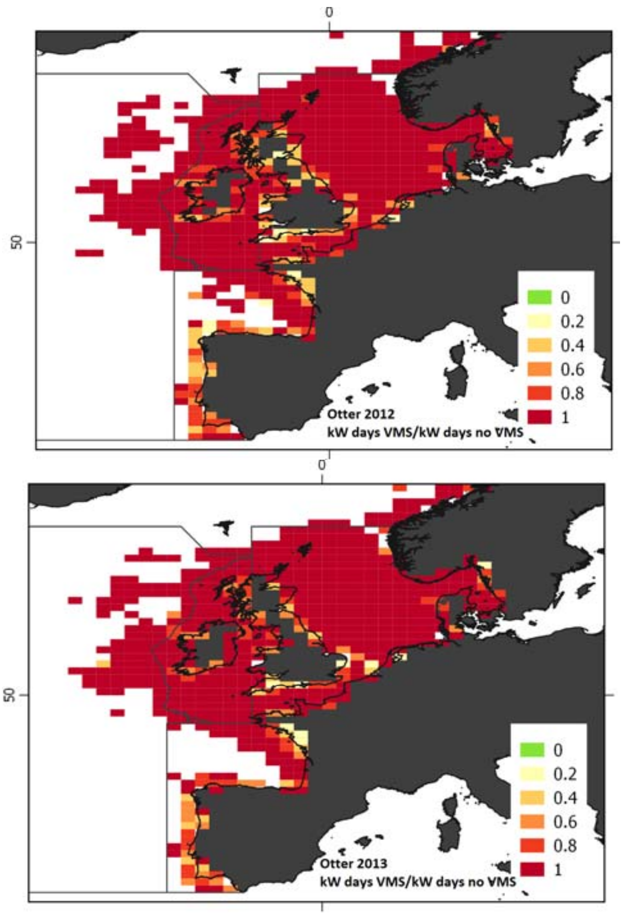
0.2
0.4
0.6
0.8
1
Otter 2011
kW days VMS/kW days no VMS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0.8
1
Otter 2012
kW days VMS/kW days no VMS
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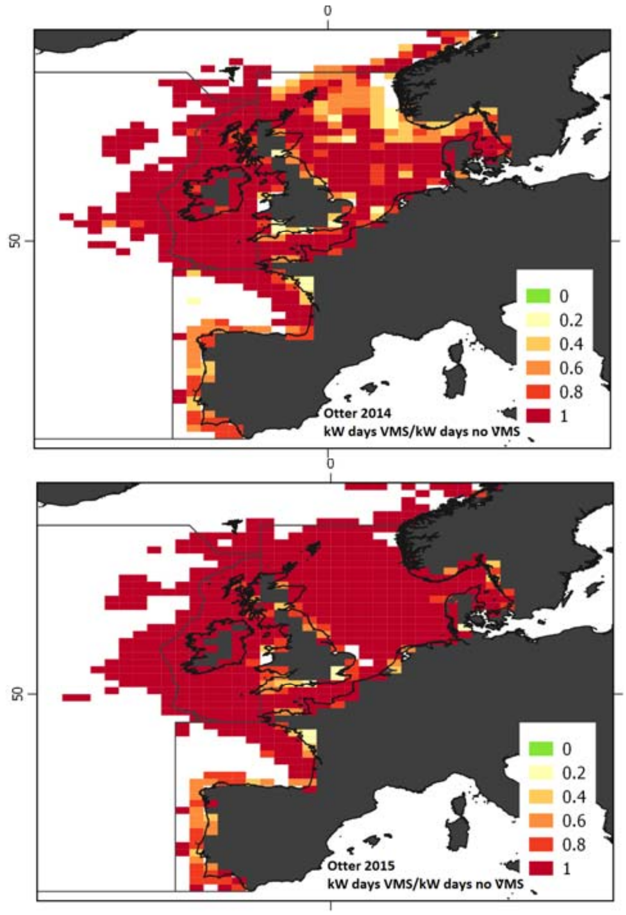
0.4
0.6
0.8
1
Otter 2013
kW days VMS/kW days no VMS


0
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0.8
1
Otter 2014
kW days VMS/kW days no VMS
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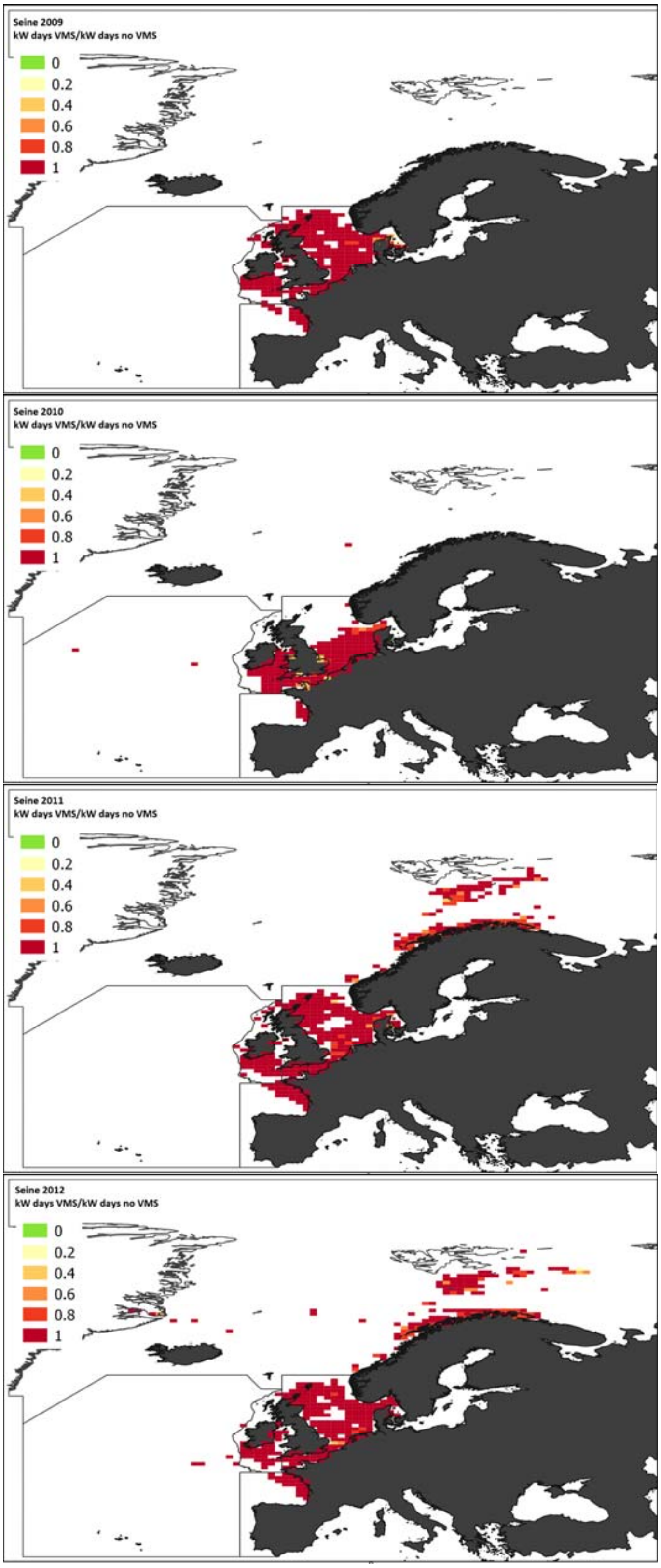
0.4
0.6
0.8
1
Otter 2015
kW days VMS/kW days no VMS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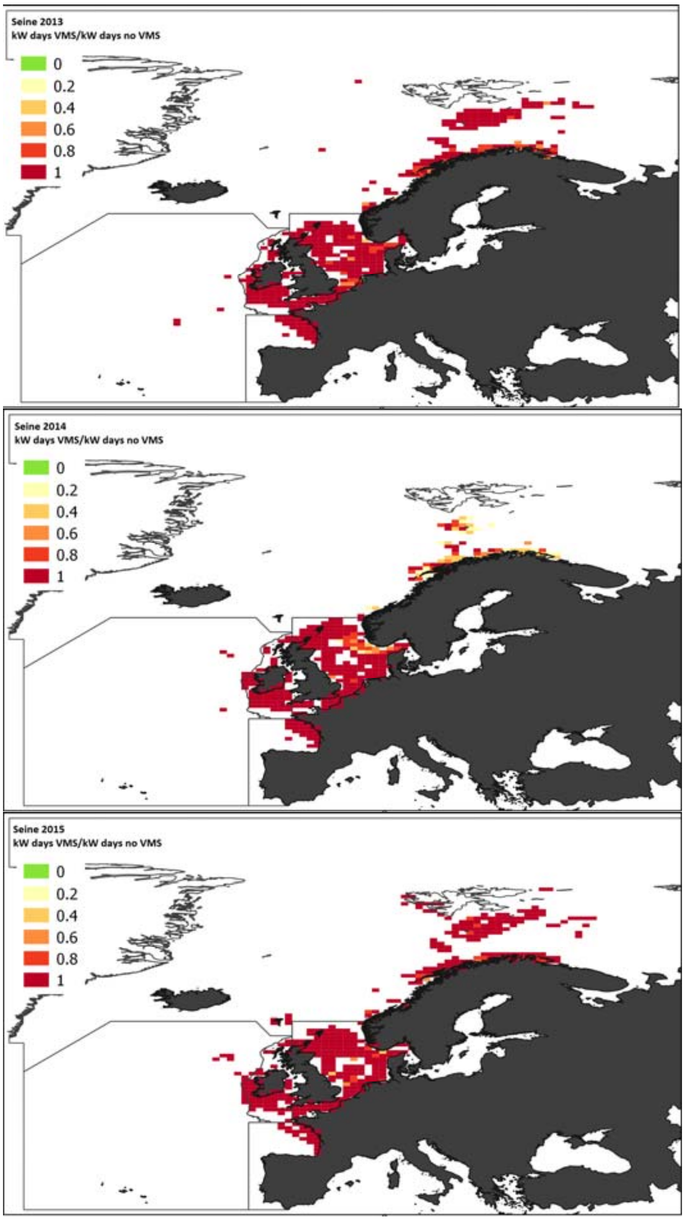
0.2
0.4
0.6
0.8
1
Seine 2010
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
Seine 2011
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1
Seine 2012
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
1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0.6
0.8
1
Seine 2014
kW days VMS/kW days no VMS
0
0.2
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1
Seine 2015
kW days VMS/kW days no VMS
0
0.2
0.4
0.6
0.8
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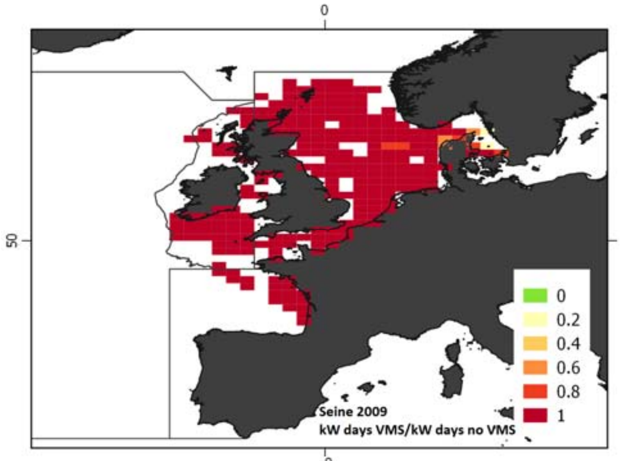
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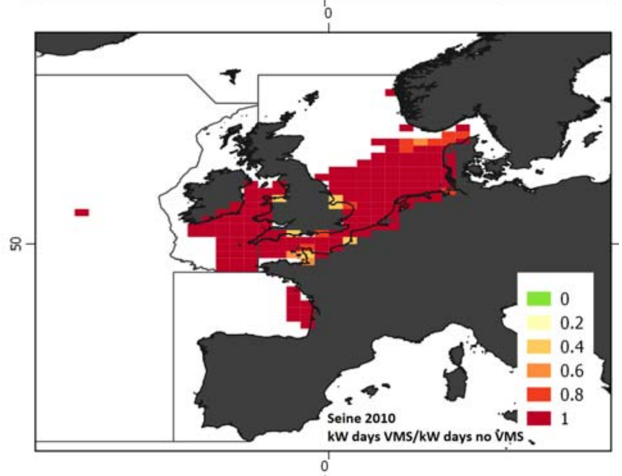
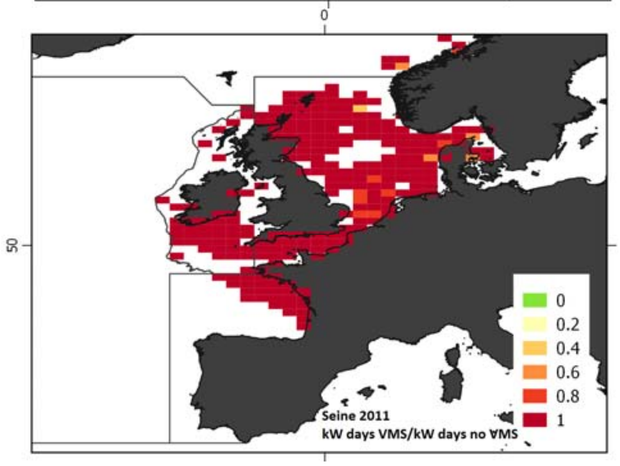
50
0
0.2
0.4
0.6
0.8
1
Seine 2009
kW days VMS/kW days no VMS


0
50
0
0.2
0.4
0.6
0.8
1
Seine 2010
kW days VMS/kW days no VMS


0
50
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0.2
0.4
0.6
0.8
1
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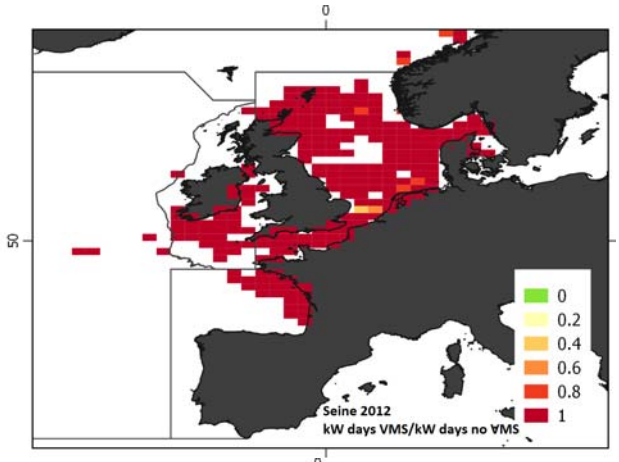
kW days VMS/kW days no VMS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0
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0.4
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0.8
1
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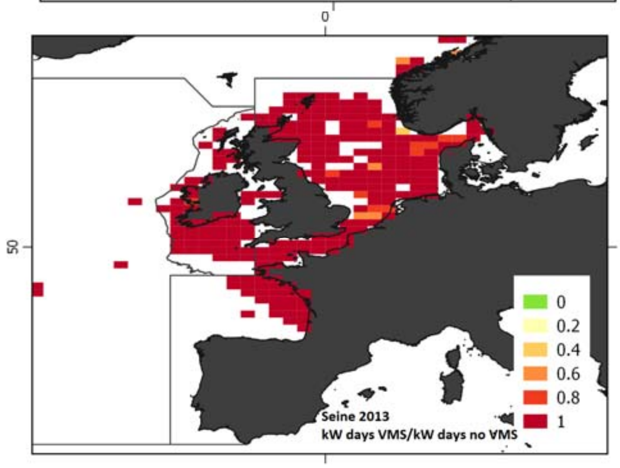
kW days VMS/kW days no VMS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0.8
1
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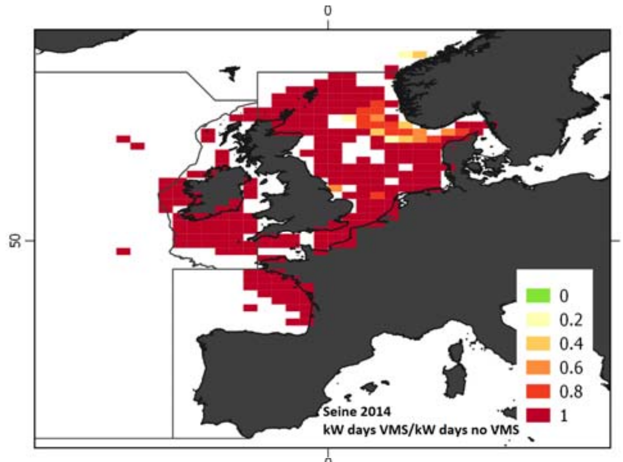
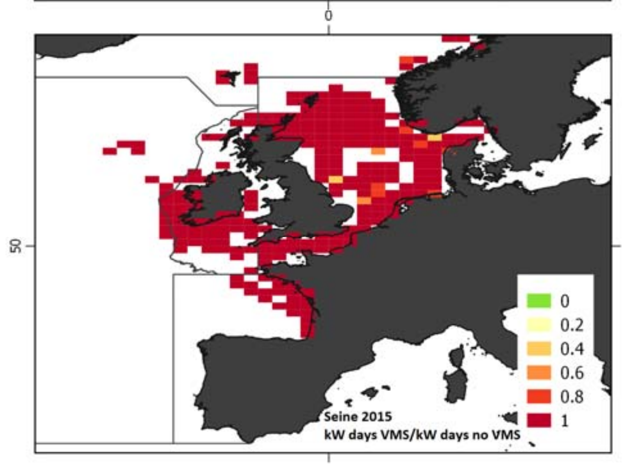
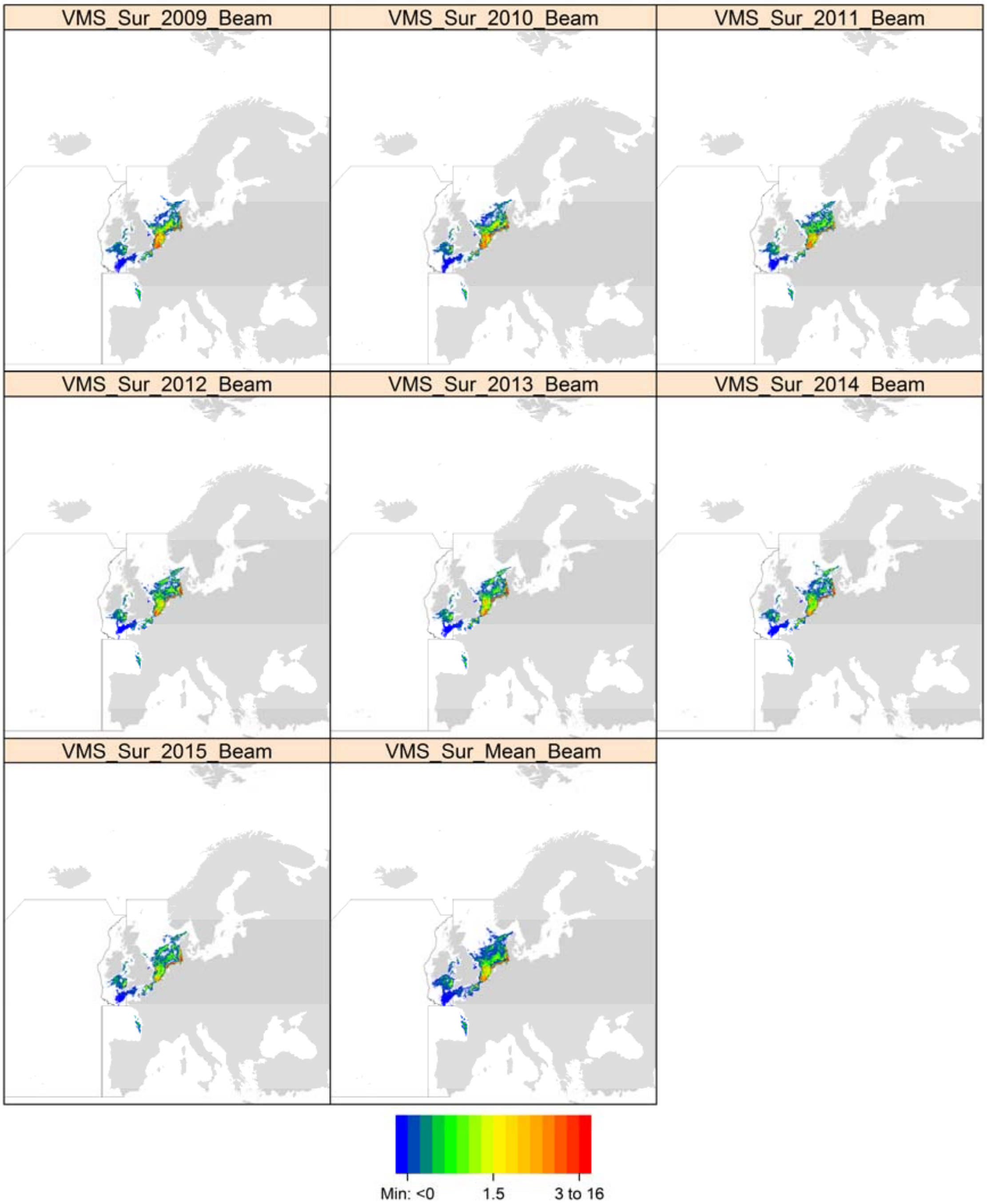
kW days VMS/kW days no VMS

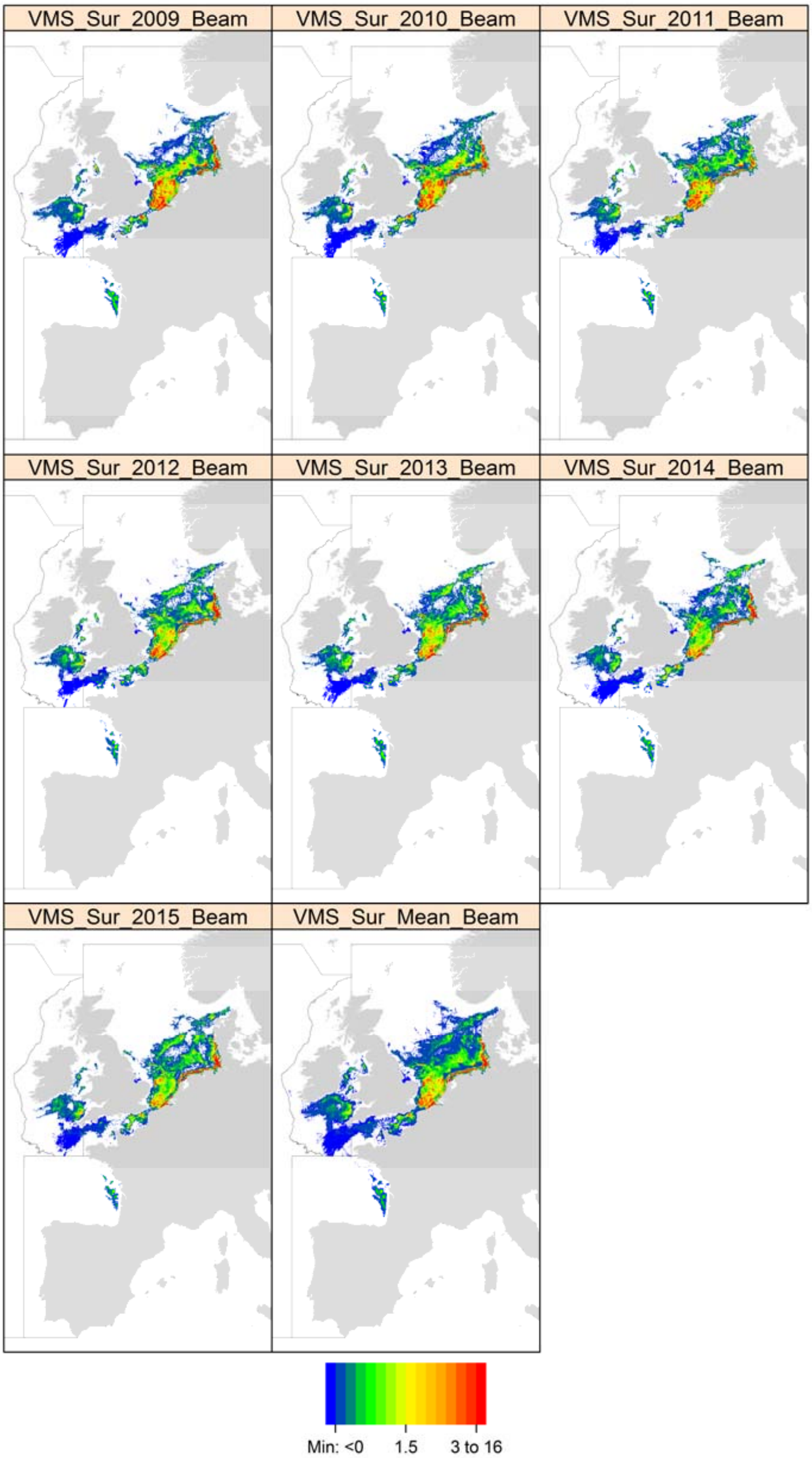

0
50
0
0.2
0.4
0.6
0.8
1
Seine 2014
kW days VMS/kW days no VMS

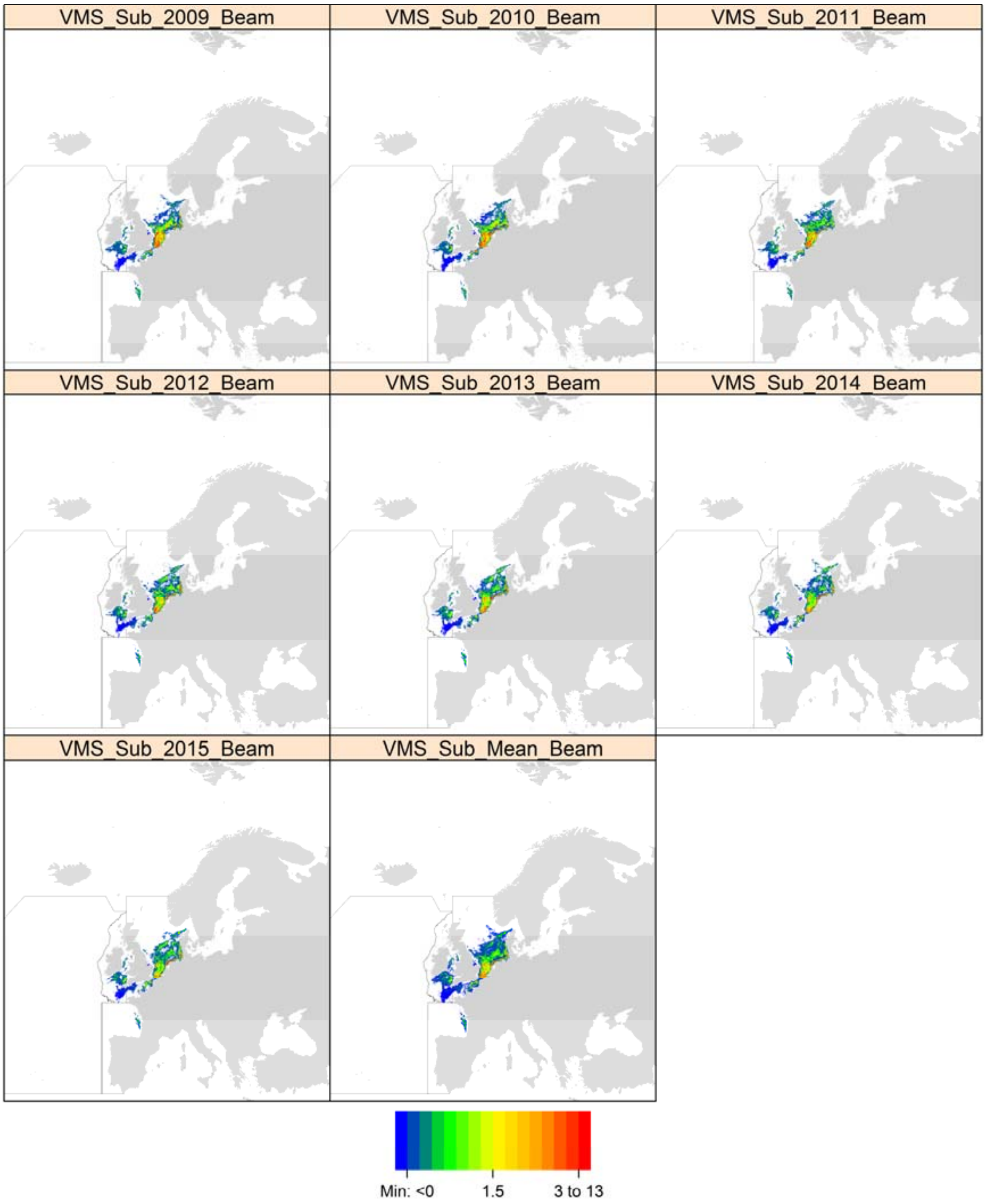

0
50
0
0.2
0.4
0.6
0.8
1
Seine 2015
kW days VMS/kW days no VMS

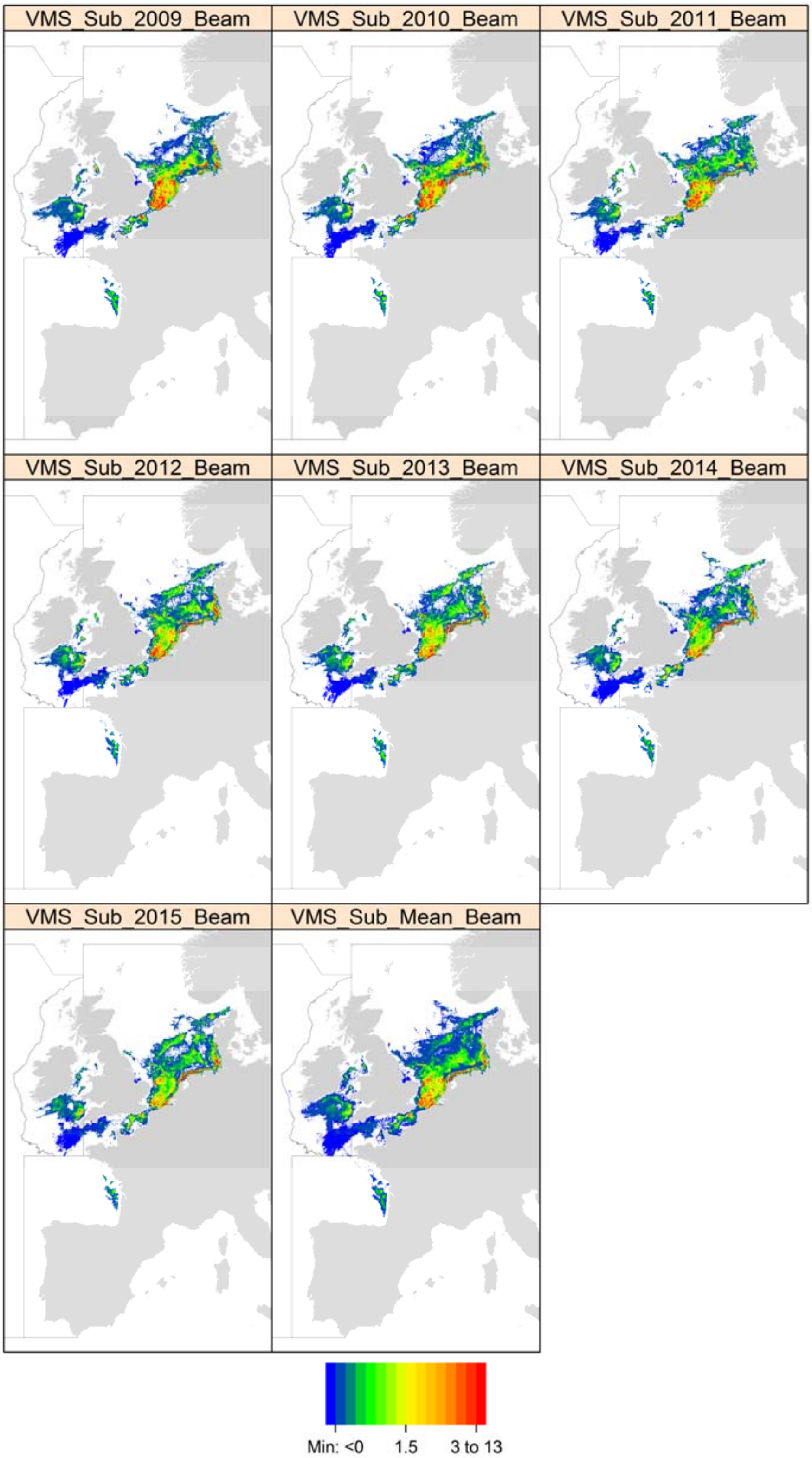
Annex 5: Maps prepared for the OSPAR request

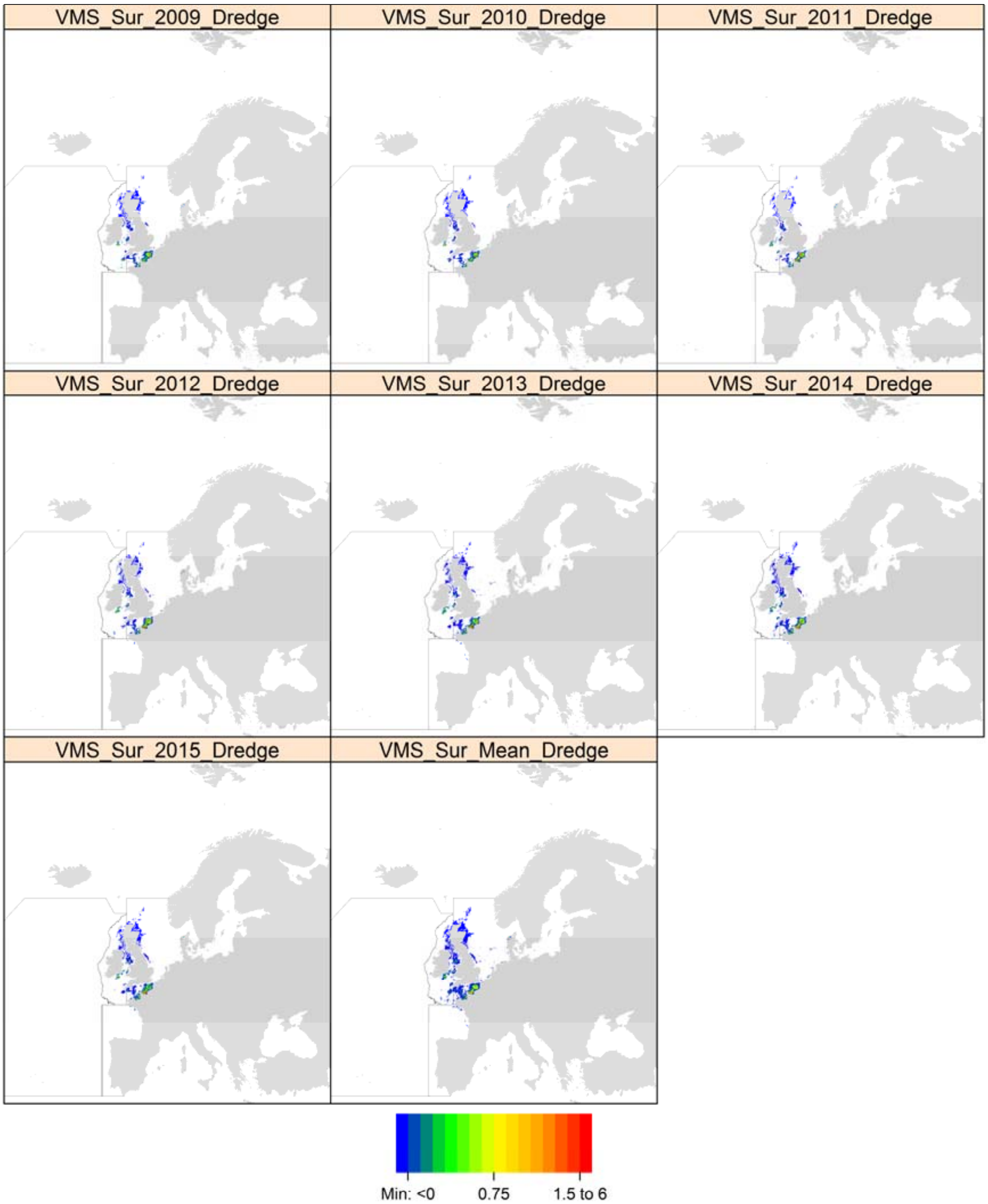
In the headings of the maps "Sur" mean surface swept area ratio. "Sub" mean subsurface swept area ratio. No data were submitted from Spain, Iceland, Greenland, Faroe Islands and Russia. Note caveats listed in section 5.1.2.

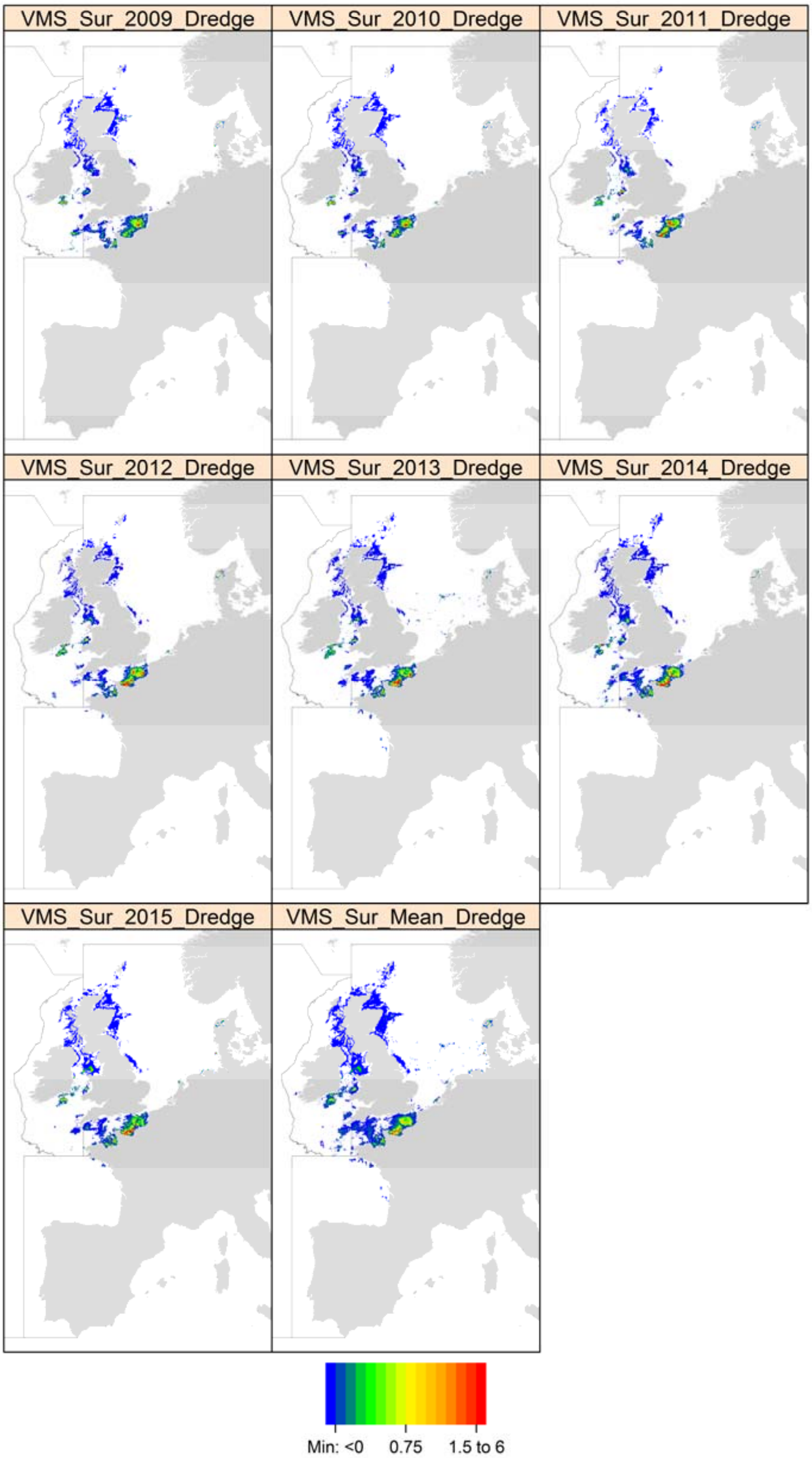


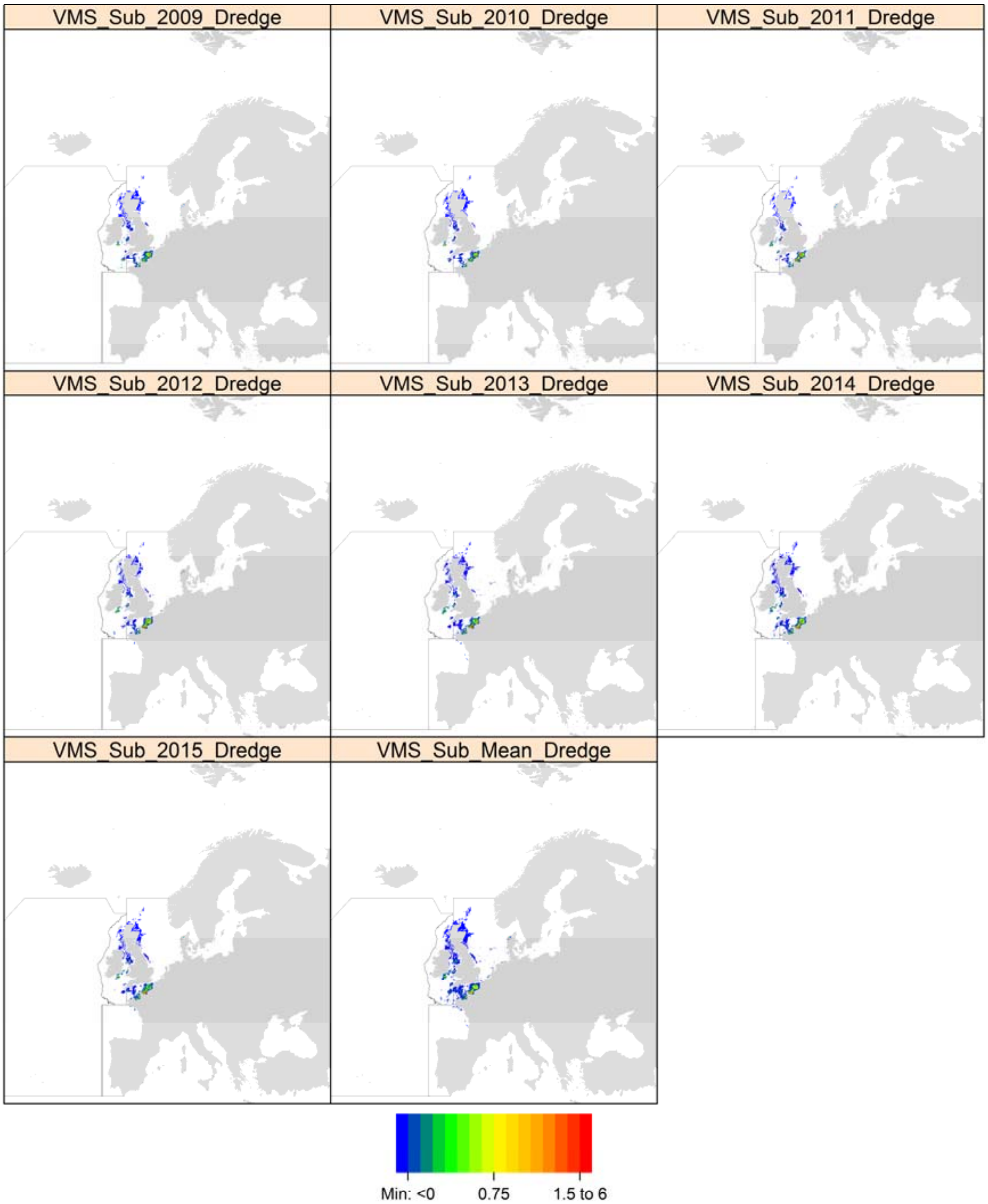

VMS_Sur_2009_Beam
VMS_Sur_2010_Beam
VMS_Sur_2011_Beam
VMS_Sur_2012_Beam
VMS_Sur_2013_Beam
VMS_Sur_2014_Beam
VMS_Sur_2015_Beam
VMS_Sur_Mean_Beam
Min: <0
1.5
3 to 16

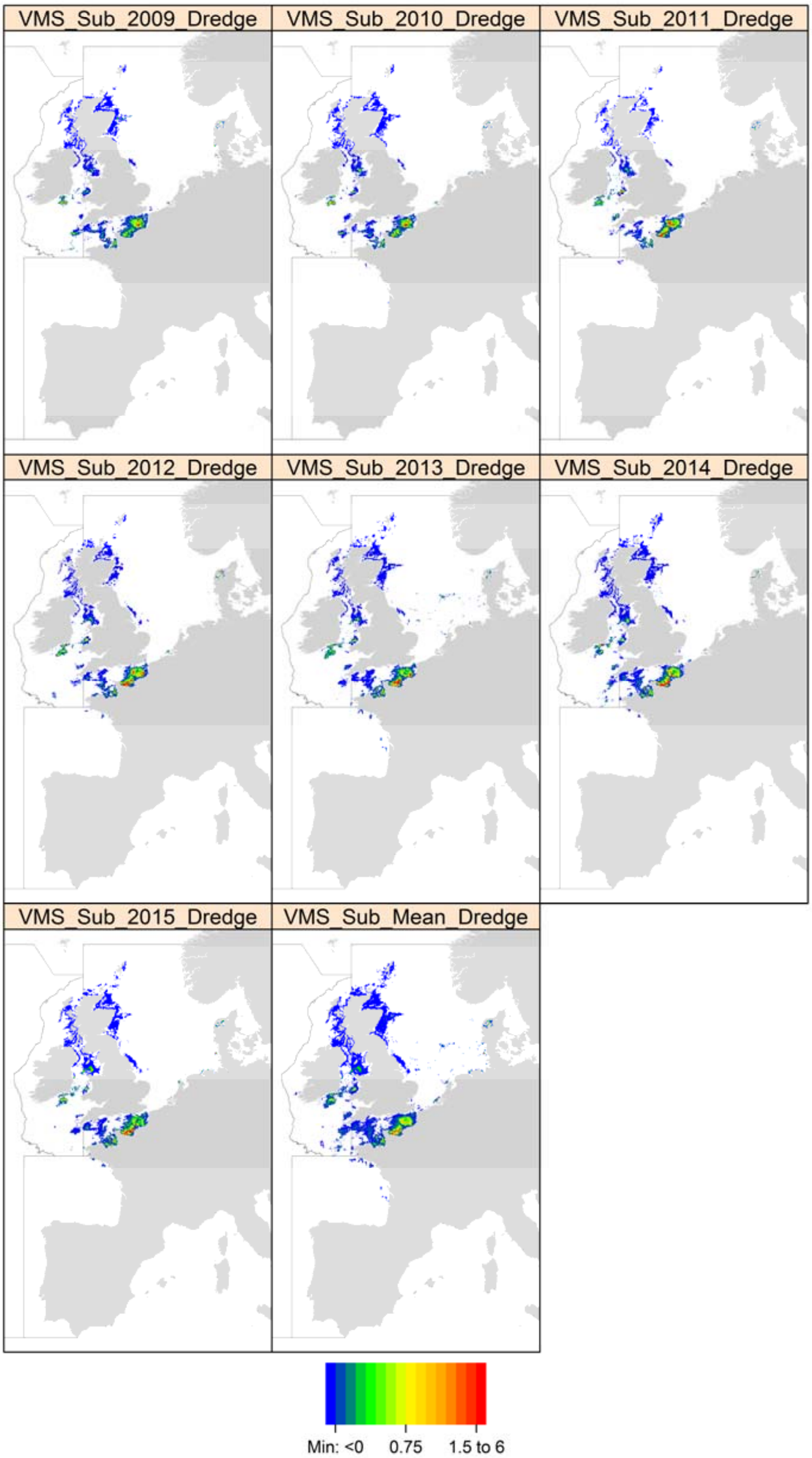

VMS_Sub_2009_Beam
VMS_Sub_2010_Beam
VMS_Sub_2011_Beam
VMS_Sub_2012_Beam
VMS_Sub_2013_Beam
VMS_Sub_2014_Beam
VMS_Sub_2015_Beam
VMS_Sub_Mean_Beam
Min: <0
1.5
3 to 13

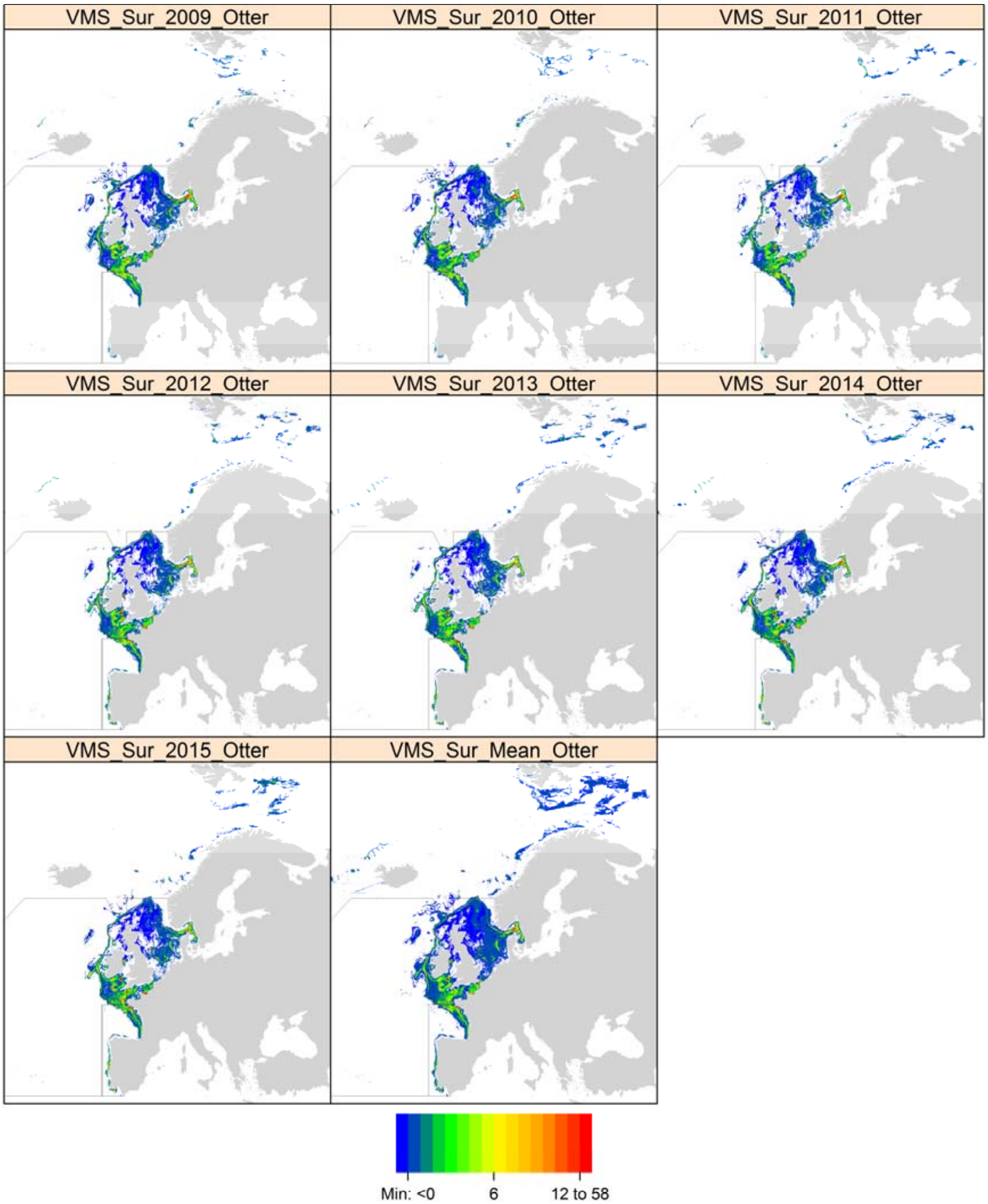

VMS_Sub_2009_Beam
VMS_Sub_2010_Beam
VMS_Sub_2011_Beam
VMS_Sub_2012_Beam
VMS_Sub_2013_Beam
VMS_Sub_2014_Beam
VMS_Sub_2015_Beam
VMS_Sub_Mean_Beam
Min: <0
1.5
3 to 13

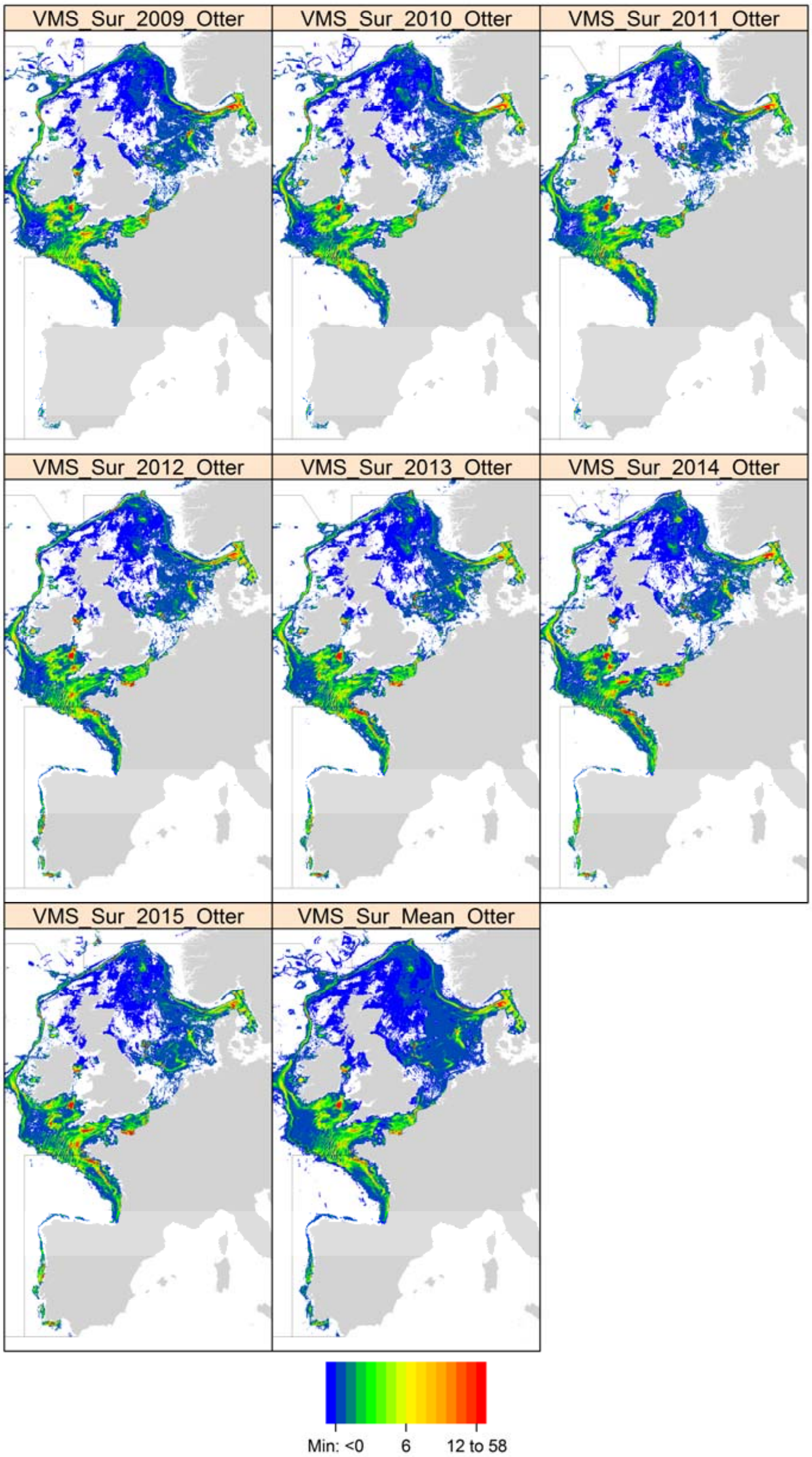

VMS_Sur_2009_Dredge
VMS_Sur_2010_Dredge
VMS_Sur_2011_Dredge
VMS_Sur_2012_Dredge
VMS_Sur_2013_Dredge
VMS_Sur_2014_Dredge
VMS_Sur_2015_Dredge
VMS_Sur_Mean_Dredge
Min: <0
0.75
1.5 to 6

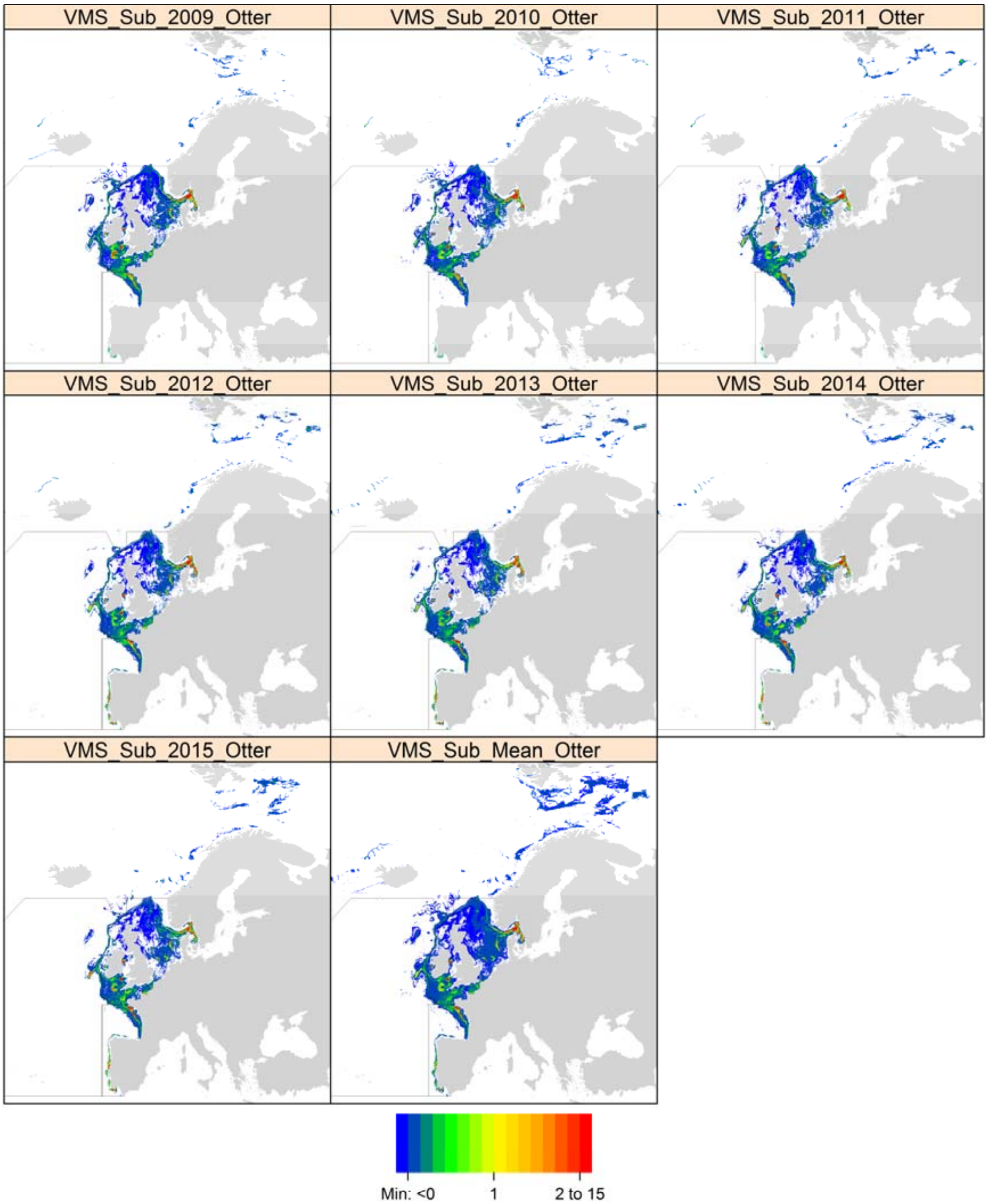

VMS_Sur_2009_Dredge
VMS_Sur_2010_Dredge
VMS_Sur_2011_Dredge
VMS_Sur_2012_Dredge
VMS_Sur_2013_Dredge
VMS_Sur_2014_Dredge
VMS_Sur_2015_Dredge
VMS_Sur_Mean_Dredge
Min: <0
0.75
1.5 to 6

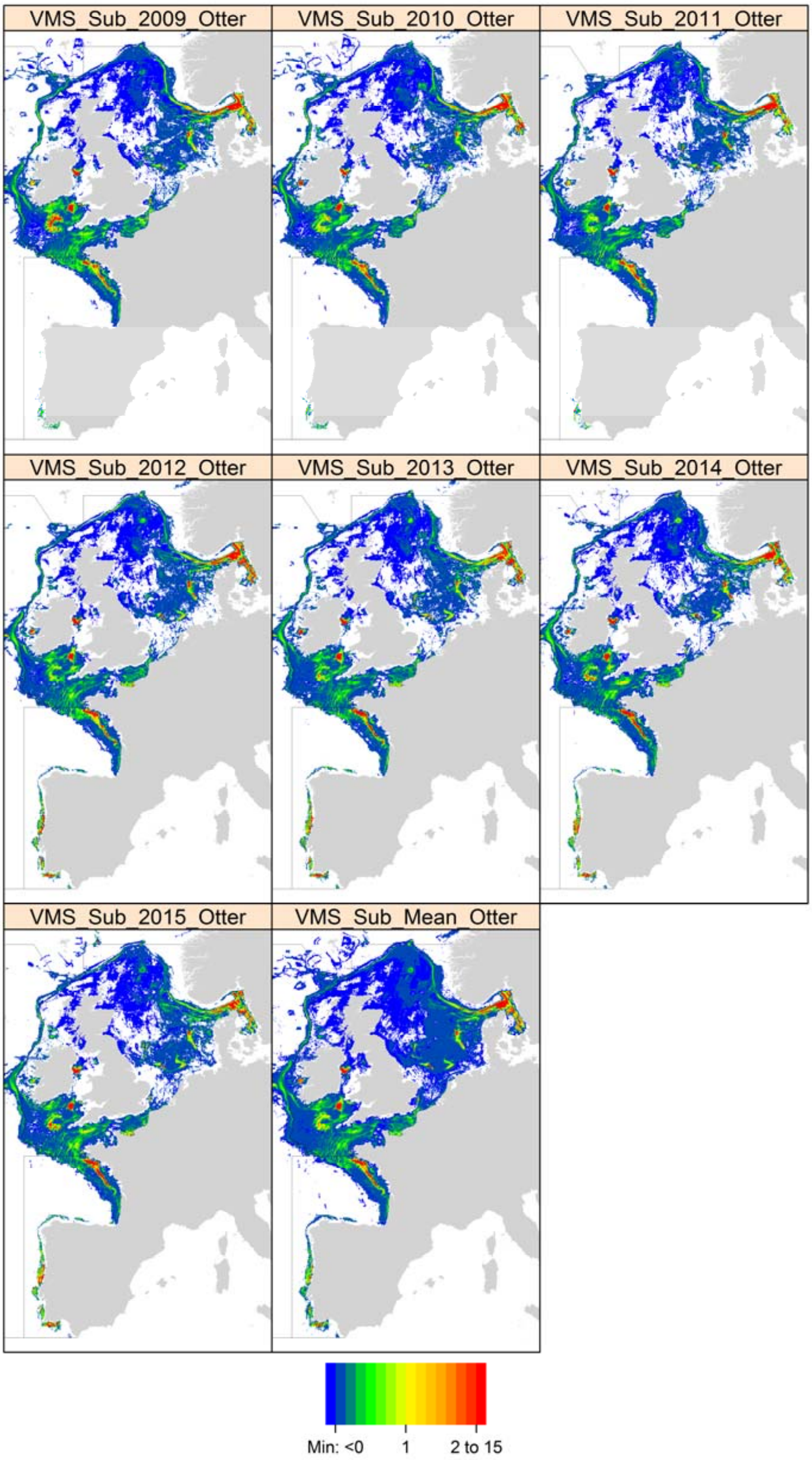

VMS_Sub_2009_Dredge
VMS_Sub_2010_Dredge
VMS_Sub_2011_Dredge
VMS_Sub_2012_Dredge
VMS_Sub_2013_Dredge
VMS_Sub_2014_Dredge
VMS_Sub_2015_Dredge
VMS_Sub_Mean_Dredge
Min: <0
0.75
1.5 to 6

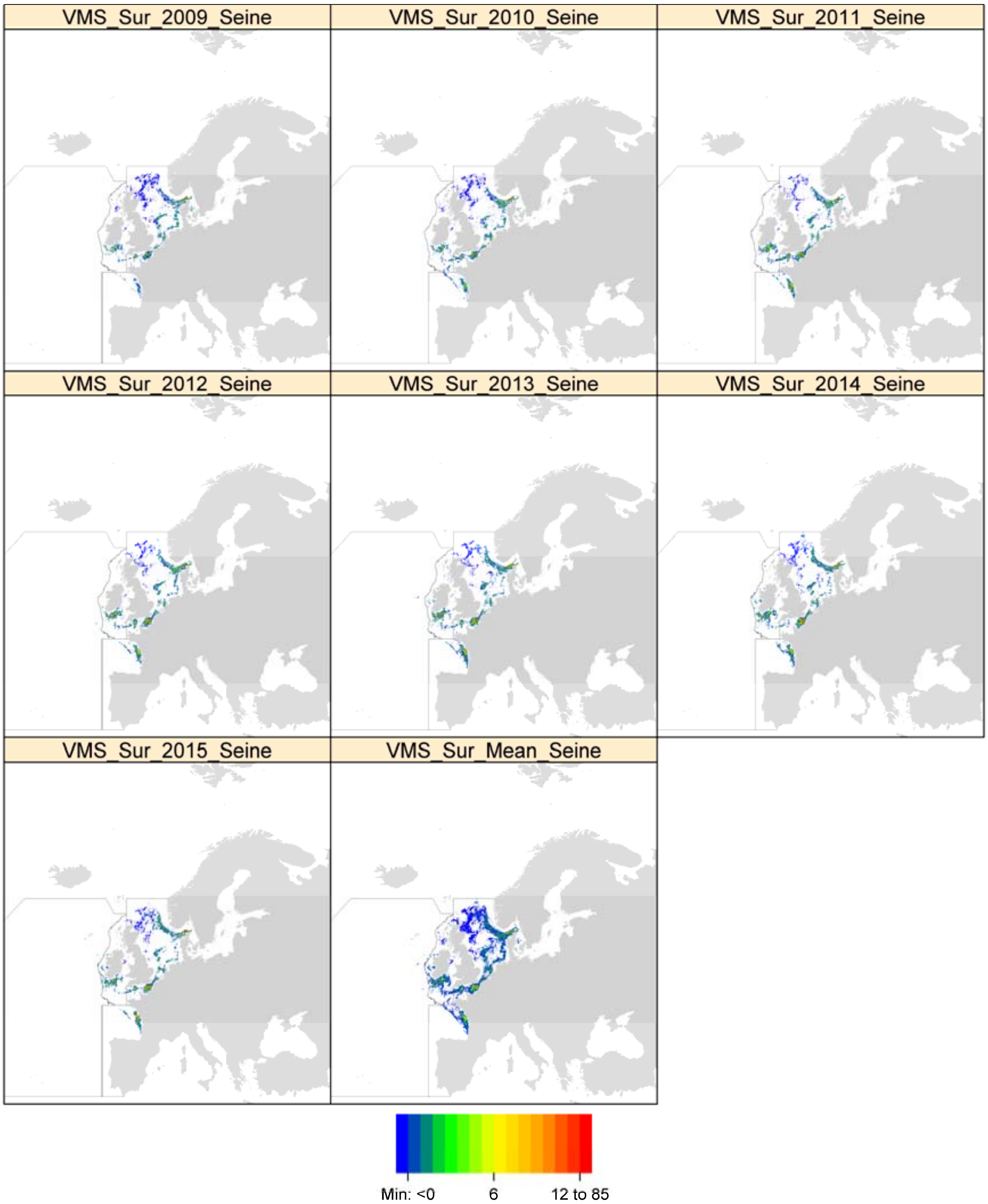

VMS_Sub_2009_Dredge
VMS_Sub_2010_Dredge
VMS_Sub_2011_Dredge
VMS_Sub_2012_Dredge
VMS_Sub_2013_Dredge
VMS_Sub_2014_Dredge
VMS_Sub_2015_Dredge
VMS_Sub_Mean_Dredge
Min: <0
0.75
1.5 to 6

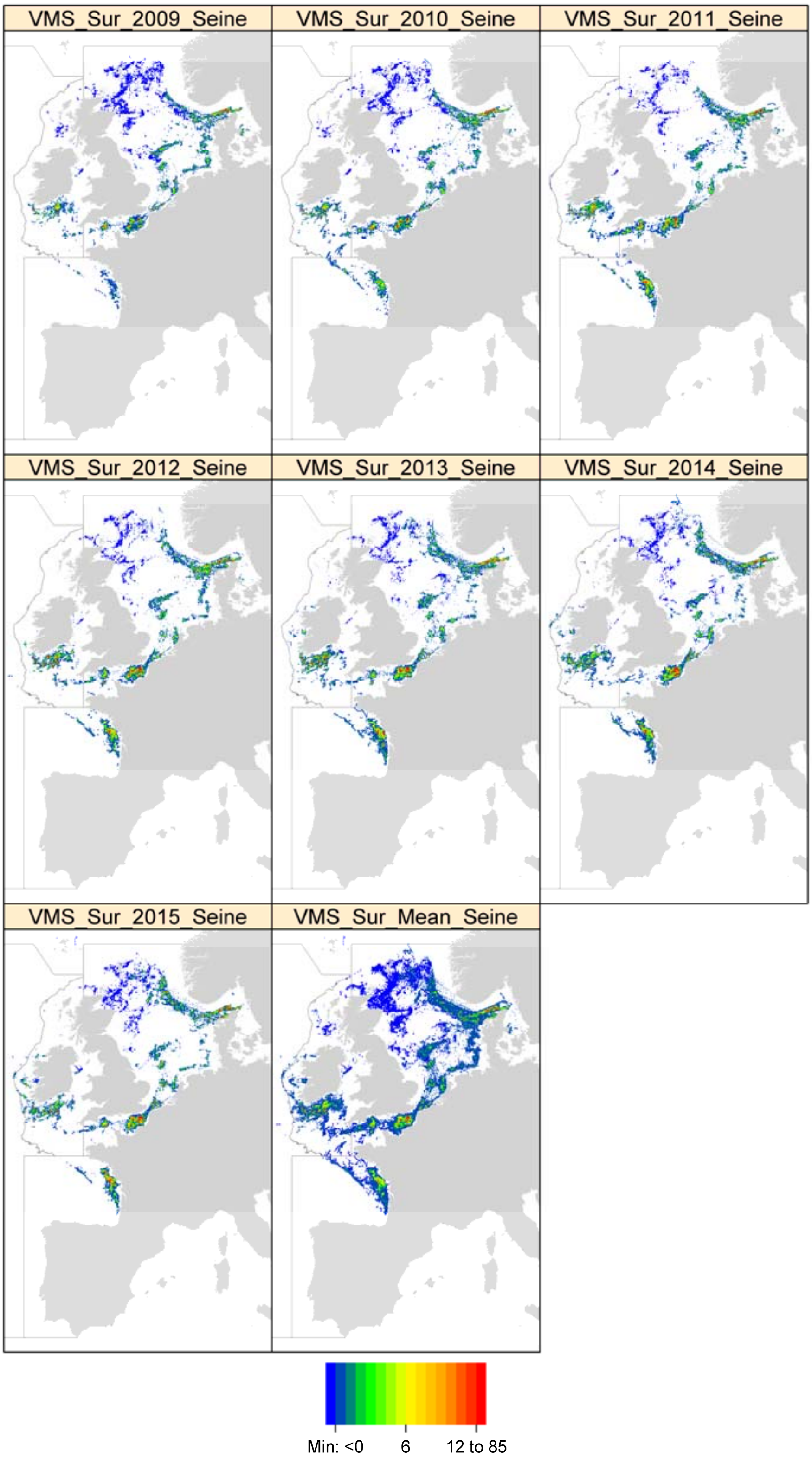

VMS_Sur_2009_Otter
VMS_Sur_2010_Otter
VMS_Sur_2011_Otter
VMS_Sur_2012_Otter
VMS_Sur_2013_Otter
VMS_Sur_2014_Otter
VMS_Sur_2015_Otter
VMS_Sur_Mean_Otter
Min: <0
6
12 to 58

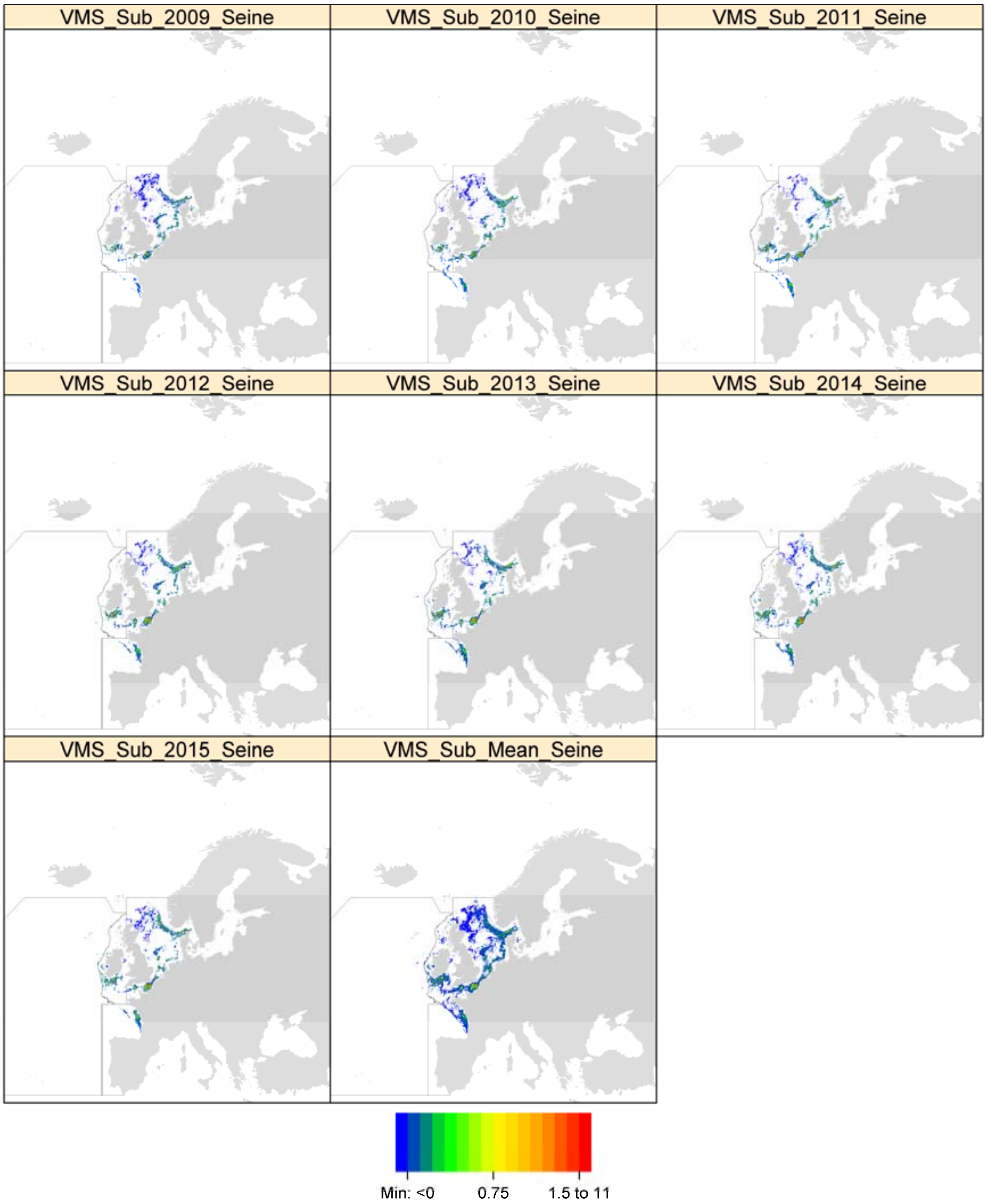

VMS_Sur_2009_Otter
VMS_Sur_2010_Otter
VMS_Sur_2011_Otter
VMS_Sur_2012_Otter
VMS_Sur_2013_Otter
VMS_Sur_2014_Otter
VMS_Sur_2015_Otter
VMS_Sur_Mean_Otter
Min: <0
6
12 to 58

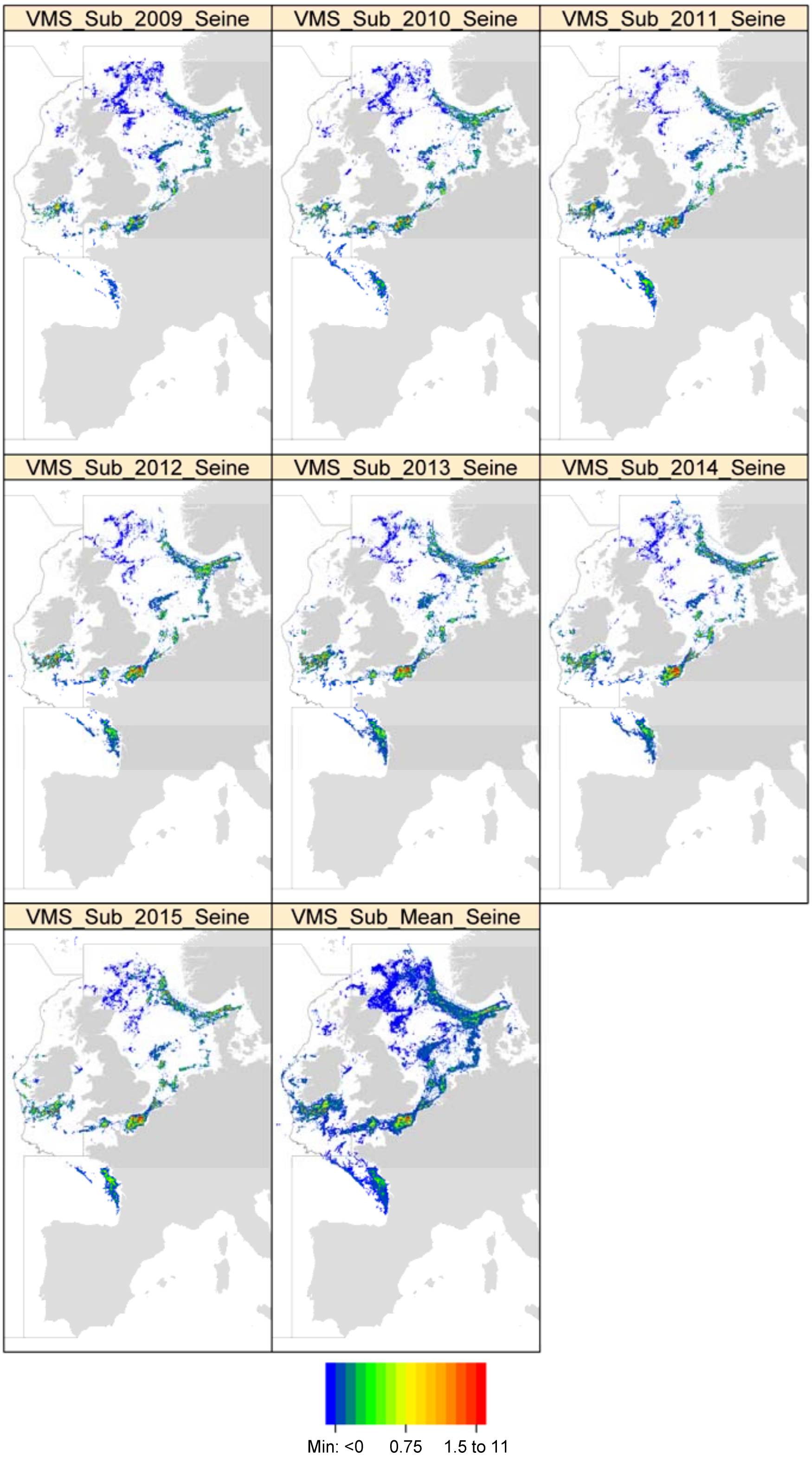

VMS_Sub_2009_Otter
VMS_Sub_2010_Otter
VMS_Sub_2011_Otter
VMS_Sub_2012_Otter
VMS_Sub_2013_Otter
VMS_Sub_2014_Otter
VMS_Sub_2015_Otter
VMS_Sub_Mean_Otter
Min: <0
1
2 to 15


VMS_Sub_2009_Otter
VMS_Sub_2010_Otter
VMS_Sub_2011_Otter
VMS_Sub_2012_Otter
VMS_Sub_2013_Otter
VMS_Sub_2014_Otter
VMS_Sub_2015_Otter
VMS_Sub_Mean_Otter
Min: <0
1
2 to 15


VMS_Sur_2009_Seine
VMS_Sur_2010_Seine
VMS_Sur_2011_Seine
VMS_Sur_2012_Seine
VMS_Sur_2013_Seine
VMS_Sur_2014_Seine
VMS_Sur_2015_Seine
VMS_Sur_Mean_Seine
Min: <0
6
12 to 85

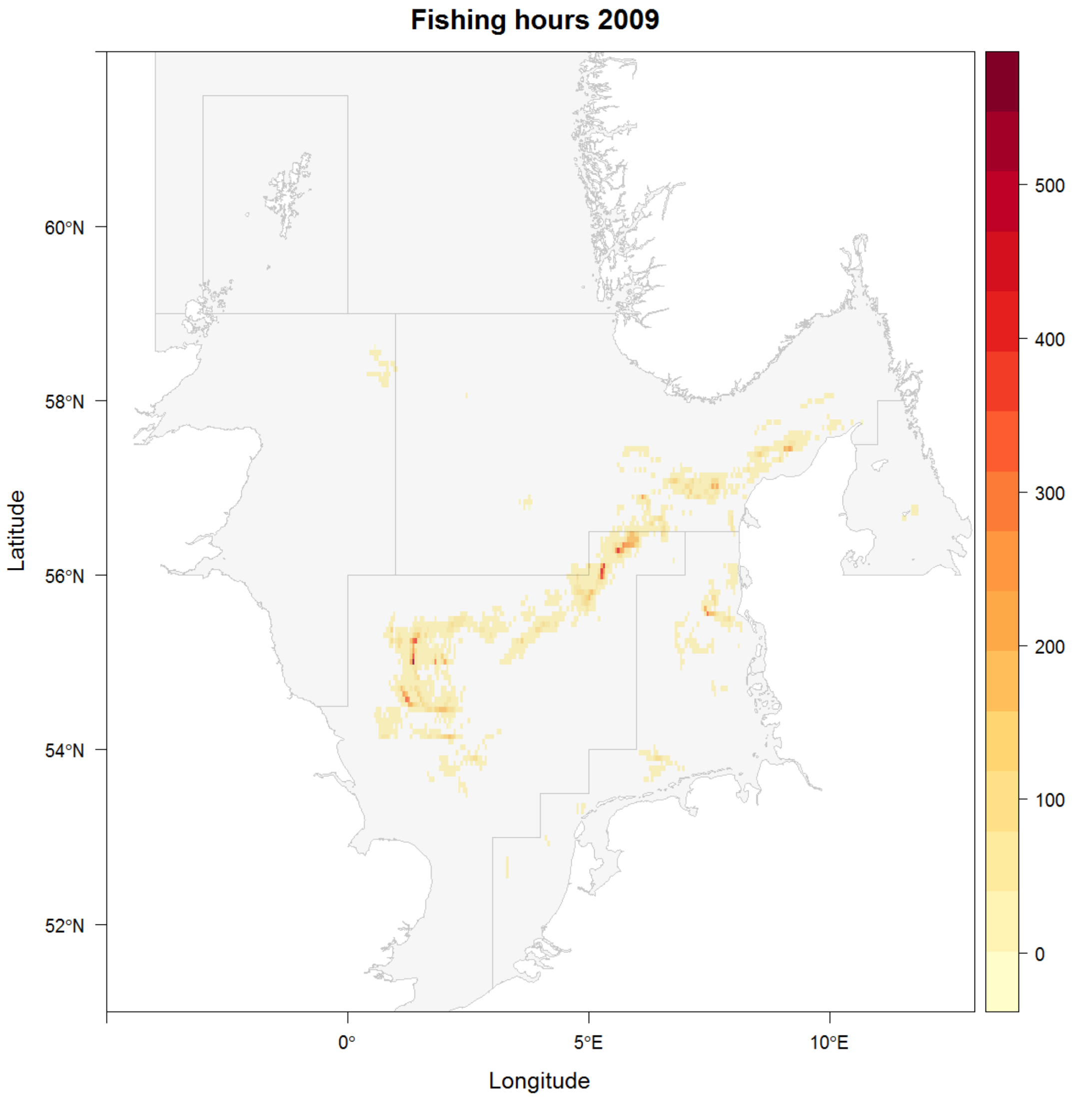

VMS_Sur_2009_Seine
VMS_Sur_2010_Seine
VMS_Sur_2011_Seine
VMS_Sur_2012_Seine
VMS_Sur_2013_Seine
VMS_Sur_2014_Seine
VMS_Sur_2015_Seine
VMS_Sur_Mean_Seine
Min: <0
6
12 to 85

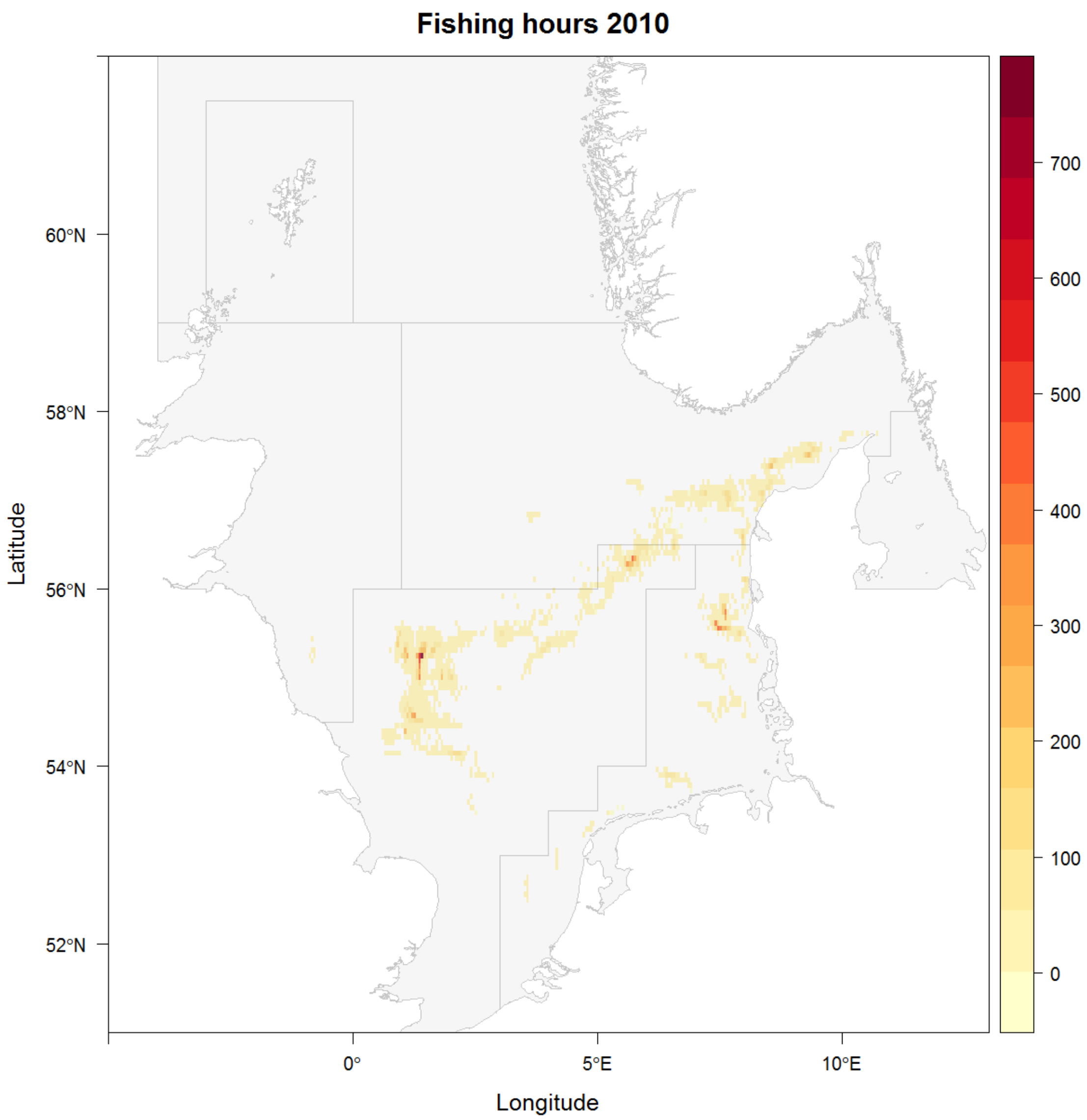

VMS_Sub_2009_Seine
VMS_Sub_2010_Seine
VMS_Sub_2011_Seine
VMS_Sub_2012_Seine
VMS_Sub_2013_Seine
VMS_Sub_2014_Seine
VMS_Sub_2015_Seine
VMS_Sub_Mean_Seine
Min: <0
0.75
1.5 to 11

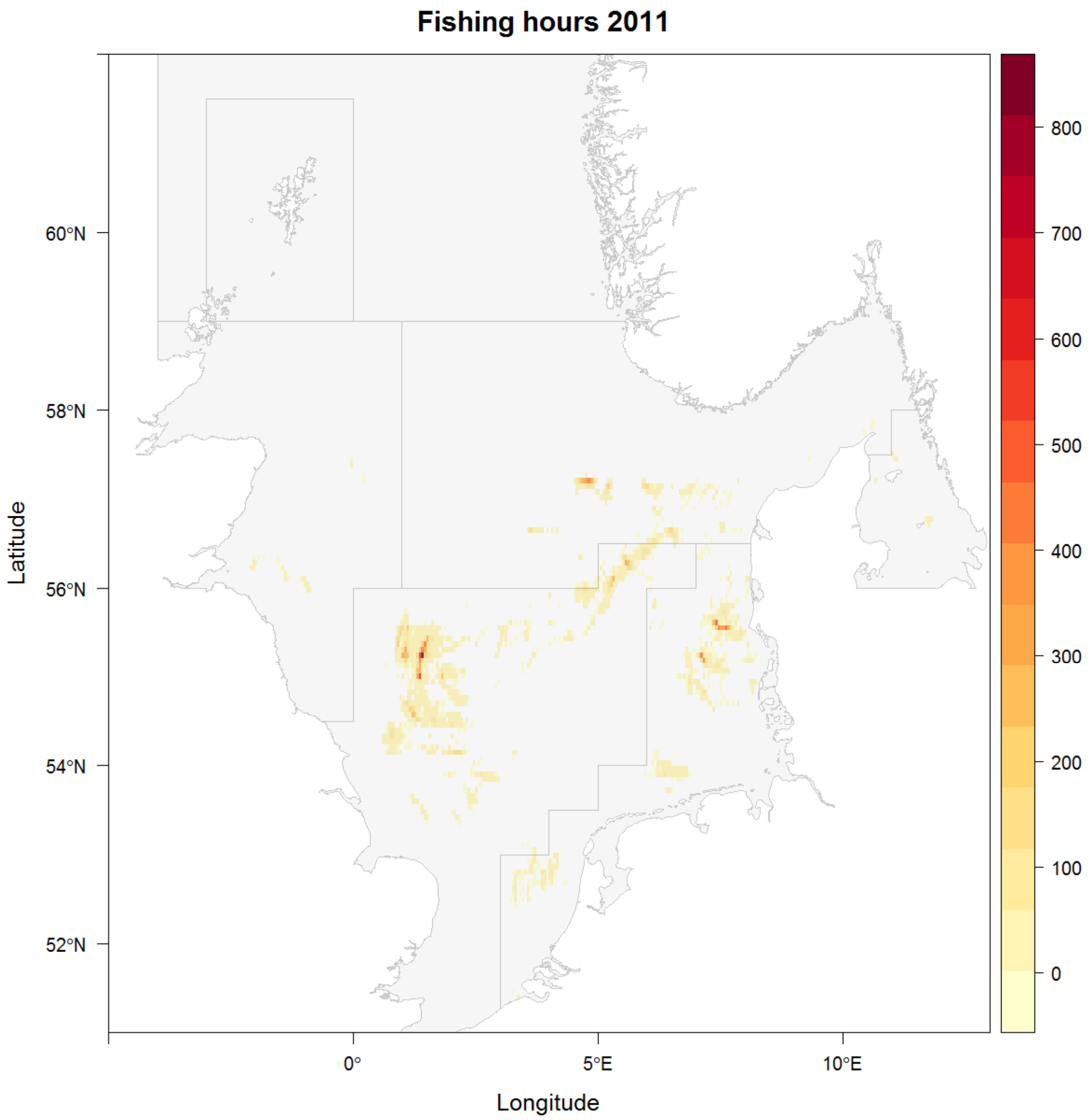

VMS_Sub_2009_Seine
VMS_Sub_2010_Seine
VMS_Sub_2011_Seine
VMS_Sub_2012_Seine
VMS_Sub_2013_Seine
VMS_Sub_2014_Seine
VMS_Sub_2015_Seine
VMS_Sub_Mean_Seine
Min: <0
0.75
1.5 to 11

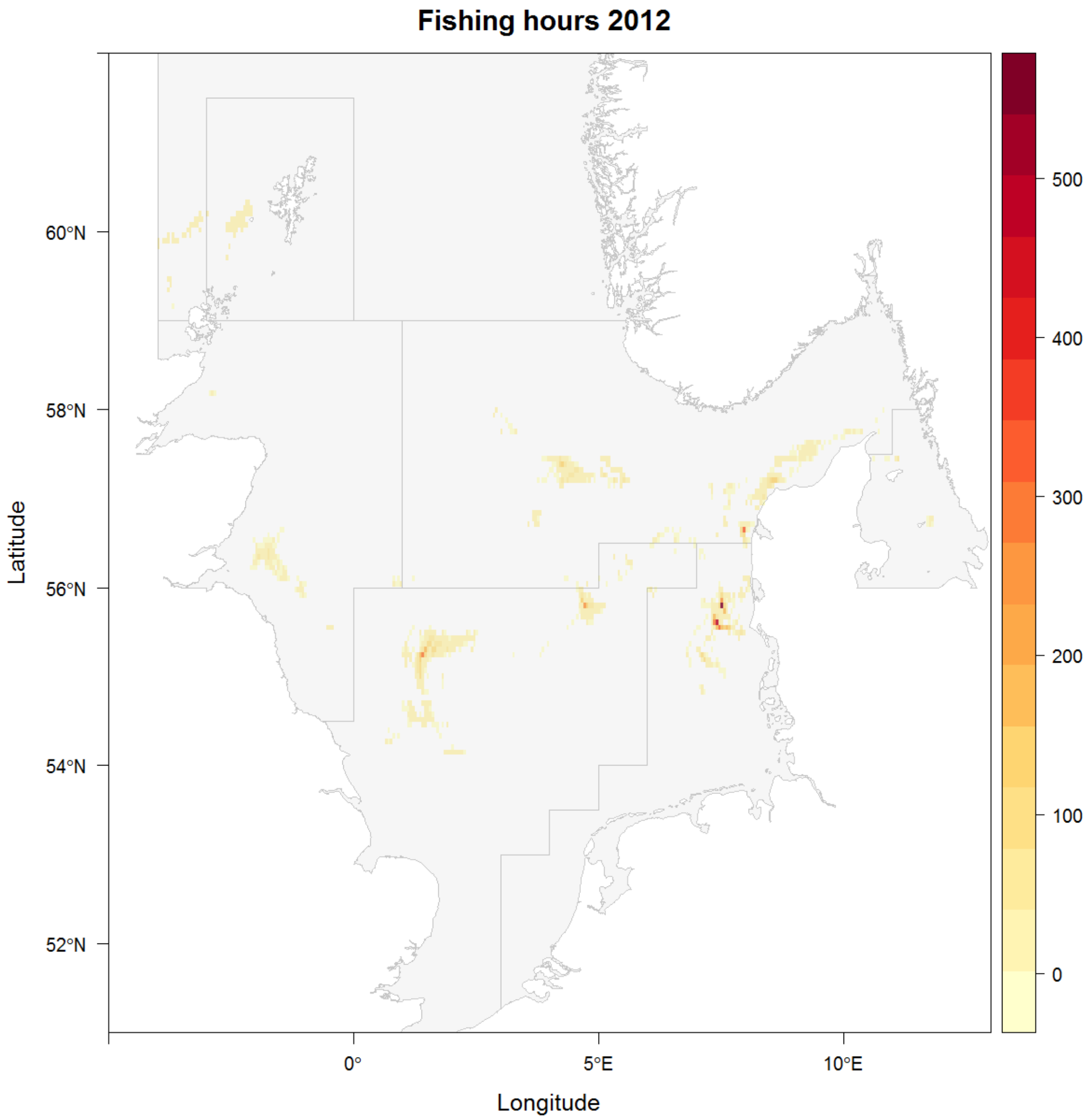
Annex 6: Maps produced for ToR f: Request from WKSand on the sandeel fishery

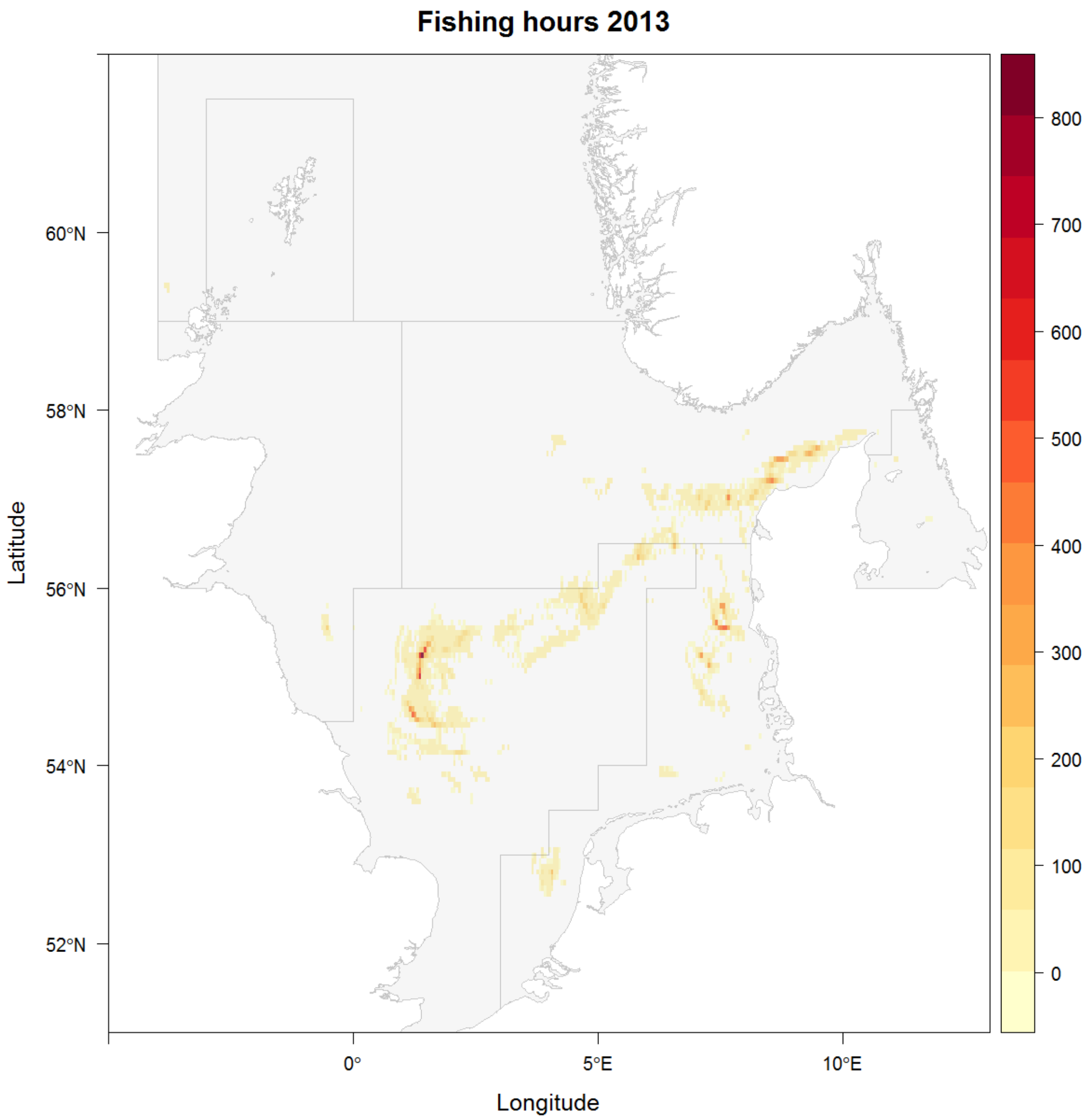
Yearly effort in fishing hour 2009–2015



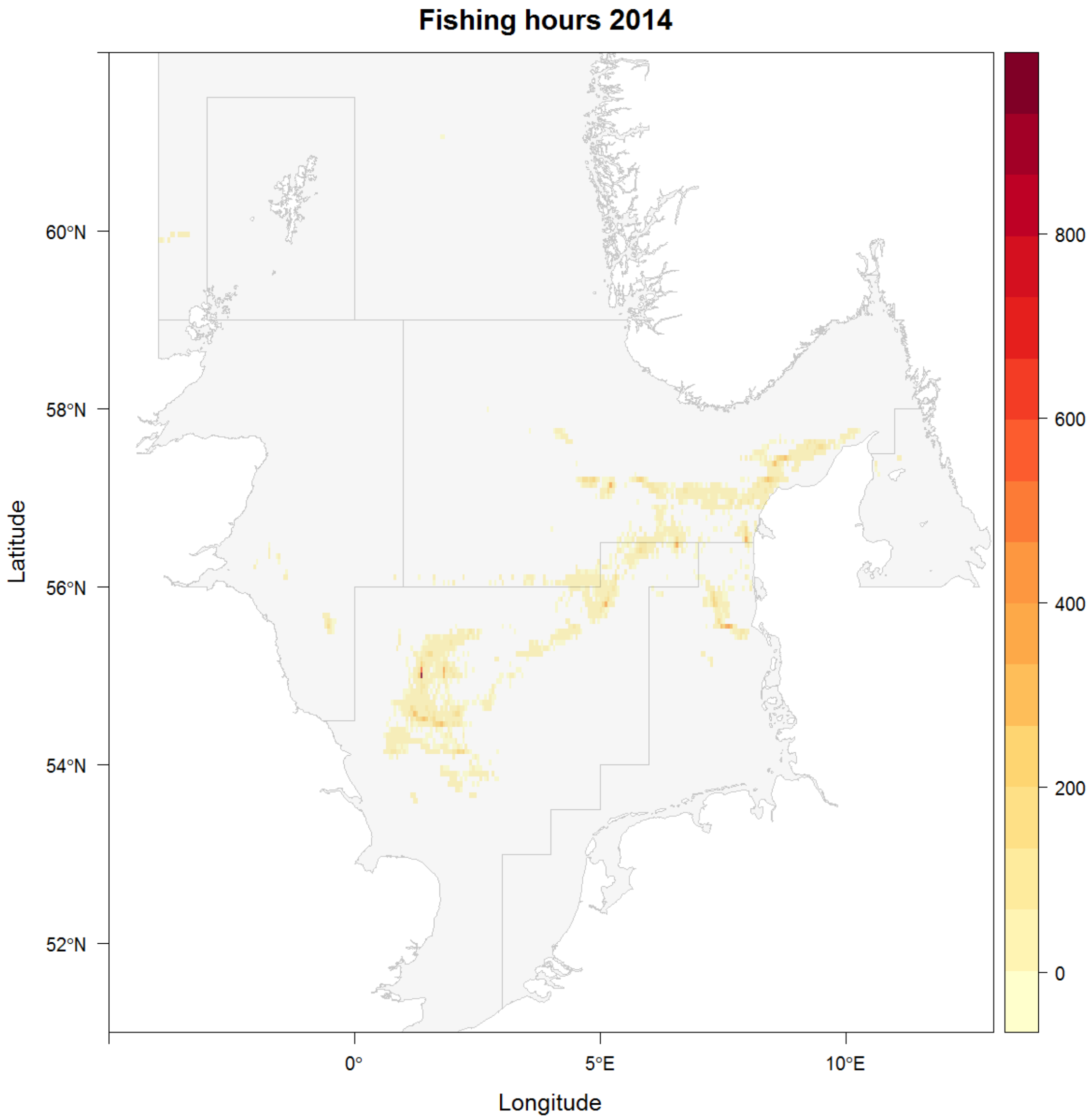

Fishing hours 2010
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
700
600
500
400
300
200
100
0

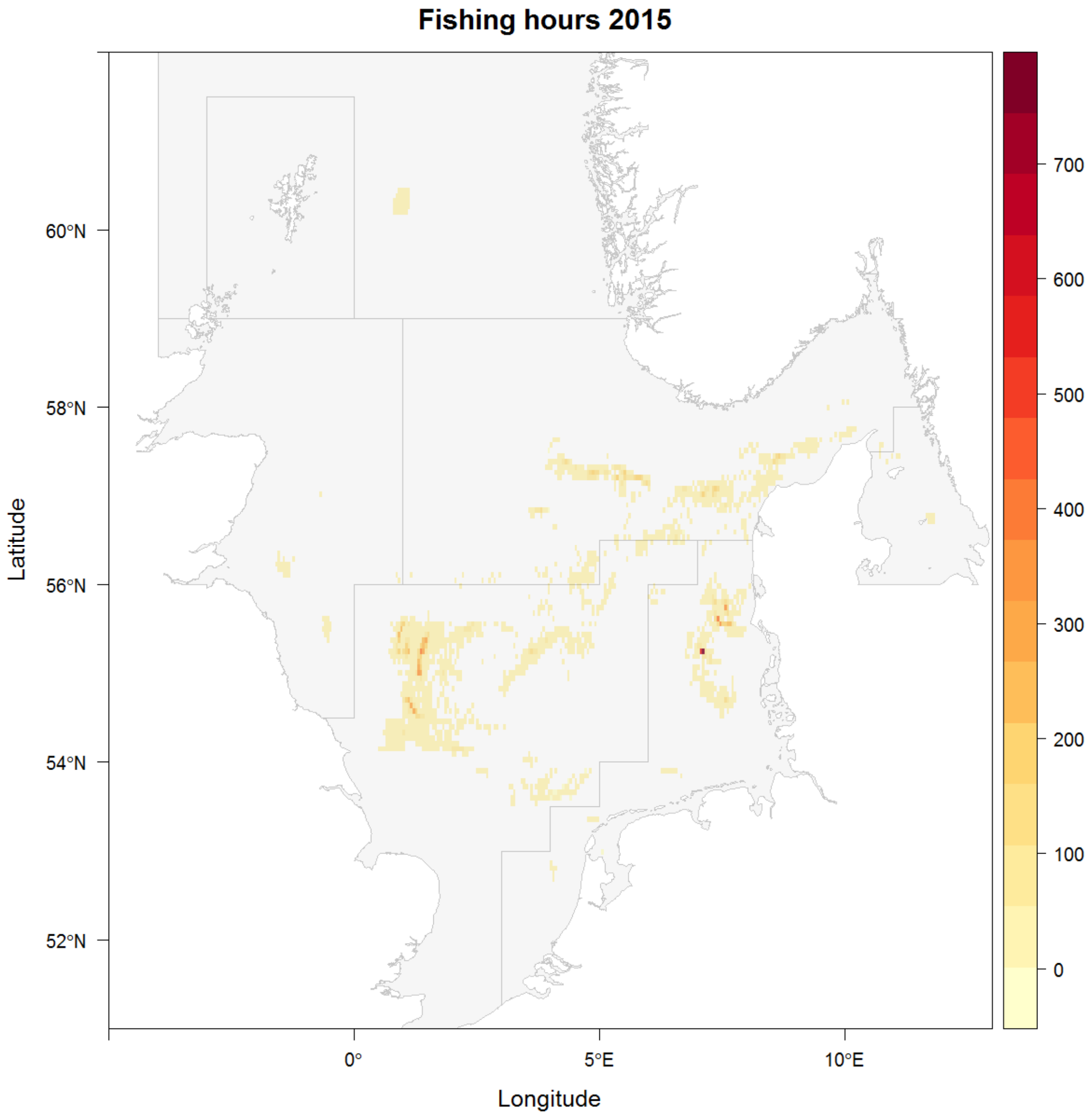

Fishing hours 2011
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
800
700
600
500
400
300
200
100
0


Fishing hours 2012
Latitude
60°N
58°N
56°N
54°N
52°N
0°
5°E
10°E
Longitude
500
400
300
200
100
0

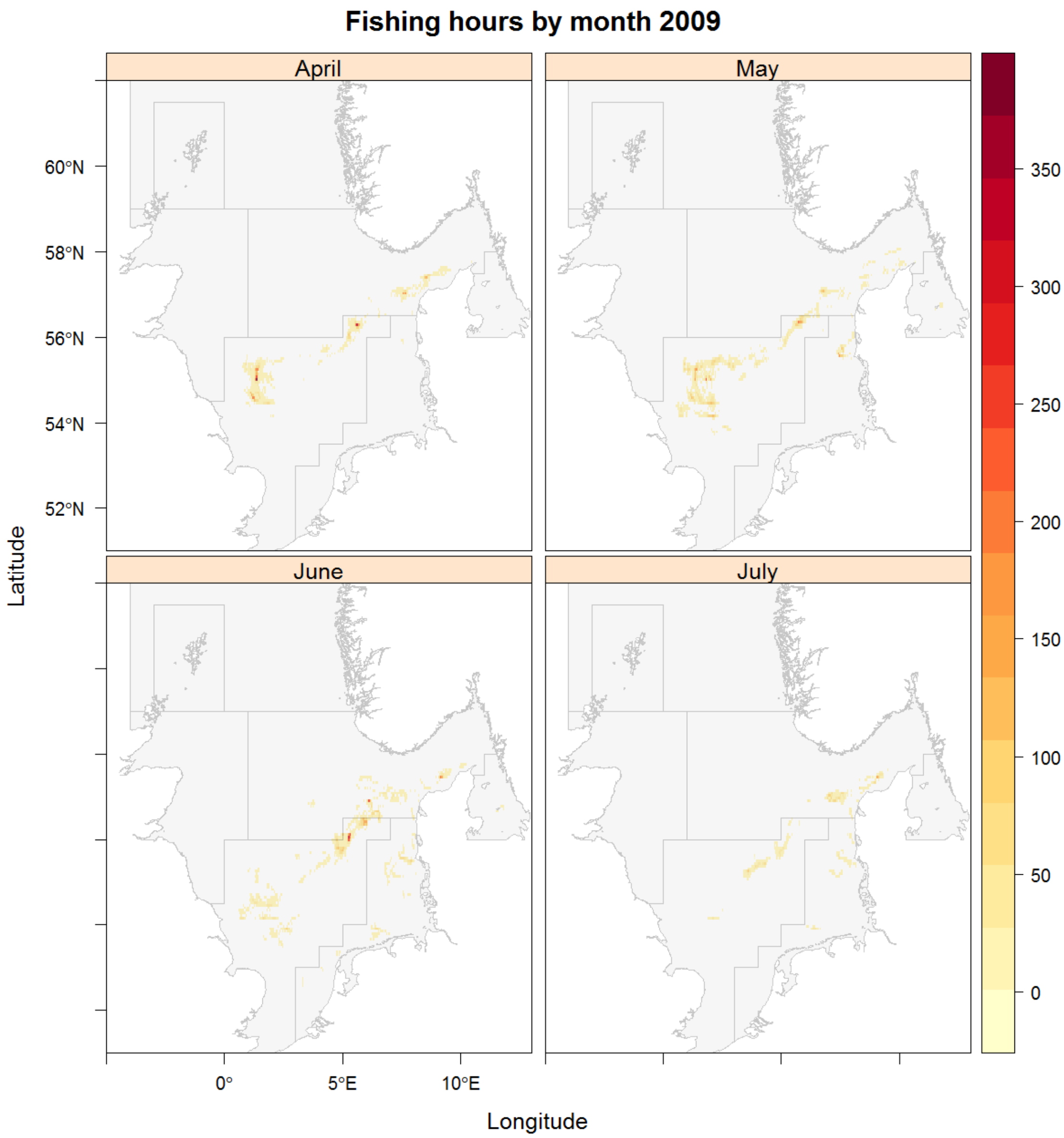


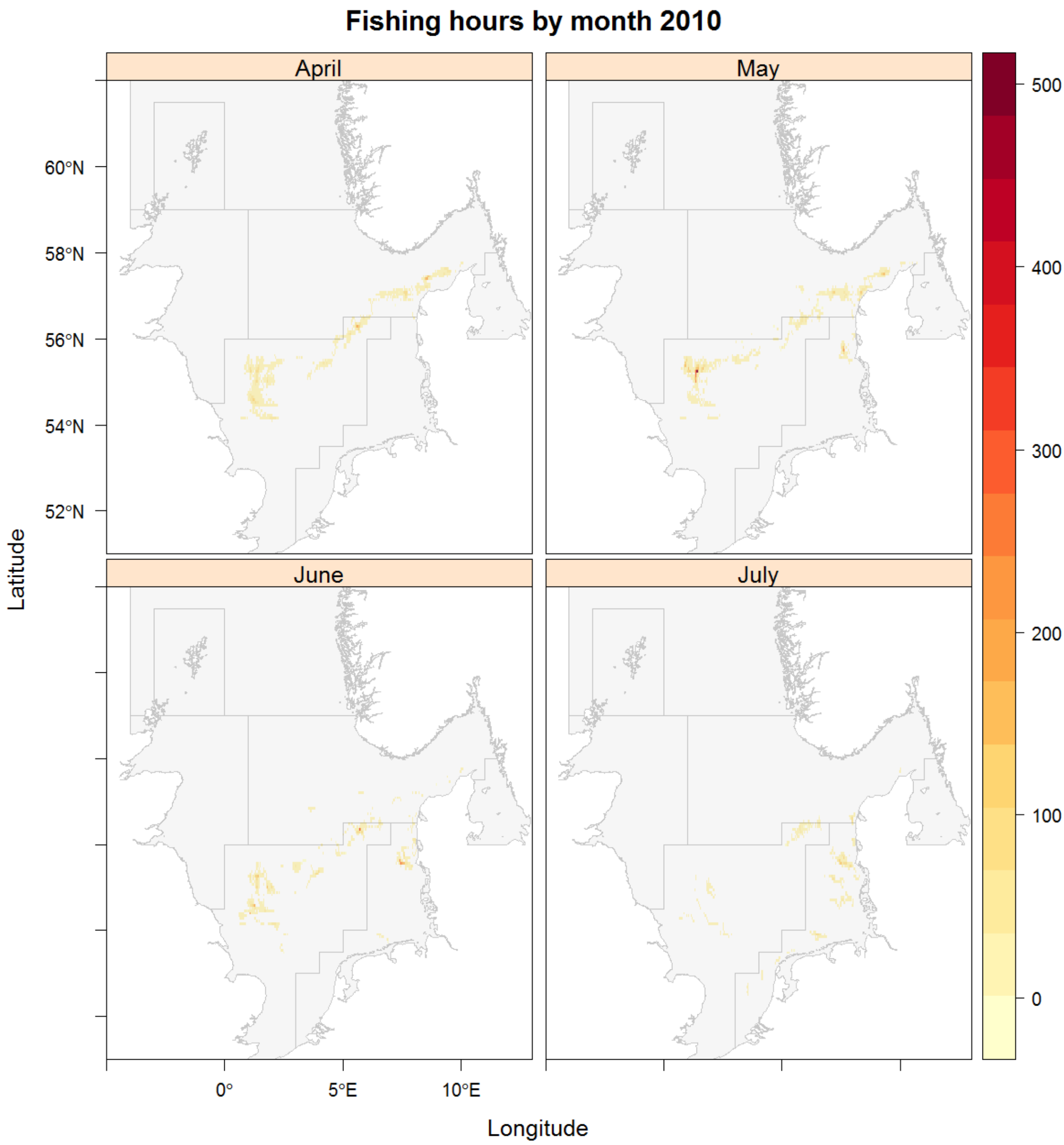
Fishing hours 2013
Latitude
Longitude
60°N
58°N
56°N
54°N
52°N
0°
5°E
10°E
800
700
600
500
400
300
200
100
0

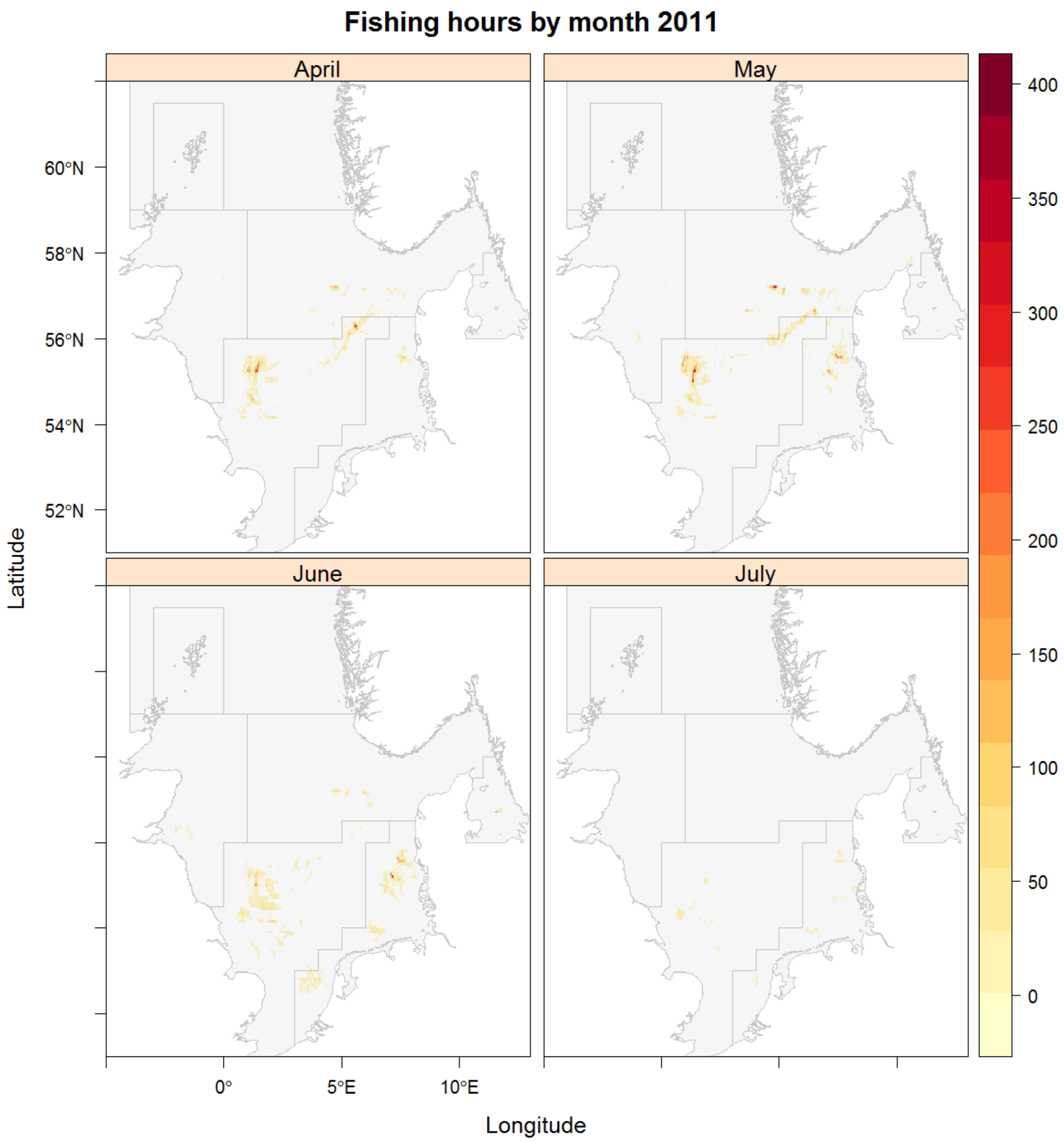

Fishing hours 2014
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
800
600
400
200
0


Fishing hours 2015
Latitude
60°N
58°N
56°N
54°N
52°N
0°
5°E
10°E
Longitude
700
600
500
400
300
200
100
0

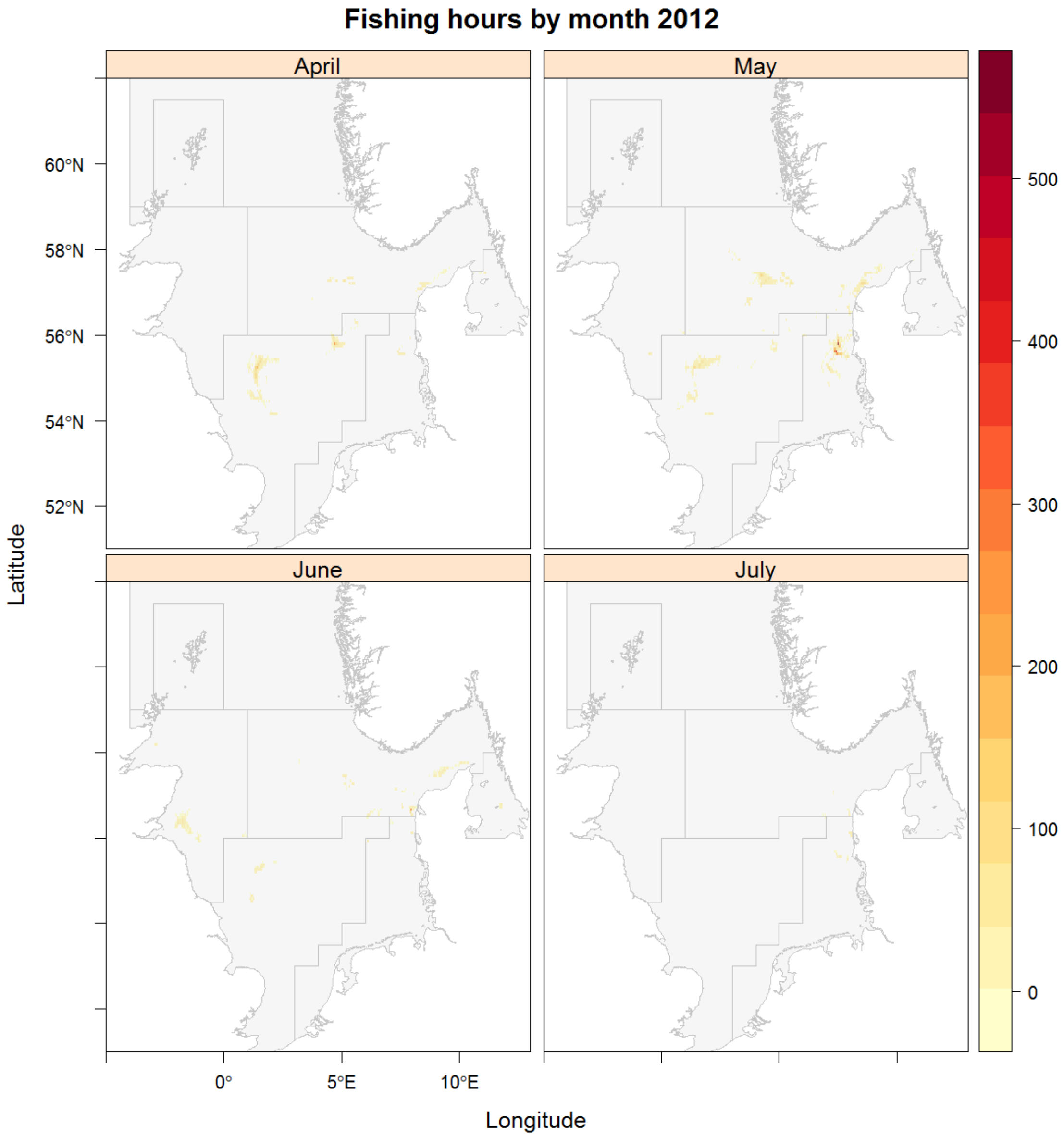
Monthly fishing effort

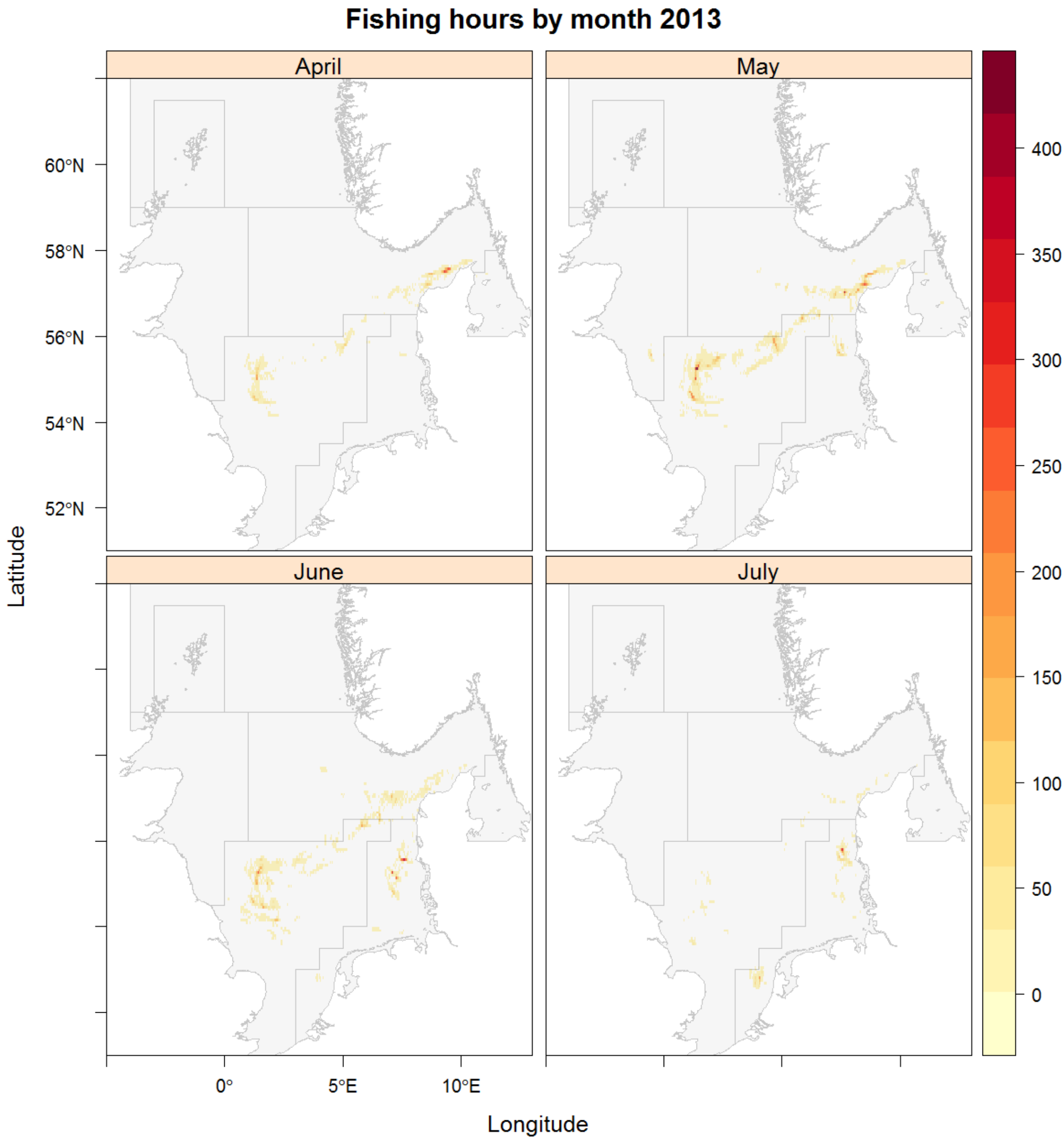


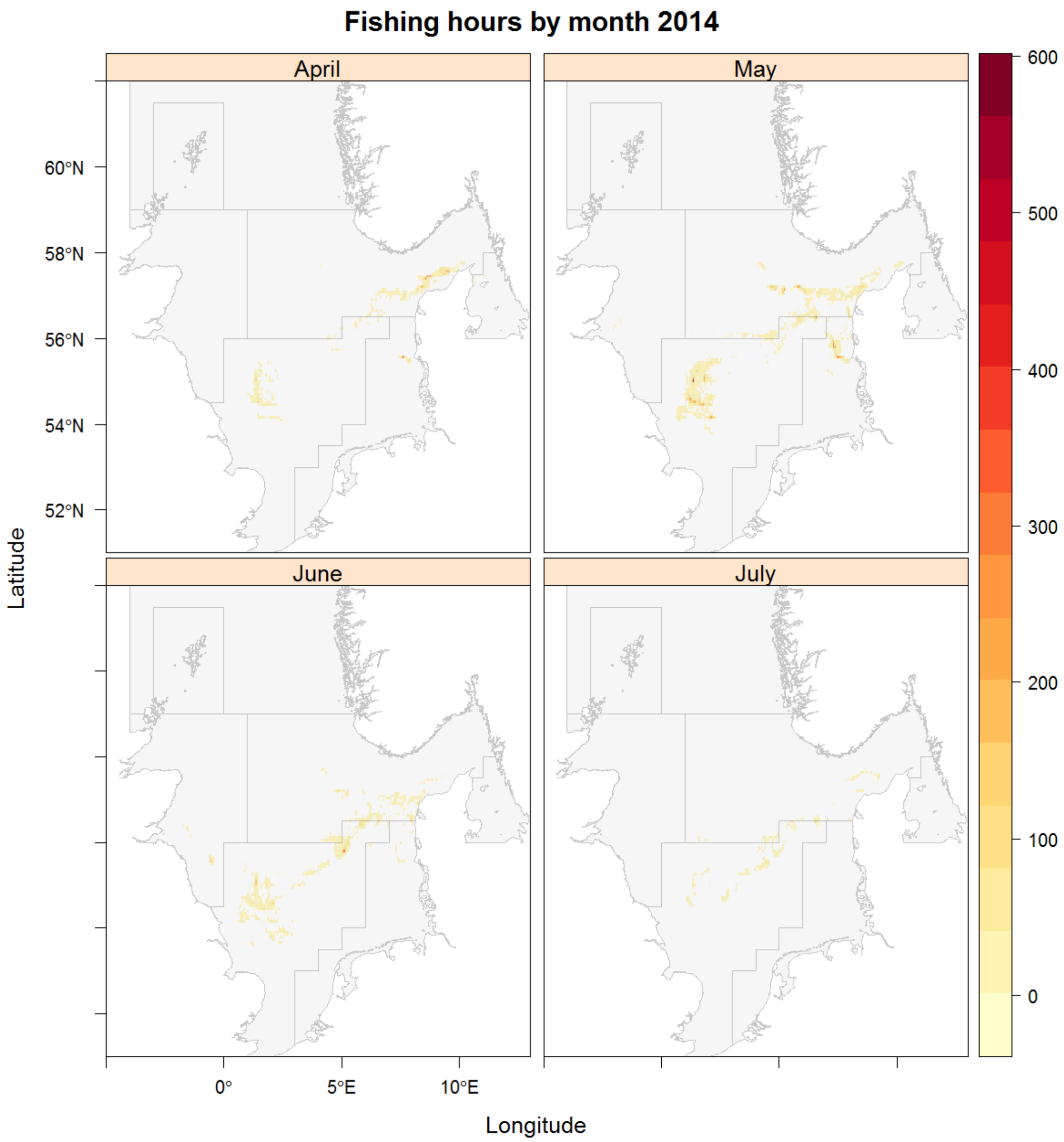

Fishing hours by month 2010
April
May
June
July
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
500
400
300
200
100
0

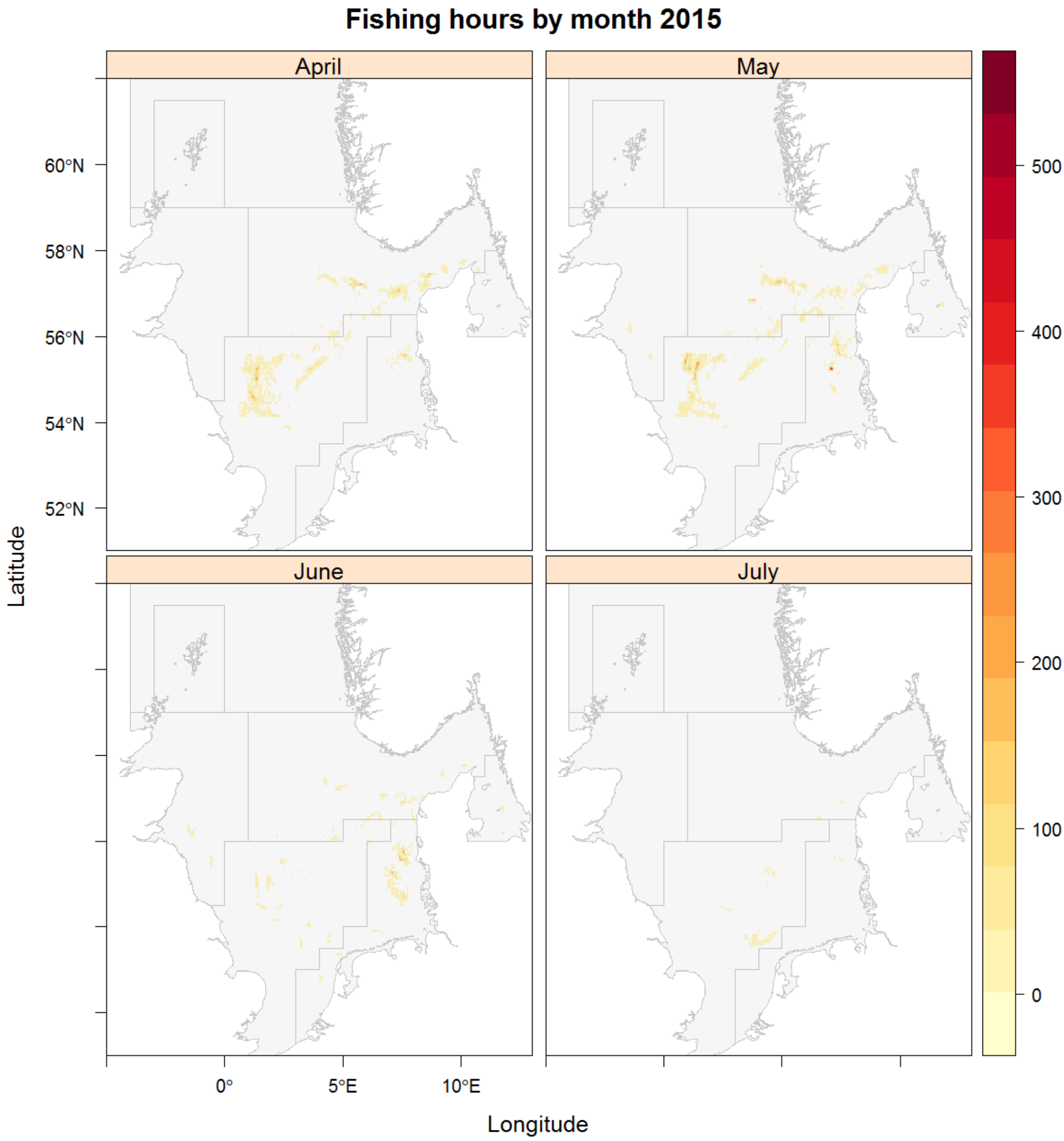


Fishing hours by month 2011
April
May
June
July
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
400
350
300
250
200
150
100
50
0

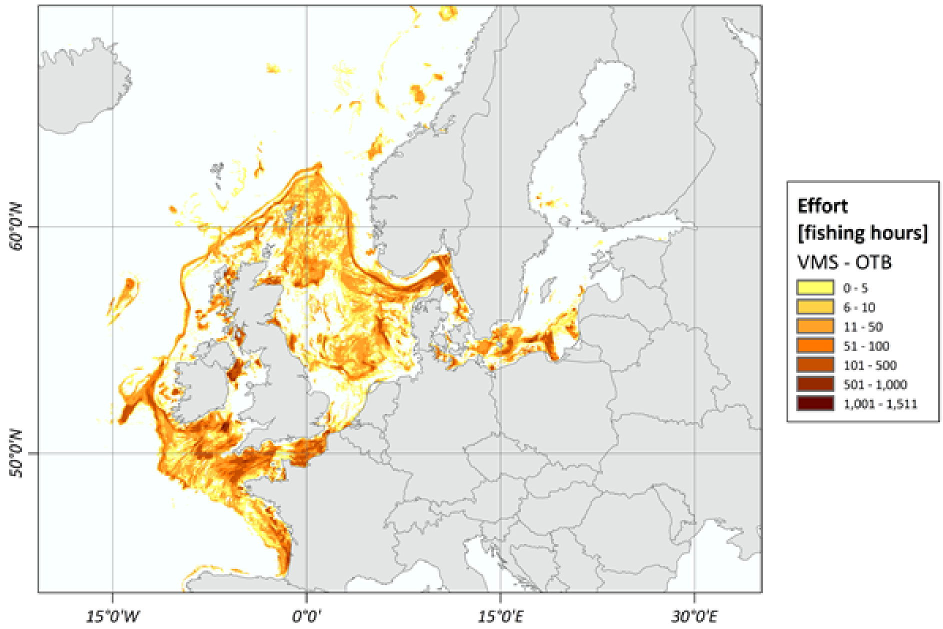

Fishing hours by month 2012
April
May
June
July
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
500
400
300
200
100
0

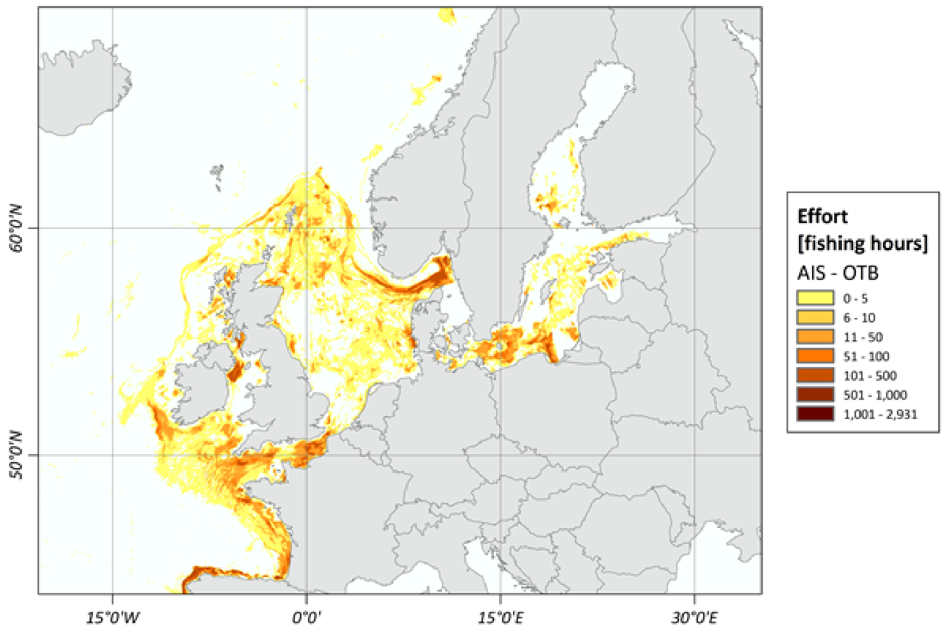

Fishing hours by month 2013
April
May
June
July
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
400
350
300
250
200
150
100
50
0

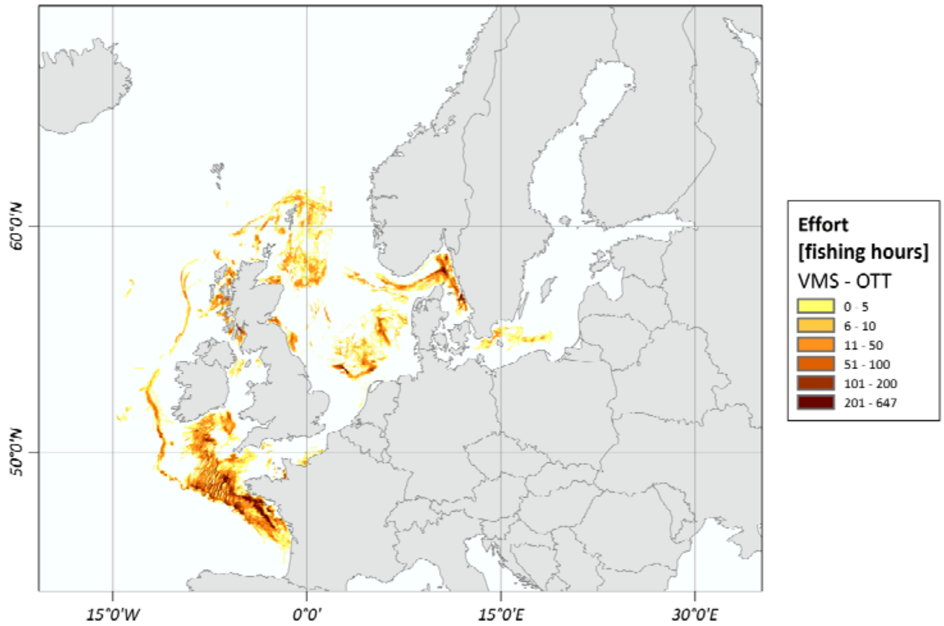

Fishing hours by month 2014
April
May
June
July
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
600
500
400
300
200
100
0

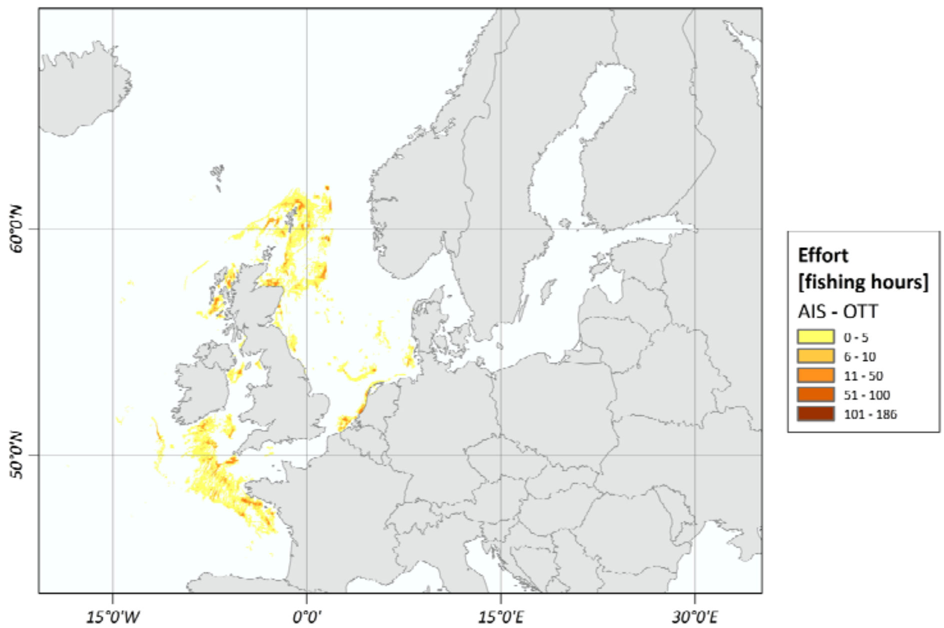

Fishing hours by month 2015
April
May
June
July
60°N
58°N
56°N
54°N
52°N
Latitude
0°
5°E
10°E
Longitude
500
400
300
200
100
0

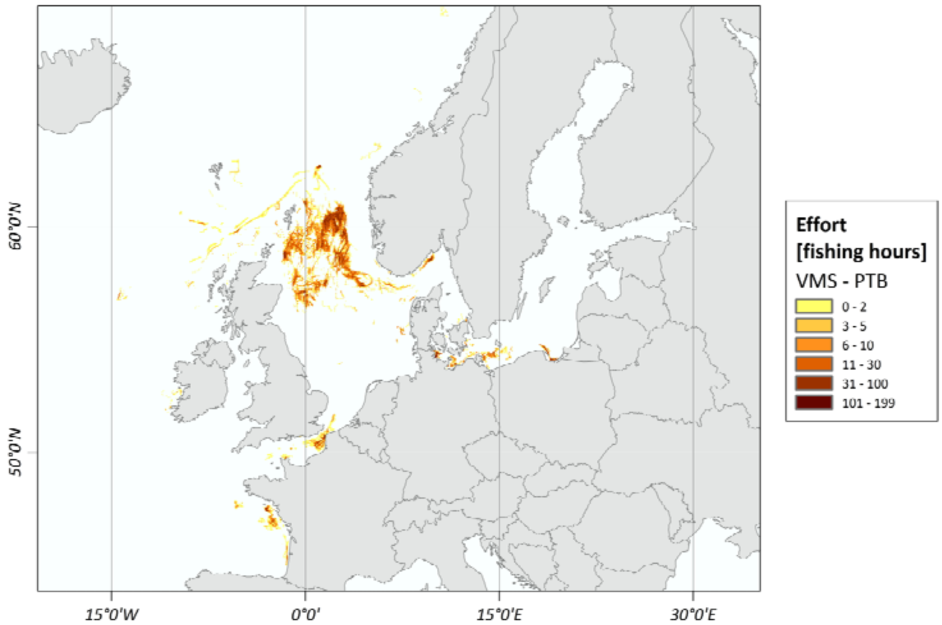
Annex 7: Maps comparing VMS and AIS data outputs

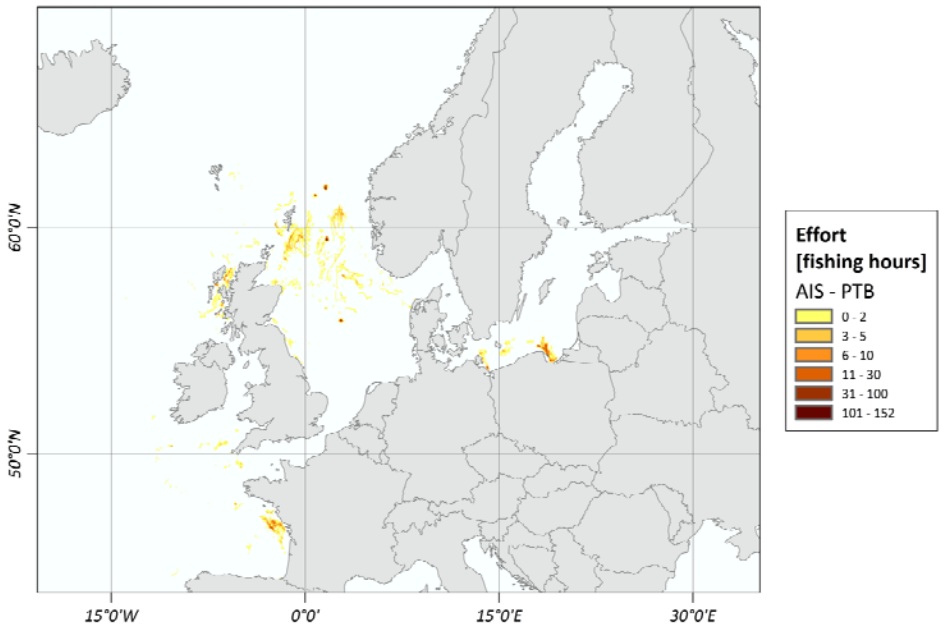


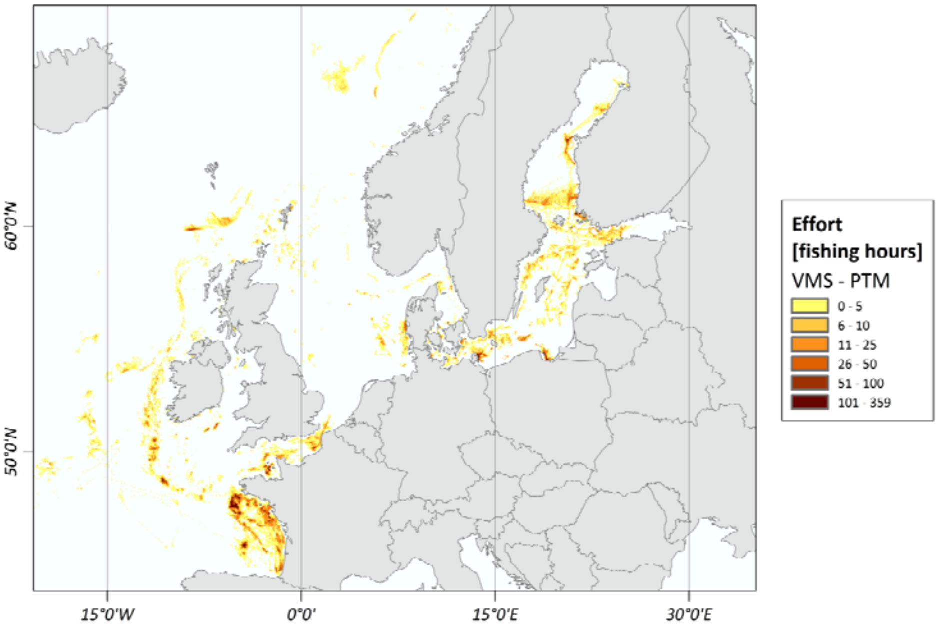


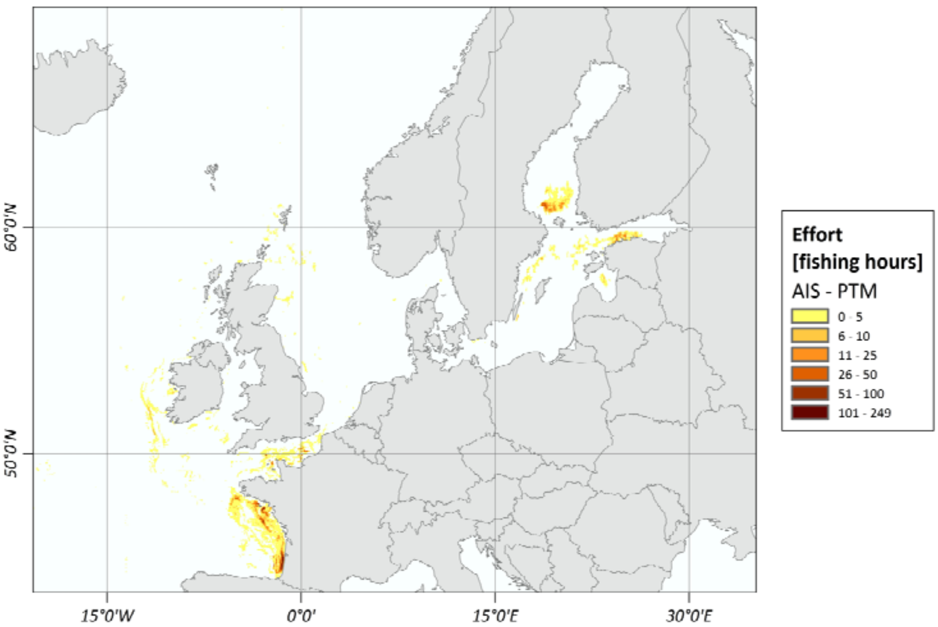

60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E
Effort
[fishing hours]
VMS - OTT
0 - 5
6 - 10
11 - 50
51 - 100
101 - 200
201 - 647

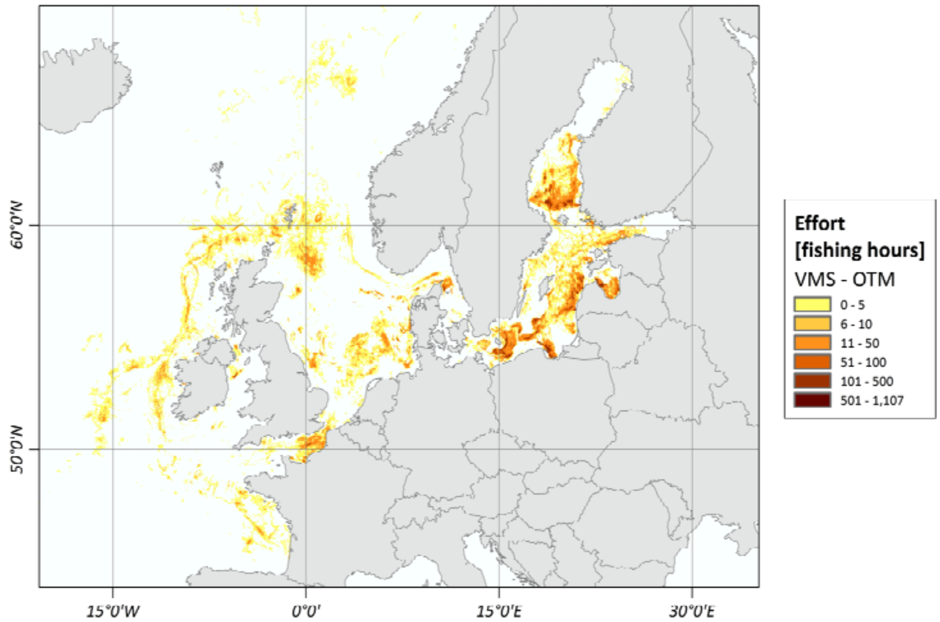

60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E
Effort
[fishing hours]
AIS - OTT
0 - 5
6 - 10
11 - 50
51 - 100
101 - 186

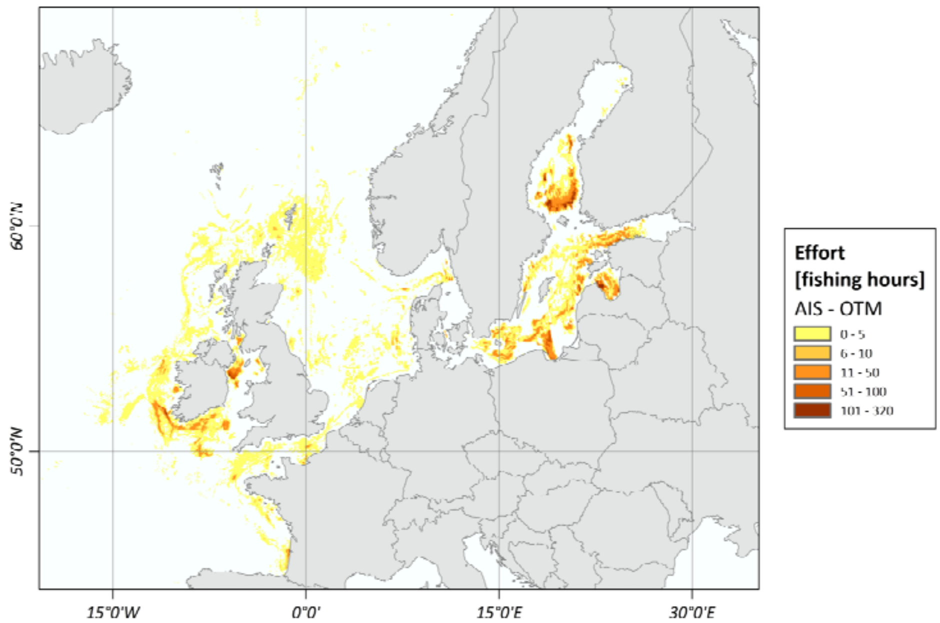

60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E
Effort
[fishing hours]
VMS - PTB
0 - 2
3 - 5
6 - 10
11 - 30
31 - 100
101 - 199

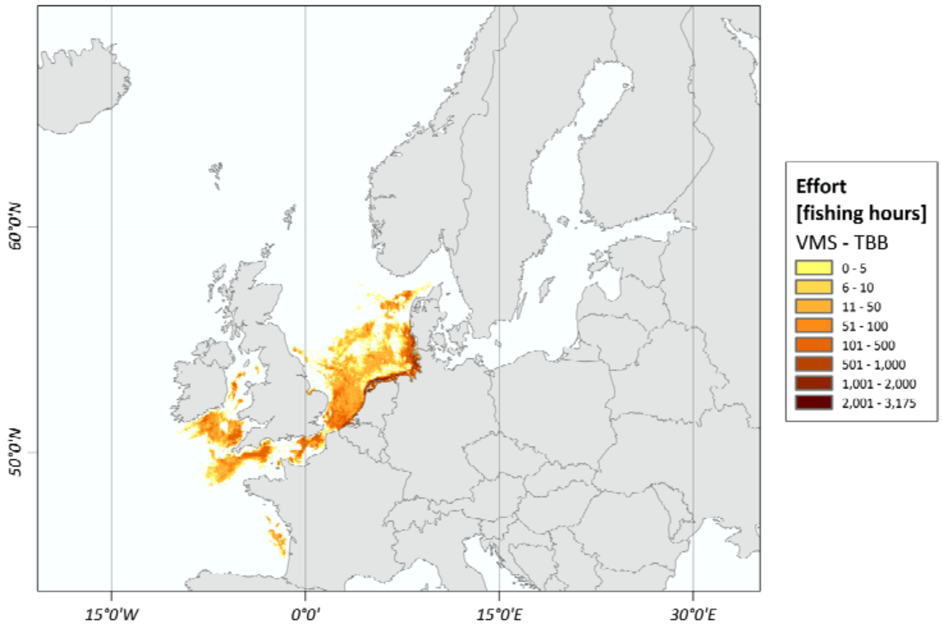

60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E
Effort
[fishing hours]
AIS - PTB
0 - 2
3 - 5
6 - 10
11 - 30
31 - 100
101 - 152

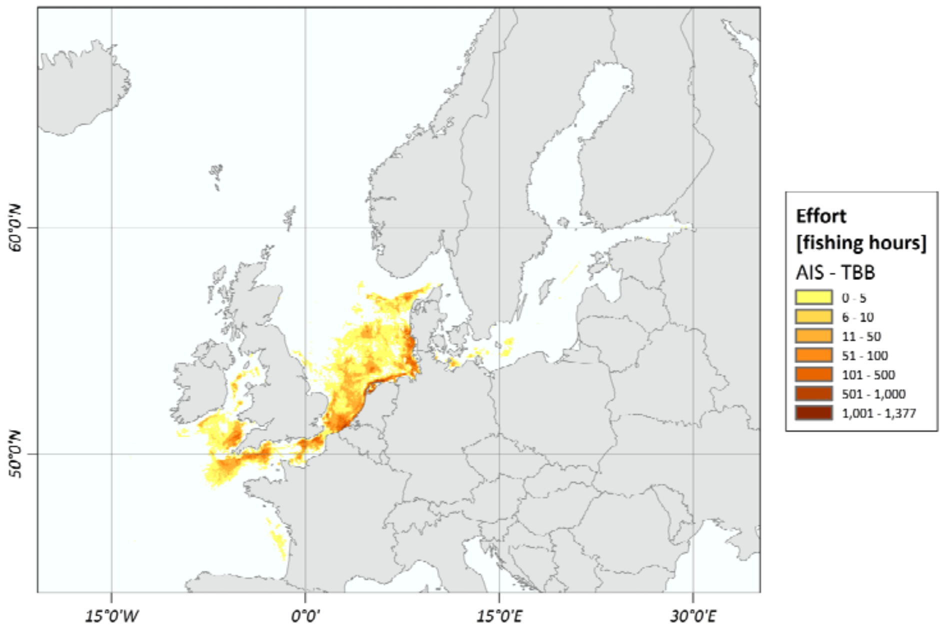

60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E
Effort
[fishing hours]
VMS - PTM
0 - 5
6 - 10
11 - 25
26 - 50
51 - 100
101 - 359


60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E
Effort
[fishing hours]
AIS - PTM
0 - 5
6 - 10
11 - 25
26 - 50
51 - 100
101 - 249


Effort
[fishing hours]
VMS - OTM
0 - 5
6 - 10
11 - 50
51 - 100
101 - 500
501 - 1,107
60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E


Effort
[fishing hours]
AIS - OTM
0 - 5
6 - 10
11 - 50
51 - 100
101 - 320
60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E

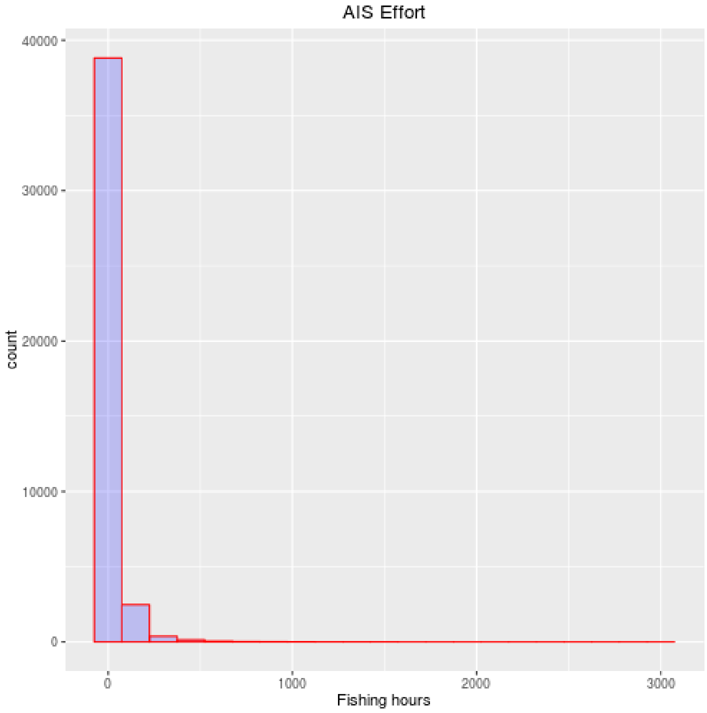

Effort
[fishing hours]
VMS - TBB
0 - 5
6 - 10
11 - 50
51 - 100
101 - 500
501 - 1,000
1,001 - 2,000
2,001 - 3,175
60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E


Effort
[fishing hours]
AIS - TBB
0 - 5
6 - 10
11 - 50
51 - 100
101 - 500
501 - 1,000
1,001 - 1,377
60°0'N
50°0'N
15°0'W
0°0'
15°0'E
30°0'E

Annex 8: Statistical analysis comparing VMS and AIS data

AIS OTB SUMMARY

Original Values



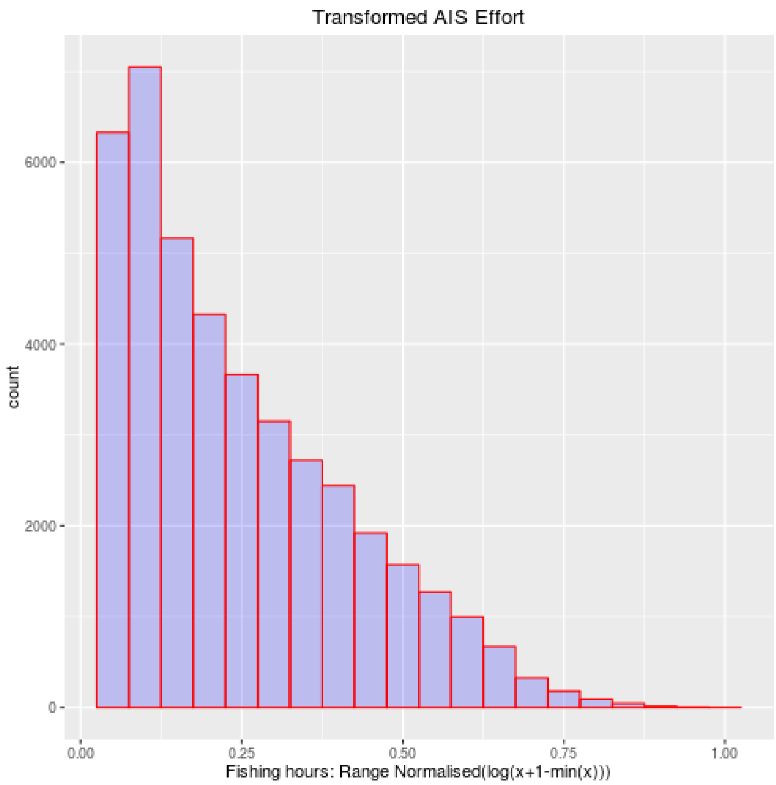
Summary statistics

	AIS OTB Fishing Hours
Values	41930.00
NULL	0.00
NA	0.00
min	0.50
max	2930.67
range	2930.17
sum	968067.08
median	4.08
mean	23.09
SE.mean	0.34
CI.mean.0.95	0.67
var	4856.20
std.dev	69.69
coef.var	3.02

Quartiles

0%	25%	50%	75%	100%
0.5	1.3	4.1	16.2	2930.7

Transformed values



Summary statistics

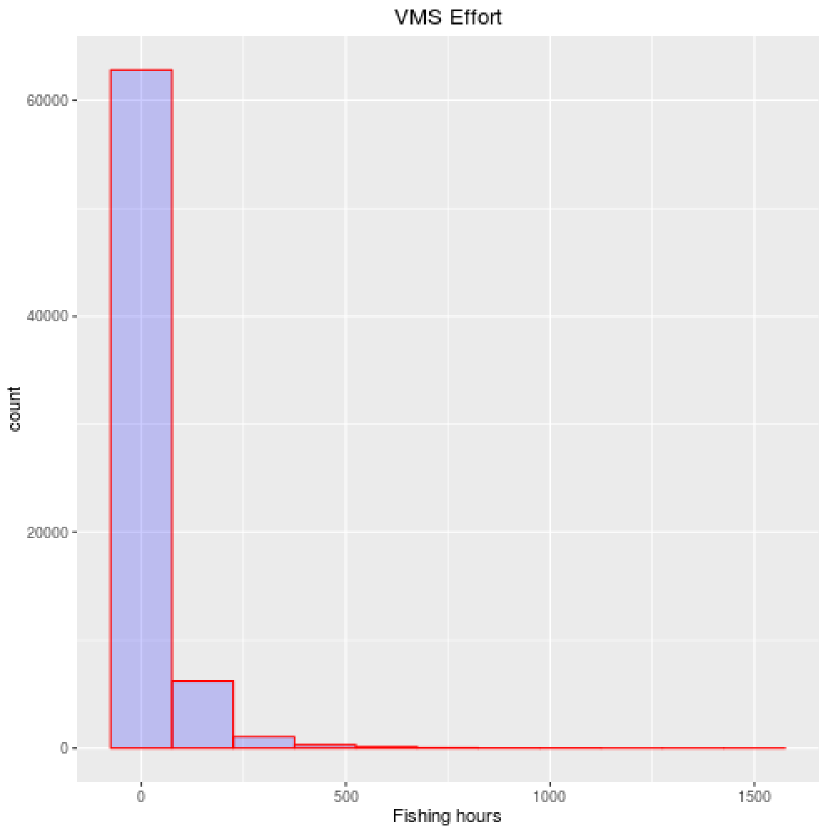
	AIS OTB Transformed Fishing Hours
Values	41930.00000
NULL	0.00000
NA	0.00000
min	0.04363
max	1.00000
range	0.95637
sum	10314.09337
median	0.20160
mean	0.24598
SE.mean	0.00084
CI.mean.0.95	0.00165
var	0.02957
std.dev	0.17196
coef.var	0.69908

Quartiles

0%	25%	50%	75%	100%
).044	0.102	0.202	0.356	1.000

VMS OTB SUMMARY

Original Values



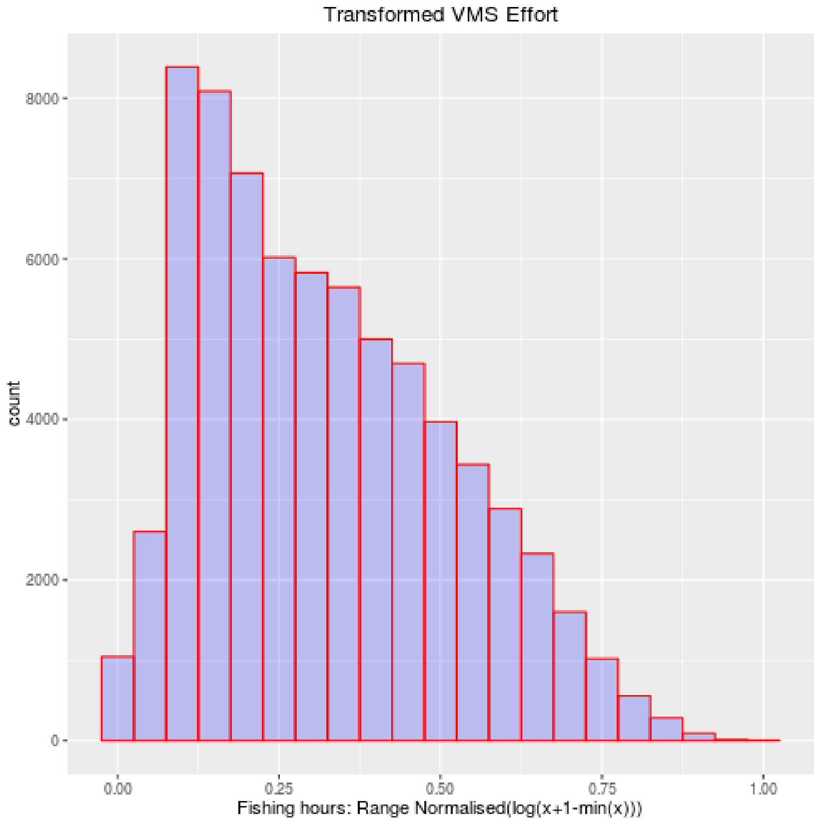
Summary statistics

VMS OTB Fishing Hours	
Values	70606.00
NULL	68.00
NA	0.00
min	0.00
max	1510.93
range	1510.93
sum	2178862.21
median	7.62
mean	30.86
SE.mean	0.25
CI.mean.0.95	0.50
var	4506.68
std.dev	67.13
coef.var	2.18

Quartiles

0%	25%	50%	75%	100%
0.0	2.0	7.6	28.0	1510.9

Transformed values



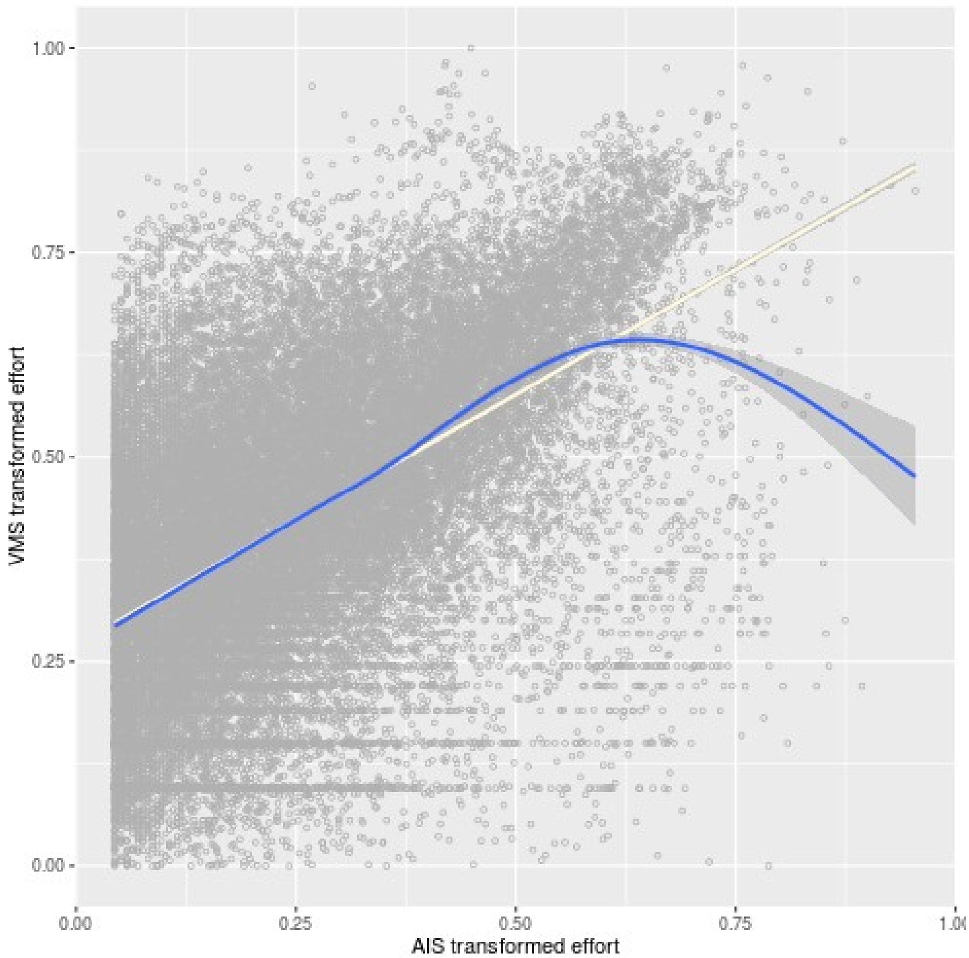
Summary statistics

	VMS OTB Transformed Fishing hours
Values	70606.00000
NULL	68.00000
NA	0.00000
min	0.00000
max	1.00000
range	1.00000
sum	22732.97733
median	0.29430
mean	0.32197
SE.mean	0.00073
CI.mean.0.95	0.00143
var	0.03746
std.dev	0.19355
coef.var	0.60113

Quartiles

0%	25%	50%	75%	100%
0.00	0.15	0.29	0.46	1.00

AIS AND VMS OTB COMPARISON



Pearson's product-moment correlation

Data: **34767** AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = **123** , df = **34765** , p-value = < 0.00000000000000022

alternative hypothesis:

true correlation is not equal to 0

95 percent confidence interval: **[0.54 ;0.56]**

sample estimates:

cor

0.55

Kendall's rank correlation tau

Data: **34767** AIS and VMS overlapping c-squares with values = Transformed Fishing Hours

z = 107 , p-value = < 0.00000000000000022

alternative hypothesis:

true tau is not equal to 0

sample estimates:

tau

0.38

Two-sample Kolmogorov-Smirnov test

Data: 34767 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours

D = 0.38 , p-value = < 0.00000000000000022

alternative hypothesis:

two-sided

Two-sample Kolmogorov-Smirnov test

Data: 34767 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours

D^+ = 0.38 , p-value = < 0.00000000000000022

alternative hypothesis:

the CDF of x lies above that of y

Welch Two Sample t-test

Data: 34767 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours

t = -127 , df = 68731 , p-value = < 0.00000000000000022

alternative hypothesis:

true difference in means is not equal to 0

95 percent confidence interval: [-0.17 ;-0.17]

sample estimates:

mean of x	mean of y
0.25	0.43

Paired t-test

Data: 34767 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = -188 , df = 34766 , p-value = < 0.00000000000000022

alternative hypothesis:

true difference in means is not equal to 0

95 percent confidence interval: [-0.17 ;-0.17]

sample estimates:

mean of the differences

-0.17

Wilcoxon signed rank test with continuity correction

Data: 34767 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours

V = 44416492 , p-value = < 0.00000000000000022

alternative hypothesis:

true location shift is not equal to 0

F test to compare two variances

Data: 34767 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours

F =0.81, num df =34766, denom df =34766, p-value = < 0.00000000000000022

alternative hypothesis:

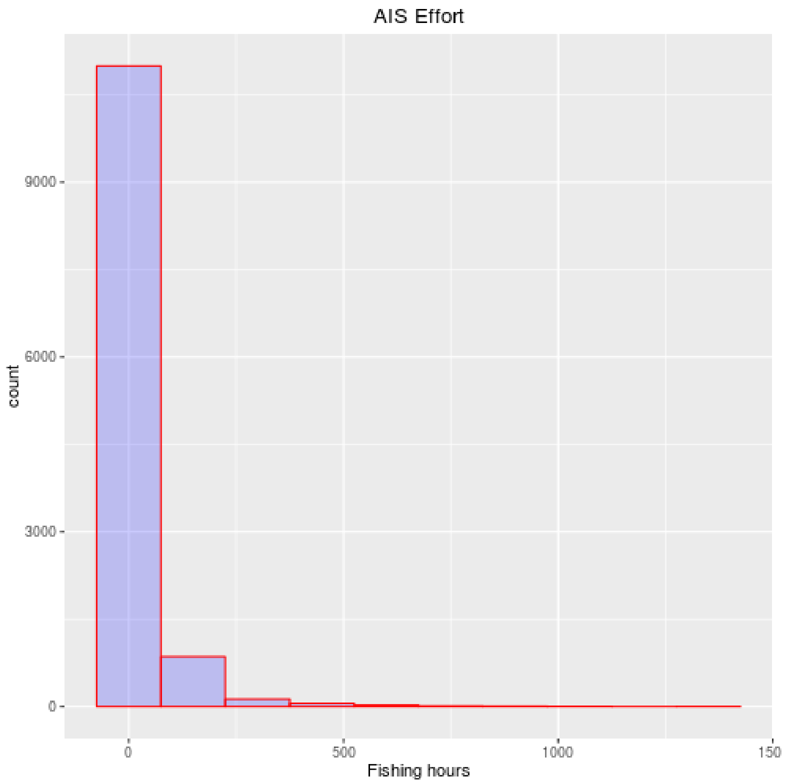
true ratio of variances is not equal to 1 95 percent confidence interval: [0.79 ;0.82]

sample estimates:

ratio of variances 0.81

AIS TBB SUMMARY

Original Values



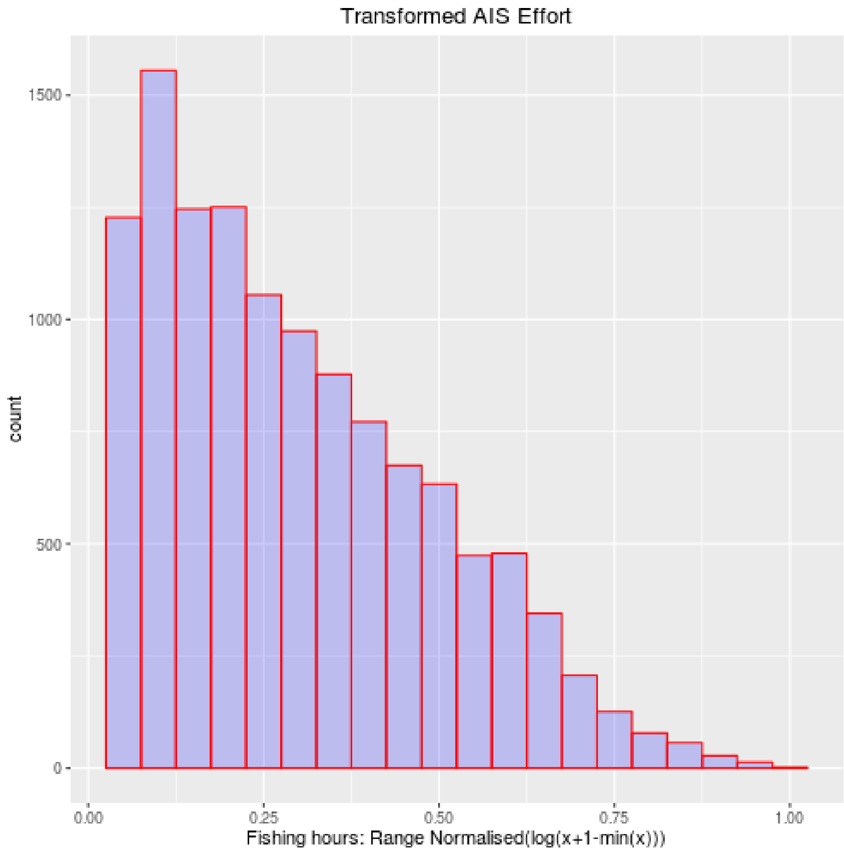
Summary statistics

AIS TBB Fishing Hours	
Values	12075.00
NULL	0.00
NA	0.00
min	0.50
max	1375.75
range	1375.25
sum	328260.58
median	5.58
mean	27.19
SE.mean	0.64
CI.mean.0.95	1.25
var	4891.36
std.dev	69.94
coef.var	2.57

Quartiles

0%	25%	50%	75%	100%
0.5	1.8	5.6	21.8	1375.8

Transformed values



Summary statistics

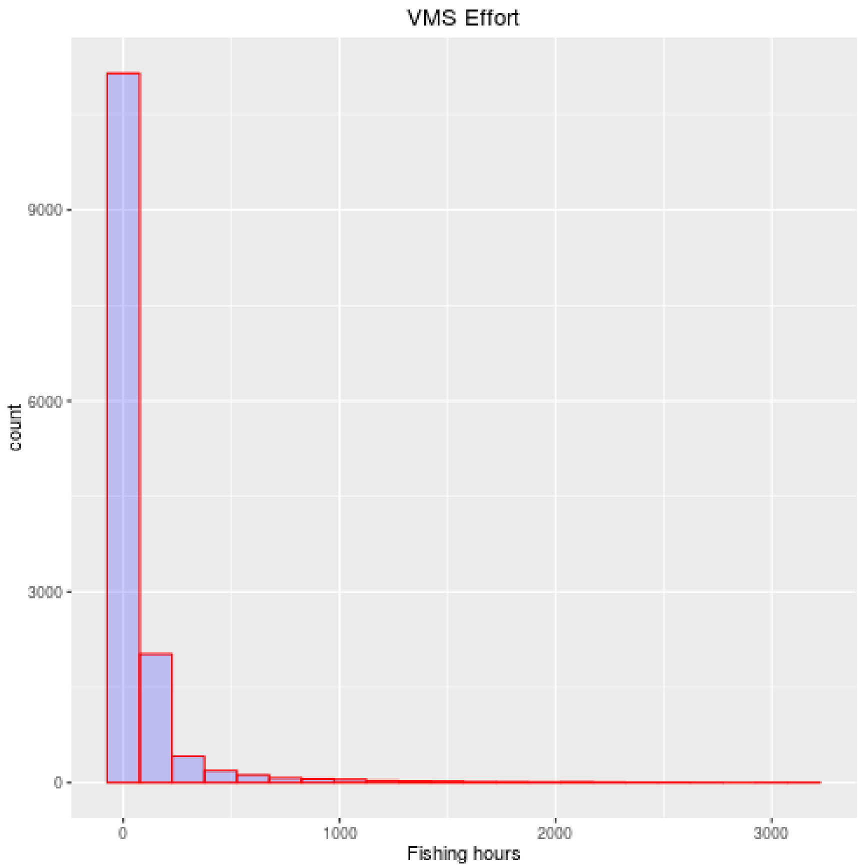
	AIS TBB Transformed Fishing Hours
Values	12075.0000
NULL	0.0000
NA	0.0000
min	0.0482
max	1.0000
range	0.9518
sum	3611.0166
median	0.2590
mean	0.2990
SE.mean	0.0018
CI.mean.0.95	0.0035
var	0.0378
std.dev	0.1944
coef.var	0.6500

Quartiles

0%	25%	50%	75%	100%
).048	0.136	0.259	0.432	1.000

VMS TBB SUMMARY

Original Values



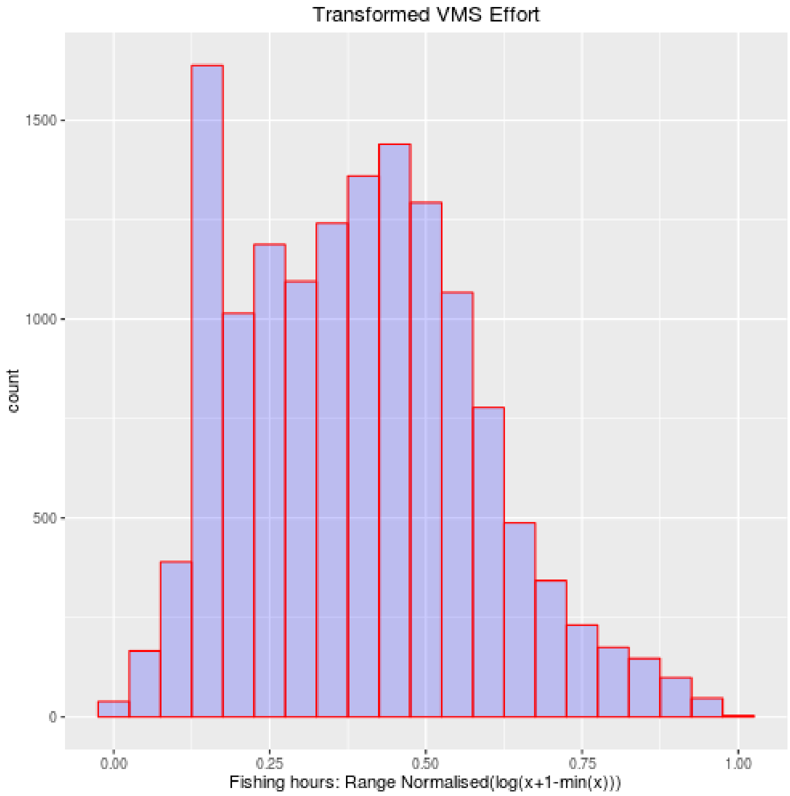
Summary statistics

VMS TBB Fishing Hours	
Values	14244.0
NULL	2.0
NA	0.0
min	0.0
max	3175.2
range	3175.2
sum	1170065.1
median	21.8
mean	82.1
SE.mean	1.8
CI.mean.0.95	3.5
var	45817.2
std.dev	214.0
coef.var	2.6

Quartiles

0%	25%	50%	75%	100%
0.0	5.9	21.8	64.0	3175.2

Transformed values



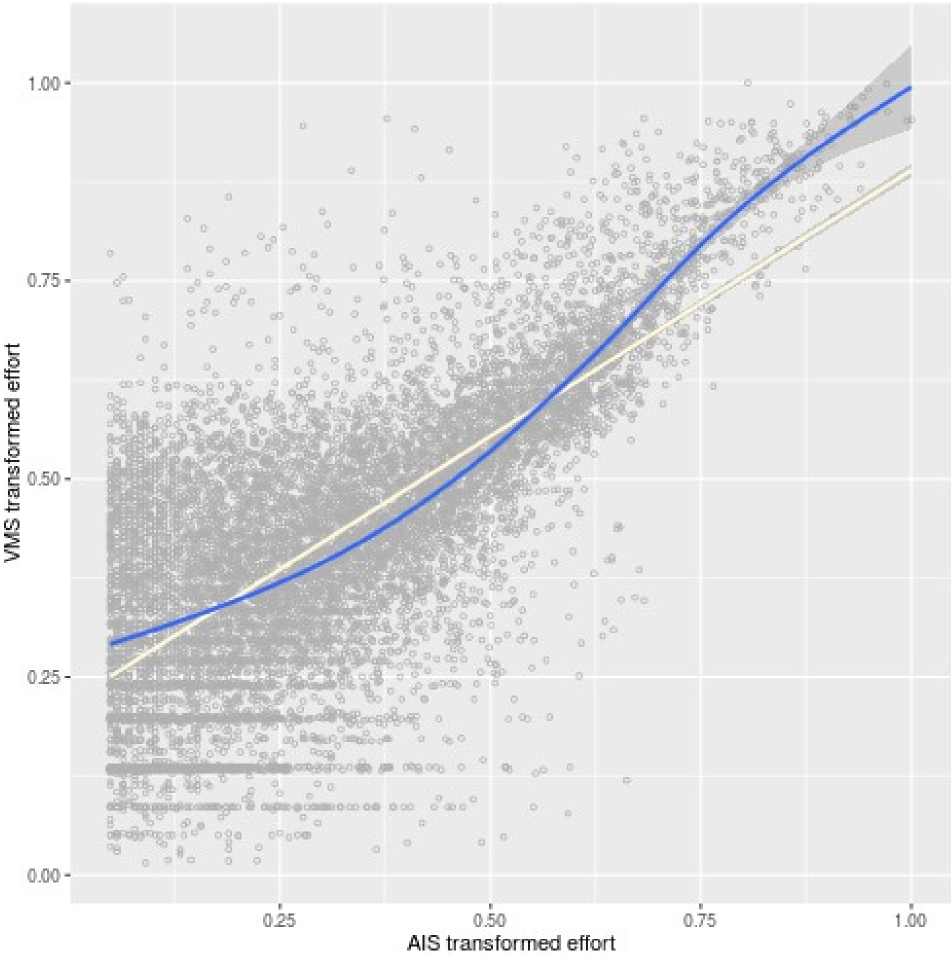
Summary statistics

	VMS TBB Transformed Fishing Hours
Values	14244.0000
NULL	2.0000
NA	0.0000
min	0.0000
max	1.0000
range	1.0000
sum	5560.6256
median	0.3876
mean	0.3904
SE.mean	0.0016
CI.mean.0.95	0.0031
var	0.0359
std.dev	0.1896
coef.var	0.4856

Quartiles

0%	25%	50%	75%	100%
0.00	0.24	0.39	0.52	1.00

AIS AND VMS TBB COMPARISON



Pearson's product-moment correlation

Data: 10636 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = 109 , df = 10634 , p-value = < 0.00000000000000022

alternative hypothesis:

true correlation is not equal to 0

95 percent confidence interval: [0.72 ;0.74]

sample estimates:

cor 0.73

Kendall's rank correlation tau

Data: 10636 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours z = 78 , p-value = < 0.00000000000000022

alternative hypothesis: tau is not equal to 0 sample estimates:

tau 0.51

Two-sample Kolmogorov-Smirnov test

Data: 10636 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours D = 0.28 , p-value = < 0.00000000000000022

alternative hypothesis:

two-sided

Two-sample Kolmogorov-Smirnov test

Data: 10636 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours D^+ = 0.28 , p-value = < 0.00000000000000022

alternative hypothesis:

the CDF of x lies above that of y

Welch Two Sample t-test

Data: 10636 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = -44 , df = 21137 , p-value = < 0.00000000000000022

alternative hypothesis:

difference in means is not equal to 0

95 percent confidence interval: [-0.12 ;-0.11]

sample estimates:

mean of x	mean of y
0.32	0.43

Paired t-test

Data: 10636 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = -84 , df = 10635 , p-value = < 0.00000000000000022

alternative hypothesis:

difference in means is not equal to 0

95 percent confidence interval: [-0.12 ;-0.11]

sample estimates:

mean of the differences

-0.11

Wilcoxon signed rank test with continuity correction

Data: 10636 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours V = 5968228 , p-value = < 0.00000000000000022

alternative hypothesis:

location shift is not equal to 0

F test to compare two variances

Data: 10636 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours F = 1.2 , num df = 10635 , denom df = 10635 , p-value = 0.000000000000000222 alternative hypothesis:

ratio of variances is not equal to 1

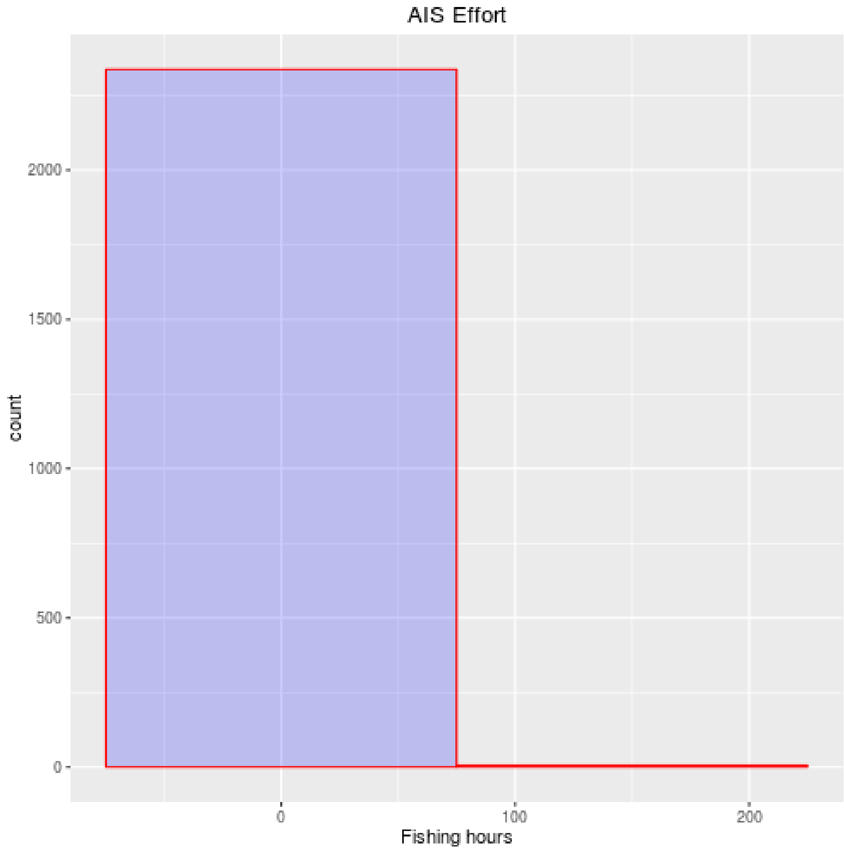
95 percent confidence interval: [1.1 ;1.2]

sample estimates:

ratio of variances 1.2

AIS PTB SUMMARY

Original Values



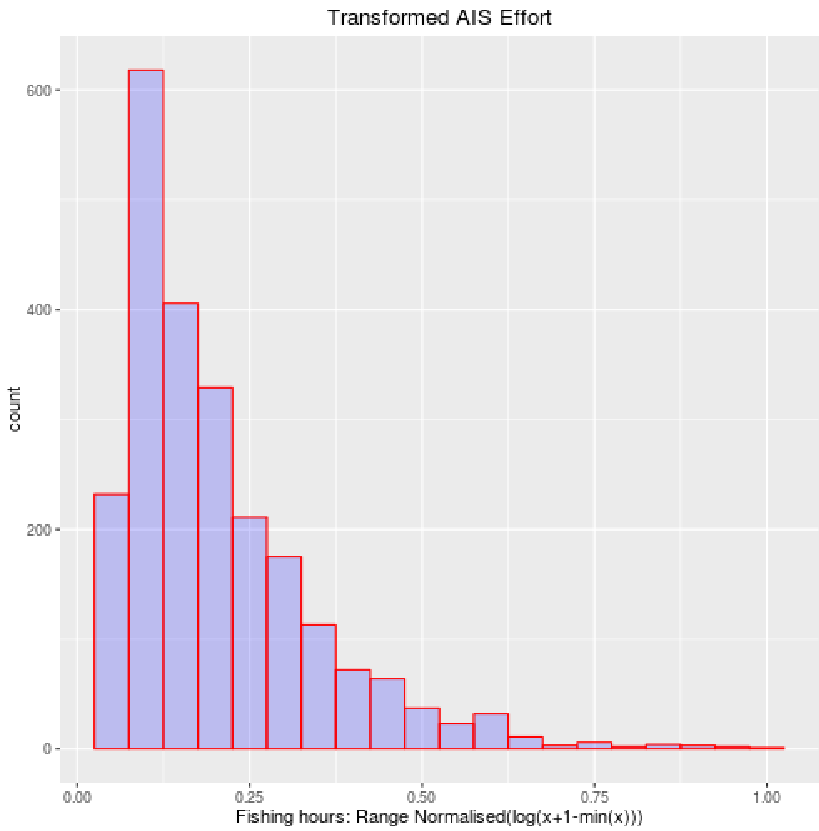
Summary statistics

AIS PTB Fishing Hours	
Values	2344.00
NULL	0.00
NA	0.00
min	0.50
max	151.83
range	151.33
sum	7473.83
median	1.33
mean	3.19
SE.mean	0.16
CI.mean.0.95	0.31
var	58.14
std.dev	7.62
coef.var	2.39

Quartiles

0%	25%	50%	75%	100%
0.50	0.75	1.33	2.83	151.83

Transformed values



Summary statistics

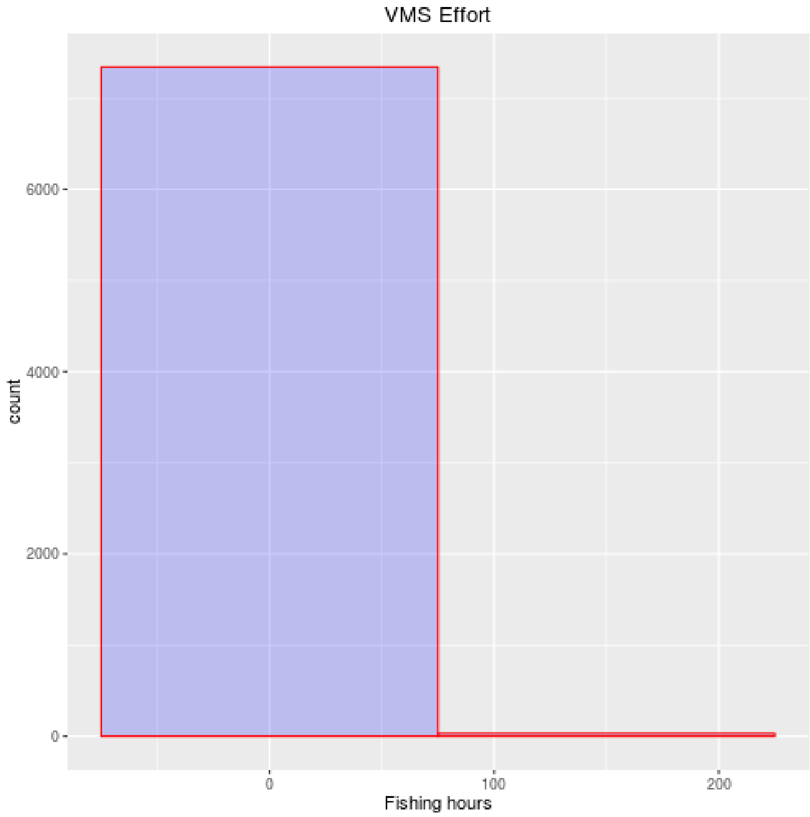
	AIS PTB Transformed Fishing Hours
Values	2344.0000
NULL	0.0000
NA	0.0000
min	0.0693
max	1.0000
range	0.9307
sum	479.1515
median	0.1613
mean	0.2044
SE.mean	0.0029
CI.mean.0.95	0.0056
var	0.0192
std.dev	0.1387
coef.var	0.6787

Quartiles

0%	25%	50%	75%	100%
).069	0.102	0.161	0.263	1.000

VMS PTB SUMMARY

Original Values



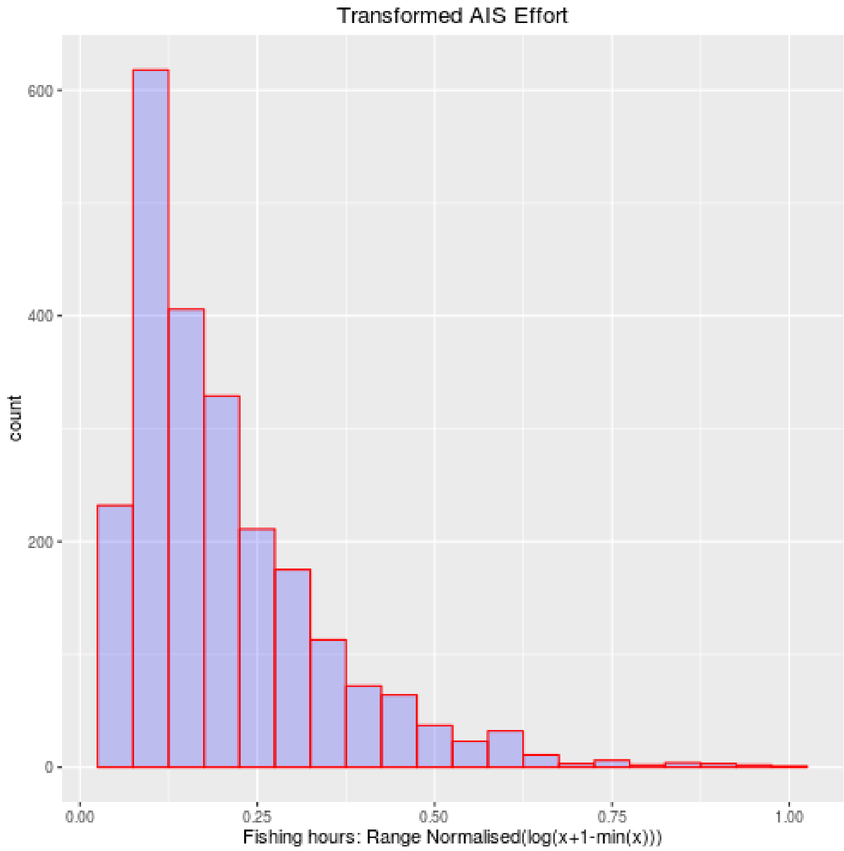
Summary statistics

	VMS PTB Fishing Hours
Values	7374.00000
NULL	0.00000
NA	0.00000
min	0.00028
max	199.96833
range	199.96806
sum	65690.32287
median	3.85000
mean	8.90837
SE.mean	0.15584
CI.mean.0.95	0.30549
var	179.08179
std.dev	13.38214
coef.var	1.50220

Quartiles

0%	25%	50%	75%	100%
0.0003	1.5018	3.8500	10.5583	199.9683

Transformed values



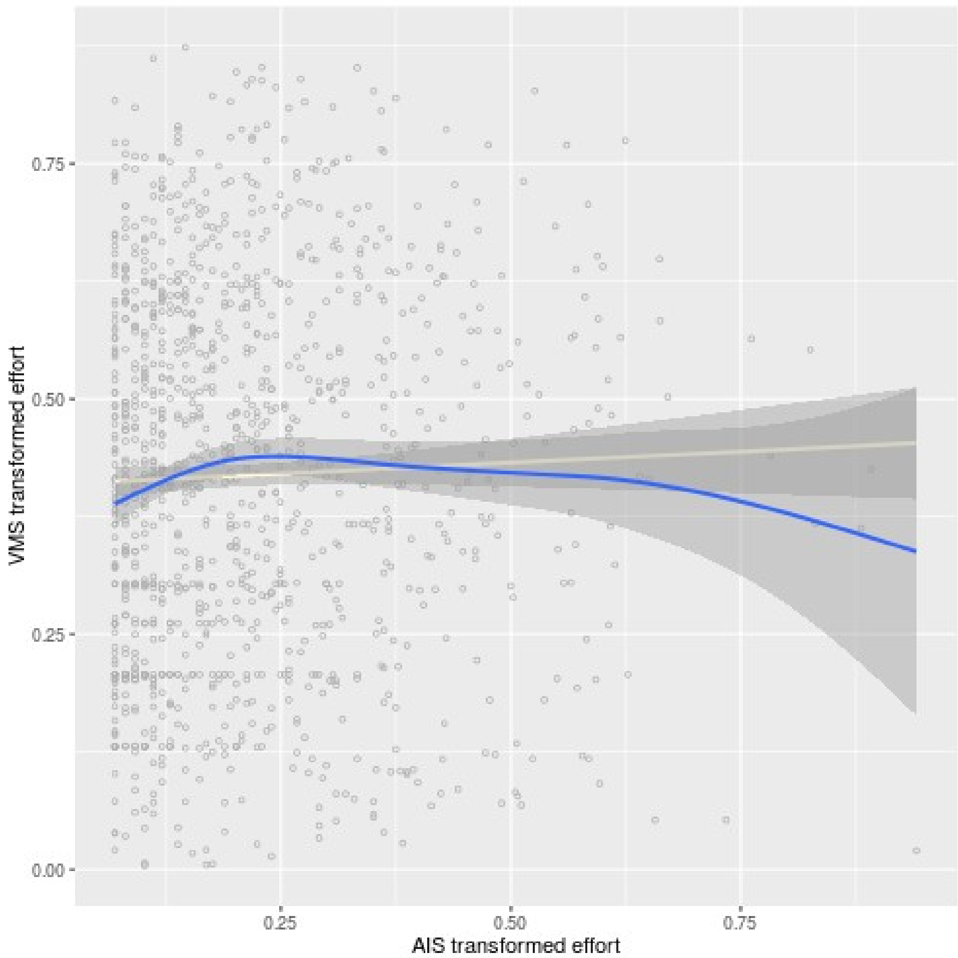
Summary statistics

	VMS PTB Transformed Fishing Hours
Values	7374.0000
NULL	1.0000
NA	0.0000
min	0.0000
max	1.0000
range	1.0000
sum	2387.3898
median	0.2977
mean	0.3238
SE.mean	0.0022
CI.mean.0.95	0.0044
var	0.0373
std.dev	0.1930
coef.var	0.5963

Quartiles

0%	25%	50%	75%	100%
).00	0.17	0.30	0.46	1.00

AIS AND VMS PTB COMPARISON



Pearson's product-moment correlation

Data: 1176 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = 1.1 , df = 1174 , p-value = 0.2523

alternative hypothesis:

correlation is not equal to 0

95 percent confidence interval: [-0.024 ; 0.090]

sample estimates:

cor 0.033

Kendall's rank correlation tau

Data: 1176 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours z = 2.4 , p-value = 0.01687

alternative hypothesis: tau is not equal to 0 sample estimates:

tau 0.047

Two-sample Kolmogorov-Smirnov test

Data: 1176 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours D = 0.47 , p-value = < 0.00000000000000022

alternative hypothesis:

two-sided

Two-sample Kolmogorov-Smirnov test

Data: 1176 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours D^+ = 0.47 , p-value = < 0.00000000000000022

alternative hypothesis:

the CDF of x lies above that of y

Welch Two Sample t-test

Data: 1176 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = -28 , df = 2125 , p-value = < 0.00000000000000022

alternative hypothesis:

difference in means is not equal to 0

95 percent confidence interval: [-0.22 ;-0.19]

sample estimates:

mean of x	mean of y
0.22	0.42

Paired t-test

Data: 1176 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = -29 , df = 1175 , p-value = < 0.00000000000000022

alternative hypothesis:

difference in means is not equal to 0

95 percent confidence interval: [-0.22 ;-0.19]

sample estimates:

mean of the differences

-0.2

Wilcoxon signed rank test with continuity correction

Data: 1176 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours V = 83418 , p-value = < 0.00000000000000022

alternative hypothesis:

location shift is not equal to 0

F test to compare two variances

Data: 1176 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours F = 0.51 , num df = 1175 , denom df = 1175 , p-value = < 0.00000000000000022 alternative hypothesis:

ratio of variances is not equal to 1

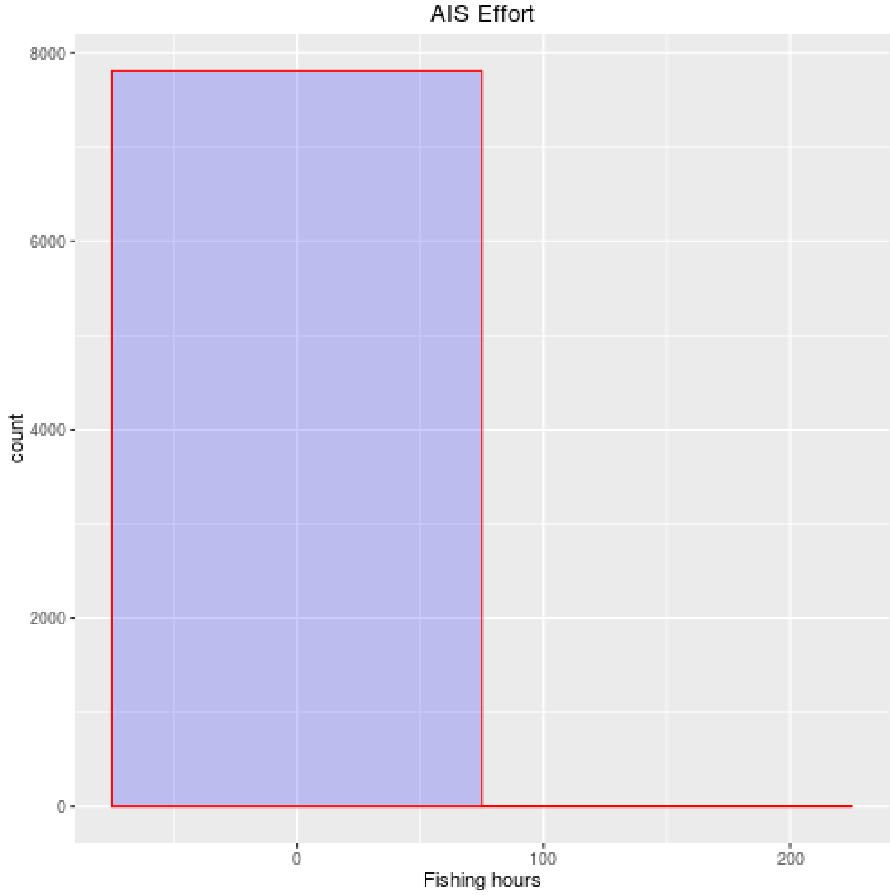
95 percent confidence interval: [0.45 ;0.57]

sample estimates:

ratio of variances 0.51

AIS OTT SUMMARY

Original Values



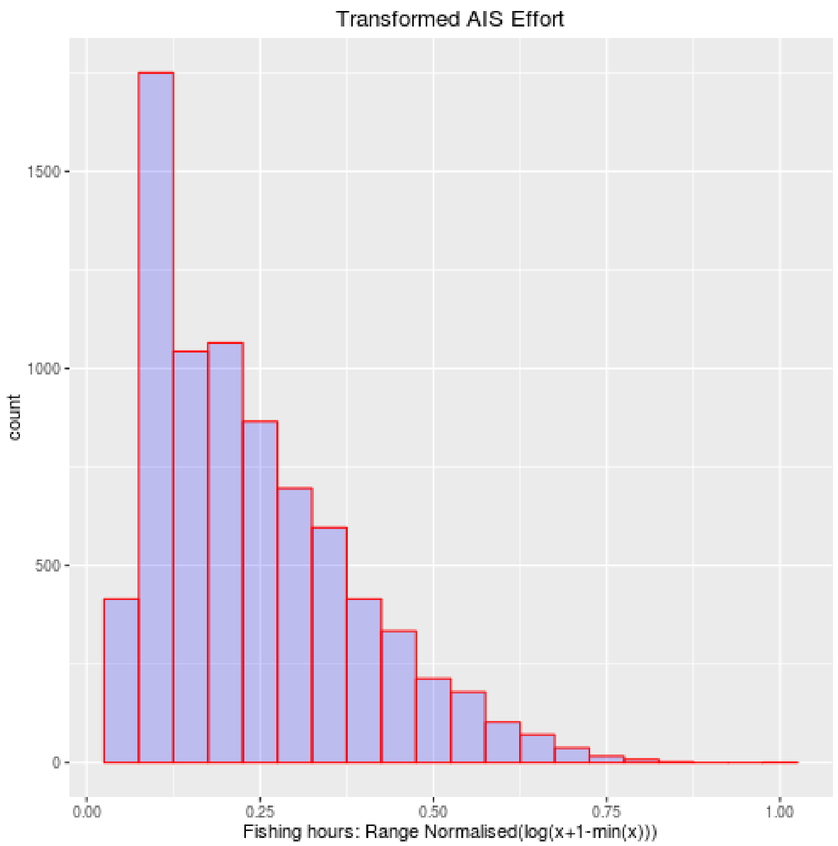
Summary statistics

	AIS OTT Fishing Hours
Values	7809.000
NULL	0.000
NA	0.000
min	0.500
max	185.583
range	185.083
sum	32266.500
median	2.000
mean	4.132
SE.mean	0.073
CI.mean.0.95	0.143
var	41.390
std.dev	6.434
coef.var	1.557

Quartiles

0%	25%	50%	75%	100%
0.5	1.0	2.0	4.6	185.6

Transformed values



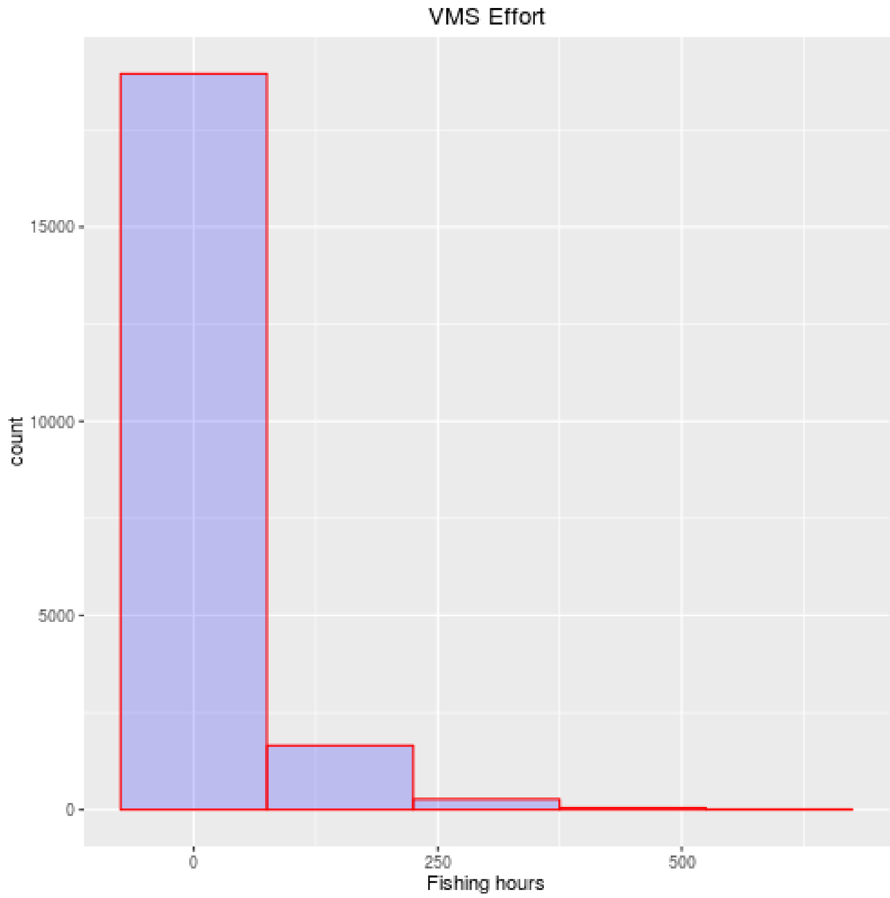
Summary statistics

	AIS OTT Transformed Fishing Hours
Values	7809.0000
NULL	0.0000
NA	0.0000
min	0.0666
max	1.0000
range	0.9334
sum	1869.7214
median	0.2047
mean	0.2394
SE.mean	0.0016
CI.mean.0.95	0.0032
var	0.0212
std.dev	0.1457
coef.var	0.6085

Quartiles

0%	25%	50%	75%	100%
).067	0.124	0.205	0.326	1.000

VMS OTT SUMMARY
Original Values



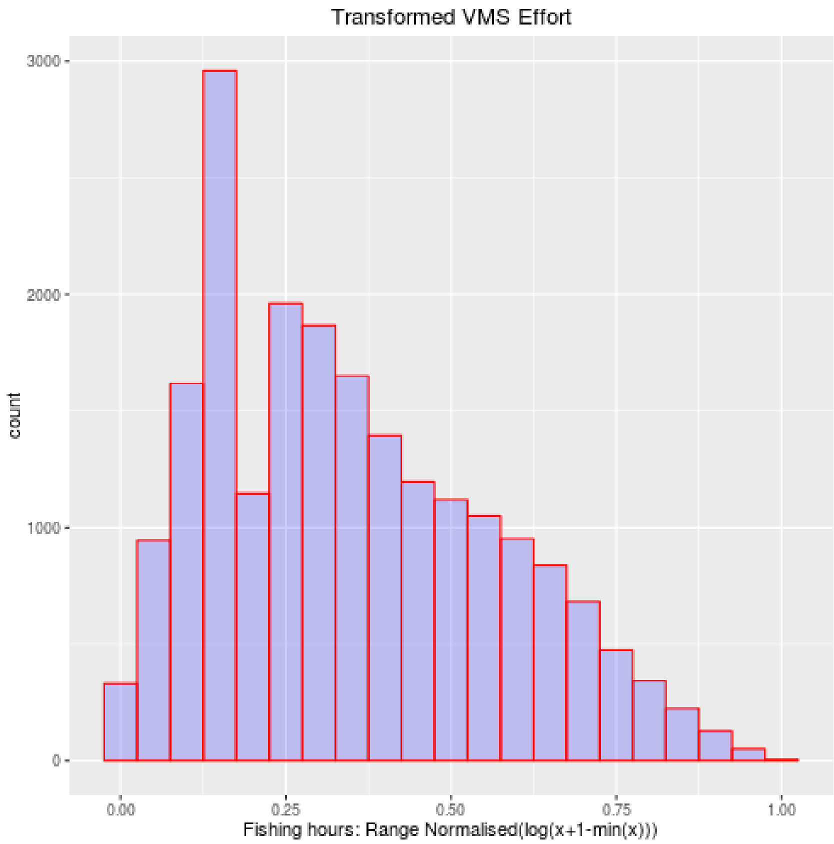
Summary statistics

	VMS OTT Fishing Hours
Values	20932.00000
NULL	0.00000
NA	0.00000
min	0.00056
max	646.14958
range	646.14903
sum	550240.31741
median	6.54972
mean	26.28704
SE.mean	0.36260
CI.mean.0.95	0.71073
var	2752.14552
std.dev	52.46090
coef.var	1.99569

Quartiles

0%	25%	50%	75%	100%
0.0006	2.0000	6.5497	24.9374	646.1496

Transformed values



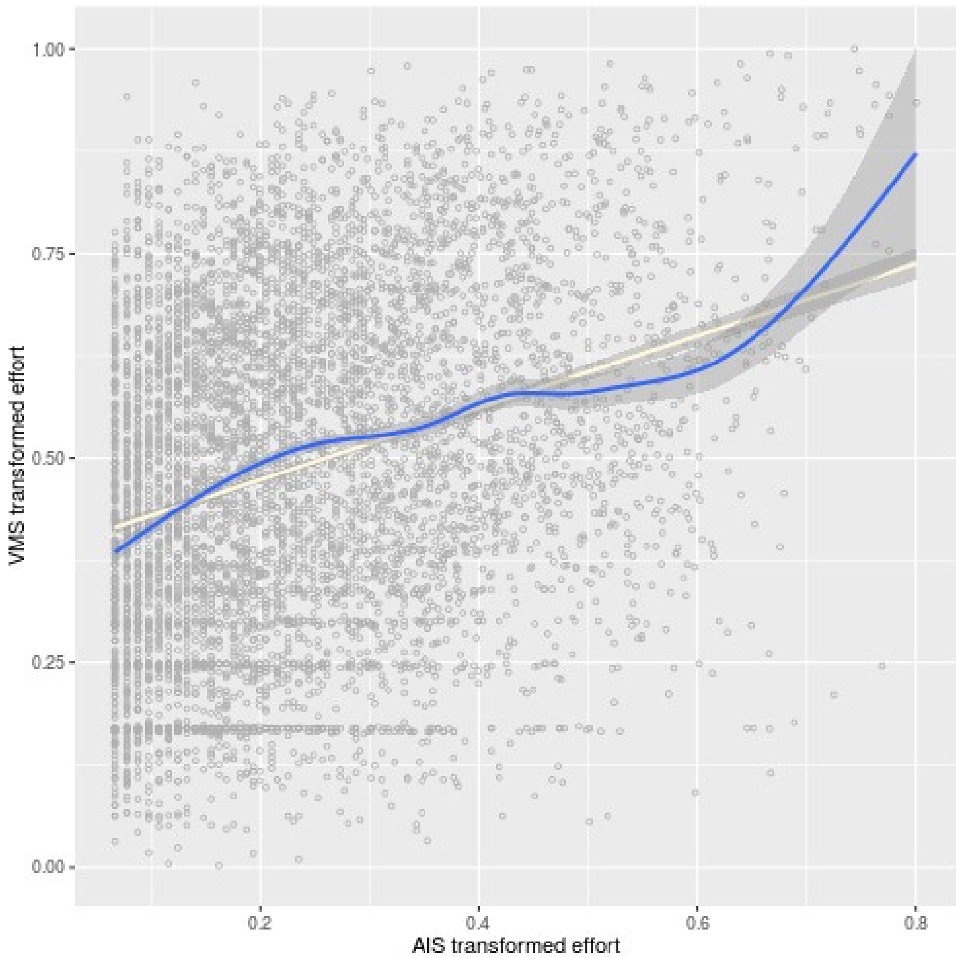
Summary statistics

	VMS OTT Transformed Fishing Hours
Values	20932.0000
NULL	1.0000
NA	0.0000
min	0.0000
max	1.0000
range	1.0000
sum	7362.1964
median	0.3123
mean	0.3517
SE.mean	0.0015
CI.mean.0.95	0.0029
var	0.0446
std.dev	0.2112
coef.var	0.6005

Quartiles

0%	25%	50%	75%	100%
).00	0.17	0.31	0.50	1.00

AIS AND VMS OTT COMPARISON



Pearson's product-moment correlation

Data: 6435 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = 25 , df = 6343 , p-value = < 0.00000000000000022

alternative hypothesis:

correlation is not equal to 0

95 percent confidence interval: [0.28 ;0.32]

sample estimates:

cor 0.3

Kendall's rank correlation tau

Data: 6435 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours z = 24 , p-value = < 0.00000000000000022

alternative hypothesis:

tau is not equal to 0 sample estimates:

tau 0.2

Two-sample Kolmogorov-Smirnov test

Data: 6435 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours D = 0.5 , p-value = < 0.00000000000000022

alternative hypothesis:

two-sided

Two-sample Kolmogorov-Smirnov test

Data: 6435 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours D^+ = 0.5 , p-value = < 0.00000000000000022

alternative hypothesis:

the CDF of x lies above that of y

Welch Two Sample t-test

Data: 6435 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = -78 , df = 11235 , p-value = < 0.00000000000000022

alternative hypothesis:

difference in means is not equal to 0

95 percent confidence interval: [-0.26 ;-0.24]

sample estimates:

mean of x	mean of y
0.24	0.49

Paired t-test

Data: 6435 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = -93 , df = 6344 , p-value = < 0.00000000000000022

alternative hypothesis:

difference in means is not equal to 0

95 percent confidence interval: [-0.25 ;-0.24]

sample estimates:

mean of the differences

-0.25

Wilcoxon signed rank test with continuity correction

Data: 6435 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours V = 1037357 , p-value = < 0.00000000000000022

alternative hypothesis:

location shift is not equal to 0

F test to compare two variances

Data: 6435 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours F = 0.47 , num df = 6344 , denom df = 6344 , p-value = < 0.00000000000000022 alternative hypothesis:

ratio of variances is not equal to 1

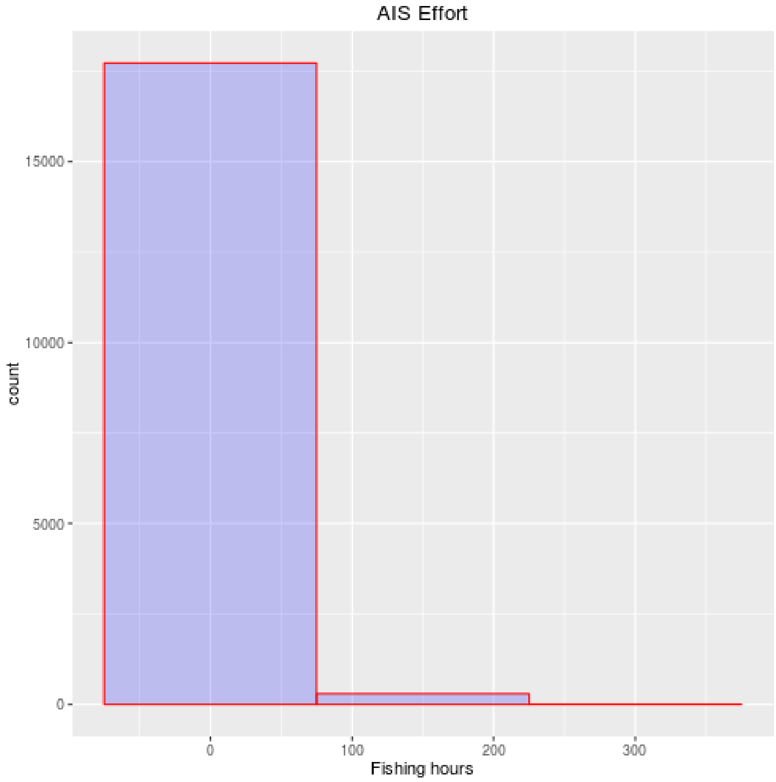
95 percent confidence interval: [0.45 ;0.49]

sample estimates:

ratio of variances 0.47

AIS OTM SUMMARY

Original Values



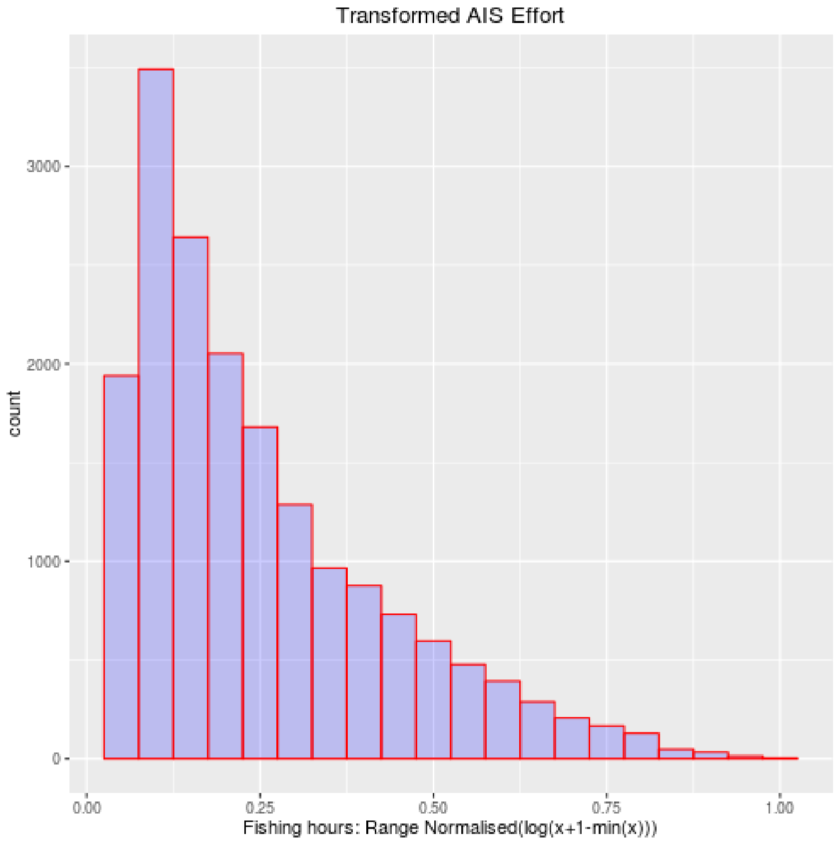
Summary statistics

	AIS OTM Fishing Hours
Values	18024.00
NULL	0.00
NA	0.00
min	0.50
max	319.92
range	319.42
sum	145711.17
median	2.17
mean	8.08
SE.mean	0.14
CI.mean.0.95	0.27
var	344.96
std.dev	18.57
coef.var	2.30

Quartiles

0%	25%	50%	75%	100%
0.5	1.0	2.2	6.5	319.9

Transformed values



Summary statistics

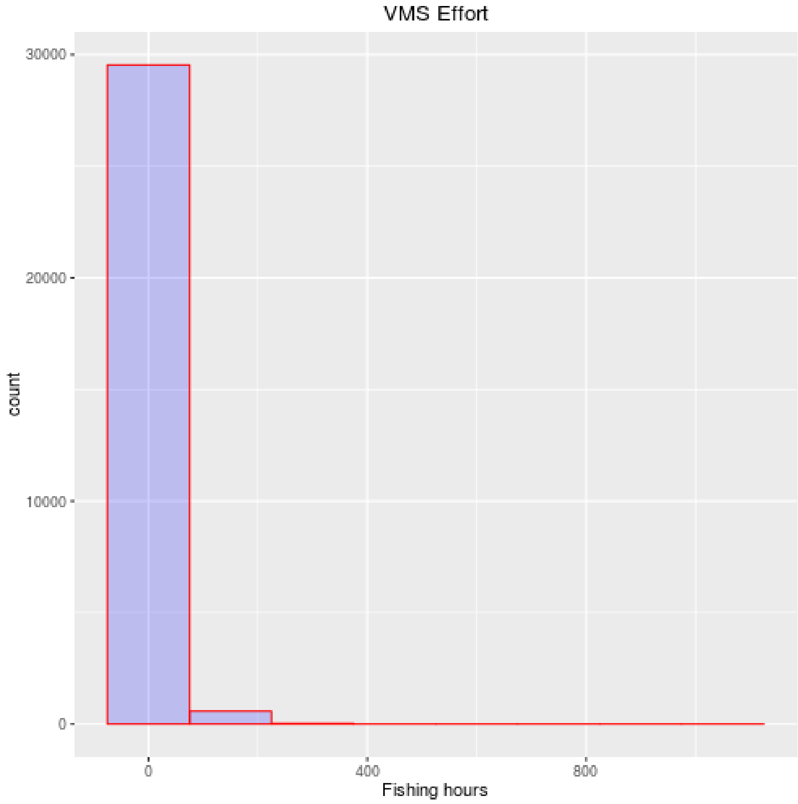
	AIS OTM Transformed Fishing Hours
Values	18024.0000
NULL	0.0000
NA	0.0000
min	0.0604
max	1.0000
range	0.9396
sum	4517.6656
median	0.1951
mean	0.2506
SE.mean	0.0013
CI.mean.0.95	0.0026
var	0.0322
std.dev	0.1794
coef.var	0.7156

Quartiles

0%	25%	50%	75%	100%
).06	0.11	0.20	0.35	1.00

VMS OTM SUMMARY

Original Values



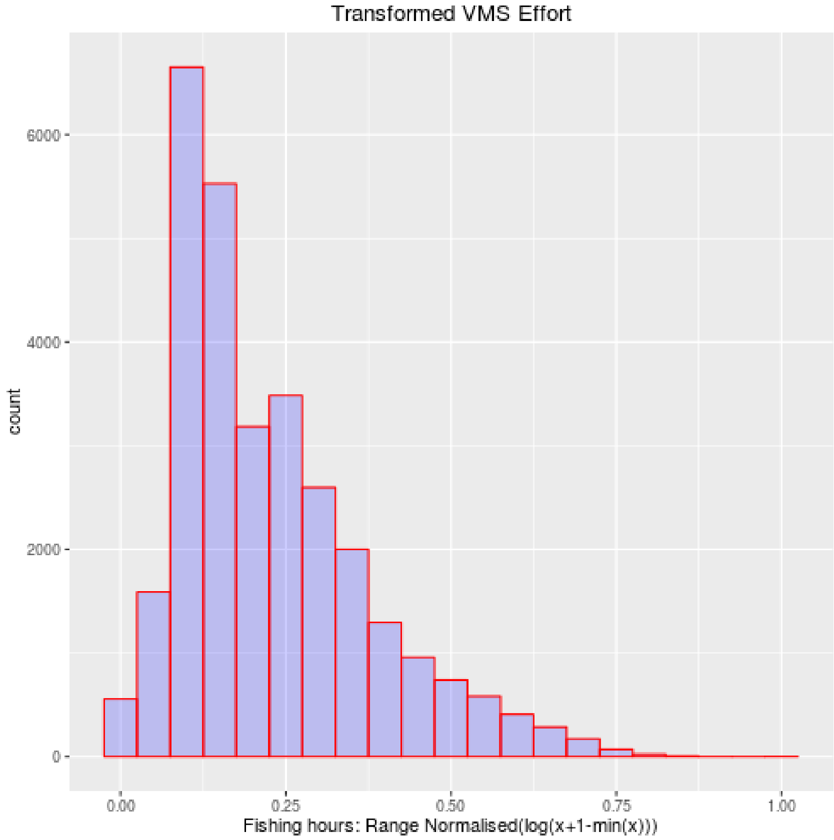
Summary statistics

	VMS OTM Fishing Hours
Values	30141.00
NULL	43.00
NA	0.00
min	0.00
max	1107.00
range	1107.00
sum	274864.43
median	2.93
mean	9.12
SE.mean	0.13
CI.mean.0.95	0.25
var	479.02
std.dev	21.89
coef.var	2.40

Quartiles

0%	25%	50%	75%	100%
0.0	1.0	2.9	7.5	1107.0

Transformed values



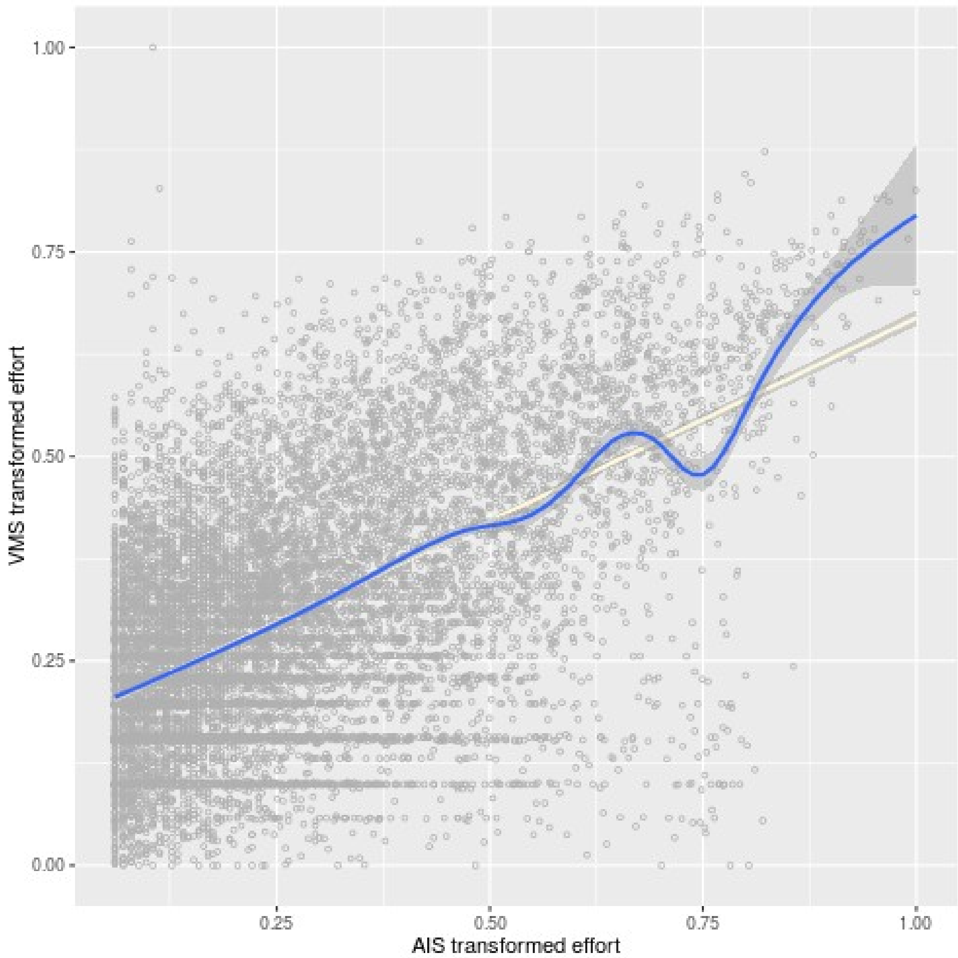
Summary statistics

	VMS OTM Transformed Fishing Hours
Values	30141.00000
NULL	43.00000
NA	0.00000
min	0.00000
max	1.00000
range	1.00000
sum	6820.69018
median	0.19520
mean	0.22629
SE.mean	0.00084
CI.mean.0.95	0.00164
var	0.02115
std.dev	0.14542
coef.var	0.64263

Quartiles

0%	25%	50%	75%	100%
).00	0.10	0.20	0.31	1.00

AIS AND VMS OTM COMPARISON



Pearson's product-moment correlation

Data: 12032 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = 76 , df = 12030 , p-value = < 0.00000000000000022

alternative hypothesis:

correlation is not equal to 0

95 percent confidence interval: [0.56 ;0.58]

sample estimates:

cor 0.57

Kendall's rank correlation tau

Data: 12032 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours z = 58 , p-value = < 0.00000000000000022

alternative hypothesis: tau is not equal to 0 sample estimates:

tau 0.36

Two-sample Kolmogorov-Smirnov test

Data: 12032 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours D = 0.2 , p-value = < 0.00000000000000022

alternative hypothesis:

two-sided

Two-sample Kolmogorov-Smirnov test

Data: 12032 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours D^+ = 0.2 , p-value = < 0.00000000000000022

alternative hypothesis:

the CDF of x lies above that of y

Welch Two Sample t-test

Data: 12032 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = -17 , df = 23619 , p-value = < 0.00000000000000022

alternative hypothesis:

difference in means is not equal to 0

95 percent confidence interval: [-0.043 ;-0.034]

sample estimates:

mean of x	mean of y
0.27	0.31

Paired t-test

Data: 12032 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = -26 , df = 12031 , p-value = < 0.00000000000000022

alternative hypothesis:

difference in means is not equal to 0

95 percent confidence interval: [-0.042 ;-0.036]

sample estimates:

mean of the differences

-0.039

Wilcoxon signed rank test with continuity correction

Data: 12032 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours V = 24744485 , p-value = < 0.00000000000000022

alternative hypothesis:

location shift is not equal to 0

F test to compare two variances

Data: 12032 AIS and VMS overlapping c-squares with values = Transformed Fishing Hours F = 1.3 , num df = 12031 , denom df = 12031 , p-value = < 0.00000000000000022 alternative hypothesis:

ratio of variances is not equal to 1

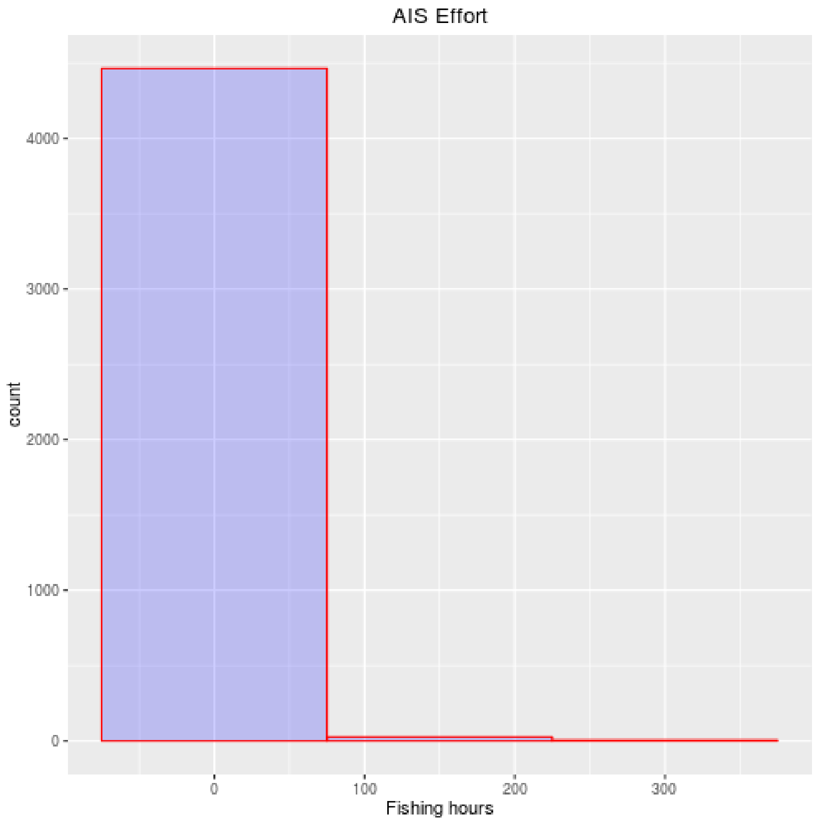
95 percent confidence interval: [1.3 ;1.4]

sample estimates:

ratio of variances 1.3

AIS PTM SUMMARY

Original Values



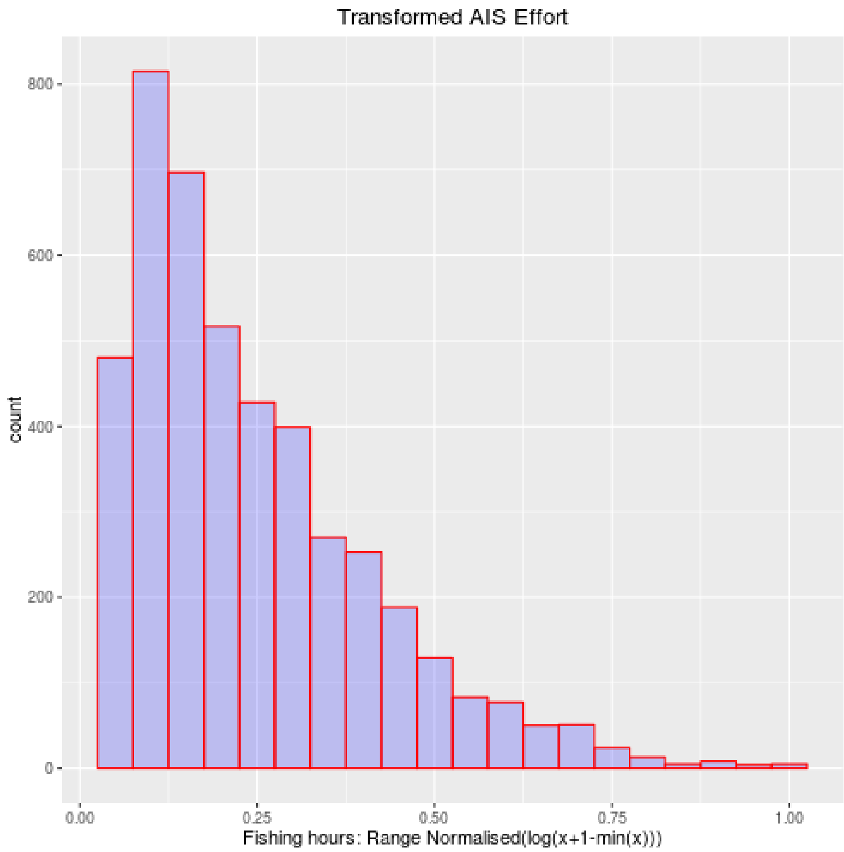
Summary statistics

AIS PTM Fishing Hours	
Values	4496.00
NULL	0.00
NA	0.00
min	0.50
max	249.67
range	249.17
sum	27679.08
median	2.00
mean	6.16
SE.mean	0.23
CI.mean.0.95	0.44
var	227.79
std.dev	15.09
coef.var	2.45

Quartiles

0%	25%	50%	75%	100%
0.50	0.92	2.00	5.33	249.67

Transformed values



Summary statistics

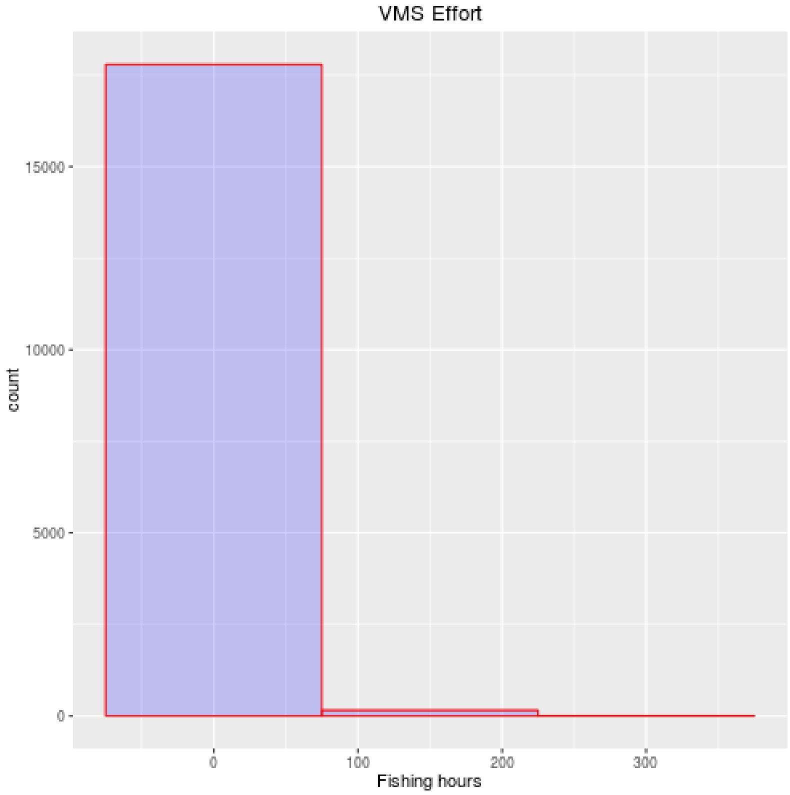
	AIS PTM Transformed Fishing Hours
Values	4496.0000
NULL	0.0000
NA	0.0000
min	0.0631
max	1.0000
range	0.9369
sum	1095.1526
median	0.1938
mean	0.2436
SE.mean	0.0025
CI.mean.0.95	0.0049
var	0.0275
std.dev	0.1659
coef.var	0.6812

Quartiles

0%	25%	50%	75%	100%
).063	0.110	0.194	0.332	1.000

VMS PTM SUMMARY

Original Values



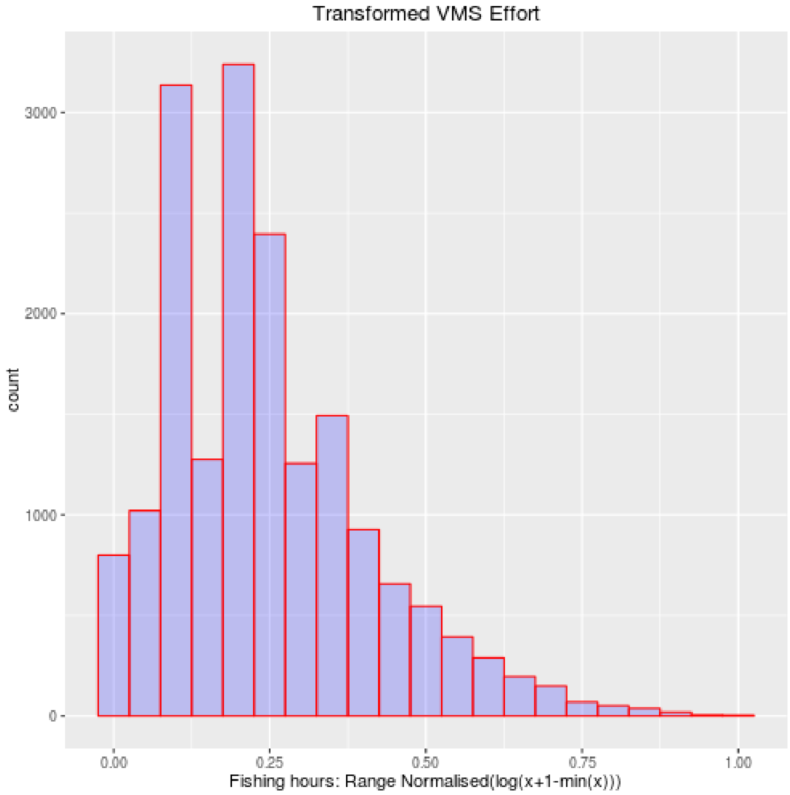
Summary statistics

	VMS PTM Fishing Hours
Values	17961.00
NULL	104.00
NA	0.00
min	0.00
max	359.20
range	359.20
sum	124169.99
median	2.30
mean	6.91
SE.mean	0.12
CI.mean.0.95	0.23
var	256.38
std.dev	16.01
coef.var	2.32

Quartiles

0%	25%	50%	75%	100%
0.0	1.0	2.3	6.0	359.2

Transformed values



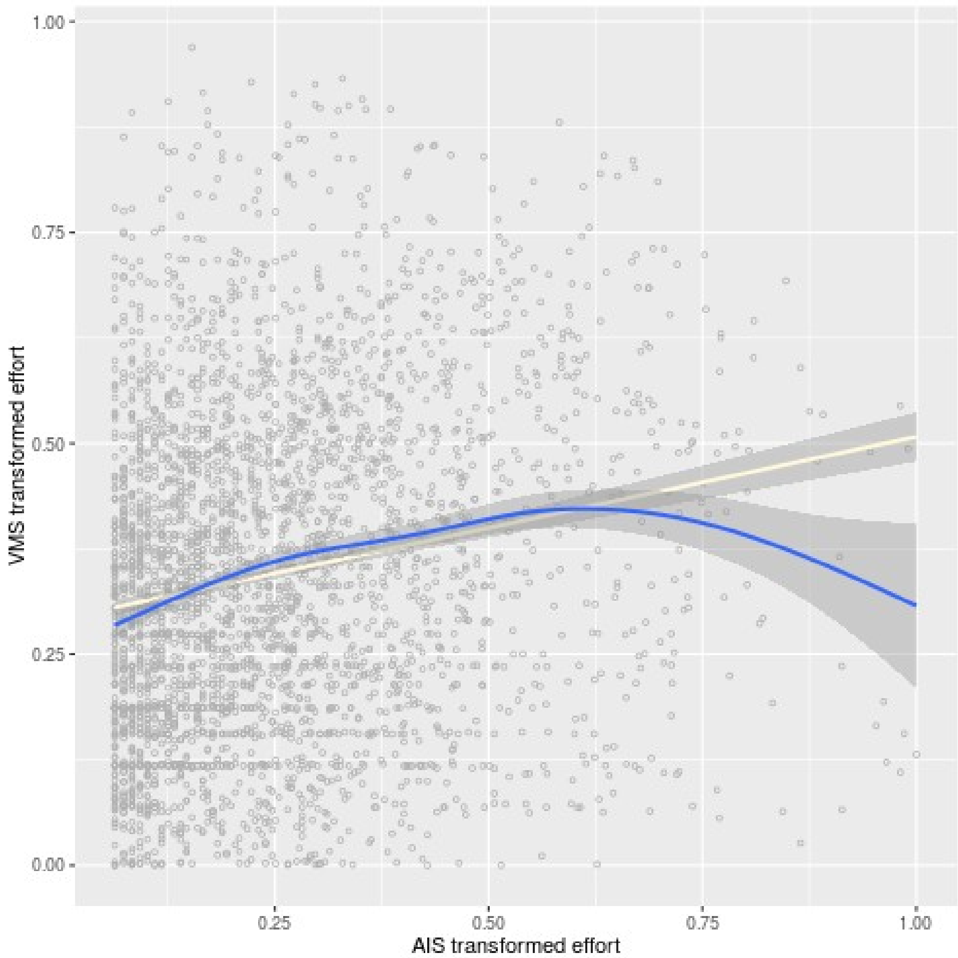
Summary statistics

	VMS PTM Transformed Fishing Hours
Values	17961.0000
NULL	104.0000
NA	0.0000
min	0.0000
max	1.0000
range	1.0000
sum	4438.3127
median	0.2026
mean	0.2471
SE.mean	0.0012
CI.mean.0.95	0.0023
var	0.0258
std.dev	0.1606
coef.var	0.6499

Quartiles

0%	25%	50%	75%	100%
).00	0.12	0.20	0.33	1.00

AIS AND VMS PTM COMPARISON



Pearson's product-moment correlation

Data: **3352** AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = **11** , df = **3350** , p-value = < 0.00000000000000022

alternative hypothesis:

correlation is not equal to 0

95 percent confidence interval: **[0.16 ;0.22]**

sample estimates:

cor 0.19

Kendall's rank correlation tau

Data: **3352** AIS and VMS overlapping c-squares with values = Transformed Fishing Hours z = **12** , p-value = < 0.00000000000000022

alternative hypothesis:

tau is not equal to 0

sample estimates:

tau 0.14

Two-sample Kolmogorov-Smirnov test

Data: **3352** AIS and VMS overlapping c-squares with values = Transformed Fishing Hours D = **0.25** , p-value = < 0.00000000000000022

alternative hypothesis:

two-sided

Two-sample Kolmogorov-Smirnov test

Data: **3352** AIS and VMS overlapping c-squares with values = Transformed Fishing Hours D^+ = **0.25** , p-value = < 0.00000000000000022

alternative hypothesis:

the CDF of x lies above that of y

Welch Two Sample t-test

Data: **3352** AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = **-21** , df = **6582** , p-value = < 0.00000000000000022

alternative hypothesis:

difference in means is not equal to 0

95 percent confidence interval: **[-0.102 ;-0.085]**

sample estimates:

mean of x	mean of y
0.25	0.35

Paired t-test

Data: **3352** AIS and VMS overlapping c-squares with values = Transformed Fishing Hours t = **-23** , df = **3351** , p-value = < 0.00000000000000022

alternative hypothesis:

difference in means is not equal to 0

95 percent confidence interval: **[-0.101 ;-0.085]**

sample estimates:

mean of the differences

-0.093

Wilcoxon signed rank test with continuity correction

Data: **3352** AIS and VMS overlapping c-squares with values = Transformed Fishing Hours V = **1520137** , p-value = < 0.00000000000000022

alternative hypothesis:

location shift is not equal to 0

F test to compare two variances

Data: **3352** AIS and VMS overlapping c-squares with values = Transformed Fishing Hours F = **0.76** , num df = **3351** , denom df = **3351** , p-value = 0.000000000000003689 alternative hypothesis:

ratio of variances is not equal to 1

95 percent confidence interval: **[0.71 ;0.82]**

sample estimates:

ratio of variances 0.76

Annex 9: Technical minutes by RGBENTH

Review of OSPAR request

Review group: Stefán Áki Ragnarsson (chair), Francis Neat and Antonello Sala

RGBENTH reviewed the work of the ICES Working Group on Spatial Fisheries Data (WGSFD) for the OSPAR request "using the latest versions of the indicator description/summaries of the 'Extent of Physical damage indicator' (BH3)" to:

- Collect relevant national VMS and logbook data for 2014. The data request should follow same format as last's year and include any amendments following the WG SFD meeting in June 2015;
- Estimate the proportions of total fisheries represented by the data;
- Using methods developed in previous advice, where possible, collect other non-VMS data for 2014 to cover other types of fisheries (e.g. fishing boats < 12m length);
- Prepare maps for the OSPAR maritime area (including ABNJ) on the spatial and temporal intensity of fishing using mobile bottom contacting gears;
- Provide advice on the development and application of alternative smaller grids (smaller resolution than 0.05°) to improve the analysis of fishing abrasion data:
    - What data and methods can be used for regional assessments, including pros and cons on data accessibility, and costings, if possible;
    - Explore any alternative approaches such as the "Nested grid approach", to ascertain if it can be used to provide supporting data to refine and calibrate the abrasion fishing layers. This can be done using a case study or pilot area.
- Provide advice on the applicability and use of AIS data, in particular to:
    - Ascertain if it can be used as supporting information for the spatial analysis of fisheries data;
    - Indicate if it can be used as an alternative source of data to VMS;
    - Indicate potential costing for the collation and management of AIS data;
    - Advice can be based on a case study or pilot area."

RGBENTH would like to congratulate WGSFD for an impressive amount of work. RGBENTH is of the view that WGSFD has successfully addressed all aspects of the request. This work is highly technical and the RGBENTH members felt that they did always not have the sufficient knowledge to evaluate the specific methodological aspects of the VMS/AIS data analysis. Most of our comments thus involve pinpointing possible errors or clarification of certain points. We also provide some general recommendations with regard to further work and research needs.

1) RGBENTH was impressed how many nations shared their VMS data. However, it is clear that there are some nations that have not shared their data (see Table 5.3.1.) and this needs to be more clearly stated in the text related to Figures 5.6.3.2-5.6.3.5 and Table 5.6.1.1. As an example, Table 5.6.1.1 shows a complete coverage of VMS data in Arctic waters, while absence of VMS data from Iceland and Greenland becomes apparent when inspecting Table 5.3.1. RGBENTH assumes that Wider Atlantic is the NEAFC RA. An

alternative option is to make a table which shows the VMS availability disaggregated at national level, although this would result in a much larger table.

Without knowing how much data is missing it is not possible to accurately '*estimate the proportions of total fisheries represented by the data*' as the ToR requests. Nevertheless, on the basis of the data that has been submitted and collated it appears that most landings (logbook data) have associated VMS data and thus the data provide a reasonably complete picture of fishing effort by those nations that submitted data within the OSPAR maritime area.

It was also clear that some nations have a significant amount of fishing activity that is without associated VMS data. Presumably, this involves mostly smaller vessels (with small catches) that are not required to be tracked with VMS systems. As an example, 65% of the total catch that is captured with static gears in Iberian waters has no associated VMS data. RGBENTH noted that the proportion of VMS data where fishing days are registered tended to be lower than for the catch and would be interested to hear the explanation offered by WGSFD for this difference.

2) RGBENTH noted that the maps prepared by WGSFD (e.g. Figure 5.6.3.2) do not include the westernmost part of the OSPAR area. RGBENTH would like WGSFD to clarify whether there is any VMS data available for the excluded area.

3) Figure 5.6.1.1 lacks a legend describing VMS availability for bottom contact fishing gear, similar to the plots prepared for the non-bottom contact gears.

4) Figure 5.6.2.1 shows the proportion of VMS coverage for otter-trawl data based on logbook data for only part of the OSPAR area. Why was not all the OSPAR area included?

5) The title of the section "5.6.2.2: Figures by country and vessel lengths" should be improved so it fits better with the original request, i.e. collation and analysis of non-VMS data from mostly small vessels. There is no reference made to Figures 5.4.2.2-5.4.2.7 in the text. These figures show interesting pattern where some of the fisheries that have no associated VMS data have quite intensive effort. As an example, the Spanish data (collected with IEO) shows that vessels fished around 400.000 days with static gears in 2012. It is clear that the effort by smaller vessels needs to be more considered in future work, e.g. with respect to benthic impacts.

6) The methods of separating surface and subsurface abrasion is clarified in section 5.8.1, but as a courtesy for the reader some sentences explaining the difference between these two pressures could be added and the link to the section 5.8.1 needs to be strengthened.

7) The histograms in the Figure 5.6.3.1 and the Figures 5.6.3.2-5.6.3.4 show that only small part of the bottom fishing effort caused subsurface abrasion. It would be useful to have also the histogram of surface abrasion to allow direct comparison. As a suggestion for future work, further comparison of surface and subsurface abrasion pressures would be of interest. No information explaining what data is analysed to prepare the histograms is provided. It is not clear on the basis of which data (i.e. whether it is the complete dataset for the whole OSPAR area or subset of the data) the histogram is based on.

8) RGBENTH thinks the way the effort is portrayed in Figures 5.6.3.2-5.6.3.5 is very useful, but recommends, in order to aid interpretability, to add more numbers in the legend

(e.g. add 2 and 4 between 0-6). The group was impressed to see that the upper sediment layers of some c-squares have been swept/abraded up to 82 times in no longer time than 6 years.

The text in second paragraph in 5.6.3 and in Figure legends for 5.6.3.2-5.6.3.5 needs to be improved so it becomes clearer how fishing abrasion was calculated The text states that the fishing intensity is expressed as fishing abrasion ratio (number of times the c-square has been swept) while the Figure legends for 5.6.3.2-5.6.3.5 refer to swept area ratio. A stronger link could be made with section 5.8.1, that describes in detail how fishing abrasion was calculated.

RGBENTH thought that the way how the trends in subsurface swept area ratio trend map are portrayed in 5.6.3.6 was very useful. It would be useful to show such map for surface abrasion as well.

9) In section 5.6.4 (Methods), RGBENTH suggest to replace “lower spatio-temporal” with “finer spatio-temporal”, as the word “lower” could cause confusion.

10) Full names of fishing gears (i.e. not only FAO gear codes) should be provided. WGFSD could also consider the gear codes listed in the Master Data Register (http://ec.europa.eu/fisheries/cfp/control/codes/index_en.htm).

11) In 5.6.5.2. It is stated that “graphs and further numerical analysis to be inserted soon as: 1) number of points estimated per 0.05*0.05, 2) fishing hours and 3) Kilo Watt per fishing hour, with a vessel power information obtained from the European Fleet Register”. There appear to be no analysis provided regarding the items 1 and 3 here above. However, on pages 37-42, figures showing fishing effort in terms of fishing hours is calculated based on VMS and AIS data for otter trawl (OTB), midwater otter trawls (OTM), otter twin trawls (OTT), midwater pair trawls (PTM), beam trawls (TBB) and bottom pair trawls (PTB) are provided but without text explaining the content of these. Inspecting these figures it is clear that the spatial coverage of the AIS data is less than for the VMS data. For some areas, there is a good consistency in the spatial distribution patterns shown with these two data sources, while closer inspection reveals differences. As an example, the AIS data does provide data on spatial distribution of fishing effort where VMS data has not been submitted to ICES (e.g. Spanish coastal waters). Considering the limited range of the AIS system (generally 10-20 nm) this data should thus provide data only on the coastal fishing effort. Clearly, some of the fishing effort is beyond that range, and these vessels were presumably tracked with satellite-based AIS system (S-AIS) systems. RGBENTH recommends WGSFD to allocate some work into producing a single map layer based on combined VMS and AIS data, where both data sets are available. This should more readily enable identifying commonalities and differences in the spatial distributions based on those two data sets (rather than comparing two maps side-by-side). The intersect option in the spatial software QGIS could be useful for such analyses. One of the advantage of the AIS data is that it can more accurately recreate fishing tracks compared to the VMS data and may thus be more useful in situations where very fine spatial analyses are required.

12) RGBENTH considered the possibility of obtaining positioning data directly from onboard GPS plotters from selected vessels with the purpose of validating the effort distribution portrayed by the VMS and/or AIS data. Analysis of such data could enable creating highly accurate fishing tracks.

13) In section 5.5, a citation to the Med VMS tool (VMSbase) is missing: Russo T, D'Andrea L, Parisi A, Cataudella S. 2014. VMSbase: An R-Package for VMS and Logbook Data Management and Analysis in Fisheries Ecology. PLoS ONE 9(6): e100195. 10.1371/journal.pone.0100195.

Review of NEAFC request

Review group: Stefán Áki Ragnarsson (Chair), Francis Neat and Antonello Sala

RGBENTH was tasked to review material from the ICES Working Group on Spatial Fisheries Data (WGSFD) for the NEAFC request to describe fisheries activities in and in the vicinity of VME (vulnerable marine ecosystem) habitats. Their work involved analysis of vessel monitoring (VMS) and fish catch data obtained within the NEAFC regulatory area (RA). The full NEAFC request is as follows:

"Using NEAFC VMS and catch data, describe "fisheries activities in and in the vicinity of such (VME) habitats" (areas defined by WGDEC) within the NEAFC Convention Area in 2015. If possible, descriptions should be made of each area near such habitats, and separate each bottom contact gear type (e.g. static or mobile gears)."

RGBENTH carefully reviewed the work of WGSFD and agrees that it provides important information for NEAFC. The group should be commended for their ability to generate fishing effort tracks from the available VMS data. However, RGBENTH identified several shortcomings regarding the accuracy of the spatial distribution patterns of bottom trawl effort and provides advice on how the analysis and interpretation of the VMS data can be improved.

1) The wording of '(VME) habitats' in the term of reference is ambiguous. WGSFD have assumed that it means the NEAFC areas that have been closed to bottom fishing for the purposes of protecting VMEs. While these closed areas represent areas where there is good information on the presence of VMEs, it is important to stress that these closed areas are not the only places where VMEs are likely to be within the NEAFC RA. Other areas include topographic features such as seamounts, ridges and canyons that provide favourable substrate for VMEs, but for which there is little actual data. For future work, it would simplify matters to use the term 'NEAFC areas closed to bottom fishing' or have a defined list of 'VME areas' provided by WGDEC for WGSFD to work from. It would also be helpful to WGSFD if the group included somebody familiar with the distribution and ecology of VMEs and the information behind the NEAFC closures.

2) WGSFD should be commended on the generation of individual fishing tracks from point data. This was somewhat hampered by a problem of lack of ID codes for significant portions of the data (most notably in early years), but nevertheless is an important advance. The method of generating 'heat maps' of fishing activity (number of tows per km^2) is also very useful. Currently these data are presented at 3 different thresholds (0-3, 3-30,>30). However, RGBENTH are of the view that it is important to distinguish between areas where there is zero fishing activity and areas where there is any fishing activity (no matter how little). This is be-

cause a single bottom trawl pass can cause significant adverse impacts to VMEs. Thus in the maps the data could be grouped as 0, 1-3, 3-30, > 30.

3) It is not clear why maps were made of pelagic fishing effort. Pelagic fishing is not a threat to VMEs and consequently not prohibited in areas closed to protect VMEs. The NEAFC regulations that serve to protect VMEs apply only to bottom fisheries. It is of course important to identify pelagic fishing and remove it from further analyses (RGBENTH makes some suggestions on how do this below in section 5).

4) The vast majority of fishing activity appears to occur outside of the NEAFC protected areas. However, the maps are not reproduced at sufficiently high spatial resolution to assess precisely how well boundaries are respected. For some areas, e.g. Edora's bank this is not an issue because there is no fishing anywhere near the bank. However, this is potentially an issue in other areas like the Hatton-Rockall area where fishing activity is in close proximity to NEAFC closed areas. There is one obvious instance of an apparent incursion into a closed area (the northern mid-Atlantic ridge). However, this is most likely pelagic fishing as the depth at the site is below the maximum possible bottom trawling depth (1500 m) and the fishery is targeting *Sebastes mentella,* which is caught with pelagic trawls in the NEAFC RA. It is important to note that NEAFC first closed areas in 2005 and since then have adopted further closures. As the data presented also dates back to 2005, it is possible that some fishing activity is shown that predates a particular closure. Therefore, it would be useful to have some means of presenting the data on a year-by-year basis so that the data can be seen in context of the history of NEAFC closures.

5) RGBENTH suggest that the VMS data could be better filtered to be more representative of bottom trawling activity. WGSFD assumes the towing speed of a fishing trawler to range between 1-6 knots. RGBENTH suggest the towing speed of a bottom trawler targeting fish is more likely to be in the range of 3-5 knots. At towing speeds below 3 knots the efficiency to capture fish decreases markedly and the fishing gear may fail altogether. One exception is bottom fisheries targeting shrimp that often tow at around 2 knots. There is generally no advantage of bottom trawling at speeds in excess of 4.5 knots as it tends to result in increased risk of gear damage and uses excessive fuel. Only pelagic trawlers tend to tow faster than 5 knots. Thus narrowing down the towing speed thresholds to, e.g. 3-5 knots should filter out a large proportion of the VMS pings that are not related to active bottom trawling. Tow duration could also be a useful way to separate bottom fishing from pelagic fishing activity. In the 2015 WGSFD report, data on tow duration is shown. Tow duration that is in the range of 0-6 hours is likely to be bottom trawling effort while tow duration that exceeds 6 hours is likely to be pelagic fishing effort. Finally, it should also be possible to filter the data in relation to underlying depth. Any VMS data at depths > 1500 m should be considered as very unlikely to be bottom trawling and thus should be safe to exclude. RGBENTH suggest that if the data could be filtered by a combination of towing

speed, tow duration and underlying water depth, then a much more representative pattern of bottom trawling would be obtained.

6) NEAFC permit bottom fishing only within the existing fishing areas (fishing footprint). Any fishing outside of the footprint is considered 'exploratory fishing' and is subject to a different set of regulations. As there are no exploratory fisheries at present in the NEAFC area, all fishing activity should be within the existing fishing areas.

   From the maps produced by WGSFD there appear to be a large amount of fishing activity outside the existing fishing grounds. This is probably mostly pelagic fishing or some non-fishing related activity such as slow steaming during bad weather. The fishing activity south of the Icelandic EEZ (just north of the Franshóll, the most northerly defined existing bottom fishing ground) is pelagic fishing targeting redfish (*Sebastes mentella)*. The fishing effort west of the northern and middle MAR areas, east and within the northern MAR area is probably also pelagic fishery, although it is less clear what species is being targeted. Many of the scattered fishing tracks shown in figure 2 outside the closed areas and the existing fishing grounds are likely to represent pelagic fishery or non-fishing activity. For example, figure 2 shows some fishing tracks forming straight lines up to a few hundred nautical miles long that are very unlikely to be bottom fishing. WGSFD would benefit from having somebody familiar with the fisheries operating in the NEAFC RA to advise on whether gear code data are likely to be erroneous or genuine.

   Second, and of greater concern, are areas in the Rockall-Hatton area where it appears that fishing extends beyond the current fishing footprint. This is less likely to be a reporting or coding error and is likely to be bottom contact fishing because it is contiguous with fishing inside the footprint. Figure X shows the Rockall-Hatton area in greater detail and indicates at least two areas where fishing extends some 30-50 km beyond the demarcated footprint. This is a concern not just from a regulatory point of view, but also from a VME risk point of view because the Hatton-Rockall area is well known to be an important area of VMEs. Closer examination is needed, possibly looking at individual tracks of vessels rather than the density 'heat map'. This raises a general issue that the maps should have been produced at a much finer scale so that it is possible to assess the fishing activity in relation to closure boundaries, topographic features etc.

7) ICES have repeatedly advised NEAFC that certain existing fishing areas are likely to contain VMEs. These include various seamounts (e.g. Josephine Seamount) and areas on the mid-Atlantic ridge. To date it has not been clear to what extent these areas are actively fished. It would have been a very useful exercise for WGSFD to provide detailed maps of any fishing activity from these areas to assess the risk to VMEs. Indeed the maps provided by WGSFD did not even extend to the area where Josephine Seamount is located. Again this could be resolved if somebody familiar with VMEs and the history of NEAFC's closed areas was present within WGSFD.

8) RGBENTH recommends WGSFD to make the following specific revisions.
   a. It is stated that "Data for active, bottom-contacting gears was processed further". Please specify the gear type this included (RGBENTH had to assume this refers to otter-trawls).
   b. Figure 3 shows NEAFC closures to bottom fisheries. These are not "FAO VME closures". Please correct.
   c. It is not clear for which period the fishing effort data is shown, although it is likely to be for 2015. This should be stated or the data should be presented on a year-by-year basis.

Recommendations

On the basis of this review, RGBENTH recommends WGSFD to:

1) improve filtering of the VMS data using water depth, towing speed and tow duration.

2) examine in detail spatial distribution patterns of fishing effort that takes place within an NEAFC closure or beyond the boundary of an existing fishing area.

3) seek expert opinion on the fisheries within the NEAFC RA to improve interpretation and analysis of the VMS data.